

# DSP56371 24-Bit Digital Signal Processor

## User Manual

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Freescale Halbleiter Deutschland GmbH  
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Freescale Semiconductor Japan Ltd.  
Headquarters  
ARCO Tower 15F  
1-8-1, Shimo-Meguro, Meguro-ku,  
Tokyo 153-0064, Japan  
0120 191014 or +81 3 5437 9125  
[support.japan@freescale.com](mailto:support.japan@freescale.com)

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Freescale Semiconductor Hong Kong Ltd.  
Technical Information Center  
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# Preface

This manual describes the DSP56371 24-bit digital signal processor (DSP), its memory, operating modes and peripheral modules. The DSP56371 is a member of the DSP56300 family of programmable CMOS DSPs. Changes in core functionality specific to the DSP56371 are also described in this manual.

The DSP56371 is targeted to applications that require digital audio compression and decompression, sound field processing, acoustic equalization and other digital audio algorithms.

This manual is intended to be used with the following publications:

- The *DSP56300 Family Manual (DSP56300FM)*, which describes the CPU, core programming models and instruction set details.
- The *DSP56371 Technical Data Sheet (DSP56371)*, which provides electrical specifications, timing, pinout and packaging descriptions of the DSP56371.

These documents, as well as Freescale's DSP development tools, can be obtained through a local Freescale Semiconductor, Inc. Sales Office or authorized distributor.

To receive the latest information on this DSP, access the Freescale DSP home page at the address given on the back cover of this document.

## Document Summary

This manual contains the following sections and appendices.

### SECTION 1—DSP56371 OVERVIEW

- Provides a brief description of the DSP56371, including a features list and block diagram. Lists related documentation needed to use this chip and describes the organization of this manual.

### SECTION 2—SIGNAL/CONNECTION DESCRIPTIONS

- Describes the signals on the DSP56371 pins and how these signals are grouped into interfaces.

### SECTION 3—MEMORY CONFIGURATION

- Describes the DSP56371 memory spaces, RAM and ROM configuration, memory configurations and their bit settings and memory maps.

### SECTION 4—CORE CONFIGURATION

- Describes the registers used to configure the DSP56300 core when programming the DSP56371, in particular the interrupt vector locations and the operation of the interrupt priority registers. Explains the operating modes and how they affect the processor's program and data memories.

## **SECTION 5—PHASE LOCKED LOOP (PLL) AND CLOCK GENERATOR**

- Describes the DSP56371 PLL and clock generator capability and the programming model for the PLL (operation, registers and control).

## **SECTION 6—GENERAL PURPOSE INPUT/OUTPUT (GPIO)**

- Describes the DSP56371 GPIO capability and the programming model for the GPIO signals (operation, registers and control).

## **SECTION 7—SERIAL HOST INTERFACE (SHI)**

- Describes the serial input/output interface providing a path for communication and program/coefficient data transfers between the DSP and an external host processor. The SHI can also communicate with other serial peripheral devices.

## **SECTION 8—ENHANCED SERIAL AUDIO INTERFACE (ESAI)**

- Describes one of the full-duplex serial port for serial communication with a variety of serial devices.

## **SECTION 9—ENHANCED SERIAL AUDIO INTERFACE 1 (ESAI\_1)**

- Describes the second full-duplex serial port for serial communication with a variety of serial devices.

## **SECTION 10—DIGITAL AUDIO TRANSMITTER (DAX)**

- Describes the SPDIF transmitter module (DAX) and its functionality.

## **SECTION 11—TRIPLE TIMER MODULE (TEC)**

- Describes the Architecture, Programming model and operating modes of three identical timer devices available for use as internals or event counters. Describes the operation of the Triple Timer and its many functions.

## **SECTION 12— ENHANCED FILTER CO-PROCESSOR (EFCOP)**

- Describes the structure and function of the EFCOP including features, architecture and programming model; Programming topics such as data transfer to and from the EFCOP, its use in different modes and examples of usage are provided.

## **APPENDIX A—BOOTSTRAP PROGRAM**

- Lists the bootstrap code used for the DSP56371.

## **APPENDIX B—EQUATES**

- Lists equates for the DSP56371.

## **APPENDIX C—PROGRAMMING REFERENCE**

- Lists peripheral addresses, interrupt addresses and interrupt priorities for the DSP56371. Contains programming sheets listing the contents of the major DSP56371 registers for programmer reference.



# Revision History

## DSP56371 Users Guide Revision History

Revision	Description
2.1	Updated document formatting to support latest document templates. No technical changes from Rev 2.
2.0	Updated document formatting to support Freescale spin-off from Motorola. No technical changes from Rev 1.0.
1.0	The latest Motorola document revision when Motorola created Freescale Semiconductor.

## Manual Conventions

The following conventions are used in this manual:

- Bits within registers are always listed from most significant bit (MSB) to least significant bit (LSB).
- When several related bits are discussed, they are referenced as AA[n:m], where  $n > m$ . For purposes of description, the bits are presented as if they are contiguous within a register. However, this is not always the case. Refer to the programming model diagrams or to the programmer's sheets to see the exact location of bits within a register.
- When a bit is described as “set”, its value is 1. When a bit is described as “cleared”, its value is 0.
- The word “assert” means that a high true (active high) signal is pulled high to  $V_{DD}$  or that a low true (active low) signal is pulled low to ground. The word “deassert” means that a high true signal is pulled low to ground or that a low true signal is pulled high to  $V_{DD}$ .

### High True/Low True Signal Conventions

Signal/Symbol	Logic State	Signal State	Voltage
$\overline{PIN}^1$	True	Asserted	Ground <sup>2</sup>
PIN	False	Deasserted	$V_{DD}^3$
PIN	True	Asserted	$V_{DD}$
PIN	False	Deasserted	Ground

<sup>1</sup> PIN is a generic term for any pin on the chip.

<sup>2</sup> Ground is an acceptable low voltage level. See the appropriate data sheet for the range of acceptable low voltage levels (typically a TTL logic low).

<sup>3</sup>  $V_{DD}$  is an acceptable high voltage level. See the appropriate data sheet for the range of acceptable high voltage levels (typically a TTL logic high).

- Pins or signals that are asserted low (made active when pulled to ground)
  - In text, have an overbar (for example,  $\overline{RESET}$  is asserted low).

- In code examples, have a tilde in front of their names. In example below, line 3 refers to the  $\overline{SS0}$  pin (shown as ~SS0).
- Sets of pins or signals are indicated by the first and last pins or signals in the set (e.g., SDO0–SDO5).
- Code examples are displayed in a monospaced font, as shown below:

#### Example Sample Code Listing

BSET	#\$000007,X:PCRC; Configure:PC7	line 1
BCLR	#\$000007,X:PRRC; Configure:PDC7	line 2
	; SDO4/SDI1 as PC7 for GPIO Input	line 3

- Hex values are indicated with a dollar sign (\$) preceding the hex value, as follows: \$FFFFFF is the X memory address for the core interrupt priority register (IPR-C).
- The word “reset” is used in four different contexts in this manual:
  - the reset signal, written as “ $\overline{\text{RESET}}$ ,”
  - the reset instruction, written as “RESET,”
  - the reset operating state, written as “Reset,” and
  - the reset function, written as “reset.”

## NOTES



# 1 DSP56371 Overview

## 1.1 Introduction

This manual describes the DSP56371 24-bit digital signal processor (DSP), its memory, operating modes and peripheral modules. The DSP56371 is a member of the DSP56300 family of programmable CMOS DSPs. The DSP56371 is targeted to applications that require digital audio compression/decompression, sound field processing, acoustic equalization and other digital audio algorithms. Changes in core functionality specific to the DSP56371 are also described in this manual. See [Figure 1-1](#) for the block diagram of the DSP56371.

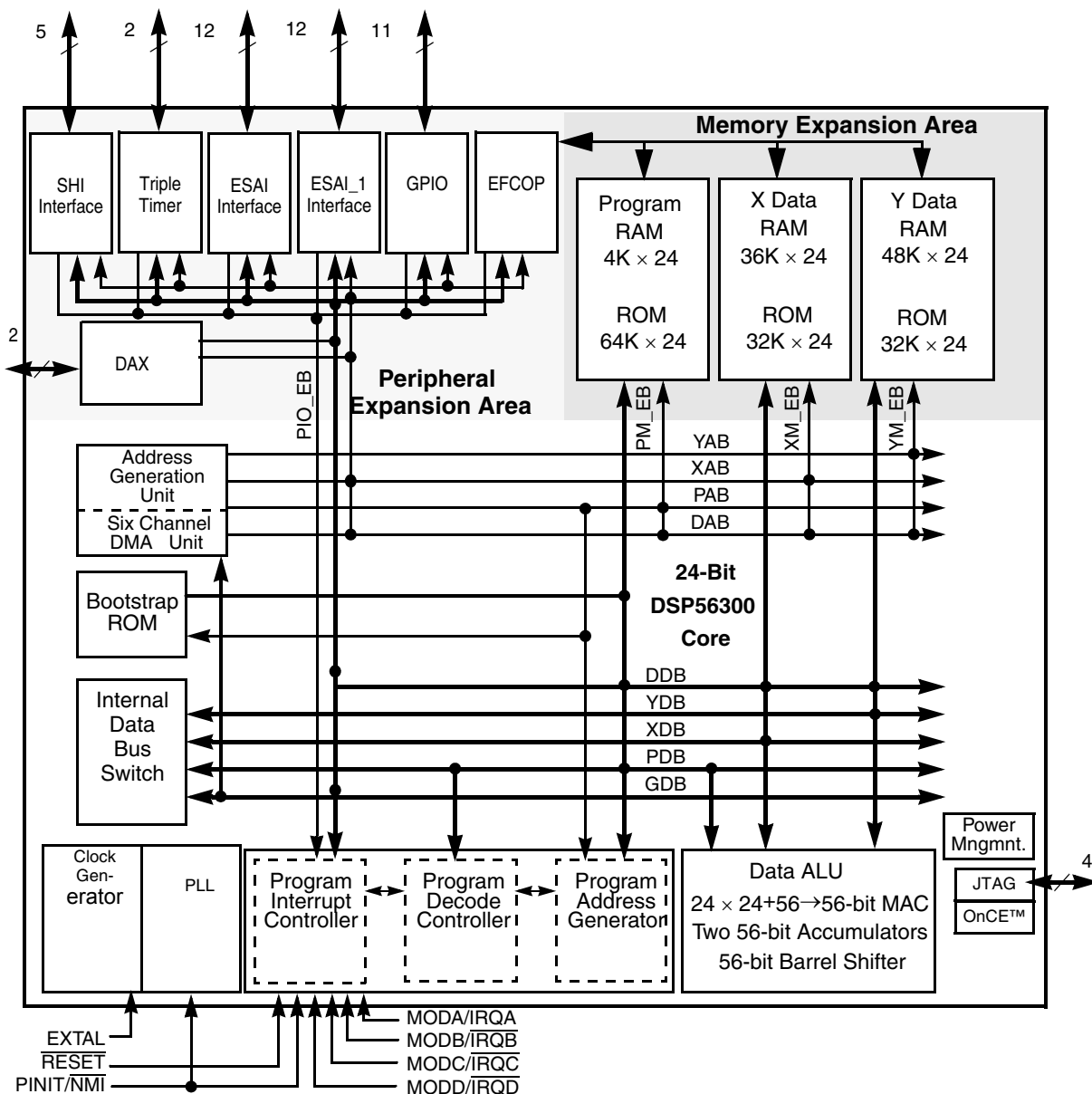


Figure 1-1 DSP56371 Block Diagram

## 1.2 DSP56300 Core Description

The DSP56371 uses the DSP56300 core, a high-performance, single clock cycle per instruction engine that provides up to twice the performance of Freescale's popular DSP56000 core family while retaining code compatibility with it.

The DSP56300 core family offers a new level of performance in speed and power, provided by its rich instruction set and low power dissipation, thus enabling a new generation of wireless, telecommunications and multimedia products. For a description of the DSP56300 core, see [Section 1.4, "DSP56300 Core](#)

[Functional Blocks](#)". Significant architectural enhancements to the DSP56300 core family include a barrel shifter, 24-bit addressing, an instruction patch module and direct memory access (DMA).

The DSP56300 core family members contain the DSP56300 core and additional modules. The modules are chosen from a library of standard predesigned elements such as memories and peripherals. New modules may be added to the library to meet customer specifications. A standard interface between the DSP56300 core and the on-chip memory and peripherals supports a wide variety of memory and peripheral configurations. Refer to [Section 3, "Memory Configuration"](#).

Core features are described fully in the *DSP56300 Family Manual*. Pinout, memory and peripheral features are described in this manual.

- DSP56300 modular chassis
  - 181 Million Instructions Per Second (MIPS) with a 181 MHz clock at an internal logic supply (QVDDL) of 1.25V.
  - Object Code Compatible with the 56K core.
  - Data ALU with a 24 x 24 bit multiplier-accumulator and a 56-bit barrel shifter. 16-bit arithmetic support.
  - Program Control with position independent code support and instruction patch support.
  - EFCOP running concurrently with the core, capable of executing 181 million filter taps per second at peak performance.
  - Six-channel DMA controller.
  - Low jitter, PLL based clocking with a wide range of frequency multiplications (1 to 255), predivider factors (1 to 31) and power saving clock divider ( $2^i$ :  $i=0$  to 7). Reduces clock noise.
  - Internal address tracing support and OnCE for Hardware/Software debugging.
  - JTAG port.
  - Very low-power CMOS design, fully static design with operating frequencies down to DC.
  - STOP and WAIT low-power standby modes.
- On-chip Memory Configuration
  - 48K × 24 Bit Y-Data RAM and 32K × 24 Bit Y-Data ROM.
  - 36K × 24 Bit X-Data RAM and 32K × 24 Bit X-Data ROM.
  - 64K × 24 Bit Program and Bootstrap ROM.
  - 4K × 24 Bit Program RAM.
  - PROM patching mechanism.
  - Up to 32K × 24 Bit from Y Data RAM and 8K × 24 Bit from X Data RAM can be switched to Program RAM resulting in up to 44K × 24 Bit of Program RAM.
- Peripheral modules
  - Enhanced Serial Audio Interface (ESAI): up to 4 receivers and up to 6 transmitters, master or slave. I<sup>2</sup>S, Left justified, Right justified, Sony, AC97, network and other programmable protocols.

- Enhanced Serial Audio Interface I (ESAI\_1): up to 4 receivers and up to 6 transmitters, master or slave. I<sup>2</sup>S, Left justified, Right justified, Sony, AC97, network and other programmable protocols.
- Serial Host Interface (SHI): SPI and I<sup>2</sup>C protocols, multi master capability in I<sup>2</sup>C mode, 10-word receive FIFO, support for 8, 16 and 24-bit words.
- Triple Timer module (TEC).
- 11 dedicated GPIO pins
- Digital Audio Transmitter (DAX): 1 serial transmitter capable of supporting the SPDIF, IEC958, CP-340 and AES/EBU digital audio formats.
- Pins of unused peripherals (except SHI) may be programmed as GPIO lines.

### 1.3 DSP56371 Audio Processor Architecture

This section defines the DSP56371 audio processor architecture. The audio processor is composed of the following units:

- The DSP56300 core is composed of the Data ALU, Address Generation Unit, Program Controller, DMA Controller, Memory Module Interface, Peripheral Module Interface and the On-Chip Emulator (OnCE). The DSP56300 core is described in the document *DSP56300 24-Bit Digital Signal Processor Family Manual*, Freescale publication DSP56300FM.
- Phased Lock Loop and Clock Generator
- Memory modules.
- Peripheral modules. The peripheral modules are defined in the following sections.

Memory sizes in the block diagram are defaults. Memory may be differently partitioned, according to the memory mode of the chip. See [Section 1.4.7, "On-Chip Memory"](#) for more details about memory size.

### 1.4 DSP56300 Core Functional Blocks

The DSP56300 core provides the following functional blocks:

- Data arithmetic logic unit (Data ALU)
- Address generation unit (AGU)
- Program control unit (PCU)
- DMA controller (with six channels)
- Instruction patch controller
- PLL-based clock oscillator
- OnCE module
- Memory

In addition, the DSP56371 provides a set of on-chip peripherals, described in [Section 1.5, "Peripheral Overview"](#).



## 1.4.1 Data ALU

The Data ALU performs all the arithmetic and logical operations on data operands in the DSP56300 core. The components of the Data ALU are as follows:

- Fully pipelined 24-bit  $\times$  24-bit parallel multiplier-accumulator (MAC)
- Bit field unit, comprising a 56-bit parallel barrel shifter (fast shift and normalization; bit stream generation and parsing)
- Conditional ALU instructions
- 24-bit or 16-bit arithmetic support under software control
- Four 24-bit input general purpose registers: X1, X0, Y1 and Y0
- Six Data ALU registers (A2, A1, A0, B2, B1 and B0) that are concatenated into two general purpose, 56-bit accumulators (A and B), accumulator shifters
- Two data bus shifter/limiter circuits

### 1.4.1.1 Data ALU Registers

The Data ALU registers can be read or written over the X memory data bus (XDB) and the Y memory data bus (YDB) as 24- or 48-bit operands (or as 16- or 32-bit operands in 16-bit arithmetic mode). The source operands for the Data ALU, which can be 24, 48, or 56 bits (16, 32, or 40 bits in 16-bit arithmetic mode), always originate from Data ALU registers. The results of all Data ALU operations are stored in an accumulator.

All the Data ALU operations are performed in two clock cycles in pipeline fashion so that a new instruction can be initiated in every clock, yielding an effective execution rate of one instruction per clock cycle. The destination of every arithmetic operation can be used as a source operand for the immediately following arithmetic operation without a time penalty (i.e., without a pipeline stall).

### 1.4.1.2 Multiplier-Accumulator (MAC)

The MAC unit comprises the main arithmetic processing unit of the DSP56300 core and performs all of the calculations on data operands. In the case of arithmetic instructions, the unit accepts as many as three input operands and outputs one 56-bit result of the following form- Extension:Most Significant Product:Least Significant Product (EXT:MSP:LSP).

The multiplier executes 24-bit  $\times$  24-bit, parallel, fractional multiplies, between two's-complement signed, unsigned, or mixed operands. The 48-bit product is right-justified and added to the 56-bit contents of either the A or B accumulator. A 56-bit result can be stored as a 24-bit operand. The LSP can either be truncated or rounded into the MSP. Rounding is performed if specified.

## 1.4.2 Address Generation Unit (AGU)

The AGU performs the effective address calculations using integer arithmetic necessary to address data operands in memory and contains the registers used to generate the addresses. It implements four types of arithmetic: linear, modulo, multiple wrap-around modulo and reverse-carry. The AGU operates in parallel with other chip resources to minimize address-generation overhead.

The AGU is divided into two halves, each with its own Address ALU. Each Address ALU has four sets of register triplets, and each register triplet is composed of an address register, an offset register and a modifier register. The two Address ALUs are identical. Each contains a 24-bit full adder (called an offset adder).

A second full adder (called a modulo adder) adds the summed result of the first full adder to a modulo value that is stored in its respective modifier register. A third full adder (called a reverse-carry adder) is also provided.

The offset adder and the reverse-carry adder are in parallel and share common inputs. The only difference between them is that the carry propagates in opposite directions. Test logic determines which of the three summed results of the full adders is output.

Each Address ALU can update one address register from its respective address register file during one instruction cycle. The contents of the associated modifier register specifies the type of arithmetic to be used in the address register update calculation. The modifier value is decoded in the Address ALU.

### 1.4.3 Program Control Unit (PCU)

The PCU performs instruction prefetch, instruction decoding, hardware DO loop control and exception processing. The PCU implements a seven-stage pipeline and controls the different processing states of the DSP56300 core. The PCU consists of the following three hardware blocks:

- Program decode controller (PDC)
- Program address generator (PAG)
- Program interrupt controller

The PDC decodes the 24-bit instruction loaded into the instruction latch and generates all signals necessary for pipeline control. The PAG contains all the hardware needed for program address generation, system stack and loop control. The Program interrupt controller arbitrates among all interrupt requests (internal interrupts, as well as the five external requests:  $\overline{IRQA}$ ,  $\overline{IRQB}$ ,  $\overline{IRQC}$ ,  $\overline{IRQD}$  and  $\overline{NMI}$ ) and generates the appropriate interrupt vector address.

PCU features include the following:

- Position independent code support
- Addressing modes optimized for DSP applications (including immediate offsets)
- On-chip instruction cache controller
- On-chip memory-expandable hardware stack
- Nested hardware DO loops
- Fast auto-return interrupts

The PCU implements its functions using the following registers:

- PC—program counter register
- SR—Status register
- LA—loop address register
- LC—loop counter register

- VBA—vector base address register
- SZ—stack size register
- SP—stack pointer
- OMR—operating mode register
- SC—stack counter register

The PCU also includes a hardware system stack (SS).

#### 1.4.4 Internal Buses

To provide data exchange between blocks, the following buses are implemented:

- Peripheral input/output expansion bus (PIO\_EB) to peripherals
- Program memory expansion bus (PM\_EB) to program memory
- X memory expansion bus (XM\_EB) to X memory
- Y memory expansion bus (YM\_EB) to Y memory
- Global data bus (GDB) between registers in the DMA, AGU, OnCE, PLL, BIU and PCU, as well as the memory-mapped registers in the peripherals
- DMA data bus (DDB) for carrying DMA data between memories and/or peripherals
- DMA address bus (DAB) for carrying DMA addresses to memories and peripherals
- Program Data Bus (PDB) for carrying program data throughout the core
- X memory Data Bus (XDB) for carrying X data throughout the core
- Y memory Data Bus (YDB) for carrying Y data throughout the core
- Program address bus (PAB) for carrying program memory addresses throughout the core
- X memory address bus (XAB) for carrying X memory addresses throughout the core
- Y memory address bus (YAB) for carrying Y memory addresses throughout the core

All internal buses on the DSP56300 family members are 24-bit buses. See [Figure 1-1](#).

#### 1.4.5 Direct Memory Access (DMA)

The DMA block has the following features:

- Six DMA channels supporting internal and external accesses
- One-, two- and three-dimensional transfers (including circular buffering)
- End-of-block-transfer interrupts
- Triggering from interrupt lines and all peripherals

#### 1.4.6 PLL-based Clock Oscillator

The clock generator in the DSP56300 core is composed of two main blocks: the PLL, which performs clock input division, frequency multiplication, skew elimination and the clock generator (CLKGEN), which performs low-power division and clock pulse generation. PLL-based clocking:

- Allows change of low-power divide factor (DF) without loss of lock
- Provides output clock with skew elimination
- Provides a wide range of frequency multiplications (1 to 255), predivider factors (1 to 31), PLL feedback multiplier (2 or 4), Output divide factor (1, 2 or 4) and a power-saving clock divider ( $2^i$ ;  $i = 0$  to 7) to reduce clock noise

The PLL allows the processor to operate at a high internal clock frequency using a low frequency clock input. This feature offers two immediate benefits:

- A lower frequency clock input reduces the overall electromagnetic interference generated by a system.
- The ability to oscillate at different frequencies reduces costs by eliminating the need to add additional oscillators to a system.

#### NOTE

The PLL will momentarily overshoot the target frequency when the PLL is first enabled or when the VCO frequency is modified. It is important that when modifying the PLL frequency or enabling the PLL that the two step procedure defined in [Section 5, "PLL and Clock Generator"](#) be followed.

### 1.4.7 On-Chip Memory

The memory space of the DSP56300 core is partitioned into program memory space, X data memory space and Y data memory space. The data memory space is divided into X and Y data memory in order to work with the two Address ALUs and to feed two operands simultaneously to the Data ALU. Memory space includes internal RAM and ROM and can not be expanded off-chip.

There is an instruction patch module. The patch module is used to patch program ROM. The memory switch mode is used to increase the size of program RAM as needed (switch from X data RAM and/or Y data RAM).

There are on-chip ROMs for program and bootstrap memory ( $64K \times 24$ -bit), X ROM ( $32K \times 24$ -bit) and Y ROM ( $32K \times 24$ -bit).

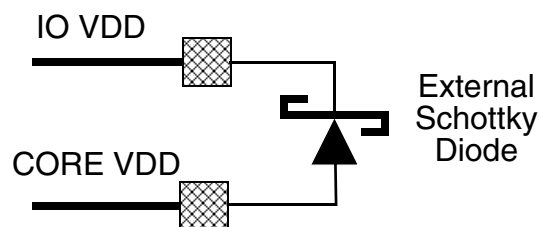
More information on the internal memory is provided in [Section 3, "Memory Configuration"](#).

### 1.4.8 Off-Chip Memory Expansion

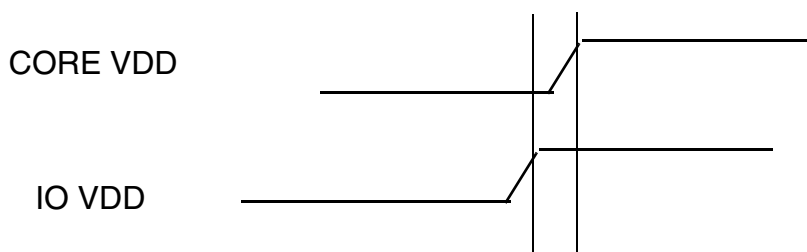
Memory cannot be expanded off-chip. There is no external memory bus.

### 1.4.9 Power Requirements

To prevent high current conditions due to possible improper sequencing of the power supplies, the connection shown below is recommended to be made between the DSP56371 IO\_VDD and CORE\_VDD power pins.



To prevent a high current condition upon power up, the IOVDD must be applied ahead of the CORE VDD as shown below if the external Schottky is not used.



## 1.5 Peripheral Overview

The DSP56371 is designed to perform a wide variety of fixed-point digital signal processing functions. In addition to the core features previously discussed, the DSP56371 provides the following peripherals:

- As many as 39 dedicated or user-configurable general purpose input/output (GPIO) signals
- Timer/event counter (TEC) module, containing three independent timers
- Memory switch mode in on-chip memory
- Four external interrupt/mode control lines and one external non-maskable interrupt line
- Enhanced serial audio interface (ESAI) with up to four receivers and up to six transmitters, master or slave, using the I<sup>2</sup>S, Sony, AC97, network and other programmable protocols
- A second enhanced serial audio interface (ESAI\_1) with up to four receivers and up to six transmitters, master or slave, using the I<sup>2</sup>S, Sony, AC97, network and other programmable protocols.
- Serial host interface (SHI) using SPI and I<sup>2</sup>C protocols, with multi-master capability, 10-word receive FIFO and support for 8-, 16- and 24-bit words
- A Digital audio transmitter (DAX): a serial transmitter capable of supporting the SPDIF, IEC958, CP-340 and AES/EBU digital audio formats

### 1.5.1 General Purpose Input/Output (GPIO)

The DSP56371 provides 11 dedicated GPIO and 28 programmable signals that can operate either as GPIO pins or peripheral pins (ESAI, ESAI\_1, DAX, and TEC). The signals are configured as GPIO after hardware reset. Register programming techniques for all GPIO functionality among these interfaces are very similar and are described in the following sections.

## 1.5.2 Triple Timer (TEC)

This section describes a peripheral module composed of a common 21-bit prescaler and three independent and identical general purpose 24-bit timer/event counters, each one having its own register set.

Each timer can use internal or external clocking and can interrupt the DSP after a specified number of events (clocks). Two of the three timers can signal an external device after counting internal events. Each timer can also be used to trigger DMA transfers after a specified number of events (clocks) occurred. Two of the three timers connect to the external world through bidirectional pins (TIO0, TIO1). When a TIO pin is configured as input, the timer functions as an external event counter or can measure external pulse width/signal period. When a TIO pin is used as output the timer is functioning as either a timer, a watchdog or a Pulse Width Modulator. When a TIO pin is not used by the timer it can be used as a General Purpose Input/Output Pin. Refer to [Section 11, "Triple Timer Module"](#).

## 1.5.3 Enhanced Serial Audio Interface (ESAI)

The ESAI provides a full-duplex serial port for serial communication with a variety of serial devices including one or more industry-standard codecs, other DSPs, microprocessors and peripherals that implement the Freescale SPI serial protocol. The ESAI consists of independent transmitter and receiver sections, each with its own clock generator. It is a superset of the DSP56300 family ESSI peripheral and of the DSP56000 family SAI peripheral. For more information on the ESAI, refer to [Section 8, "Enhanced Serial Audio Interface \(ESAI\)"](#).

## 1.5.4 Enhanced Serial Audio Interface 1 (ESAI\_1)

The ESAI\_1 is a second ESAI interface. The ESAI\_1 is functionally identical to ESAI. For more information on the ESAI\_1, refer to [Section 9, "Enhanced Serial Audio Interface 1 \(ESAI\\_1\)"](#).

## 1.5.5 Serial Host Interface (SHI)

The SHI is a serial input/output interface providing a path for communication and program/coefficient data transfers between the DSP and an external host processor. The SHI can also communicate with other serial peripheral devices. The SHI can interface directly to either of two well-known and widely used synchronous serial buses: the Freescale serial peripheral interface (SPI) bus and the Philips inter-integrated-circuit control (I<sup>2</sup>C) bus. The SHI supports either the SPI or I<sup>2</sup>C bus protocol, as required, from a slave or a single-master device. To minimize DSP overhead, the SHI supports single-, double- and triple-byte data transfers. The SHI has a 10-word receive FIFO that permits receiving up to 30 bytes before generating a receive interrupt, reducing the overhead for data reception. For more information on the SHI, refer to [Section 7, "Serial Host Interface"](#).

## 1.5.6 Digital Audio Transmitter (DAX)

The DAX is a serial audio interface module that outputs digital audio data in the AES/EBU, CP-340 and IEC958 formats. For more information on the DAX, refer to [Section 10, "Digital Audio Transmitter"](#).

## 2 Signal/Connection Descriptions

### 2.1 Signal Groupings

The input and output signals of the DSP56371 are organized into functional groups, which are listed in [Table 2-1](#) and illustrated in [Figure 2-1](#).

The DSP56371 is operated from a 1.25 V and 3.3 V supply; however, some of the inputs can tolerate 5.0 V. A special notice for this feature is added to the signal descriptions of those inputs.

**Table 2-1 DSP56371 Functional Signal Groupings**

Functional Group		Number of Signals	Detailed Description
Power ( $V_{DD}$ )		12	<a href="#">Table 2-2</a>
Ground (GND)		12	<a href="#">Table 2-3</a>
Scan Pins		1	<a href="#">Table 2-4</a>
Clock and PLL		2	<a href="#">Table 2-5</a>
Interrupt and mode control		5	<a href="#">Table 2-6</a>
SHI		5	<a href="#">Table 2-7</a>
ESAI	Port C <sup>1</sup>	12	<a href="#">Table 2-8</a>
ESAI_1	Port E <sup>2</sup>	12	<a href="#">Table 2-9</a>
SPDIF Transmitter (DAX)	Port D <sup>3</sup>	2	<a href="#">Table 2-10</a>
Dedicated GPIO	Port F <sup>4</sup>	11	<a href="#">Table 2-11</a>
Timer		2	<a href="#">Table 2-12</a>
JTAG/OnCE Port		4	<a href="#">Table 2-13</a>

<sup>1</sup> Port C signals are the GPIO port signals which are multiplexed with the ESAI signals.

<sup>2</sup> Port E signals are the GPIO port signals which are multiplexed with the ESAI\_1 signals.

<sup>3</sup> Port D signals are the GPIO port signals which are multiplexed with the DAX signals.

<sup>4</sup> Port F signals are the dedicated GPIO port signals.

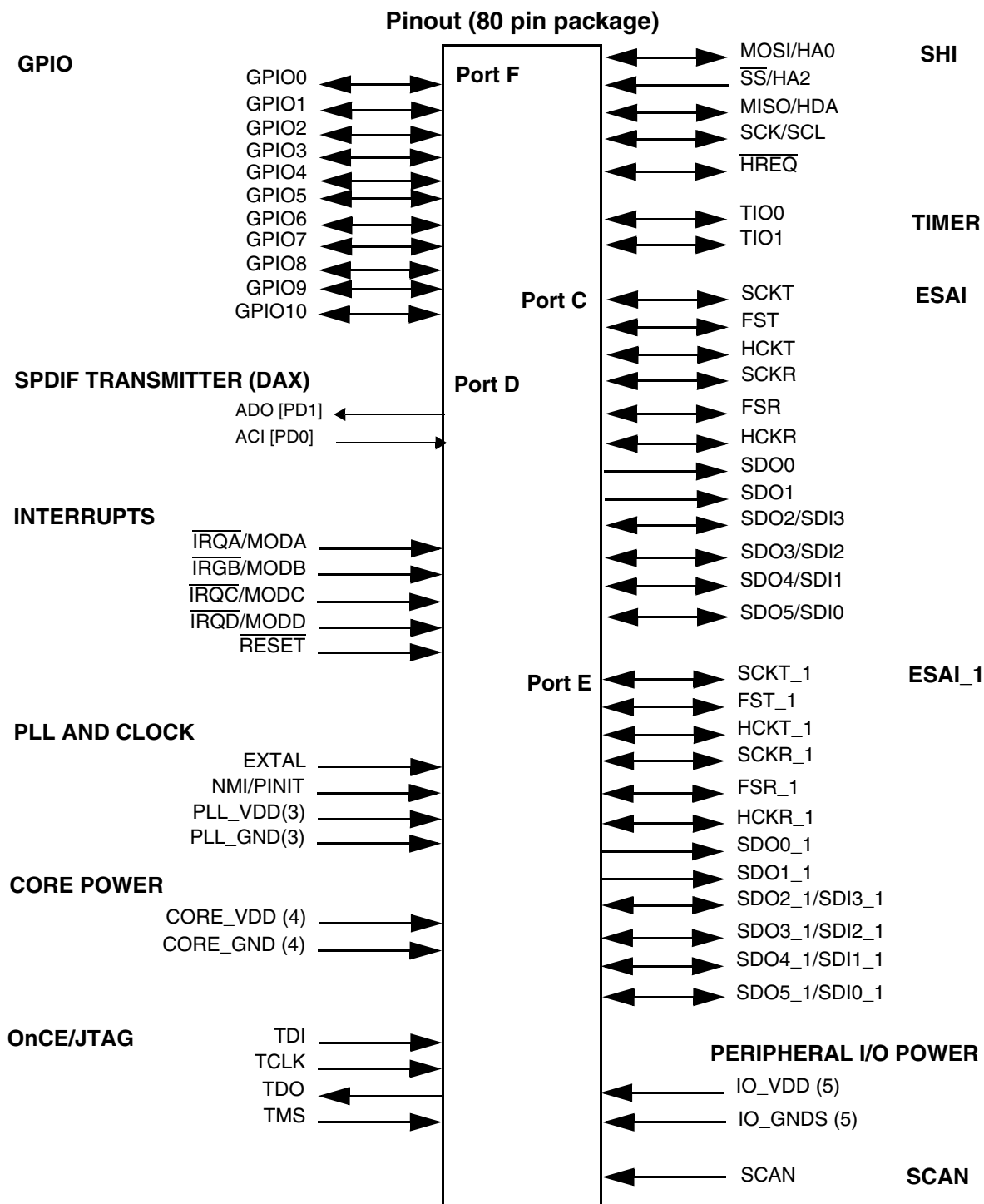


Figure 2-1 Signals Identified by Functional Group



## 2.2 Power

Table 2-2 Power Inputs

Power Name	Description
PLLA_VDD (1) PLL_P_VDD(1)	<b>PLL Power</b> — The voltage (3.3 V) should be well-regulated and the input should be provided with an extremely low impedance path to the 3.3 V <sub>DD</sub> power rail. The user must provide adequate external decoupling capacitors.
PLLD_VDD (1)	<b>PLL Power</b> — The voltage (1.25 V) should be well-regulated and the input should be provided with an extremely low impedance path to the 1.25 V <sub>DD</sub> power rail. The user must provide adequate external decoupling capacitors.
CORE_VDD (4)	<b>Core Power</b> —The voltage (1.25 V) should be well-regulated and the input should be provided with an extremely low impedance path to the 1.25 V <sub>DD</sub> power rail. The user must provide adequate decoupling capacitors.
IO_VDD (5)	<b>SHI, ESAI, ESAI_1, DAX and Timer I/O Power</b> —The voltage (3.3 V) should be well-regulated and the input should be provided with an extremely low impedance path to the 3.3 V <sub>DD</sub> power rail. This is an isolated power for the SHI, ESAI, ESAI_1, DAX and Timer I/O. The user must provide adequate external decoupling capacitors.

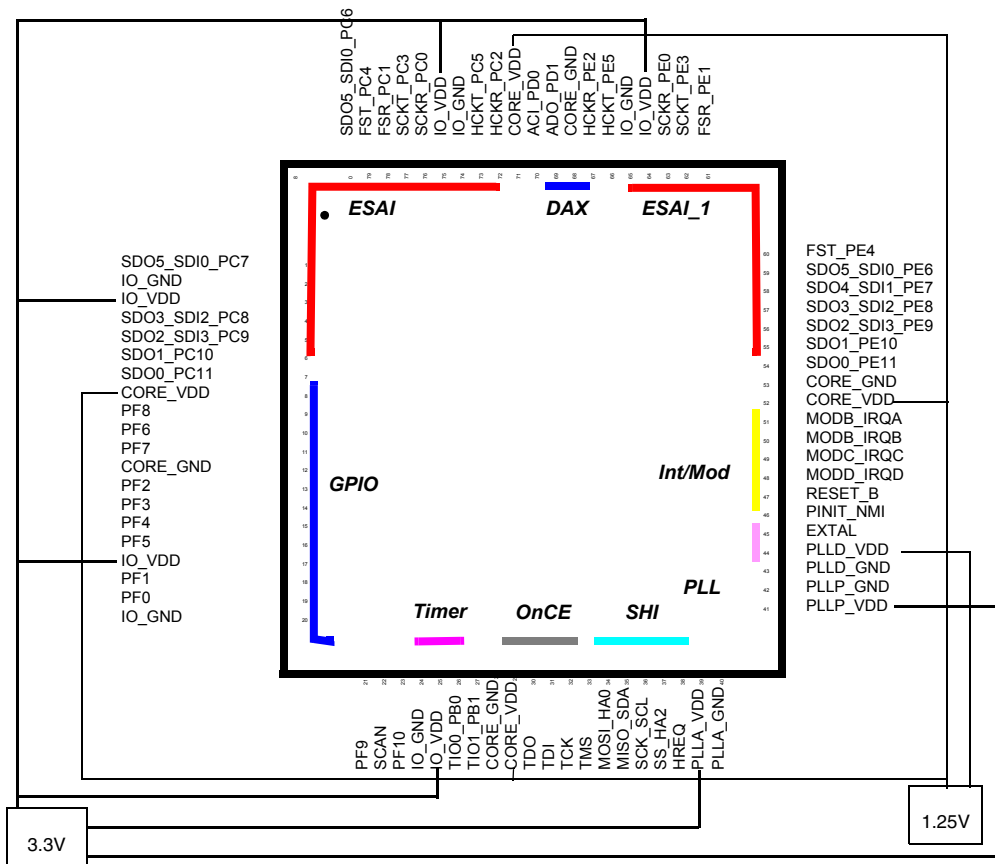


Figure 2-2 VDD connections

## 2.3 Ground

Table 2-3 Grounds

Ground Name	Description
PLLA_GND(1) PLLP_GND(1)	<b>PLL Ground</b> —The PLL ground should be provided with an extremely low-impedance path to ground. The user must provide adequate external decoupling capacitors.
PLLD_GND(1)	<b>PLL Ground</b> —The PLL ground should be provided with an extremely low-impedance path to ground. The user must provide adequate external decoupling capacitors.
CORE_GND (4)	<b>Core Ground</b> —The Core ground should be provided with an extremely low-impedance path to ground. This connection must be tied externally to all other chip ground connections. The user must provide adequate external decoupling capacitors.
IO_GND (5)	<b>SHI, ESAI, ESAI_1, DAX and Timer I/O Ground</b> —IO_GND is an isolated ground for the SHI, ESAI, ESAI_1, DAX and Timer I/O. This connection must be tied externally to all other chip ground connections. The user must provide adequate external decoupling capacitors.

## 2.4 SCAN

Table 2-4 SCAN signals

Signal Name	Type	State during Reset	Signal Description
SCAN	Input	Input	<b>SCAN</b> —Manufacturing test pin. This pin should be pulled low. <i>Internal pull-down resistor.</i>

## 2.5 Clock and PLL

Table 2-5 Clock and PLL Signals

Signal Name	Type	State during Reset	Signal Description
EXTAL	Input	Input	<b>External Clock Input</b> —An external clock source must be connected to EXTAL in order to supply the clock to the internal clock generator and PLL. <i>This input cannot tolerate 5 V.</i>
PINIT/NM $\bar{I}$	Input	Input	<b>PLL Initial/Nonmaskable Interrupt</b> —During assertion of $\overline{\text{RESET}}$ , the value of PINIT/NM $\bar{I}$ is written into the PLL Enable (PEN) bit of the PLL control register, determining whether the PLL is enabled or disabled. After $\overline{\text{RESET}}$ de assertion and during normal instruction processing, the PINIT/NM $\bar{I}$ Schmitt-trigger input is a negative-edge-triggered nonmaskable interrupt (NMI) request internally synchronized to internal system clock. <i>Internal pull-up resistor.</i> <i>This input is 5 V tolerant.</i>

## 2.6 Interrupt and Mode Control

The interrupt and mode control signals select the chip's operating mode as it comes out of hardware reset. After  $\overline{\text{RESET}}$  is deasserted, these inputs are hardware interrupt request lines.

**Table 2-6 Interrupt and Mode Control**

Signal Name	Type	State during Reset	Signal Description
MODA/ $\overline{\text{IRQA}}$	Input	Input	<p><b>Mode Select A/External Interrupt Request A</b>—MODA/<math>\overline{\text{IRQA}}</math> is an active-low Schmitt-trigger input, internally synchronized to the DSP clock. MODA/<math>\overline{\text{IRQA}}</math> selects the initial chip operating mode during hardware reset and becomes a level-sensitive or negative-edge-triggered, maskable interrupt request input during normal instruction processing. MODA, MODB, MODC and MODD select one of 16 initial chip operating modes, latched into the OMR when the <math>\overline{\text{RESET}}</math> signal is deasserted. If the processor is in the stop standby state and the MODA/<math>\overline{\text{IRQA}}</math> pin is pulled to GND, the processor will exit the stop state.</p> <p><i>Internal pull-up resistor.</i>  <i>This input is 5 V tolerant.</i></p>
MODB/ $\overline{\text{IRQB}}$	Input	Input	<p><b>Mode Select B/External Interrupt Request B</b>—MODB/<math>\overline{\text{IRQB}}</math> is an active-low Schmitt-trigger input, internally synchronized to the DSP clock. MODB/<math>\overline{\text{IRQB}}</math> selects the initial chip operating mode during hardware reset and becomes a level-sensitive or negative-edge-triggered, maskable interrupt request input during normal instruction processing. MODA, MODB, MODC and MODD select one of 16 initial chip operating modes, latched into OMR when the <math>\overline{\text{RESET}}</math> signal is deasserted.</p> <p><i>Internal pull-up resistor.</i>  <i>This input is 5 V tolerant.</i></p>
MODC/ $\overline{\text{IRQC}}$	Input	Input	<p><b>Mode Select C/External Interrupt Request C</b>—MODC/<math>\overline{\text{IRQC}}</math> is an active-low Schmitt-trigger input, internally synchronized to the DSP clock. MODC/<math>\overline{\text{IRQC}}</math> selects the initial chip operating mode during hardware reset and becomes a level-sensitive or negative-edge-triggered, maskable interrupt request input during normal instruction processing. MODA, MODB, MODC and MODD select one of 16 initial chip operating modes, latched into OMR when the <math>\overline{\text{RESET}}</math> signal is deasserted.</p> <p><i>Internal pull-up resistor.</i>  <i>This input is 5 V tolerant.</i></p>

Table 2-6 Interrupt and Mode Control (continued)

Signal Name	Type	State during Reset	Signal Description
MODD/ $\overline{\text{IRQD}}$	Input	Input	<p><b>Mode Select D/External Interrupt Request D</b>—MODD/<math>\overline{\text{IRQD}}</math> is an active-low Schmitt-trigger input, internally synchronized to the DSP clock. MODD/<math>\overline{\text{IRQD}}</math> selects the initial chip operating mode during hardware reset and becomes a level-sensitive or negative-edge-triggered, maskable interrupt request input during normal instruction processing. MODA, MODB, MODC and MODD select one of 16 initial chip operating modes, latched into OMR when the <math>\overline{\text{RESET}}</math> signal is deasserted.</p> <p><i>Internal pull-up resistor.</i>  <i>This input is 5 V tolerant.</i></p>
RESET	Input	Input	<p><b>Reset</b>—<math>\overline{\text{RESET}}</math> is an active-low, Schmitt-trigger input. When asserted, the chip is placed in the Reset state and the internal phase generator is reset. The Schmitt-trigger input allows a slowly rising input (such as a capacitor charging) to reset the chip reliably. When the <math>\overline{\text{RESET}}</math> signal is deasserted, the initial chip operating mode is latched from the MODA, MODB, MODC and MODD inputs. The <math>\overline{\text{RESET}}</math> signal must be asserted during power up. A stable EXTAL signal must be supplied while <math>\overline{\text{RESET}}</math> is being asserted.</p> <p><i>Internal pull-up resistor.</i>  <i>This input is 5 V tolerant.</i></p>

## 2.7 Serial Host Interface

The SHI has five I/O signals that can be configured to allow the SHI to operate in either SPI or I<sup>2</sup>C mode.

Table 2-7 Serial Host Interface Signals

Signal Name	Signal Type	State during Reset	Signal Description
SCK	Input or output	Tri-stated	<p><b>SPI Serial Clock</b>—The SCK signal is an output when the SPI is configured as a master and a Schmitt-trigger input when the SPI is configured as a slave. When the SPI is configured as a master, the SCK signal is derived from the internal SHI clock generator. When the SPI is configured as a slave, the SCK signal is an input, and the clock signal from the external master synchronizes the data transfer. The SCK signal is ignored by the SPI if it is defined as a slave and the slave select (<math>\overline{\text{SS}}</math>) signal is not asserted. In both the master and slave SPI devices, data is shifted on one edge of the SCK signal and is sampled on the opposite edge where data is stable. Edge polarity is determined by the SPI transfer protocol.</p>
SCL	Input or output		<p><b>I<sup>2</sup>C Serial Clock</b>—SCL carries the clock for I<sup>2</sup>C bus transactions in the I<sup>2</sup>C mode. SCL is a Schmitt-trigger input when configured as a slave and an open-drain output when configured as a master. SCL should be connected to V<sub>DD</sub> through a pull-up resistor.</p>
			<p>This signal is tri-stated during hardware, software and individual reset. Thus, there is no need for an external pull-up in this state.</p> <p><i>Internal Pull-up resistor.</i>  <i>This input is 5 V tolerant.</i></p>

Table 2-7 Serial Host Interface Signals (continued)

Signal Name	Signal Type	State during Reset	Signal Description
MISO	Input or output	Tri-stated	<b>SPI Master-In-Slave-Out</b> —When the SPI is configured as a master, MISO is the master data input line. The MISO signal is used in conjunction with the MOSI signal for transmitting and receiving serial data. This signal is a Schmitt-trigger input when configured for the SPI Master mode, an output when configured for the SPI Slave mode, and tri-stated if configured for the SPI Slave mode when $\overline{SS}$ is deasserted. An external pull-up resistor is not required for SPI operation.
SDA	Input or open-drain output		<b>I<sup>2</sup>C Data and Acknowledge</b> —In I <sup>2</sup> C mode, SDA is a Schmitt-trigger input when receiving and an open-drain output when transmitting. SDA should be connected to $V_{DD}$ through a pull-up resistor. SDA carries the data for I <sup>2</sup> C transactions. The data in SDA must be stable during the high period of SCL. The data in SDA is only allowed to change when SCL is low. When the bus is free, SDA is high. The SDA line is only allowed to change during the time SCL is high in the case of start and stop events. A high-to-low transition of the SDA line while SCL is high is a unique situation, and it is defined as the start event. A low-to-high transition of SDA while SCL is high is a unique situation defined as the stop event.
			This signal is tri-stated during hardware, software and individual reset. Thus, there is no need for an external pull-up in this state. <i>Internal pull-up resistor.</i> <i>This input is 5 V tolerant.</i>
MOSI	Input or output	Tri-stated	<b>SPI Master-Out-Slave-In</b> —When the SPI is configured as a master, MOSI is the master data output line. The MOSI signal is used in conjunction with the MISO signal for transmitting and receiving serial data. MOSI is the slave data input line when the SPI is configured as a slave. This signal is a Schmitt-trigger input when configured for the SPI Slave mode.
HA0	Input		<b>I<sup>2</sup>C Slave Address 0</b> —This signal uses a Schmitt-trigger input when configured for the I <sup>2</sup> C mode. When configured for I <sup>2</sup> C slave mode, the HA0 signal is used to form the slave device address. HA0 is ignored when configured for the I <sup>2</sup> C master mode.
			This signal is tri-stated during hardware, software and individual reset. Thus, there is no need for an external pull-up in this state. <i>Internal pull-up resistor.</i> <i>This input is 5 V tolerant.</i>

Table 2-7 Serial Host Interface Signals (continued)

Signal Name	Signal Type	State during Reset	Signal Description
$\overline{SS}$	Input	Tri-stated	<b>SPI Slave Select</b> —This signal is an active low Schmitt-trigger input when configured for the SPI mode. When configured for the SPI Slave mode, this signal is used to enable the SPI slave for transfer. When configured for the SPI master mode, this signal should be kept deasserted (pulled high). If it is asserted while configured as SPI master, a bus error condition is flagged. If $\overline{SS}$ is deasserted, the SHI ignores SCK clocks and keeps the MISO output signal in the high-impedance state.
HA2	Input		<b>I<sup>2</sup>C Slave Address 2</b> —This signal uses a Schmitt-trigger input when configured for the I <sup>2</sup> C mode. When configured for the I <sup>2</sup> C Slave mode, the HA2 signal is used to form the slave device address. HA2 is ignored in the I <sup>2</sup> C master mode.
			This signal is tri-stated during hardware, software and individual reset. Thus, there is no need for an external pull-up in this state. <i>Internal pull-up resistor.</i> <i>This input is 5 V tolerant.</i>
$\overline{HREQ}$	Input or Output	Tri-stated	<b>Host Request</b> —This signal is an active low Schmitt-trigger input when configured for the master mode but an active low output when configured for the slave mode.
			When configured for the slave mode, $\overline{HREQ}$ is asserted to indicate that the SHI is ready for the next data word transfer and deasserted at the first clock pulse of the new data word transfer. When configured for the master mode, $\overline{HREQ}$ is an input. When asserted by the external slave device, it will trigger the start of the data word transfer by the master. After finishing the data word transfer, the master will await the next assertion of $\overline{HREQ}$ to proceed to the next transfer.
			This signal is tri-stated during hardware, software, personal reset, or when the HREQ1–HREQ0 bits in the HCSR are cleared. There is no need for an external pull-up in this state. <i>Internal pull-up resistor.</i> <i>This input is 5 V tolerant.</i>

## 2.8 Enhanced Serial Audio Interface

Table 2-8 Enhanced Serial Audio Interface Signals

Signal Name	Signal Type	State during Reset	Signal Description
HCKR	Input or output	GPIO disconnected	<b>High Frequency Clock for Receiver</b> —When programmed as an input, this signal provides a high frequency clock source for the ESAI receiver as an alternate to the DSP core clock. When programmed as an output, this signal can serve as a high-frequency sample clock (e.g., for external digital to analog converters [DACs]) or as an additional system clock.
PC2	Input, output, or disconnected	GPIO disconnected	<b>Port C2</b> —When the ESAI is configured as GPIO, this signal is individually programmable as input, output, or internally disconnected.  The default state after reset is GPIO disconnected. <i>Internal pull-down resistor.</i> <i>This input is 5 V tolerant..</i>
HCKT	Input or output	GPIO disconnected	<b>High Frequency Clock for Transmitter</b> —When programmed as an input, this signal provides a high frequency clock source for the ESAI transmitter as an alternate to the DSP core clock. When programmed as an output, this signal can serve as a high frequency sample clock (e.g., for external DACs) or as an additional system clock.
PC5	Input, output, or disconnected	GPIO disconnected	<b>Port C5</b> —When the ESAI is configured as GPIO, this signal is individually programmable as input, output, or internally disconnected.  The default state after reset is GPIO disconnected. <i>Internal pull-down resistor.</i> <i>This input is 5 V tolerant.</i>

Table 2-8 Enhanced Serial Audio Interface Signals (continued)

Signal Name	Signal Type	State during Reset	Signal Description
FSR	Input or output	GPIO disconnected	<p><b>Frame Sync for Receiver</b>—This is the receiver frame sync input/output signal. In the asynchronous mode (SYN=0), the FSR pin operates as the frame sync input or output used by all the enabled receivers. In the synchronous mode (SYN=1), it operates as either the serial flag 1 pin (TEBE=0), or as the transmitter external buffer enable control (TEBE=1, RFSD=1).</p> <p>When this pin is configured as serial flag pin, its direction is determined by the RFSD bit in the RCCR register. When configured as the output flag OF1, this pin will reflect the value of the OF1 bit in the SAICR register, and the data in the OF1 bit will show up at the pin synchronized to the frame sync in normal mode or the slot in network mode. When configured as the input flag IF1, the data value at the pin will be stored in the IF1 bit in the SAISR register, synchronized by the frame sync in normal mode or the slot in network mode.</p>
PC1	Input, output, or disconnected	GPIO disconnected	<p><b>Port C1</b>—When the ESAI is configured as GPIO, this signal is individually programmable as input, output, or internally disconnected.</p> <p>The default state after reset is GPIO disconnected.</p> <p><i>Internal pull-down resistor.</i> <i>This input is 5 V tolerant.</i></p>
FST	Input or output	GPIO disconnected	<p><b>Frame Sync for Transmitter</b>—This is the transmitter frame sync input/output signal. For synchronous mode, this signal is the frame sync for both transmitters and receivers. For asynchronous mode, FST is the frame sync for the transmitters only. The direction is determined by the transmitter frame sync direction (TFSD) bit in the ESAI transmit clock control register (TCCR).</p>
PC4	Input, output, or disconnected	GPIO disconnected	<p><b>Port C4</b>—When the ESAI is configured as GPIO, this signal is individually programmable as input, output, or internally disconnected.</p> <p>The default state after reset is GPIO disconnected.</p> <p><i>Internal pull-down resistor.</i> <i>This input is 5 V tolerant.</i></p>



Table 2-8 Enhanced Serial Audio Interface Signals (continued)

Signal Name	Signal Type	State during Reset	Signal Description
SCKR	Input or output	GPIO disconnected	<p><b>Receiver Serial Clock</b>—SCKR provides the receiver serial bit clock for the ESAI. The SCKR operates as a clock input or output used by all the enabled receivers in the asynchronous mode (SYN=0), or as serial flag 0 pin in the synchronous mode (SYN=1).</p> <p>When this pin is configured as serial flag pin, its direction is determined by the RCKD bit in the RCCR register. When configured as the output flag OF0, this pin will reflect the value of the OF0 bit in the SAICR register, and the data in the OF0 bit will show up at the pin synchronized to the frame sync in normal mode or the slot in network mode. When configured as the input flag IF0, the data value at the pin will be stored in the IF0 bit in the SAISR register, synchronized by the frame sync in normal mode or the slot in network mode.</p>
PC0	Input, output, or disconnected	GPIO disconnected	<p><b>Port C0</b>—When the ESAI is configured as GPIO, this signal is individually programmable as input, output, or internally disconnected.</p> <p>The default state after reset is GPIO disconnected.</p> <p><i>Internal pull-down resistor.</i> <i>This input is 5 V tolerant.</i></p>
SCKT	Input or output	GPIO disconnected	<p><b>Transmitter Serial Clock</b>—This signal provides the serial bit rate clock for the ESAI. SCKT is a clock input or output used by all enabled transmitters and receivers in synchronous mode, or by all enabled transmitters in asynchronous mode.</p>
PC3	Input, output, or disconnected	GPIO disconnected	<p><b>Port C3</b>—When the ESAI is configured as GPIO, this signal is individually programmable as input, output, or internally disconnected.</p> <p>The default state after reset is GPIO disconnected.</p> <p><i>Internal pull-down resistor.</i> <i>This input is 5 V tolerant.</i></p>
SDO5	Output	GPIO disconnected	<p><b>Serial Data Output 5</b>—When programmed as a transmitter, SDO5 is used to transmit data from the TX5 serial transmit shift register.</p>
SDI0	Input	GPIO disconnected	<p><b>Serial Data Input 0</b>—When programmed as a receiver, SDI0 is used to receive serial data into the RX0 serial receive shift register.</p>
PC6	Input, output, or disconnected	GPIO disconnected	<p><b>Port C6</b>—When the ESAI is configured as GPIO, this signal is individually programmable as input, output, or internally disconnected.</p> <p>The default state after reset is GPIO disconnected.</p> <p><i>Internal pull-down resistor.</i> <i>This input is 5 V tolerant.</i></p>

Table 2-8 Enhanced Serial Audio Interface Signals (continued)

Signal Name	Signal Type	State during Reset	Signal Description
SDO4	Output	GPIO disconnected	<b>Serial Data Output 4</b> —When programmed as a transmitter, SDO4 is used to transmit data from the TX4 serial transmit shift register.
SDI1	Input		<b>Serial Data Input 1</b> —When programmed as a receiver, SDI1 is used to receive serial data into the RX1 serial receive shift register.
PC7	Input, output, or disconnected		<b>Port C7</b> —When the ESAI is configured as GPIO, this signal is individually programmable as input, output, or internally disconnected.  The default state after reset is GPIO disconnected. <i>Internal pull-down resistor.</i> <i>This input is 5 V tolerant.</i>
SDO3	Output	GPIO disconnected	<b>Serial Data Output 3</b> —When programmed as a transmitter, SDO3 is used to transmit data from the TX3 serial transmit shift register.
SDI2	Input		<b>Serial Data Input 2</b> —When programmed as a receiver, SDI2 is used to receive serial data into the RX2 serial receive shift register.
PC8	Input, output, or disconnected		<b>Port C8</b> —When the ESAI is configured as GPIO, this signal is individually programmable as input, output, or internally disconnected.  The default state after reset is GPIO disconnected. <i>Internal pull-down resistor.</i> <i>This input is 5 V tolerant.</i>
SDO2	Output	GPIO disconnected	<b>Serial Data Output 2</b> —When programmed as a transmitter, SDO2 is used to transmit data from the TX2 serial transmit shift register
SDI3	Input		<b>Serial Data Input 3</b> —When programmed as a receiver, SDI3 is used to receive serial data into the RX3 serial receive shift register.
PC9	Input, output, or disconnected		<b>Port C9</b> —When the ESAI is configured as GPIO, this signal is individually programmable as input, output, or internally disconnected.  The default state after reset is GPIO disconnected. <i>Internal pull-down resistor.</i> <i>This input is 5 V tolerant.</i>
SDO1	Output	GPIO disconnected	<b>Serial Data Output 1</b> —SDO1 is used to transmit data from the TX1 serial transmit shift register.
PC10	Input, output, or disconnected		<b>Port C10</b> —When the ESAI is configured as GPIO, this signal is individually programmable as input, output, or internally disconnected.  The default state after reset is GPIO disconnected. <i>Internal pull-down resistor.</i> <i>This input is 5 V tolerant.</i>

Table 2-8 Enhanced Serial Audio Interface Signals (continued)

Signal Name	Signal Type	State during Reset	Signal Description
SDO0	Output	GPIO disconnected	<b>Serial Data Output 0</b> —SDO0 is used to transmit data from the TX0 serial transmit shift register.
PC11	Input, output, or disconnected	GPIO disconnected	<p><b>Port C11</b>—When the ESAI is configured as GPIO, this signal is individually programmable as input, output, or internally disconnected.</p> <p>The default state after reset is GPIO disconnected.</p> <p><i>Internal pull-down resistor.</i></p> <p><i>This input is 5 V tolerant.</i></p>

## 2.9 Enhanced Serial Audio Interface\_1

Table 2-9 Enhanced Serial Audio Interface\_1 Signals

Signal Name	Signal Type	State during Reset	Signal Description
HCKR_1	Input or output	GPIO disconnected	<b>High Frequency Clock for Receiver</b> —When programmed as an input, this signal provides a high frequency clock source for the ESAI_1 receiver as an alternate to the DSP core clock. When programmed as an output, this signal can serve as a high-frequency sample clock (e.g., for external digital to analog converters [DACs]) or as an additional system clock.
PE2	Input, output, or disconnected	GPIO disconnected	<p><b>Port E2</b>—When the ESAI_1 is configured as GPIO, this signal is individually programmable as input, output, or internally disconnected.</p> <p>The default state after reset is GPIO disconnected.</p> <p><i>Internal pull-down resistor.</i></p> <p><i>This input is 5 V tolerant.</i></p>
HCKT_1	Input or output	GPIO disconnected	<b>High Frequency Clock for Transmitter</b> —When programmed as an input, this signal provides a high frequency clock source for the ESAI_1 transmitter as an alternate to the DSP core clock. When programmed as an output, this signal can serve as a high frequency sample clock (e.g., for external DACs) or as an additional system clock.
PE5	Input, output, or disconnected	GPIO disconnected	<p><b>Port E5</b>—When the ESAI_1 is configured as GPIO, this signal is individually programmable as input, output, or internally disconnected.</p> <p>The default state after reset is GPIO disconnected.</p> <p><i>Internal pull-down resistor.</i></p> <p><i>This input is 5 V tolerant.</i></p>

Table 2-9 Enhanced Serial Audio Interface\_1 Signals (continued)

Signal Name	Signal Type	State during Reset	Signal Description
FSR_1	Input or output	GPIO disconnected	<p><b>Frame Sync for Receiver_1</b>—This is the receiver frame sync input/output signal. In the asynchronous mode (SYN=0), the FSR_1 pin operates as the frame sync input or output used by all the enabled receivers. In the synchronous mode (SYN=1), it operates as either the serial flag 1 pin (TEBE=0), or as the transmitter external buffer enable control (TEBE=1, RFSD=1).</p> <p>When this pin is configured as serial flag pin, its direction is determined by the RFSD bit in the RCCR_1 register. When configured as the output flag OF1, this pin will reflect the value of the OF1 bit in the SAICR_1 register, and the data in the OF1 bit will show up at the pin synchronized to the frame sync in normal mode or the slot in network mode. When configured as the input flag IF1, the data value at the pin will be stored in the IF1 bit in the SAISR register, synchronized by the frame sync in normal mode or the slot in network mode.</p>
PE1	Input, output, or disconnected	GPIO disconnected	<p><b>Port E1</b>—When the ESAI_1 is configured as GPIO, this signal is individually programmable as input, output, or internally disconnected.</p> <p>The default state after reset is GPIO disconnected.</p> <p><i>Internal pull-down resistor.</i></p> <p><i>This input is 5 V tolerant.</i></p>
FST_1	Input or output	GPIO disconnected	<p><b>Frame Sync for Transmitter_1</b>—This is the transmitter frame sync input/output signal. For synchronous mode, this signal is the frame sync for both transmitters and receivers. For asynchronous mode, FST_1 is the frame sync for the transmitters only. The direction is determined by the transmitter frame sync direction (TFSD) bit in the ESAI_1 transmit clock control register (TCCR_1).</p>
PE4	Input, output, or disconnected	GPIO disconnected	<p><b>Port E4</b>—When the ESAI_1 is configured as GPIO, this signal is individually programmable as input, output, or internally disconnected.</p> <p>The default state after reset is GPIO disconnected.</p> <p><i>Internal pull-down resistor.</i></p> <p><i>This input is 5 V tolerant.</i></p>

Table 2-9 Enhanced Serial Audio Interface\_1 Signals (continued)

Signal Name	Signal Type	State during Reset	Signal Description
SCKR_1	Input or output	GPIO disconnected	<p><b>Receiver Serial Clock_1</b>—SCKR_1 provides the receiver serial bit clock for the ESAI_1. The SCKR_1 operates as a clock input or output used by all the enabled receivers in the asynchronous mode (SYN=0), or as serial flag 0 pin in the synchronous mode (SYN=1).</p> <p>When this pin is configured as serial flag pin, its direction is determined by the RCKD bit in the RCCR_1 register. When configured as the output flag OF0, this pin will reflect the value of the OF0 bit in the SAICR_1 register, and the data in the OF0 bit will show up at the pin synchronized to the frame sync in normal mode or the slot in network mode. When configured as the input flag IF0, the data value at the pin will be stored in the IF0 bit in the SAISR_1 register, synchronized by the frame sync in normal mode or the slot in network mode.</p>
PE0	Input, output, or disconnected		<p><b>Port E0</b>—When the ESAI_1 is configured as GPIO, this signal is individually programmable as input, output, or internally disconnected.</p> <p>The default state after reset is GPIO disconnected.</p> <p><i>Internal pull-down resistor.</i>  <i>This input is 5 V tolerant.</i></p>
SCKT_1	Input or output	GPIO disconnected	<p><b>Transmitter Serial Clock_1</b>—This signal provides the serial bit rate clock for the ESAI_1. SCKT_1 is a clock input or output used by all enabled transmitters and receivers in synchronous mode, or by all enabled transmitters in asynchronous mode.</p>
PE3	Input, output, or disconnected		<p><b>Port E3</b>—When the ESAI_1 is configured as GPIO, this signal is individually programmable as input, output, or internally disconnected.</p> <p>The default state after reset is GPIO disconnected.</p> <p><i>Internal pull-down resistor.</i>  <i>This input is 5 V tolerant.</i></p>
SDO5_1	Output	GPIO disconnected	<p><b>Serial Data Output 5_1</b>—When programmed as a transmitter, SDO5_1 is used to transmit data from the TX5 serial transmit shift register.</p>
SDI0_1	Input		<p><b>Serial Data Input 0_1</b>—When programmed as a receiver, SDI0_1 is used to receive serial data into the RX0 serial receive shift register.</p>
PE6	Input, output, or disconnected		<p><b>Port E6</b>—When the ESAI_1 is configured as GPIO, this signal is individually programmable as input, output, or internally disconnected.</p> <p>The default state after reset is GPIO disconnected.</p> <p><i>Internal pull-down resistor.</i>  <i>This input is 5 V tolerant.</i></p>

Table 2-9 Enhanced Serial Audio Interface\_1 Signals (continued)

Signal Name	Signal Type	State during Reset	Signal Description
SDO4_1	Output	GPIO disconnected	<b>Serial Data Output 4_1</b> —When programmed as a transmitter, SDO4_1 is used to transmit data from the TX4 serial transmit shift register.
SDI1_1	Input		<b>Serial Data Input 1_1</b> —When programmed as a receiver, SDI1_1 is used to receive serial data into the RX1 serial receive shift register.
PE7	Input, output, or disconnected		<b>Port E7</b> —When the ESAI_1 is configured as GPIO, this signal is individually programmable as input, output, or internally disconnected.  The default state after reset is GPIO disconnected. <i>Internal pull-down resistor.</i> <i>This input is 5 V tolerant.</i>
SDO3_1	Output	GPIO disconnected	<b>Serial Data Output 3</b> —When programmed as a transmitter, SDO3_1 is used to transmit data from the TX3 serial transmit shift register.
SDI2_1	Input		<b>Serial Data Input 2</b> —When programmed as a receiver, SDI2_1 is used to receive serial data into the RX2 serial receive shift register.
PE8	Input, output, or disconnected		<b>Port E8</b> —When the ESAI_1 is configured as GPIO, this signal is individually programmable as input, output, or internally disconnected.  The default state after reset is GPIO disconnected. <i>Internal pull-down resistor.</i> <i>This input is 5 V tolerant.</i>
SDO2_1	Output	GPIO disconnected	<b>Serial Data Output 2</b> —When programmed as a transmitter, SDO2_1 is used to transmit data from the TX2 serial transmit shift register.
SDI3_1	Input		<b>Serial Data Input 3</b> —When programmed as a receiver, SDI3_1 is used to receive serial data into the RX3 serial receive shift register.
PE9	Input, output, or disconnected		<b>Port E9</b> —When the ESAI_1 is configured as GPIO, this signal is individually programmable as input, output, or internally disconnected.  The default state after reset is GPIO disconnected. <i>Internal pull-down resistor.</i> <i>This input is 5 V tolerant.</i>
SDO1_1	Output	GPIO disconnected	<b>Serial Data Output 1</b> —SDO1_1 is used to transmit data from the TX1 serial transmit shift register.
PE10	Input, output, or disconnected		<b>Port E10</b> —When the ESAI_1 is configured as GPIO, this signal is individually programmable as input, output, or internally disconnected.  The default state after reset is GPIO disconnected. <i>Internal pull-down resistor.</i> <i>This input is 5 V tolerant.</i>

Table 2-9 Enhanced Serial Audio Interface\_1 Signals (continued)

Signal Name	Signal Type	State during Reset	Signal Description
SDO0_1	Output	GPIO disconnected	<b>Serial Data Output 0</b> —SDO0_1 is used to transmit data from the TX0 serial transmit shift register.
PE11	Input, output, or disconnected		<p><b>Port E11</b>—When the ESAI_1 is configured as GPIO, this signal is individually programmable as input, output, or internally disconnected.</p> <p>The default state after reset is GPIO disconnected.</p> <p><i>Internal pull-down resistor.</i></p> <p><i>This input is 5 V tolerant.</i></p>

## 2.10 SPDIF Transmitter Digital Audio Interface

Table 2-10 Digital Audio Interface (DAX) Signals

Signal Name	Type	State During Reset	Signal Description
ACI	Input	GPIO Disconnected	<b>Audio Clock Input</b> —This is the DAX clock input. When programmed to use an external clock, this input supplies the DAX clock. The external clock frequency must be 256, 384, or 512 times the audio sampling frequency ( $256 \times F_s$ , $384 \times F_s$ or $512 \times F_s$ , respectively).
PD0	Input, output, or disconnected		<p><b>Port D0</b>—When the DAX is configured as GPIO, this signal is individually programmable as input, output, or internally disconnected.</p> <p>The default state after reset is GPIO disconnected.</p> <p><i>Internal pull-down resistor.</i></p> <p><i>This input is 5 V tolerant.</i></p>
ADO	Output	GPIO Disconnected	<b>Digital Audio Data Output</b> —This signal is an audio and non-audio output in the form of AES/SPDIF, CP340 and IEC958 data in a biphase mark format.
PD1	Input, output, or disconnected		<p><b>Port D1</b>—When the DAX is configured as GPIO, this signal is individually programmable as input, output, or internally disconnected.</p> <p>The default state after reset is GPIO disconnected.</p> <p><i>Internal pull-down resistor.</i></p> <p><i>This input is 5 V tolerant.</i></p>

## 2.11 Dedicated GPIO Interface

Table 2-11 Dedicated GPIO Signals

Signal Name	Type	State During Reset	Signal Description
PF0	Input, output, or disconnected	GPIO disconnected	<b>Port F0</b> —this signal is individually programmable as input, output, or internally disconnected. The default state after reset is GPIO disconnected. <i>Internal pull-down resistor.</i> <i>This input is 5 V tolerant.</i>
PF1	Input, output, or disconnected	GPIO disconnected	<b>Port F1</b> — this signal is individually programmable as input, output, or internally disconnected. The default state after reset is GPIO disconnected. <i>Internal pull-down resistor.</i> <i>This input is 5 V tolerant.</i>
PF2	Input, output, or disconnected	GPIO disconnected	<b>Port F2</b> — this signal is individually programmable as input, output, or internally disconnected. The default state after reset is GPIO disconnected. <i>Internal pull-down resistor.</i> <i>This input is 5 V tolerant.</i>
PF3	Input, output, or disconnected	GPIO disconnected	<b>Port F3</b> —this signal is individually programmable as input, output, or internally disconnected. The default state after reset is GPIO disconnected. <i>Internal pull-down resistor.</i> <i>This input is 5 V tolerant.</i>
PF4	Input, output, or disconnected	GPIO disconnected	<b>Port F4</b> — this signal is individually programmable as input, output, or internally disconnected. The default state after reset is GPIO disconnected. <i>Internal pull-down resistor.</i> <i>This input is 5 V tolerant.</i>
PF5	Input, output, or disconnected	GPIO disconnected	<b>Port F5</b> —this signal is individually programmable as input, output, or internally disconnected. The default state after reset is GPIO disconnected. <i>Internal pull-down resistor.</i> <i>This input is 5 V tolerant.</i>
PF6	Input, output, or disconnected	GPIO disconnected	<b>Port F6</b> —this signal is individually programmable as input, output, or internally disconnected. The default state after reset is GPIO disconnected. <i>Internal pull-down resistor.</i> <i>This input is 5 V tolerant.</i>
PF7	Input, output, or disconnected	GPIO disconnected	<b>Port F7</b> — this signal is individually programmable as input, output, or internally disconnected. The default state after reset is GPIO disconnected. <i>Internal pull-down resistor.</i> <i>This input is 5 V tolerant.</i>
PF8	Input, output, or disconnected	GPIO disconnected	<b>Port F8</b> — this signal is individually programmable as input, output, or internally disconnected. The default state after reset is GPIO disconnected. <i>Internal pull-down resistor.</i> <i>This input is 5 V tolerant.</i>



Table 2-11 Dedicated GPIO Signals (continued)

Signal Name	Type	State During Reset	Signal Description
PF9	Input, output, or disconnected	GPIO disconnected	<b>Port F9</b> — this signal is individually programmable as input, output, or internally disconnected. The default state after reset is GPIO disconnected. <i>Internal pull-down resistor.</i> <i>This input is 5 V tolerant.</i>
PF10	Input, output, or disconnected	GPIO disconnected	<b>Port F10</b> — this signal is individually programmable as input, output, or internally disconnected. The default state after reset is GPIO disconnected. <i>Internal pull-down resistor.</i> <i>This input is 5 V tolerant.</i>

## 2.12 Timer

Table 2-12 Timer Signal

Signal Name	Type	State during Reset	Signal Description
TIO0	Input or Output	GPIO Input	<b>Timer 0 Schmitt-Trigger Input/Output</b> —When timer 0 functions as an external event counter or in measurement mode, TIO0 is used as input. When timer 0 functions in watchdog, timer, or pulse modulation mode, TIO0 is used as output. The default mode after reset is GPIO input. This can be changed to output or configured as a timer input/output through the timer 0 control/status register (TCSR0). If TIO0 is not being used, it is recommended to either define it as GPIO output immediately at the beginning of operation or leave it defined as GPIO input but connected to VDD through a pull-up resistor in order to ensure a stable logic level at this input. <i>Internal pull-down resistor.</i> <i>This input is 5 V tolerant.</i>
TIO1	Input or Output	GPIO Input	<b>Timer 1 Schmitt-Trigger Input/Output</b> —When timer 1 functions as an external event counter or in measurement mode, TIO1 is used as input. When timer 1 functions in watchdog, timer, or pulse modulation mode, TIO1 is used as output. The default mode after reset is GPIO input. This can be changed to output or configured as a timer input/output through the timer 1 control/status register (TCSR1). If TIO1 is not being used, it is recommended to either define it as GPIO output immediately at the beginning of operation or leave it defined as GPIO input but connected to Vdd through a pull-up resistor in order to ensure a stable logic level at this input. <i>Internal pull-down resistor.</i> <i>This input is 5 V tolerant.</i>

## 2.13 JTAG/OnCE Interface

Table 2-13 JTAG/OnCE Interface

Signal Name	Signal Type	State during Reset	Signal Description
TCK	Input	Input	<b>Test Clock</b> —TCK is a test clock input signal used to synchronize the JTAG test logic. It has an internal pull-up resistor. <i>Internal pull-up resistor.</i> <i>This input is 5 V tolerant..</i>
TDI	Input	Input	<b>Test Data Input</b> —TDI is a test data serial input signal used for test instructions and data. TDI is sampled on the rising edge of TCK and has an internal pull-up resistor. <i>Internal pull-up resistor.</i> <i>This input is 5 V tolerant.</i>
TDO	Output	Tri-state	<b>Test Data Output</b> —TDO is a test data serial output signal used for test instructions and data. TDO is tri-statable and is actively driven in the shift-IR and shift-DR controller states. TDO changes on the falling edge of TCK.
TMS	Input	Input	<b>Test Mode Select</b> —TMS is an input signal used to sequence the test controller's state machine. TMS is sampled on the rising edge of TCK and has an internal pull-up resistor. <i>Internal pull-up resistor.</i> <i>This input is 5 V tolerant.</i>

## 3 Memory Configuration

### 3.1 Data and Program Memory Maps

The DSP56371 provides 88K words of RAM divided between three memory spaces (X, Y, and P). The default memory allocation and memory block sizes are as follows (See [Figure 3-1](#)):

- Program RAM - 4K words (4 - 1K blocks) in the lowest memory addresses between \$000000 - \$000FFF.
- XRAM - 12K words (12 - 1K blocks) in the lowest memory addresses between \$000000 - \$002FFF and 24K words (3 - 8K blocks) in the memory addresses between \$00C000 - \$011FFF.
- YRAM - 8K words (8 - 1K blocks) in the lowest memory addresses between \$000000 - \$001FFF and 40K words (5 - 8K blocks) in the memory addresses between \$00C000 - \$015FFF.

The DSP56371 provides 128K words of ROM divided between three memory spaces (X, Y, and P). The memory allocations are as follows:

- Program ROM - 64K words.
- XROM - 32K words in the memory addresses between \$004000 - \$00BFFF.
- YROM - 32K words in the memory addresses between \$004000 - \$00BFFF.

The on-chip memory configuration of the DSP56371 is affected by the state of the MSW0, MSW1 and MS (Memory Switch) control bits in the OMR register in the Status Register. The internal data and program memory configurations are shown in [Table 3-6](#). The address ranges for the internal memory are shown in [Table 3-1](#). The memory maps for each memory configuration are shown in [Figure 3-1](#) to [Figure 3-5](#).

Table 3-1 Internal Memory Locations

Program RAM	Program + Bootstrap ROM	X Data RAM	X Data ROM	Y Data RAM	Y Data ROM
4K Words	64K Words	36K Words	32K Words	48K Words	32K Words
\$000000 - \$000FFF	\$FF0000 - \$FFFFFF	\$000000 - \$002FFF and \$00C000 - \$011FFF	\$004000 - \$00BFFF	\$000000 - \$001FFF and \$00C000 - \$015FFF	\$004000 - \$00BFFF

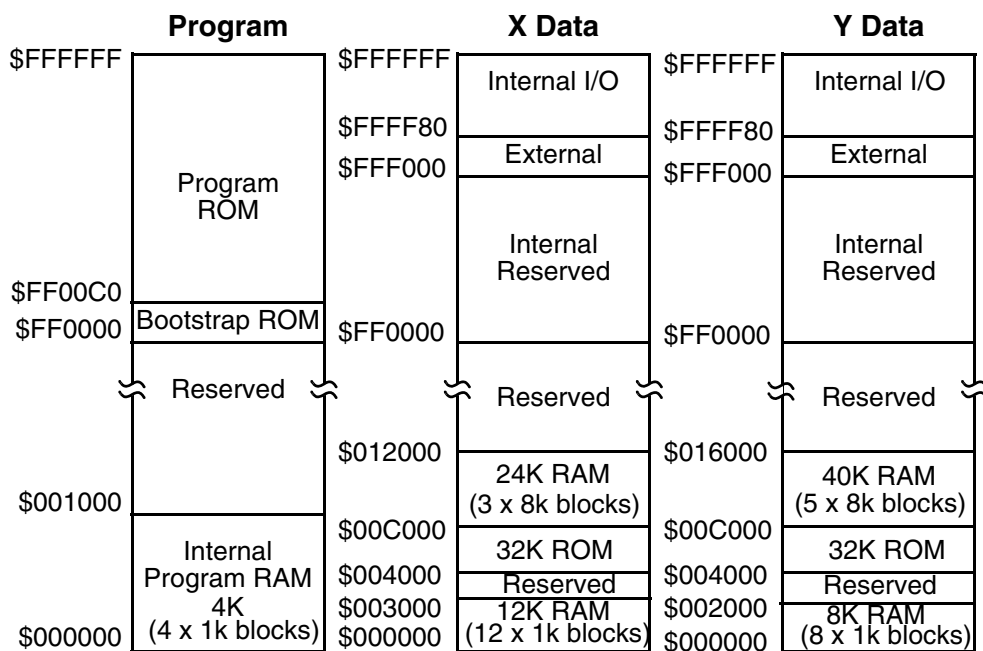


Figure 3-1 Default Memory Map (MS - 0, MSW - na)

Table 3-2 Internal Memory Locations

Program RAM	Program + Bootstrap ROM	X Data RAM	X Data ROM	Y Data RAM	Y Data ROM
12K Words	64K Words	28K Words	32K Words	48K Words	32K Words
\$000000 - \$002FFF	\$FF0000 - \$FFFFFF	\$000000 - \$002FFF and \$00C000 - \$00FFFF	\$004000 - \$00BFFF	\$000000 - \$001FFF and \$00C000 - \$015FFF	\$004000 - \$00BFFF

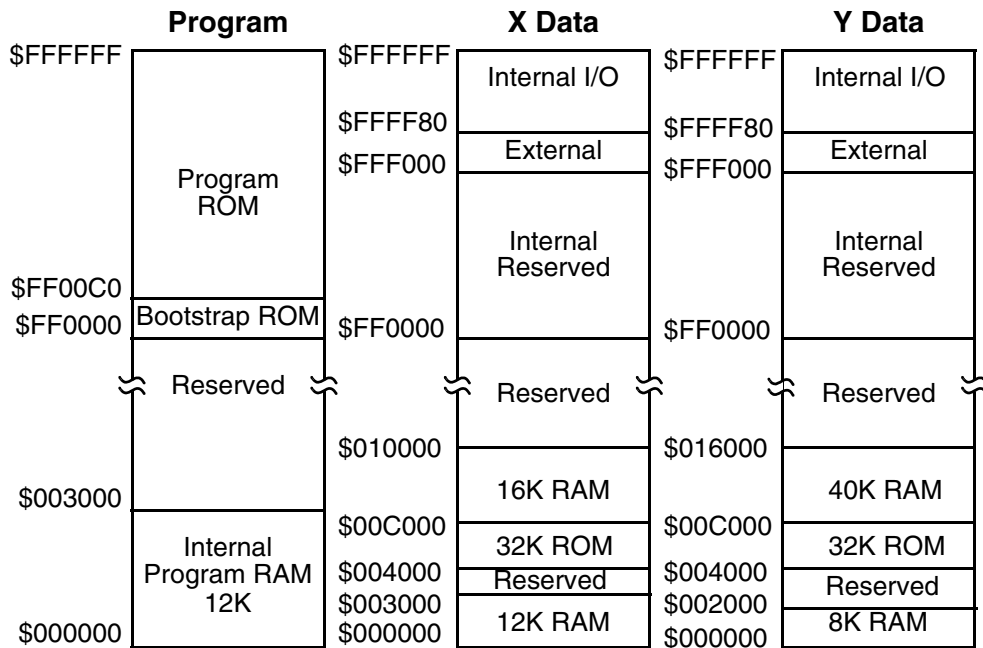


Figure 3-2 Memory Map (MS - 1, MSW1 - 1, MSW0 - 1)

Table 3-3 Internal Memory Locations

Program RAM	Program + Bootstrap ROM	X Data RAM	X Data ROM	Y Data RAM	Y Data ROM
20K Words	64K Words	28K Words	32K Words	40K Words	32K Words
\$000000 - \$004FFF	\$FF0000 - \$FFFFFF	\$000000 - \$002FFF and \$00C000 - \$00FFFF	\$004000 - \$00BFFF	\$000000 - \$001FFF and \$00C000 - \$013FFF	\$004000 - \$00BFFF

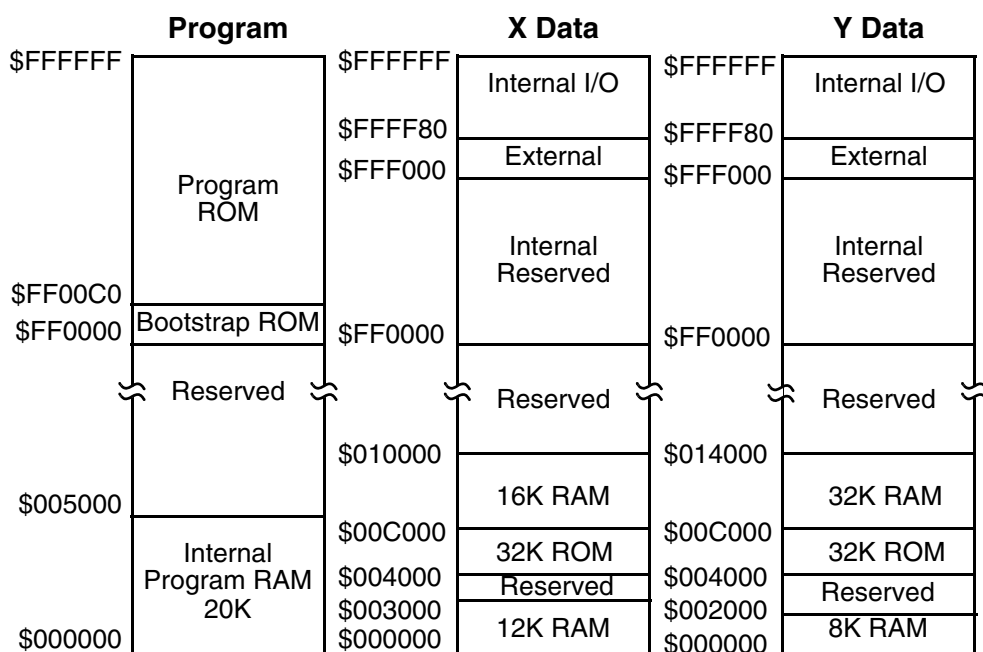


Figure 3-3 Memory Map (MS - 1, MSW1 - 1, MSW0 - 0)

Table 3-4 Internal Memory Locations

Program RAM	Program + Bootstrap ROM	X Data RAM	X Data ROM	Y Data RAM	Y Data ROM
36K Words	64K Words	28K Words	32K Words	24K Words	32K Words
\$000000 - \$008FFF	\$FF0000 - \$FFFFFF	\$000000 - \$002FFF and \$00C000 - \$00FFFF	\$004000 - \$00BFFF	\$000000 - \$001FFF and \$00C000 - \$00FFFF	\$004000 - \$00BFFF

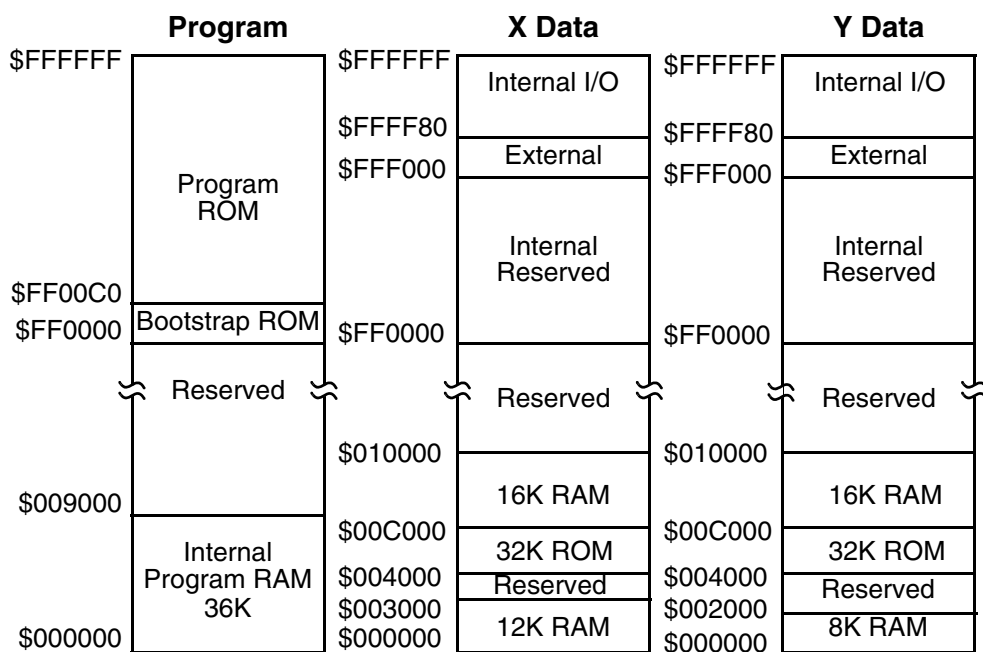


Figure 3-4 Memory Map (MS 1, MSW1 - 0, MSW0 - 1)

Table 3-5 Internal Memory Locations

Program RAM	Program + Bootstrap ROM	X Data RAM	X Data ROM	Y Data RAM	Y Data ROM
44K Words	64K Words	28K Words	32K Words	16K Words	32K Words
\$000000 - \$00AFFF	\$FF0000 - \$FFFFFF	\$000000 - \$002FFF and \$00C000 - \$00FFFF	\$004000 - \$00BFFF	\$000000 - \$001FFF and \$00C000 - \$00DFFF	\$004000 - \$00BFFF

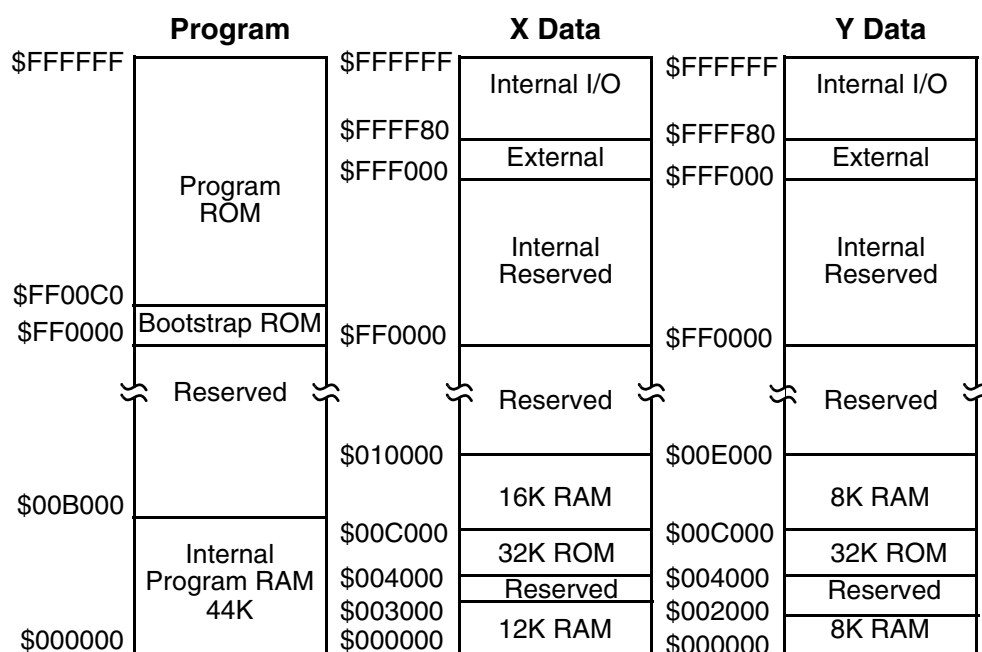


Figure 3-5 Memory Map (MS 1, MSW1 - 0, MSW0 - 0)

### 3.1.1 Reserved Memory Spaces

The reserved memory spaces should not be accessed by the user. They are reserved for future expansion.

### 3.1.2 Bootstrap ROM

The 192-word Bootstrap ROM occupies locations \$FF0000-\$FF00BF of the program ROM. The bootstrap ROM is factory-programmed to perform the bootstrap operation following hardware reset. The contents of the Bootstrap ROM are defined by the Bootstrap ROM source code in [Appendix A, "Bootstrap ROM Contents"](#).



### 3.1.3 Dynamic Memory Configuration Switching

The internal memory configuration is altered by re-mapping RAM blocks from Y and X data memory into program memory space. The contents of the switched RAM blocks are preserved.

The memory can be dynamically switched from one configuration to another by changing the MS, MSW0 or MSW1 bits in OMR. The address ranges that are directly affected by the switch operation are specified in [Table 3-1](#). The memory switch can be accomplished provided that the affected address ranges are not being accessed during the instruction cycle in which the switch operation takes place. Accordingly, the following condition must be observed for trouble-free dynamic switching:

#### NOTE

No accesses (including instruction fetches) to or from the affected address ranges in program and data memories are allowed during the switch cycle.

#### NOTE

The switch cycle actually occurs 3 instruction cycles after the instruction that modifies the MS, MSW0 or MSW1 bits.

Any sequence that complies with the switch condition is valid. For example, if the program flow executes in the address range that is not affected by the switch, the switch condition can be met very easily. In this case a switch can be accomplished by just changing the MS, MSW0 or MSW1 bits in OMR in the regular program flow, assuming no accesses to the affected address ranges of the data memory occur up to 3 instructions after the instruction that changes the OMR bit. Special care should be taken in relation to the interrupt vector routines since an interrupt could cause the DSP to fetch instructions out of sequence and might violate the switch condition.

Special attention should be given when running a memory switch routine using the OnCE™ port. Running the switch routine in Trace mode, for example, can cause the switch to complete after the MS bit change while the DSP is in Debug mode. As a result, subsequent instructions might be fetched according to the new memory configuration (after the switch) and, thus, might execute improperly.

**Table 3-6 Internal Memory Configurations**

Bit Settings			Memory Sizes (24-bit words)					
MSW1	MSW0	MS	Prog RAM	Prog ROM	X Data RAM	Y Data RAM	X Data ROM	Y Data ROM
X	X	0	4K	64K	36K	48K	32K	32K
0	0	1	44K	64K	28K	16K	32K	32K
0	1	1	36K	64K	28K	24K	32K	32K
1	0	1	20K	64K	28K	40K	32K	32K
1	1	1	12K	64K	28K	48K	32K	32K

### 3.1.4 External Memory Support

The DSP56371 is not capable of directly accessing external memory.

### 3.1.5 DMA and Memory

The first 12K words of X-memory and 8K words of Y-memory are implemented using 1k word memory blocks while the rest of data memory consists of 8K word memory blocks. It is important to understand that the DMA is designed for operation on 1K word blocks, thus a DMA access to the lower memory in X and Y data spaces provides for complete hardware protected operation. If software does not prevent core/DMA access to the same 1K word block in the lower X and Y memory spaces, hardware will delay the DMA access until the core has completed its operation. The DMA will continue to operate the expected access. However, if DMA access is executed to an 8K word block while the core simultaneously accesses the same block, hardware protection may not be provided and DMA operation may not be performed during the core access. The DMA access may be missed. Protection for Core/DMA contention is only provided in an 8K word block if both the core and DMA are accessing the same 1K section of the 8K block. Software should be written to prevent contention where hardware protection is not available.

### 3.1.6 EFCOP and Memory

Note that the EFCOP memory is located in the first 16K words of X and Y data spaces starting at address \$00C000 where the memory blocks are 8K words. When MS = 1, MSW1 = 0 and MSW0 = 0, only 8K of shared EFCOP memory is available in the Y data space.

### 3.1.7 Memory BLOCKS

The regular RAM memory is implemented in a combination of 1K-word and 8K-word RAM memory blocks. The finer granularity of the 1k-word memory blocks permit DMA and core accesses to the same memory spaces with less possibility of contention. See [Section 3.1.5, "DMA and Memory"](#) [Section 3.1.5, "DMA and Memory"](#).

## 3.2 Memory Patch Module

The patch module provides a means to replace instructions in program ROM with instructions written into the patch module's instruction registers. A program ROM instruction is replaced by storing the ROM memory address in a patch module address register. The new instruction is to be loaded into the corresponding patch module instruction register.

After reset (either hard reset or the RESET instruction), none of the patch module address registers are enabled for patching. The patch module address registers are initially cleared. Whenever an address register is written to, that address register (and corresponding instruction register) is enabled for patching.

Once an address register is enabled for patching, whenever there is an internal program read (by the core) of that address, the contents of the corresponding instruction register are substituted onto the Program Read Data bus, instead of the actual contents of memory at that address.

The Patch module has no effect on DMA accesses, or writes to program memory. It also has no effect if the address programmed is considered an external address.

Note that writing to an instruction register does not enable it for patching. Only writing to an address register enables patching. Therefore, if not used for patching, the instruction registers can be used as general purpose registers.

#### Patching example:

Begin

```

bset    #23,omr                ; enable patch

; initialize patch module registers
; addresses first

move     #$fff000,r1
movep    r1,y:$ffffa0          ;load ROM address $fff000 into patch address 0
move     #$fff001,r1
movep    r1,y:$ffffa1          ;load ROM address $fff001 into patch address 1
move     #$fff003,r1
movep    r1,y:$ffffa2          ;load ROM address $fff003 into patch address 2

; instructions

move     #patch_pattern,r2
movep    p:(r2)+,y:$ffffa8      ;load instruction #1 into patch instruction 0
movep    p:(r2)+,y:$ffffa9      ;load instruction #2 into patch instruction 1
movep    p:(r2)+,y:$ffffaa      ;load instruction #3 into patch instruction 2
jmp      program                ;start running program

org      P:$800

patch_pattern

bset     #0,a                   ;instruction #1 = bset #0,a
bset     #1,a                   ;instruction #2 = bset #1,a
bset     #2,a                   ;instruction #3 = bset #2,a

```

Anytime the program control unit fetches an instruction from P:\$fff000, instruction 1 (bset #0,a) will be fetched in place of the instruction stored in ROM location P:\$fff000. Also, when the program control unit fetches an instruction from P:\$fff001, instruction 2 (bset #1,a) will be fetched instead. Also, when the program control unit fetches an instruction from P:\$fff003, instruction 3 (bset #2,a) will be fetched instead.

### 3.3 Internal I/O Memory Map

The DSP56371 on-chip peripheral modules have their register files programmed to the addresses in the internal X-I/O memory range (the top 128 locations of the X data memory space) and internal Y-I/O memory range (48 locations of the Y data memory space) as shown in [Table 3-7](#) and [Table 3-8](#).

**Table 3-7 Internal I/O Memory Map (X memory Space)**

Peripheral	Address	Register Name
IPR	X:\$FFFFFFF	INTERRUPT PRIORITY REGISTER CORE (IPR-C)
	X:\$FFFFFFE	INTERRUPT PRIORITY REGISTER PERIPHERAL (IPR-P)
PLL	X:\$FFFFFFD	PLL CONTROL REGISTER (PCTL)
ONCE	X:\$FFFFFFC	ONCE GDB REGISTER (OGDB)
BIU	X:\$FFFFFFB	BCR
	X:\$FFFFFFA	Reserved
	X:\$FFFFFF9	Reserved
	X:\$FFFFFF8	Reserved
	X:\$FFFFFF7	Reserved
	X:\$FFFFFF6	Reserved
	X:\$FFFFFF5	ID Register (IDR)
DMA	X:\$FFFFFF4	DMA STATUS REGISTER (DSTR)
	X:\$FFFFFF3	DMA OFFSET REGISTER 0 (DOR0)
	X:\$FFFFFF2	DMA OFFSET REGISTER 1 (DOR1)
	X:\$FFFFFF1	DMA OFFSET REGISTER 2 (DOR2)
	X:\$FFFFFF0	DMA OFFSET REGISTER 3 (DOR3)
DMA0	X:\$FFFFFEF	DMA SOURCE ADDRESS REGISTER (DSR0)
	X:\$FFFFFEE	DMA DESTINATION ADDRESS REGISTER (DDR0)
	X:\$FFFFFED	DMA COUNTER (DCO0)
	X:\$FFFFFEC	DMA CONTROL REGISTER (DCR0)
DMA1	X:\$FFFFFEB	DMA SOURCE ADDRESS REGISTER (DSR1)
	X:\$FFFFFEA	DMA DESTINATION ADDRESS REGISTER (DDR1)
	X:\$FFFFFE9	DMA COUNTER (DCO1)
	X:\$FFFFFE8	DMA CONTROL REGISTER (DCR1)
DMA2	X:\$FFFFFE7	DMA SOURCE ADDRESS REGISTER (DSR2)
	X:\$FFFFFE6	DMA DESTINATION ADDRESS REGISTER (DDR2)
	X:\$FFFFFE5	DMA COUNTER (DCO2)
	X:\$FFFFFE4	DMA CONTROL REGISTER (DCR2)
DMA3	X:\$FFFFFE3	DMA SOURCE ADDRESS REGISTER (DSR3)
	X:\$FFFFFE2	DMA DESTINATION ADDRESS REGISTER (DDR3)
	X:\$FFFFFE1	DMA COUNTER (DCO3)
	X:\$FFFFFE0	DMA CONTROL REGISTER (DCR3)

Table 3-7 Internal I/O Memory Map (X memory Space) (continued)

Peripheral	Address	Register Name
DMA4	X:\$FFFFDF	DMA SOURCE ADDRESS REGISTER (DSR4)
	X:\$FFFFDE	DMA DESTINATION ADDRESS REGISTER (DDR4)
	X:\$FFFFDD	DMA COUNTER (DCO4)
	X:\$FFFFDC	DMA CONTROL REGISTER (DCR4)
DMA5	X:\$FFFFDB	DMA SOURCE ADDRESS REGISTER (DSR5)
	X:\$FFFFDA	DMA DESTINATION ADDRESS REGISTER (DDR5)
	X:\$FFFFD9	DMA COUNTER (DCO5)
	X:\$FFFFD8	DMA CONTROL REGISTER (DCR5)
PORT D	X:\$FFFFD7	PORT D CONTROL REGISTER (PCRD)
	X:\$FFFFD6	PORT D DIRECTION REGISTER (PRRD)
	X:\$FFFFD5	PORT D DATA REGISTER (PDRD)
DAX	X:\$FFFFD4	DAX STATUS REGISTER (XSTR)
	X:\$FFFFD3	DAX AUDIO DATA REGISTER B (XADRB)
	X:\$FFFFD2	DAX AUDIO DATA REGISTER A (XADRA)
	X:\$FFFFD1	DAX NON-AUDIO DATA REGISTER (XNADR)
	X:\$FFFFD0	DAX CONTROL REGISTER (XCTR)
	X:\$FFFFCF	Reserved
	X:\$FFFFCE	Reserved
	X:\$FFFFCD	Reserved
	X:\$FFFFCC	Reserved
	X:\$FFFFCB	Reserved
	X:\$FFFFCA	Reserved
	X:\$FFFFC9	Reserved
	X:\$FFFFC8	Reserved
	X:\$FFFFC7	Reserved
	X:\$FFFFC6	Reserved
	X:\$FFFFC5	Reserved
	X:\$FFFFC4	Reserved
	X:\$FFFFC3	Reserved
	X:\$FFFFC2	Reserved
	X:\$FFFFC1	Reserved
	X:\$FFFFC0	Reserved
PORT C	X:\$FFFFBF	PORT C CONTROL REGISTER (PCRC)
	X:\$FFFFBE	PORT C DIRECTION REGISTER (PRRC)
	X:\$FFFFBD	PORT C GPIO DATA REGISTER (PDRC)

Table 3-7 Internal I/O Memory Map (X memory Space) (continued)

Peripheral	Address	Register Name
ESAI	X:\$FFFFBC	ESAI RECEIVE SLOT MASK REGISTER B (RSMB)
	X:\$FFFFBB	ESAI RECEIVE SLOT MASK REGISTER A (RSMA)
	X:\$FFFFBA	ESAI TRANSMIT SLOT MASK REGISTER B (TSMB)
	X:\$FFFFB9	ESAI TRANSMIT SLOT MASK REGISTER A (TSMA)
	X:\$FFFFB8	ESAI RECEIVE CLOCK CONTROL REGISTER (RCCR)
	X:\$FFFFB7	ESAI RECEIVE CONTROL REGISTER (RCR)
	X:\$FFFFB6	ESAI TRANSMIT CLOCK CONTROL REGISTER (TCCR)
	X:\$FFFFB5	ESAI TRANSMIT CONTROL REGISTER (TCR)
	X:\$FFFFB4	ESAI COMMON CONTROL REGISTER (SAICR)
	X:\$FFFFB3	ESAI STATUS REGISTER (SAISR)
	X:\$FFFFB2	Reserved
	X:\$FFFFB1	Reserved
	X:\$FFFFB0	Reserved
	X:\$FFFFAF	Reserved
	X:\$FFFFAE	Reserved
	X:\$FFFFAD	Reserved
	X:\$FFFFAC	Reserved
	X:\$FFFFAB	ESAI RECEIVE DATA REGISTER 3 (RX3)
	X:\$FFFFAA	ESAI RECEIVE DATA REGISTER 2 (RX2)
	X:\$FFFFA9	ESAI RECEIVE DATA REGISTER 1 (RX1)
	X:\$FFFFA8	ESAI RECEIVE DATA REGISTER 0 (RX0)
	X:\$FFFFA7	Reserved
	X:\$FFFFA6	ESAI TIME SLOT REGISTER (TSR)
	X:\$FFFFA5	ESAI TRANSMIT DATA REGISTER 5 (TX5)
	X:\$FFFFA4	ESAI TRANSMIT DATA REGISTER 4 (TX4)
	X:\$FFFFA3	ESAI TRANSMIT DATA REGISTER 3 (TX3)
	X:\$FFFFA2	ESAI TRANSMIT DATA REGISTER 2 (TX2)
	X:\$FFFFA1	ESAI TRANSMIT DATA REGISTER 1 (TX1)
	X:\$FFFFA0	ESAI TRANSMIT DATA REGISTER 0 (TX0)
	X:\$FFFF9F	Reserved
	X:\$FFFF9E	Reserved
	X:\$FFFF9D	Reserved
	X:\$FFFF9C	Reserved
	X:\$FFFF9B	Reserved
	X:\$FFFF9A	Reserved
	X:\$FFFF99	Reserved
	X:\$FFFF98	Reserved

Table 3-7 Internal I/O Memory Map (X memory Space) (continued)

Peripheral	Address	Register Name
	X:\$FFFF97	Reserved
	X:\$FFFF96	Reserved
	X:\$FFFF95	Reserved
SHI	X:\$FFFF94	SHI RECEIVE FIFO (HRX)
	X:\$FFFF93	SHI TRANSMIT REGISTER (HTX)
	X:\$FFFF92	SHI I <sup>2</sup> C SLAVE ADDRESS REGISTER (HSAR)
	X:\$FFFF91	SHI CONTROL/STATUS REGISTER (HCSR)
	X:\$FFFF90	SHI CLOCK CONTROL REGISTER (HCKR)
TRIPLE TIMER	X:\$FFFF8F	TIMER 0 CONTROL/STATUS REGISTER (TCSR0)
	X:\$FFFF8E	TIMER 0 LOAD REGISTER (TLR0)
	X:\$FFFF8D	TIMER 0 COMPARE REGISTER (TCPR0)
	X:\$FFFF8C	TIMER 0 COUNT REGISTER (TCR0)
	X:\$FFFF8B	TIMER 1 CONTROL/STATUS REGISTER (TCSR1)
	X:\$FFFF8A	TIMER 1 LOAD REGISTER (TLR1)
	X:\$FFFF89	TIMER 1 COMPARE REGISTER (TCPR1)
	X:\$FFFF88	TIMER 1 COUNT REGISTER (TCR1)
	X:\$FFFF87	TIMER 2 CONTROL/STATUS REGISTER (TCSR2)
	X:\$FFFF86	TIMER 2 LOAD REGISTER (TLR2)
	X:\$FFFF85	TIMER 2 COMPARE REGISTER (TCPR2)
	X:\$FFFF84	TIMER 2 COUNT REGISTER (TCR2)
	X:\$FFFF83	TIMER PRESCALER LOAD REGISTER (TPLR)
	X:\$FFFF82	TIMER PRESCALER COUNT REGISTER (TPCR)
	X:\$FFFF81	Reserved
	X:\$FFFF80	Reserved

Table 3-8 Internal I/O Memory Map (Y memory Space)

Peripheral	Address	Register Name
	Y:\$FFFFFFF	Reserved
	Y:\$FFFFFFE	Reserved
	Y:\$FFFFFFD	Reserved
	Y:\$FFFFFFC	Reserved
	Y:\$FFFFFFB	Reserved
	Y:\$FFFFFFA	Reserved
	Y:\$FFFFFF9	Reserved
	Y:\$FFFFFF8	Reserved
PORT F	Y:\$FFFFFF7	PORT F CONTROL REGISTER (PCRF)
	Y:\$FFFFFF6	PORT F DIRECTION REGISTER (PRRF)
	Y:\$FFFFFF5	PORT F GPIO DATA REGISTER (PDRF)
	Y:\$FFFFFF4	Reserved
	Y:\$FFFFFF3	Reserved
	Y:\$FFFFFF2	Reserved
	Y:\$FFFFFF1	Reserved
	Y:\$FFFFFF0	Reserved
	Y:\$FFFFFEF	Reserved
	Y:\$FFFFFEE	Reserved
	Y:\$FFFFFED	Reserved
	Y:\$FFFFFEC	Reserved
	Y:\$FFFFFEB	Reserved
	Y:\$FFFFFEA	Reserved
	Y:\$FFFFFE9	Reserved
	Y:\$FFFFFE8	Reserved
	Y:\$FFFFFE7	Reserved
	Y:\$FFFFFE6	Reserved
	Y:\$FFFFFE5	Reserved
	Y:\$FFFFFE4	Reserved
	Y:\$FFFFFE3	Reserved
	Y:\$FFFFFE2	Reserved
	Y:\$FFFFFE1	Reserved
	Y:\$FFFFFE0	Reserved
	Y:\$FFFFFDF	Reserved



Table 3-8 Internal I/O Memory Map (Y memory Space) (continued)

Peripheral	Address	Register Name
	Y:\$FFFFDE	Reserved
	Y:\$FFFFDD	Reserved
	Y:\$FFFFDC	Reserved
	Y:\$FFFFDB	Reserved
	Y:\$FFFFDA	Reserved
	Y:\$FFFFD9	Reserved
	Y:\$FFFFD8	Reserved
	Y:\$FFFFD7	Reserved
	Y:\$FFFFD6	Reserved
	Y:\$FFFFD5	Reserved
	Y:\$FFFFD4	Reserved
	Y:\$FFFFD3	Reserved
	Y:\$FFFFD2	Reserved
	Y:\$FFFFD1	Reserved
	Y:\$FFFFD0	Reserved
	Y:\$FFFFCF	Reserved
	Y:\$FFFFCE	Reserved
	Y:\$FFFFCD	Reserved
	Y:\$FFFFCC	Reserved
	Y:\$FFFFCB	Reserved
	Y:\$FFFFCA	Reserved
	Y:\$FFFFC9	Reserved
	Y:\$FFFFC8	Reserved
	Y:\$FFFFC7	Reserved
	Y:\$FFFFC6	Reserved
	Y:\$FFFFC5	Reserved
	Y:\$FFFFC4	Reserved
	Y:\$FFFFC3	Reserved
	Y:\$FFFFC2	Reserved
	Y:\$FFFFC1	Reserved
	Y:\$FFFFC0	Reserved
	Y:\$FFFFBF	Reserved
	Y:\$FFFFBE	Reserved

Table 3-8 Internal I/O Memory Map (Y memory Space) (continued)

Peripheral	Address	Register Name
	Y:\$FFFFBD	Reserved
	Y:\$FFFFBC	Reserved
	Y:\$FFFFBB	Reserved
	Y:\$FFFFBA	Reserved
	Y:\$FFFFB9	Reserved
EFCOP	Y:\$FFFFB8	EFCOP Filter decimation/channel register (FDCH)
	Y:\$FFFFB7	EFCOP Filter coefficient base address (FCBA)
	Y:\$FFFFB6	EFCOP Filter Data buffer base address (FDBA)
	Y:\$FFFFB5	EFCOP Filter ALU control register (FACR)
	Y:\$FFFFB4	EFCOP Filter control status register (FCSR)
	Y:\$FFFFB3	EFCOP Filter count register (FCNT)
	Y:\$FFFFB2	EFCOP Filter K-constant register (FKIR)
	Y:\$FFFFB1	EFCOP Filter data output register (FDOR)
	Y:\$FFFFB0	EFCOP Filter data input register (FDIR)
Patch Module	Y:\$FFFFAF	Patch Instruction 7
	Y:\$FFFFAE	Patch Instruction 6
	Y:\$FFFFAD	Patch Instruction 5
	Y:\$FFFFAC	Patch Instruction 4
	Y:\$FFFFAB	Patch Instruction 3
	Y:\$FFFFAA	Patch Instruction 2
	Y:\$FFFFA9	Patch Instruction 1
	Y:\$FFFFA8	Patch Instruction 0
	Y:\$FFFFA7	Patch Address 7
	Y:\$FFFFA6	Patch Address 6
	Y:\$FFFFA5	Patch Address 5
	Y:\$FFFFA4	Patch Address 4
	Y:\$FFFFA3	Patch Address 3
	Y:\$FFFFA2	Patch Address 2
	Y:\$FFFFA1	Patch Address 1
	Y:\$FFFFA0	Patch Address 0
PORT E	Y:\$FFFF9F	PORT E CONTROL REGISTER (PCRE)
	Y:\$FFFF9E	PORT E DIRECTION REGISTER (PRRE)
	Y:\$FFFF9D	PORT E GPIO DATA REGISTER (PDRE)

Table 3-8 Internal I/O Memory Map (Y memory Space) (continued)

Peripheral	Address	Register Name
ESAI_1	Y:\$FFFF9C	ESAI_1 RECEIVE SLOT MASK REGISTER B (RSMB_1)
	Y:\$FFFF9B	ESAI_1 RECEIVE SLOT MASK REGISTER A (RSMA_1)
	Y:\$FFFF9A	ESAI_1 TRANSMIT SLOT MASK REGISTER B (TSMB_1)
	Y:\$FFFF99	ESAI_1 TRANSMIT SLOT MASK REGISTER A (TSMA_1)
	Y:\$FFFF98	ESAI_1 RECEIVE CLOCK CONTROL REGISTER (RCCR_1)
	Y:\$FFFF97	ESAI_1 RECEIVE CONTROL REGISTER (RCR_1)
	Y:\$FFFF96	ESAI_1 TRANSMIT CLOCK CONTROL REGISTER (TCCR_1)
	Y:\$FFFF95	ESAI_1 TRANSMIT CONTROL REGISTER (TCR_1)
	Y:\$FFFF94	ESAI_1 COMMON CONTROL REGISTER (SAICR_1)
	Y:\$FFFF93	ESAI_1 STATUS REGISTER (SAISR_1)
	Y:\$FFFF92	Reserved
	Y:\$FFFF91	Reserved
	Y:\$FFFF90	Reserved
	Y:\$FFFF8F	Reserved
	Y:\$FFFF8E	Reserved
	Y:\$FFFF8D	Reserved
	Y:\$FFFF8C	Reserved
	Y:\$FFFF8B	ESAI_1 RECEIVE DATA REGISTER 3 (RX3_1)
	Y:\$FFFF8A	ESAI_1 RECEIVE DATA REGISTER 2 (RX2_1)
	Y:\$FFFF89	ESAI_1 RECEIVE DATA REGISTER 1 (RX1_1)
	Y:\$FFFF88	ESAI_1 RECEIVE DATA REGISTER 0 (RX0_1)
	Y:\$FFFF87	Reserved
	Y:\$FFFF86	ESAI_1 TIME SLOT REGISTER (TSR_1)
	Y:\$FFFF85	ESAI_1 TRANSMIT DATA REGISTER 5 (TX5_1)
	Y:\$FFFF84	ESAI_1 TRANSMIT DATA REGISTER 4 (TX4_1)
	Y:\$FFFF83	ESAI_1 TRANSMIT DATA REGISTER 3 (TX3_1)
	Y:\$FFFF82	ESAI_1 TRANSMIT DATA REGISTER 2 (TX2_1)
	Y:\$FFFF81	ESAI_1 TRANSMIT DATA REGISTER 1 (TX1_1)
	Y:\$FFFF80	ESAI_1 TRANSMIT DATA REGISTER 0 (TX0_1)

## NOTES

## 4 Core Configuration

### 4.1 Introduction

This chapter contains DSP56300 core configuration information details specific to the DSP56371. These include the following:

- Operating modes
- Bootstrap program
- Interrupt sources and priorities
- DMA request sources
- OMR
- PLL control register
- JTAG

For more information on specific registers or modules in the DSP56300 core, refer to the *DSP56300 Family Manual (DSP56300FM)*.

### 4.2 Operating Mode Register (OMR)

The contents of the Operating Mode Register (OMR) are shown in [Table 4-1](#). Refer to the *DSP56300 24-Bit Digital Signal Processor Family Manual*, Freescale publication DSP56300FM for a description of the OMR bits.

**Table 4-1 Operating Mode Register (OMR)**

SCS								EOM								COM									
23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0		
	MSW 1 : 0		SEN	WRP	EOV	EUN	XYS							CDP1:0		MS	SD			MD	MC	MB	MA		
																MS		- Master Memory Switch Mode							
																SD		- Stop Delay							
MSW1		- Memory Switch Mode 1																							
MSW0		- Memory Switch Mode 0																							
SEN		- Stack Extension Enable																							
WRP		- Extended Stack Wrap Flag										MD		- Operating Mode D											
EOV		- Extended Stack Overflow Flag										MC		- Operating Mode C											
EUN		- Extended Stack Underflow Flag										CDP1		- Core-DMA Priority 1						MB		- Operating Mode B			
XYS		- Stack Extension Space Select										CDP0		- Core-DMA Priority 0						MA		- Operating Mode A			
		- Reserved bit. Read as zero, should be written with zero for future compatibility																							

### 4.2.1 RESERVED - Bits 4, 5, 10 - 15 and 23

These bits are reserved.

## 4.3 Operating Modes

The operating modes are defined as shown in [Table 4-2](#). The operating modes are latched from MODA, MODB, MODC and MODD pins during reset. Each operating mode is briefly described below. The operation of all modes is defined by the Bootstrap ROM source code in [Appendix A, "Bootstrap ROM Contents"](#).

**Table 4-2 DSP56371 Operating Modes**

Mode	MODD	MODC	MODB	MODA	Reset Vector	Description
0	0	0	0	0	\$000000	Reserved
1	0	0	0	1	\$FF0000	Reserved
2	0	0	1	0	\$FF0000	Jump to PROM starting address
3	0	0	1	1	\$FF0000	Reserved
4	0	1	0	0	\$FF0000	Reserved
5	0	1	0	1	\$FF0000	Bootstrap from SHI (slave SPI mode)
6	0	1	1	0	\$FF0000	Reserved
7	0	1	1	1	\$FF0000	Bootstrap from SHI (slave I <sup>2</sup> C mode)(HCKFR=0)
8	1	0	0	0	\$004000	Reserved
9	1	0	0	1	\$FF0000	Bootstrap from SHI (Serial EEPROM mode)
A	1	0	1	0	\$FF0000	Burn-in test mode
B	1	0	1	1	\$FF0000	Reserved
C	1	1	0	0	\$FF0000	Reserved
D	1	1	0	1	\$FF0000	Reserved
E	1	1	1	0	\$FF0000	Reserved
F	1	1	1	1	\$FF0000	Reserved

Table 4-3 DSP56371 Mode Descriptions

Mode	Mode Description
Mode 0	Reserved
Mode 1	Reserved
Mode 2	The DSP starts fetching instructions from the starting address of the on-chip Program ROM.
Mode 3	Reserved.
Mode 4	Reserved.
Mode 5	In this mode, the internal PRAM is loaded from the Serial Host Interface (SHI). The SHI operates in the SPI slave mode, with 24-bit word width. The bootstrap code expects to read a 24-bit word specifying the number of program words, a 24-bit word specifying the address to start loading the program words and then a 24-bit word for each program word to be loaded. The program words will be stored in contiguous PRAM memory locations starting at the specified starting address. After reading the program words, program execution starts from the same address where loading started.
Mode 6	Reserved.
Mode 7	Same as Mode 5 except SHI interface operates in the I <sup>2</sup> C slave mode with HCKFR set to 0.
Mode 8	Reserved.
Mode 9	In this mode, the internal memory (PRAM, XRAM, or YRAM) is loaded from an external serial EEPROM in I2C mode. <sup>1</sup>
Mode A	Reserved.
Mode B	Reserved.
Mode C	Reserved.
Mode D	Reserved.
Mode E	Reserved.
Mode F	Reserved.

<sup>1</sup> See [A.2, "Using the Serial EEPROM Boot Mode"](#) for details on using this boot mode.

## 4.4 Interrupt Priority Registers

There are two interrupt priority registers in the DSP56371:

1. IPR-C is dedicated for DSP56300 Core interrupt sources.
2. IPR-P is dedicated for DSP56371 Peripheral interrupt sources.

The interrupt priority registers are shown in [Figure 4-1](#) and [Figure 4-2](#). The Interrupt Priority Level bits are defined in [Table 4-4](#). The interrupt vectors are shown in [Table 4-6](#) and the interrupt priorities are shown in [Table 4-5](#).

Table 4-4 Interrupt Priority Level Bits

IPL bits		Interrupts Enabled	Interrupt Priority Level
xxL1	xxL0		
0	0	No	—
0	1	Yes	0
1	0	Yes	1
1	1	Yes	2

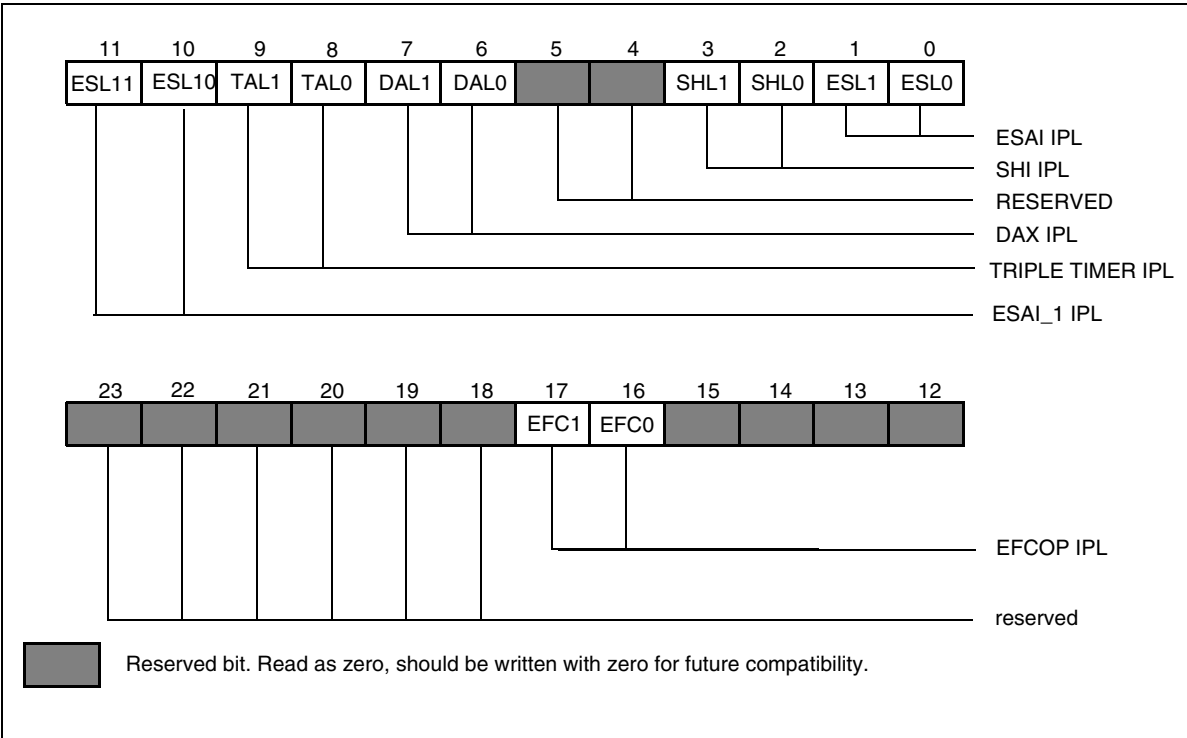


Figure 4-1 Interrupt Priority Register P



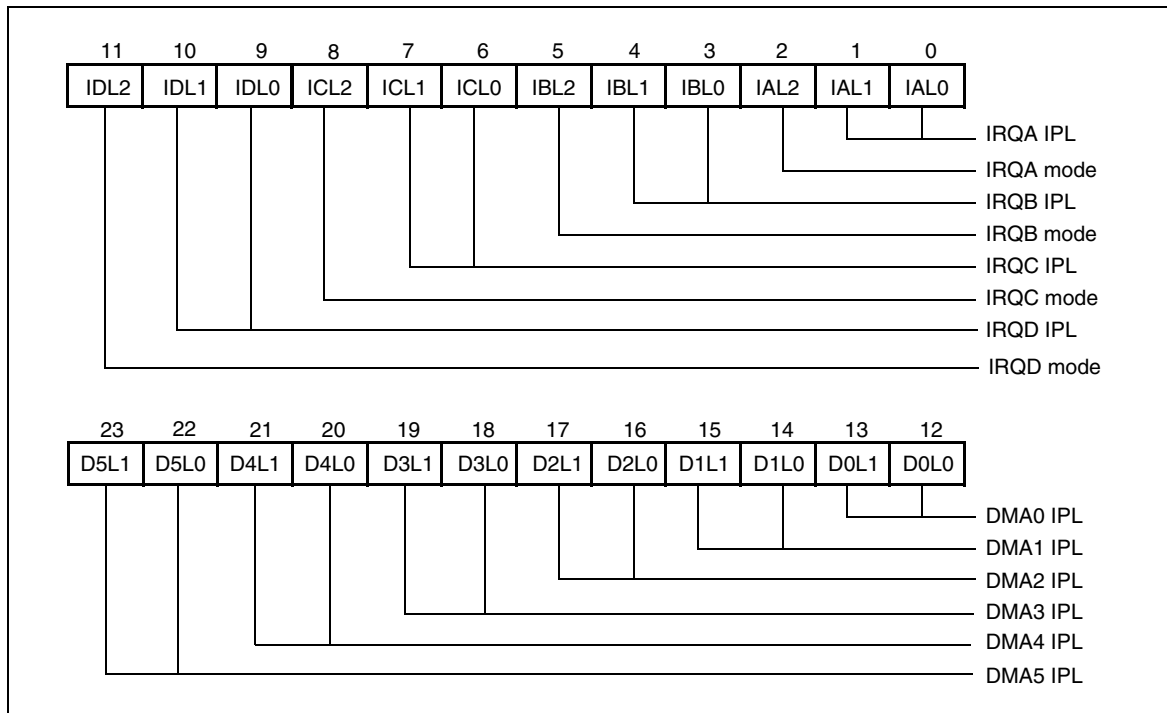


Figure 4-2 Interrupt Priority Register C

Table 4-5 Interrupt Sources Priorities Within an IPL

Priority	Interrupt Source
Level 3 (Nonmaskable)	
Highest	Hardware $\overline{\text{RESET}}$
	Stack Error
	Illegal Instruction
	Debug Request Interrupt
	Trap
Lowest	Non-Maskable Interrupt
Levels 0, 1, 2 (Maskable)	
Highest	$\overline{\text{IRQA}}$ (External Interrupt)
	$\overline{\text{IRQB}}$ (External Interrupt)
	$\overline{\text{IRQC}}$ (External Interrupt)
	$\overline{\text{IRQD}}$ (External Interrupt)
	DMA Channel 0 Interrupt
	DMA Channel 1 Interrupt

Table 4-5 Interrupt Sources Priorities Within an IPL (continued)

Priority	Interrupt Source
	DMA Channel 2 Interrupt
	DMA Channel 3 Interrupt
	DMA Channel 4 Interrupt
	DMA Channel 5 Interrupt
	ESAI Receive Data with Exception Status
	ESAI Receive Even Data
	ESAI Receive Data
	ESAI Receive Last Slot
	ESAI Transmit Data with Exception Status
	ESAI Transmit Last Slot
	ESAI Transmit Even Data
	ESAI Transmit Data
	SHI Bus Error
	SHI Receive Overrun Error
	SHI Transmit Underrun Error
	SHI Receive FIFO Full
	SHI Transmit Data
	SHI Receive FIFO Not Empty
	DAX Transmit Underrun Error
	DAX Block Transferred
	DAX Transmit Register Empty
	TIMER0 Overflow Interrupt
	TIMER0 Compare Interrupt
	TIMER1 Overflow Interrupt
	TIMER1 Compare Interrupt
	TIMER2 Overflow Interrupt
	TIMER2 Compare Interrupt
	ESAI_1 Receive Data with Exception Status

Table 4-5 Interrupt Sources Priorities Within an IPL (continued)

Priority	Interrupt Source
	ESAI_1 Receive Even Data
	ESAI_1 Receive Data
	ESAI_1 Receive Last Slot
	ESAI_1 Transmit Data with Exception Status
	ESAI_1 Transmit Last Slot
	ESAI_1 Transmit Even Data
	ESAI_1 Transmit Data
	EFCOP Data input buffer empty
Lowest	EFCOP Data output buffer full

Table 4-6 DSP56371 Interrupt Vectors

Interrupt Starting Address	Interrupt Priority Level Range	Interrupt Source
VBA:\$00	3	Hardware $\overline{\text{RESET}}$
VBA:\$02	3	Stack Error
VBA:\$04	3	Illegal Instruction
VBA:\$06	3	Debug Request Interrupt
VBA:\$08	3	Trap
VBA:\$0A	3	Non-Maskable Interrupt ( $\overline{\text{NMI}}$ )
VBA:\$0C	3	<i>Reserved For Future Level-3 Interrupt Source</i>
VBA:\$0E	3	<i>Reserved For Future Level-3 Interrupt Source</i>
VBA:\$10	0 - 2	IRQA
VBA:\$12	0 - 2	IRQB
VBA:\$14	0 - 2	IRQC
VBA:\$16	0 - 2	IRQD
VBA:\$18	0 - 2	DMA Channel 0
VBA:\$1A	0 - 2	DMA Channel 1
VBA:\$1C	0 - 2	DMA Channel 2
VBA:\$1E	0 - 2	DMA Channel 3

Table 4-6 DSP56371 Interrupt Vectors (continued)

Interrupt Starting Address	Interrupt Priority Level Range	Interrupt Source
VBA:\$20	0 - 2	DMA Channel 4
VBA:\$22	0 - 2	DMA Channel 5
VBA:\$24	0 - 2	<i>Reserved</i>
VBA:\$26	0 - 2	<i>Reserved</i>
VBA:\$28	0 - 2	DAX Underrun Error
VBA:\$2A	0 - 2	DAX Block Transferred
VBA:\$2C	0 - 2	<i>Reserved</i>
VBA:\$2E	0 - 2	DAX Audio Data Empty
VBA:\$30	0 - 2	ESAI Receive Data
VBA:\$32	0 - 2	ESAI Receive Even Data
VBA:\$34	0 - 2	ESAI Receive Data With Exception Status
VBA:\$36	0 - 2	ESAI Receive Last Slot
VBA:\$38	0 - 2	ESAI Transmit Data
VBA:\$3A	0 - 2	ESAI Transmit Even Data
VBA:\$3C	0 - 2	ESAI Transmit Data with Exception Status
VBA:\$3E	0 - 2	ESAI Transmit Last Slot
VBA:\$40	0 - 2	SHI Transmit Data
VBA:\$42	0 - 2	SHI Transmit Underrun Error
VBA:\$44	0 - 2	SHI Receive FIFO Not Empty
VBA:\$46	0 - 2	<i>Reserved</i>
VBA:\$48	0 - 2	SHI Receive FIFO Full
VBA:\$4A	0 - 2	SHI Receive Overrun Error
VBA:\$4C	0 - 2	SHI Bus Error
VBA:\$4E	0 - 2	<i>Reserved</i>
VBA:\$50	0 - 2	<i>Reserved</i>
VBA:\$52	0 - 2	<i>Reserved</i>
VBA:\$54	0 - 2	TIMER0 Compare

Table 4-6 DSP56371 Interrupt Vectors (continued)

Interrupt Starting Address	Interrupt Priority Level Range	Interrupt Source
VBA:\$56	0 - 2	TIMER0 Overflow
VBA:\$58	0 - 2	TIMER1 Compare
VBA:\$5A	0 - 2	TIMER1 Overflow
VBA:\$5C	0 - 2	TIMER2 Compare
VBA:\$5E	0 - 2	TIMER2 Overflow
VBA:\$60	0 - 2	<i>Reserved</i>
VBA:\$62	0 - 2	<i>Reserved</i>
VBA:\$64	0 - 2	<i>Reserved</i>
VBA:\$66	0 - 2	<i>Reserved</i>
VBA:\$68	0 - 2	EFCOP Data input buffer empty
VBA:\$6A	0 - 2	EFCOP Data output buffer full
VBA:\$6C	0 - 2	<i>Reserved</i>
VBA:\$6E	0 - 2	<i>Reserved</i>
VBA:\$70	0 - 2	ESAI_1 Receive Data
VBA:\$72	0 - 2	ESAI_1 Receive Even Data
VBA:\$74	0 - 2	ESAI_1 Receive Data With Exception Status
VBA:\$76	0 - 2	ESAI_1 Receive Last Slot
VBA:\$78	0 - 2	ESAI_1 Transmit Data
VBA:\$7A	0 - 2	ESAI_1 Transmit Even Data
VBA:\$7C	0 - 2	ESAI_1 Transmit Data with Exception Status
VBA:\$7E	0 - 2	ESAI_1 Transmit Last Slot
VBA:\$80	0 - 2	<i>Reserved</i>
VBA:\$82	0 - 2	<i>Reserved</i>
VBA:\$84	0 - 2	<i>Reserved</i>
VBA:\$86	0 - 2	<i>Reserved</i>
VBA:\$88	0 - 2	<i>Reserved</i>
VBA:\$8A	0 - 2	<i>Reserved</i>

Table 4-6 DSP56371 Interrupt Vectors (continued)

Interrupt Starting Address	Interrupt Priority Level Range	Interrupt Source
VBA:\$8C	0 - 2	Reserved
VBA:\$8E	0 - 2	Reserved
VBA:\$90	0 - 2	Reserved
VBA:\$92	0 - 2	Reserved
VBA:\$94	0 - 2	Reserved
VBA:\$96	0 - 2	Reserved
VBA:\$98	0 - 2	Reserved
VBA:\$9A	0 - 2	Reserved
VBA:\$9C	0 - 2	Reserved
VBA:\$9E	0 - 2	Reserved
VBA:\$A0	0 - 2	Reserved
VBA:\$A2	0 - 2	Reserved
VBA:\$A4	0 - 2	Reserved
VBA:\$A6	0 - 2	Reserved
VBA:\$A8	0 - 2	Reserved
VBA:\$AA	0 - 2	Reserved
VBA:\$AC	0 - 2	Reserved
VBA:\$AE	0 - 2	Reserved
VBA:\$B0	0 - 2	Reserved
VBA:\$B2	0 - 2	Reserved
VBA:\$B4	0 - 2	Reserved
VBA:\$B6	0 - 2	Reserved
VBA:\$B8	0 - 2	Reserved
VBA:\$BA	0 - 2	Reserved
:	:	:
VBA:\$FE	0 - 2	Reserved

## 4.5 DMA Request Sources

The DMA Request Source bits (DRS4-DRS0 bits in the DMA Control/Status registers) encode the source of DMA requests used to trigger the DMA transfers. The DMA request sources may be the internal peripherals or external devices requesting service through the  $\overline{\text{IRQA}}$ ,  $\overline{\text{IRQB}}$ ,  $\overline{\text{IRQC}}$  and  $\overline{\text{IRQD}}$  pins. The DMA Request Sources are shown in Table 4-7.

**Table 4-7 DMA Request Sources**

DMA Request Source Bits DRS4...DRS0	Requesting Device
00000	External ( $\overline{\text{IRQA}}$ pin)
00001	External ( $\overline{\text{IRQB}}$ pin)
00010	External ( $\overline{\text{IRQC}}$ pin)
00011	External ( $\overline{\text{IRQD}}$ pin)
00100	Transfer Done from DMA channel 0
00101	Transfer Done from DMA channel 1
00110	Transfer Done from DMA channel 2
00111	Transfer Done from DMA channel 3
01000	Transfer Done from DMA channel 4
01001	Transfer Done from DMA channel 5
01010	DAX Transmit Data
01011	ESAI Receive Data (RDF=1)
01100	ESAI Transmit Data (TDE=1)
01101	SHI HTX Empty
01110	SHI FIFO Not Empty
01111	SHI FIFO Full
10000	EFCOP input buffer empty (FDIBE = 1)
10001	EFCOP output buffer full (FDOBF = 1)
10010	TIMER0 (TCF=1)
10011	TIMER1 (TCF=1)
10100	TIMER2 (TCF=1)
10101	ESAI_1 Receive Data (RDF=1)
10110	ESAI_1 Transmit Data (TDE=1)
10111	<i>Reserved</i>
11000	<i>Reserved</i>
11001-11111	<i>Reserved</i>

## 4.6 PLL Initialization

The following figure displays the PLL control register (PCTL). This register is used to control the PLL operation including its multiplication/divide factors and enabling bits.

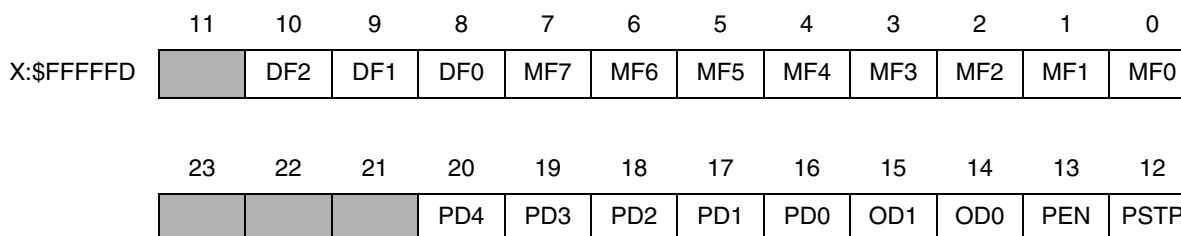


Figure 4-3 PCTL Register

### 4.6.1 PLL Pre-Divider Factor (PD0-PD4)

The DSP56371 PLL Pre-Divider factor is set to 4 during hardware reset, i.e., the Pre-Divider Factor Bits PD0-PD4 in the PLL Control Register (PCTL) are set to \$4.

### 4.6.2 PLL Multiplication Factor (MF0-MF7)

The DSP56371 PLL multiplication factor is set to 29 during hardware reset, i.e., the Multiplication Factor Bits MF0-MF7 in the PLL Control Register (PCTL) are set to \$1D.

### 4.6.3 PLL Feedback Multiplier (OD1)

The DSP56371 PLL Feedback Multiplier is set to 2 during hardware reset, i.e., OD1 is cleared (\$0) in the PLL Control Register (PCTL).

### 4.6.4 PLL Output Divide Factor (OD0-OD1)

The DSP56371 PLL Output Divider factor is set to 2 during hardware reset, i.e., OD1 is cleared (\$0) and OD0 is set (\$1) in the PLL Control Register (PCTL).

### 4.6.5 PLL Divider Factor (DF0-DF2)

The DSP56371 PLL Divider factor is set to 1 during hardware reset, i.e., the Divider Factor Bits DF0-DF2 in the PLL Control Register (PCTL) are set to \$0.

## 4.7 Device Identification (ID) Register

The Device Identification Register (IDR) is a 24 bit read only factory programmed register used to identify the different DSP56300 core-based family members. This register specifies the derivative number and revision number. This information may be used in testing or by software. [Table 4-8](#) shows the ID register configuration.



**Table 4-8 Identification Register Configuration**

23	16	15	12	11	0
<b>Reserved</b>		<b>Revision Number</b>			<b>Derivative Number</b>
\$00		\$0			\$371

## 4.8 JTAG Identification (ID) Register

The JTAG Identification (ID) Register is a 32 bit, read only thought JTAG, factory programmed register used to distinguish the component on a board according to the IEEE 1149.1 standard. [Table 4-9](#) shows the JTAG ID register configuration.

**Table 4-9 JTAG Identification Register Configuration**

31	28	27	22	21	12	11	1	0
<b>Version Information</b>				<b>Customer Part Number</b>				<b>Sequence Number</b>
0000				000111				000000000000
								00000001110
								1

## NOTES

## 5 PLL and Clock Generator

### 5.1 Introduction

The DSP56371 core features a Phase-Locked Loop (PLL) clock generator in its central processing module. The PLL operation is controlled by a PLL control register (PCTL). The PLL allows the processor to operate at a high internal clock frequency derived from a low-frequency clock input, a feature that offers two immediate benefits. First, the lower frequency clock input can reduce the overall electromagnetic interference generated by a system. Second, the ability to oscillate at different frequencies reduces costs by eliminating the need to add additional oscillators to a system. Figure 5-1 shows the two main blocks of the clock generator in the DSP56371 core:

- Phase-Locked Loop (PLL) that performs:
  - Clock input division
  - Frequency multiplication
  - Skew elimination
- Clock Generator (CLKGEN) that performs:
  - Low-power division
  - Internal clock generation

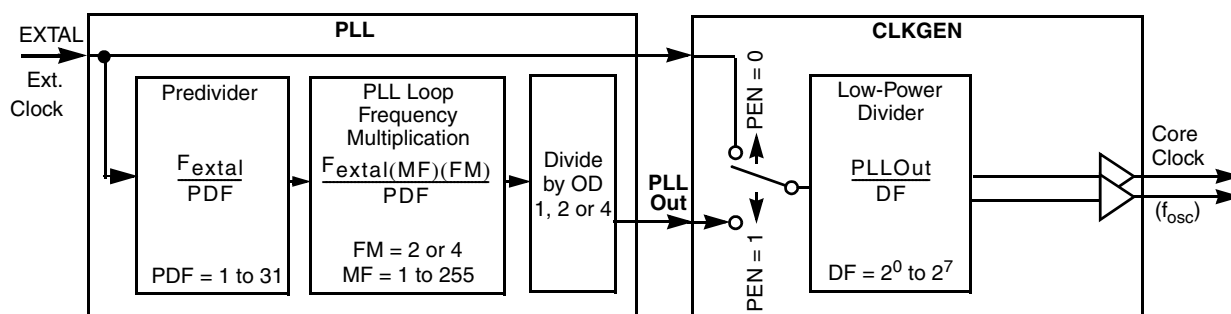


Figure 5-1 PLL Clock Generator Block Diagram

### 5.2 PLL and Clock Signals

The PLL and clock pin configuration for the DSP56371 is available in the device-specific technical data sheet. The following pins are dedicated to the PLL and clock operation:

- PINIT: During assertion of hardware reset, the value of the PINIT input pin is written into the PCTL PLL Enable (PEN) bit. After hardware reset is deasserted, the PLL ignores the PINIT pin. The default PCTL setting when PINIT is asserted is: \$04601D.
- EXTAL: An external clock is required to drive the DSP. The external clock is input via the EXTAL pin passing the clock through the PLL and Clock generator for optional frequency multiplication.

## 5.3 PLL Block

This section describes the PLL control components and operation. Figure 5-2 shows the PLL block diagram.

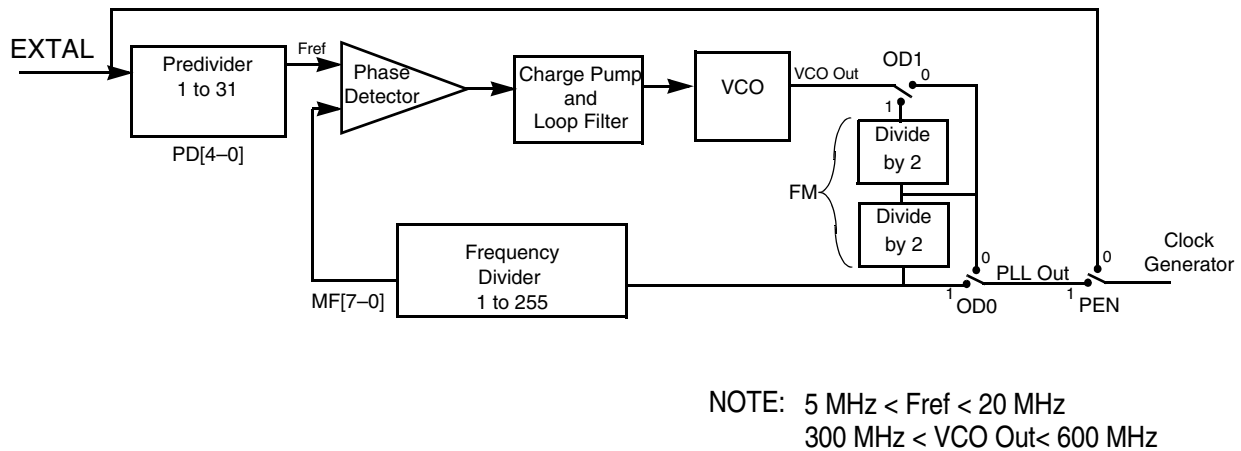


Figure 5-2 PLL Block Diagram

### 5.3.1 Frequency Predivider

Clock input frequency division is accomplished by means of a frequency predivider of the input frequency. The pre-divider ranges from 1 to 31. The pre-divider must never be set to zero. The output frequency of the pre-divider (Fref) must be between 5 MHz and 20 MHz to guarantee proper operation.

### 5.3.2 Phase Detector and Charge Pump Loop Filter

The Phase Detector detects any phase difference between the external clock (EXTAL) and the phase of the clock generated by the PLL. At the point where there is negligible phase difference and the frequency of the two inputs is identical, the PLL is in the locked state. The charge pump loop filter receives signals from the Phase Detector and either increases or decreases the voltage applied to the VCO based on the Phase Detector signals.

### 5.3.3 Voltage Controlled Oscillator (VCO)

The Voltage Controlled Oscillator (VCO) can oscillate at frequencies from 300 MHz to 600 MHz. The VCO output frequency is determined by the voltage applied to it by the charge pump that corresponds to the PLL input frequency (Fref). The VCO frequency is a function of the input frequency as well as the multiplication components (Multiplication factor (MF) and Feedback Multiplier (FM)).

### 5.3.4 PLL Dividers

As part of the PLL output stage, there are two divide modules (each is a divide by 2 module) controlled by the OD0 and OD1 bits in the PCTL register. These two bits control the PLL *feedback multiplier* (FM) as well as the *output divide* factor (OD). The feedback multiplier is a frequency divider implemented in the

PLL feedback loop thus operating as a PLL multiplier and can be programmed to multiply the VCO output frequency up by a factor of 2 or 4. See Table 5-1. The number of divide modules in the PLL loop is determined by the OD1 bit. When one divide module is in the feedback loop (OD1=0) FM = 2. When two divide modules are in the feedback loop (OD1=1) FM = 4. Note that when OD1 is changed, the PLL will lose lock.

**Table 5-1 Feedback Multiplier (FM);  $FM = 2(1 + OD1)$**

	FM
OD1 = 0	2
OD1 = 1	4

The output divide factor (OD) determines the PLL output frequency as a function of the VCO frequency. The PLL output frequency can be programmed to be the VCO frequency divided by 1, 2 or 4. Note that the output divide factor (OD) should not be programmed to be 1. The main oscillator frequency will exceed the maximum specified value when OD=1. The output divide factor (OD) is determined by both OD1 and OD0 bits. See Table 5-2. Note that the PLL will not lose lock when OD0 is changed as OD0 is not in the PLL loop.

**Table 5-2 Output Divide Factor (OD)**

	OD0 = 0	OD0 = 1
OD1 = 0	div by 1	div by 2
OD1 = 1	div by 2	div by 4

### 5.3.5 PLL Multiplication Factor (MF)

The Frequency Divider portion of the PLL feedback loop divides the VCO output by an additional programmable 8-bit value before entering the Phase Detector. The net result is an additional multiplication of the input clock by the programmed value. This is called the *Multiplication Factor (MF)* and is programmed using the PCTL[MF] bits. The Multiplication Factor can range from 1 to 255. The MF must never be set to zero and although there are 8 bits for programming the MF ranging from 1 to 255, due to VCO output frequency and Fref frequency limitations, the MF should always be programmed between the values of 4 and 60.

## 5.4 PLL Operation

The PLL uses two major control elements in its circuitry:

- Clock input division
- Frequency multiplication

The following describes the operation of the PLL and its components.

### 5.4.1 EXTAL Clock Input Division

The PLL can divide the input frequency (EXTAL) by any integer between 1 and 31. The Division Factor can be modified by changing the value of the PCTL Predivider Factor (PDF) bits (PD[4–0]). The output frequency of the predivider is called the reference frequency (Fref) and is determined using the following formula:

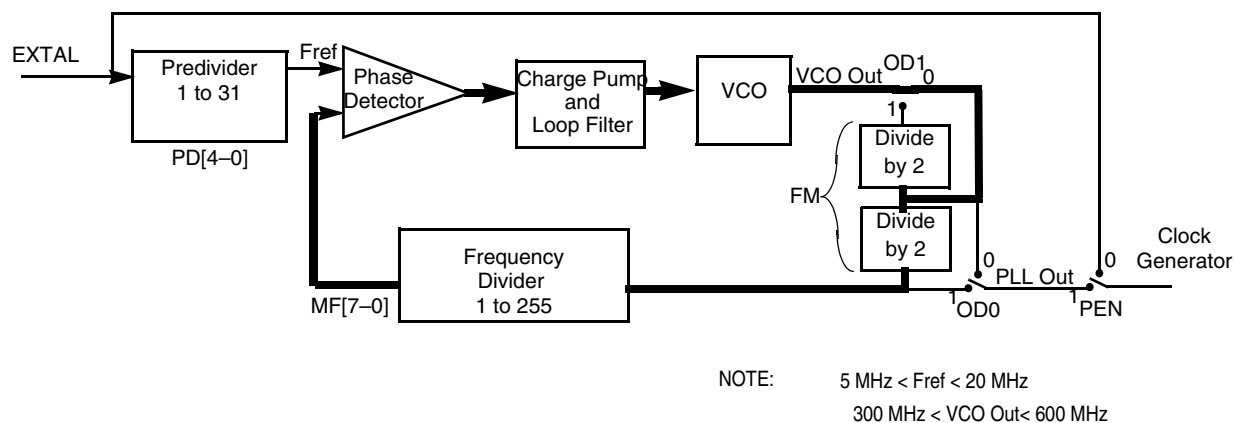
$$F_{ref} = \frac{F_{extal}}{PDF} \quad ; 5\text{MHz} < F_{ref} < 20\text{MHz}$$

### 5.4.2 PLL Frequency Multiplication

The PLL can multiply the reference frequency by using the MF and FM multipliers in the PLL feedback loop. This is performed by writing to the Multiplication Factor (MF[7–0]) bits and the OD[1] bit (affecting the Feedback Multiplier) in the PCTL register. The output frequency of the VCO (that is, VCO Out as shown in [Figure 5-1](#)) is computed using the following formula:

$$V_{COOut} = \frac{F_{extal} \times MF \times FM}{PDF} \quad ; 300MHz < VCO < 600MHz$$

The following figures display how the OD1 bit affects the PLL loop and the VCO output freakiness. **Figure 5-3** shows that when OD1 is clear, only one divider module is in the PLL loop, effectively applying a feedback multiplier of 2. **Figure 5-4** shows that when OD1 is set, two divider modules are in the PLL loop, effectively applying a feedback multiplier of 4. Note that, since OD1 is in the closed loop of the PLL, changes to OD1 do cause a loss of lock condition.



**Figure 5-3 PLL Loop with One Divider when OD1=0 (FM = 2)**

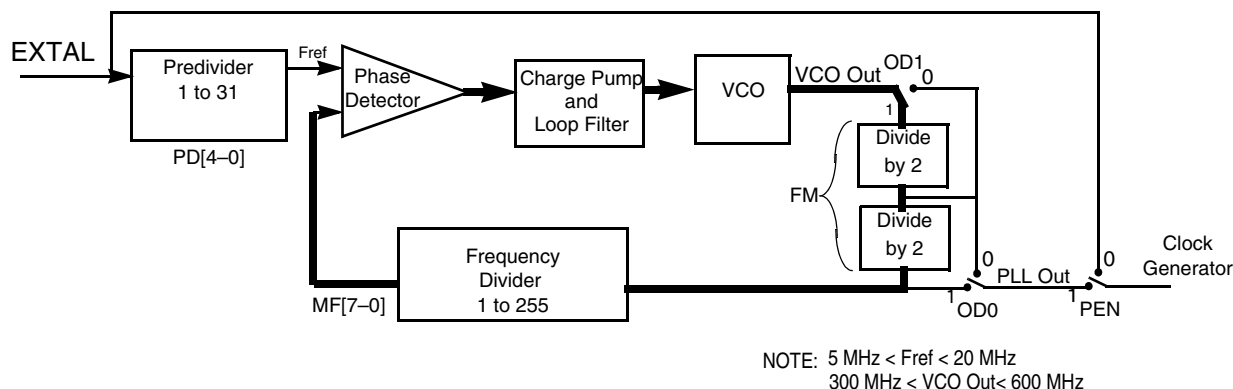


Figure 5-4 PLL Loop with Two Dividers when OD1=1 (FM = 4)

### 5.4.3 PLL Output Frequency (PLL Out)

The PLL Output frequency is a function of the VCO frequency as follows:

$$\text{PLL Out} = \frac{\text{VCO}}{\text{OD}}$$

As described above the Output Divider Factor is 1, 2 or 4 as determined by the OD1 and OD0 bits. The output divide factor (OD) should not be programmed to be 1. Note that since OD0 is not in the closed loop of the PLL, changes to OD0 do not cause a loss of lock condition. The figures below show how the OD [1-0] bits affect the PLL Output frequency by dividing the VCO Output. Figure 5-5 displays how setting OD1 = 0 and OD0 = 1 divides the VCO output to generate a PLL Output that is VCO Out/2.

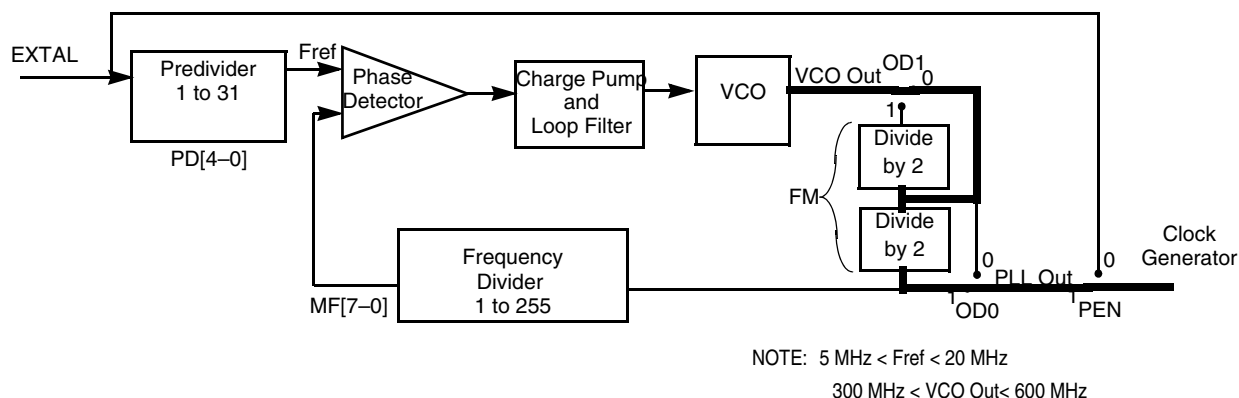
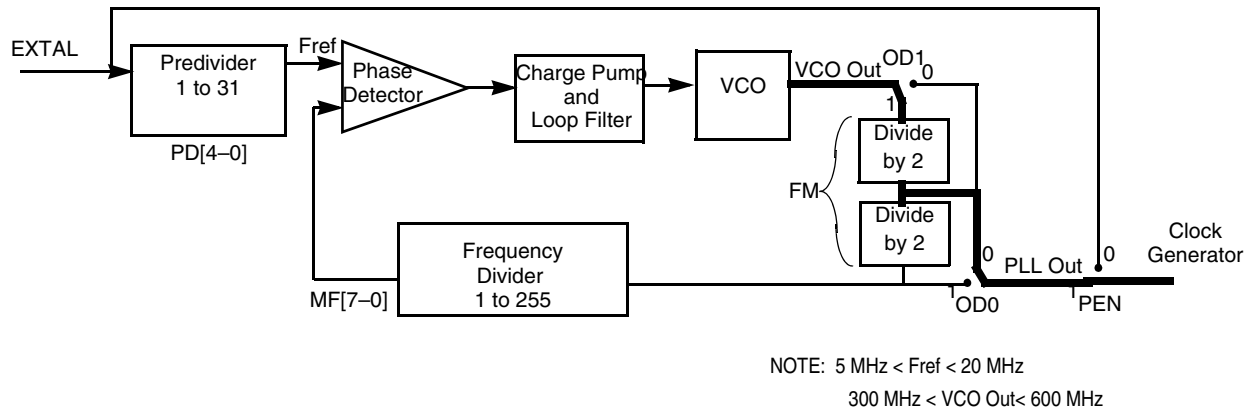


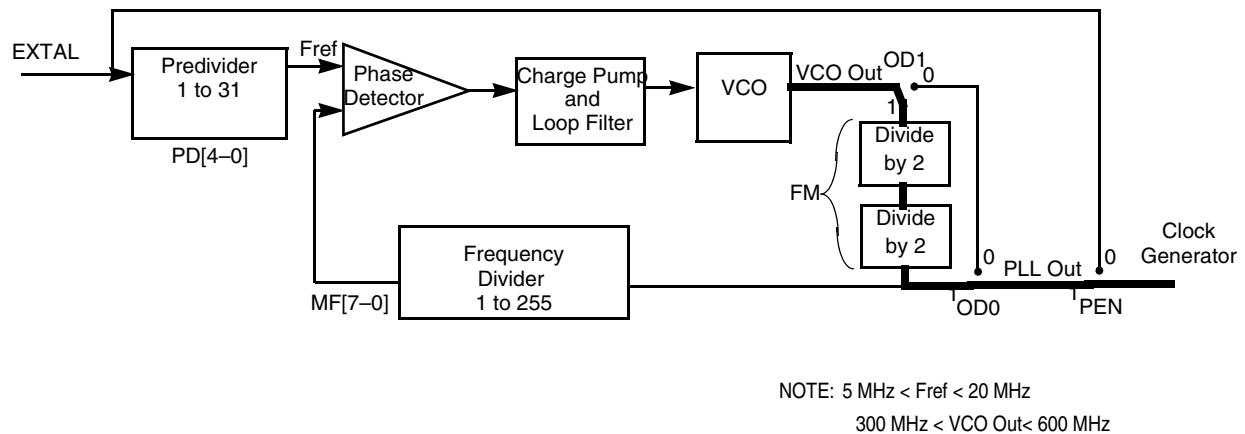
Figure 5-5 PLL Out = VCO Out/2 [OD1 = 0, OD0 = 1]

Figure 5-6 displays how setting OD1 = 1 and OD0 = 0 divides the VCO output to generate a PLL Output that is VCO Out/2.



**Figure 5-6 PLL Out = VCO Out/2 [OD1 = 1, OD0 = 0]**

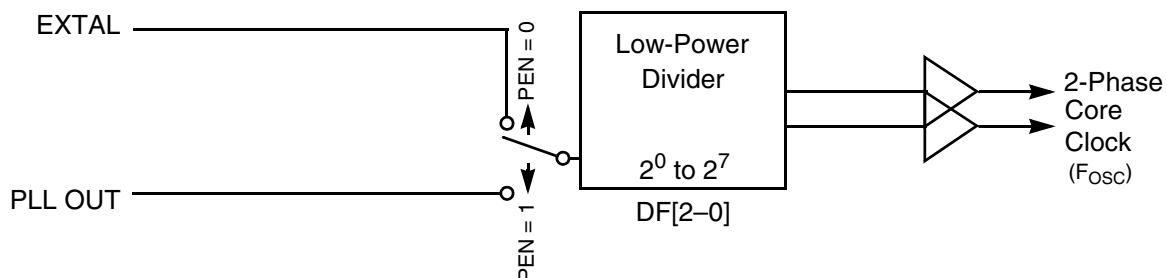
Figure 5-7 displays how setting OD1 = 1 and OD0 = 1 divides the VCO output to generate a PLL Output that is VCO Out/4.



**Figure 5-7 PLL Out = VCO Out/4 [OD1 = 1, OD0 = 1]**

## 5.5 Clock Generator

Figure 5-8 shows the Clock Generator block diagram. The components of the Clock Generator are described in the following sections.



**Figure 5-8 CLKGEN Block Diagram**



### 5.5.1 Low-Power Divider (LPD)

The Clock Generator section consists of a divider connected to the output of the PLL. The Low-Power Divider (LPD) divides the output frequency of the PLL by any power of 2 from  $2^0$  to  $2^7$ . The Division Factor (DF) of the LPD can be modified by changing the value of the PLL Control Register (PCTL) Division Factor bits DF[2–0]. Since the LPD is not in the closed loop of the PLL, changes to the DF [2–0] bits do not cause a loss of lock condition. The result is a significant power savings when the LPD operates in low-power consumption modes as the device is not involved in intensive calculations. When the device is required to exit a low-power mode, it can immediately do so with no time needed for clock recovery or PLL lock.

## 5.6 Operating Frequency (Fosc)

The output stage of the Clock Generator generates the clock signals to the core and the device peripherals. The input source to the clock generator is selected between:

- EXTAL (PEN = 0, PLL disabled), which generates the device frequency from the EXTAL clock directly.

$$F_{osc} = \frac{F_{extal}}{DF}$$

- PLL Output (PEN = 1, PLL enabled), which generates a device frequency defined by the following formula:

$$F_{osc} = \frac{F_{extal} \times MF \times FM}{PDF \times DF \times OD}$$

where:

MF is the Multiplication Factor defined by MF[7–0]

PDF is the Predivider Factor defined by PD[4–0]

DF is the Division Factor defined by DF[2–0]

OD is the Output Divide Factor defined by OD[1–0].

FM is the Feedback Multiplication Factor defined by OD[1]

$F_{OSC}$  is the device operating frequency

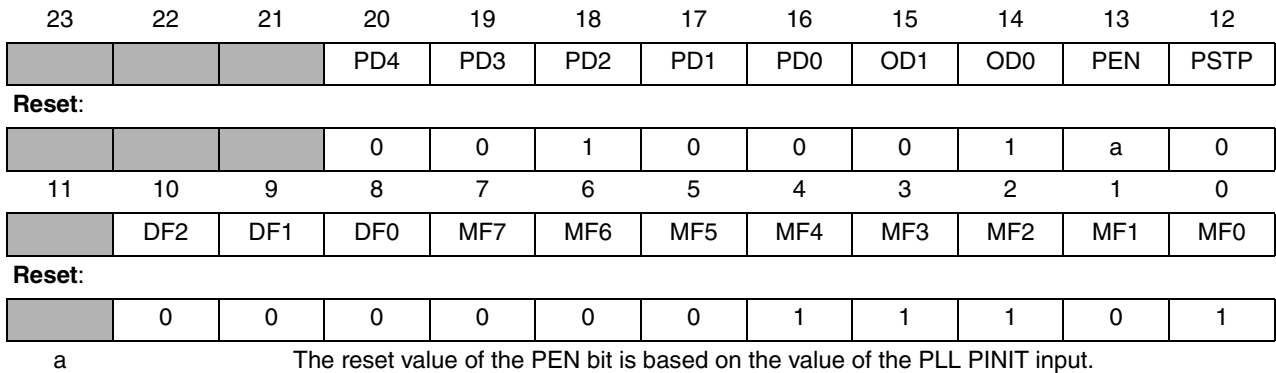
$F_{EXTAL}$  is the external EXTAL input

## 5.7 PLL Programming Model

The PLL clock generator uses a single register, the PCTL Register, for PLL control. The PCTL is an X I/O mapped 24-bit read/write register used to direct the operation of the on-chip PLL.

Figure 5-9 shows the PCTL control bits. The PCTL bits are described in Table 5-3.

# PLL Programming Model



The reset value of the PEN bit is based on the value of the PLL PINIT input.

Figure 5-9 PLL Control (PCTL) Register

Table 5-3 PLL Control (PCTL) Register Bit Definitions

Bit Number	Bit Name	Reset Value	Description
20–16	PD[4–0]	\$4	<p><b>Predivider Factor</b></p> <p>Defines the PDF value that is applied to the input frequency. PDF can be any integer from 1 to 31. The VCO is a function of PDF and oscillates at a frequency defined by the following formula:</p> $\frac{F_{\text{extal}} \times MF \times FM}{PDF}$ <p>PDF must be chosen to ensure that Fref lies in a range specified in the device-specific technical data sheet (5 MHz - 20 MHz) and the resulting VCO output frequency lies in the range specified in the device-specific technical data sheet (300 MHz - 600 MHz). Any time a new value is written into the PD[4–0] bits, the PLL loses the lock condition. The PDF bits (PD[4–0]) are set to \$4 during hardware reset. The PDF value should never be set to \$0.</p>

Because of an order from the United States International Trade Commission, BGA-packaged product lines and part numbers indicated here currently are not available from Freescale for import or sale in the United States prior to September 2010: DSP56303

Table 5-3 PLL Control (PCTL) Register Bit Definitions (continued)

Bit Number	Bit Name	Reset Value	Description									
15–14	OD[1–0]	01	<p><b>Output Divider Factor and Feedback Multiplier</b></p> <p>Defines the OD and FM values that are applied to the output VCO frequency. The VCO oscillates at a frequency defined by the following formula:</p> $\frac{F_{\text{extal}} \times MF \times FM}{PDF}$ <p>FM = 2(1 + OD1). OD1 must be chosen to ensure that the resulting VCO output frequency lies in the range specified in the device-specific technical data sheet (300 MHz - 600 MHz). Any time OD1 is changed, the PLL loses the lock condition.</p> <p>OD1 is initially cleared (0) following reset. OD0 is initially set (1) following reset. Changes to OD0 do not cause the PLL to lose the lock condition. OD0 and OD1 bits together define the output divide factor (OD). The output divide factor divides the VCO output frequency by a factor of 1, 2 or 4 according to <a href="#">Table 5-4</a>. Note that OD0 and OD1 should not simultaneously be cleared (i.e. divide by 1). The resulting Fosc frequency will exceed the maximum operating frequency when OD = 1.</p> <p style="text-align: center;"><b>Table 5-4 Output Divide Factor</b></p> <table><tr><td></td><td><b>OD0 = 0</b></td><td><b>OD0 = 1</b></td></tr><tr><td><b>OD1 = 0</b></td><td>div by 1</td><td>div by 2</td></tr><tr><td><b>OD1 = 1</b></td><td>div by 2</td><td>div by 4</td></tr></table> <p>The PLL Output is defined by the following formula when OD = 1:</p> $\frac{VCO_{\text{Out}}}{OD}$		<b>OD0 = 0</b>	<b>OD0 = 1</b>	<b>OD1 = 0</b>	div by 1	div by 2	<b>OD1 = 1</b>	div by 2	div by 4
	<b>OD0 = 0</b>	<b>OD0 = 1</b>										
<b>OD1 = 0</b>	div by 1	div by 2										
<b>OD1 = 1</b>	div by 2	div by 4										
13	PEN	a	<p><b>PLL Enable</b></p> <p>Enables PLL operation. When PEN is set, the PLL is enabled and the internal clocks are derived from the PLL VCO output. When PEN is cleared, the PLL is disabled and the internal clocks are derived directly from the EXTAL signal. When the PLL is disabled, the VCO stops to minimize power consumption. The PEN bit may be set or cleared by software any time during the device operation. During hardware reset, this bit is set or cleared based on the value of the PLL PINIT input.</p> <p><b>Note:</b> The PLL will momentarily overshoot the target frequency when the PLL is first enabled or when the VCO frequency is modified. It is important that the PLL output initially be programmed to a target value less than 150 MHz and the main oscillator (Fosc) initially be programmed to a frequency less than one-half the maximum specified operating frequency until the PLL is locked. See <a href="#">Section 5.8, "PLL Initialization Procedure"</a>.</p>									

Table 5-3 PLL Control (PCTL) Register Bit Definitions (continued)

Bit Number	Bit Name	Reset Value	Description					
12	PSTP	0	<b>PLL Stop State</b> Controls PLL and on-chip crystal oscillator behavior during the Stop processing state. When PSTP is set, the PLL remains operating when the chip is in the Stop state. When PSTP is cleared and the device enters the Stop state, the PLL is disabled, to further reduce power consumption. This however results in longer recovery time upon exit from the Stop state. To enable rapid recovery when exiting the Stop state (but at the cost of higher power consumption during the Stop state), PSTP should be set.					
			PSTP	PEN	Operation During Stop State		Recovery Time From Stop State	Power Consumption During Stop State
					PLL	Oscillator		
			0	x	Disabled	Disabled	Long	Minimal
			1	0	Disabled	Enabled	Short	Lower
			1	1	Enabled	Enabled	Short	Higher
10–8	DF[2–0]	0	<b>Division Factor</b> Define the DF of the low-power divider. These bits specify the DF as a power of two in the range from 2 <sup>0</sup> to 2 <sup>7</sup> . Changing the value of the DF[2–0] bits does not cause a loss of lock condition. Whenever possible, changes of the operating frequency of the device (for example, to enter a low-power mode) should be made by changing the value of the DF[2–0] bits rather than changing the MF[7–0] bits.					
			DF[2–0]		DF Value			
			000		2 <sup>0</sup>			
			001		2 <sup>1</sup>			
			010		2 <sup>2</sup>			
			011		2 <sup>3</sup>			
			100		2 <sup>4</sup>			
			101		2 <sup>5</sup>			
			110		2 <sup>6</sup>			
			111		2 <sup>7</sup>			

Table 5-3 PLL Control (PCTL) Register Bit Definitions (continued)

Bit Number	Bit Name	Reset Value	Description
7–0	MF[7–0]	\$1D	<p><b>Multiplication Factor</b>            Defines the Multiplication Factor (MF) that is applied to the PLL input frequency. The MF can be any integer from 1 to 255. The VCO oscillates at a frequency defined by the following formula where PDF is the Predivider Division Factor and FM is the Feedback Multiplier:</p> $\frac{F_{\text{extal}} \times MF \times FM}{PDF}$ <p>The MF must be chosen to ensure that the resulting VCO output frequency is in the range specified in the device-specific technical data sheet (300 MHz - 600 MHz). Any time a new value is written into the MF[7–0] bits, the PLL loses the lock condition. The Multiplication Factor bits MF[7–0] are set to \$1D (29) during hardware reset.</p>
a The reset value of the PEN bit is based on the value of the PLL PINIT input			

## 5.8 PLL Initialization Procedure

The PLL will momentarily overshoot the target frequency when the PLL is first enabled or when the VCO frequency is modified. If the main oscillator (Fosc) is allowed to exceed the maximum specified operating frequency as a result of the overshoot, corrupted operation may occur. Like-wise the input to the low power divider should be limited during the overshoot to prevent corrupt operation. A simple two step process described below is required when enabling the PLL or modifying the VCO frequency.

It is important that when modifying the VCO frequency or enabling the PLL that the PLL output initially be programmed to a value less than 150 MHz and the main oscillator (Fosc) initially be programmed to a frequency less than one-half the maximum specified operating frequency until the PLL has locked. After the PLL has locked, both the PLL output and the main oscillator frequency can be modified to reach their corresponding target frequencies (step 2). The PLL lock time is 0.5 ms.

The following two step process must be followed when enabling the PLL or when modifying the VCO frequency:

1. See table below. Program the VCO for the target VCO frequency (i.e., 362 MHz). The PLL output must be programmed to a frequency less than 150 MHz and Fosc for a frequency that is less than one-half the maximum specified operating frequency (90.5 MHz). You must use the output divider (OD) and low per divider (DF) to lower the main oscillator frequency.
2. After 0.5 ms (PLL stabilization time), program Fosc to match the target Fosc frequency (181 MHz):

PLL Programming Example	VCO Target	Fosc Target
Step #1	362 MHz	45.25 MHz
Step #2	362 MHz	181 MHz

## PLL Initialization Procedure

### PLL Programming Example:

Input Frequency (EXTAL) - 24.576 MHz

Target Operating Frequency - 181 MHz

1. Program the PLL control register (PCTL) - \$03E10B.
  - This multiplies up the input frequency to a VCO frequency of 360.448 MHz
  - The PLL output is VCO / 4 via the output divider to 90.112 MHz
  - The Fosc frequency is VCO / 8 via the output divider and low power divider to 45.056 MHz
2. After 0.5 ms, re-program the PLL control register (PCTL) - \$03A00B.
  - This maintains the VCO frequency at 360.448 MHz (PLL remains locked)
  - The PLL output frequency and Fosc is now VCO / 2. The PLL output frequency and Fosc reach as close as possible to the target frequency: - 180.224 MHz

This procedure is required to prevent the possibility of momentarily over clocking the main oscillator and corrupting operation of the DSP. This two step procedure is not required when enabling the PLL by setting the PINIT pin high during reset. The default PCTL value is \$04601D. The reset pin must be asserted for at least 0.5ms.

Use the following table to determine the appropriate final PCTL value for generating the maximum operating frequency (Fosc). Locate the maximum Fref value in the table that is larger than the target Fref. Use the corresponding final PCTL value to generate the maximum operating frequency given the target Fref.

181 MHz		
	Maximum Fref (MHz)	Final PCTL
1	5.05	\$0xA012
2	5.347	\$0xA011
3	5.68125	\$0xA010
4	6.0516	\$0xA00F
5	6.4928	\$0xA00E
6	6.9923	\$0xA00D
7	7.575	\$0xA00C
8	8.2636	\$0xA00B
9	9.09	\$0xA00A
10	10.1	\$0xA009
11	11.3625	\$0xA008
12	12.9857	\$0xA007
13	15.15	\$0xA006
14	18.18	\$0xA005

150 MHz		
	Maximum Fref (MHz)	Final PCTL
1	5.00	\$0xE01E
2	5.15	\$0xE01D
3	5.35	\$0xE01C
4	6.55	\$0xE01B
5	6.75	\$0xE01A
6	6.00	\$0xE019
7	6.25	\$0xE018
8	6.521	\$0xE017
9	6.82	\$0xE016
10	7.142	\$0xE015
11	7.5	\$0xE014
12	7.89	\$0xE013
13	8.33	\$0xE012
14	8.82	\$0xE011
15	9.4	\$0xE010
16	10	\$0xE00F
17	10.7	\$0xE00E
18	11.54	\$0xE00D

181 MHz		
	Maximum Fref (MHz)	Final PCTL

150 MHz		
	Maximum Fref (MHz)	Final PCTL
19	12.5	\$0xE00C
20	13.636	\$0xE00B
21	15	\$0xE00A
22	16.666	\$0xE009
23	18.75	\$0xE008

### Example:

Maximum Operating Frequency = 181 MHz.

EXTAL Frequency = 11.2896 MHz

Target Fref = 5.6448 MHz (EXTAL / PD, PD = 2)

The maximum Fref value that is greater than the Target Fref is #3: 5.6812 MHz. The corresponding final PCTL value is \$0xA010. x represents the PLL Pre-Divider used to determine the target Fref value. In the example the Pre-Divider (PD) = 2. Thus, the PCTL value is \$02A010. The following PLL parameters can be determined from the final PCTL setting.

VCO frequency = 5.6448 MHz \* 4 \* 16 = 361.2672 MHz

PLL Output = VCO / 2 = 180.6336 MHz.

Fosc = PLL Output = 180.6336 MHz.

This represents the maximum operating frequency obtainable with a target Fref frequency of 5.6448 MHz.

## 5.9 PLL Programming Examples

Table 5-5 PLL Programming Examples

PLL Enabling Step	EXTAL (MHz)	PDF	Fref (MHz) 5 MHz - 20 MHz	OD1	OD0	FM	MF	VCO Output (MHz) 300 MHz - 600 MHz	OD	PLL Output (MHz)	LPD	Fosc (MHz)	PCTL
*	24.576	4	6.144	0	1	2	29	356.352	2	178.18	0	178.18	\$04601D
1	27.00	3	9.0	1	1	4	10	360.0	4	90.0	1	45.0	\$03E10A
2	27.00	3	9.0	1	0	4	10	360.0	2	180.0	0	180.0	\$03A00A
1	24.576	3	8.192	1	1	4	11	360.448	4	90.112	1	45.056	\$03E10B
2	24.576	3	8.192	1	0	4	11	360.448	2	180.224	0	180.224	\$03A00B
1	12.288	2	6.144	1	1	4	14	344.064	4	86.016	1	43.008	\$02E10E
2	12.288	2	6.144	1	0	4	14	344.064	2	172.032	0	172.032	\$02A00E

Table 5-5 PLL Programming Examples (continued)

PLL Enabling Step	EXTAL (MHz)	PDF	Fref (MHz) 5 MHz - 20 MHz	OD1	OD0	FM	MF	VCO Output (MHz) 300 MHz - 600 MHz	OD	PLL Output (MHz)	LPD	Fosc (MHz)	PCTL
1	11.2896	1	11.2896	1	1	4	8	361.267	4	90.316	1	45.158	\$01E108
2	11.2896	1	11.2896	1	0	4	8	361.267	2	180.634	0	180.634	\$01A008
1	27.00	3	9.0	1	1	4	16	576	4	144	1	72.0	\$03E110
2	27.00	3	9.0	1	1	4	16	576	4	144	0	144	\$03E010
1	24.576	3	8.192	1	1	4	18	589.824.	4	147.456	1	73.728	\$03E112
2	24.576	3	8.192	1	1	4	18	589.824.	4	147.456	0	147.456	\$03E012
1	12.288	2	6.144	1	1	4	24	589.824	4	147.456	1	73.728	\$02E118
2	12.288	2	6.144	1	1	4	24	589.824	4	147.456	0	147.456	\$02E018
1	11.2896	1	11.2896	1	1	4	13	587.0592	4	146.764	1	73.382	\$01E10D
2	11.2896	1	11.2896	1	1	4	13	587.0592	4	146.764	0	146.764	\$01E00D

\* Default state is highlighted in the table. The default state can be applied by pulling high the PINIT pin without the 2 step PLL enabling method if reset is asserted for longer than 0.5ms. The values shown for the default state assumes a 24.576 MHz input frequency on the EXTAL pin. Different input frequencies will have different Fref, VCO and PLL Output frequencies.



## 6 General Purpose Input/Output

### 6.1 Introduction

The DSP56371 provides up to 39 bidirectional signals that can be configured as GPIO signals or as peripheral dedicated signals. All of these signals are GPIO by default after reset. The techniques for register programming for all GPIO functionality is very similar between these interfaces. This section describes how signals may be used as GPIO.

### 6.2 Programming Model

The signals description section of this manual describes the special uses of these signals in detail. There are six groups of these signals which can be controlled separately or as groups:

- Port C: twelve GPIO signals (shared with the ESAI signals)
- Port D: two GPIO signals (shared with the DAX signals)
- Port E: twelve GPIO signals (shared with the ESAI\_1 signals)
- Port F: eleven GPIO signals (dedicated GPIO signals)
- Timer: two GPIO signals (shared with the timer/event counter signals)

#### 6.2.1 Port C Signals and Registers

Each of the 12 port C signals not used as an ESAI signal can be configured individually as a GPIO signal. The GPIO functionality of port C is controlled by three registers: port C control register (PCRC), port C direction register (PRRC) and port C data register (PDRC). These registers are described in [Section 8, "Enhanced Serial Audio Interface \(ESAI\)"](#).

#### 6.2.2 Port D Signals and Registers

Each of the two Port D signals not used as a DAX signal can be configured individually as a GPIO signal. The GPIO functionality of Port D is controlled by three registers: Port D control register (PCRD), Port D direction register (PRRD) and Port D data register (PDRD). These registers are described in [Section 10, "Digital Audio Transmitter"](#).

#### 6.2.3 Port E Signals and Registers

Each of the 12 port E signals not used as an ESAI\_1 signal can be configured individually as a GPIO signal. The GPIO functionality of port E is controlled by three registers: port E control register (PCRE), port E direction register (PRRE) and port E data register (PDRE). These registers are described in [Section 9, "Enhanced Serial Audio Interface 1 \(ESAI\\_1\)"](#).

### 6.2.4 Port F Signals and Registers

Each of the 11 Port F signals can be configured individually as a GPIO signal. **Note that Port F interfaces the DSP via the Bus Interface Unit (BIU) and must be enabled by writing \$01FFFF to the BCR register.** See the *DSP56300 Family Manual, DSP56300FM* for details on the BIU and BCR register. This establishes the appropriate waitstate setting for correct operation of the interface. The GPIO functionality of Port F is controlled by three registers: Port F control register (PCRF), Port F direction register (PRRF), and Port F data register (PDRF). These registers are described below.

#### 6.2.4.1 Port F Control Register (PCRF)

The read/write 24-bit Port F Control Register (PCRF) in conjunction with the Port F Direction Register (PRRF) controls the functionality of the dedicated GPIO pins. Each of the PF(10:0) bits controls the functionality of the corresponding port pin. See [Table 6-1](#) for the port pin configurations. Hardware and software reset clear all PCRF bits.

#### 6.2.4.2 Port F Direction Register (PRRF)

The read/write 24-bit Port F Direction Register (PRRF) in conjunction with the Port F Control Register (PCRF) controls the functionality of the dedicated GPIO pins. [Table 6-1](#) describes the port pin configurations. Hardware and software reset clear all PRRF bits.

Table 6-1 PCRF and PRRF Bits Functionality

PDF[i]	PF[i]	Port Pin[i] Function
0	0	Disconnected
0	1	GPIO input
1	0	GPIO output
1	1	Reserved

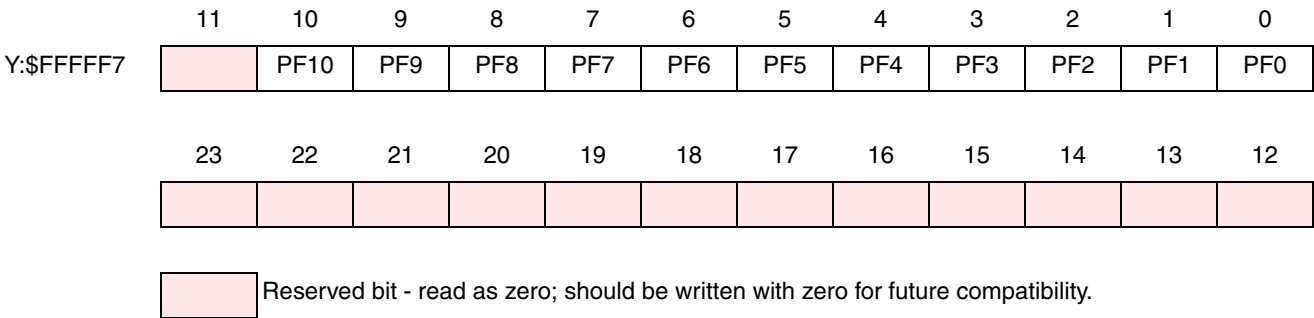


Figure 6-1 PCRF Register

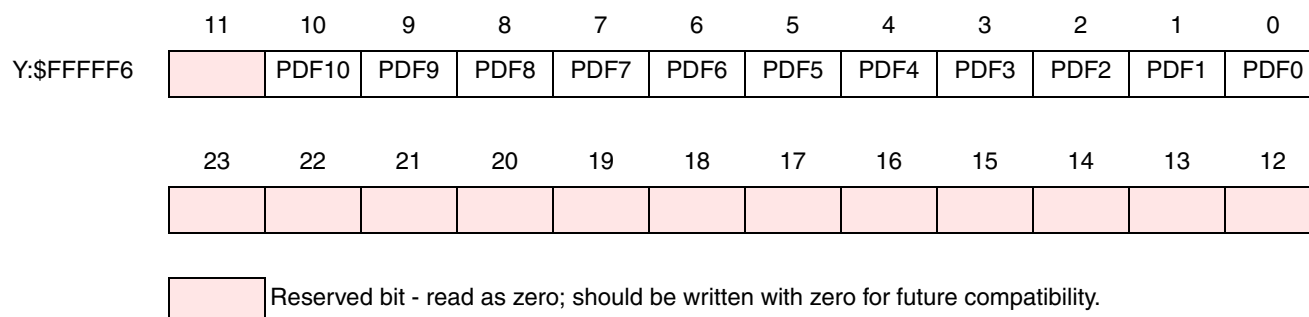


Figure 6-2 PRRF Register

### 6.2.4.3 Port F Data register (PDRF)

The read/write 24-bit Port F Data Register (see [Figure 6-3](#)) is used to read or write data to/from the dedicated GPIO pins. Bits PD(9:0) are used to read or write data from/to the corresponding port pins if they are configured as GPIO. If a port pin [i] is configured as a GPIO input, the corresponding PD[i] bit reflects the value present on this pin. If a port pin [i] is configured as a GPIO output, the value written into the corresponding PD[i] bit is reflected on this pin. If a port pin [i] is configured as disconnected, the corresponding PD[i] bit is not reset and contains undefined data.

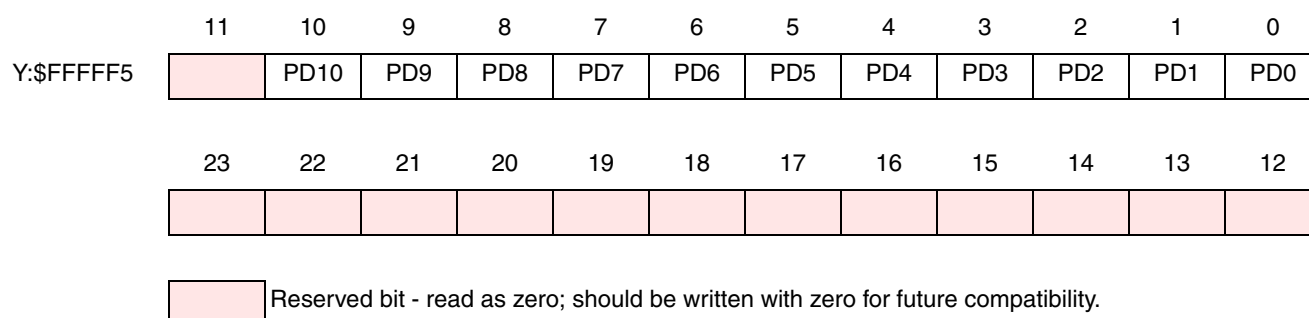


Figure 6-3 PDRF Register

The PDF and PF bits should not be set simultaneously.

### 6.2.5 Timer/Event Counter Signals

The timer/event counter signals (TIO0, and TIO1), when not used as timer signals can be configured as GPIO signals. These signals are controlled by the appropriate timer control status register (TCSR). The register is described in [Section 11, "Triple Timer Module"](#).

## NOTES

## 7 Serial Host Interface

### 7.1 Introduction

The Serial Host Interface (SHI) is a serial I/O interface that provides a path for communication and program/coefficient data transfers between the DSP and an external host processor. The SHI can also communicate with other serial peripheral devices. The SHI supports two well-known and widely used synchronous serial buses: the Freescale Serial Peripheral Interface (SPI) bus and the Philips Inter-Integrated-Circuit Control (I<sup>2</sup>C) bus. The SHI supports either bus protocol as either a slave or a single-master device. To minimize DSP overhead, the SHI supports 8-bit, 16-bit and 24-bit data transfers. The SHI has a 1 or 10-word receive FIFO that permits receiving up to 30 bytes before generating a receive interrupt, reducing the overhead for data reception.

When configured in the SPI mode, the SHI can perform the following functions:

- Identify its slave selection (in slave mode)
- Simultaneously transmit (shift out) and receive (shift in) serial data
- Directly operate with 8-, 16- and 24-bit words
- Generate vectored interrupts separately for receive and transmit events and update status bits
- Generate a separate vectored interrupt for a receive exception
- Generate a separate vectored interrupt for a bus-error exception
- Generate the serial clock signal (in master mode)
- Trigger DMA interrupts to service the transmit and receive events

When configured in the I<sup>2</sup>C mode, the SHI can perform the following functions:

- Detect/generate start and stop events
- Identify its slave (ID) address (in slave mode)
- Identify the transfer direction (receive/transmit)
- Transfer data byte-wise according to the SCL clock line
- Generate ACK signal following a byte receive
- Inspect ACK signal following a byte transmit
- Directly operate with 8-, 16- and 24-bit words
- Generate vectored interrupts separately for receive and transmit events and update status bits
- Generate a separate vectored interrupt for a receive exception
- Generate a separate vectored interrupt for a bus error exception
- Generate the clock signal (in master mode)
- Trigger DMA interrupts to service the transmit and receive events

## 7.2 Serial Host Interface Internal Architecture

The DSP views the SHI as a memory-mapped peripheral in the X data memory space. The DSP uses the SHI as a normal memory-mapped peripheral using standard polling, interrupt programming techniques, or DMA transfers. Memory mapping allows DSP communication with the SHI registers to be accomplished using standard instructions and addressing modes. In addition, the MOVEP instruction allows interface-to-memory and memory-to-interface data transfers without going through an intermediate register. The DMA controller may be used to service the receive or transmit data path. The single master configuration allows the DSP to directly connect to dumb peripheral devices. For that purpose, a programmable baud-rate generator is included to generate the clock signal for serial transfers. The host side invokes the SHI for communication and data transfer with the DSP through a shift register that may be accessed serially using either the I<sup>2</sup>C or the SPI bus protocols. Figure 7-1 shows the SHI block diagram.

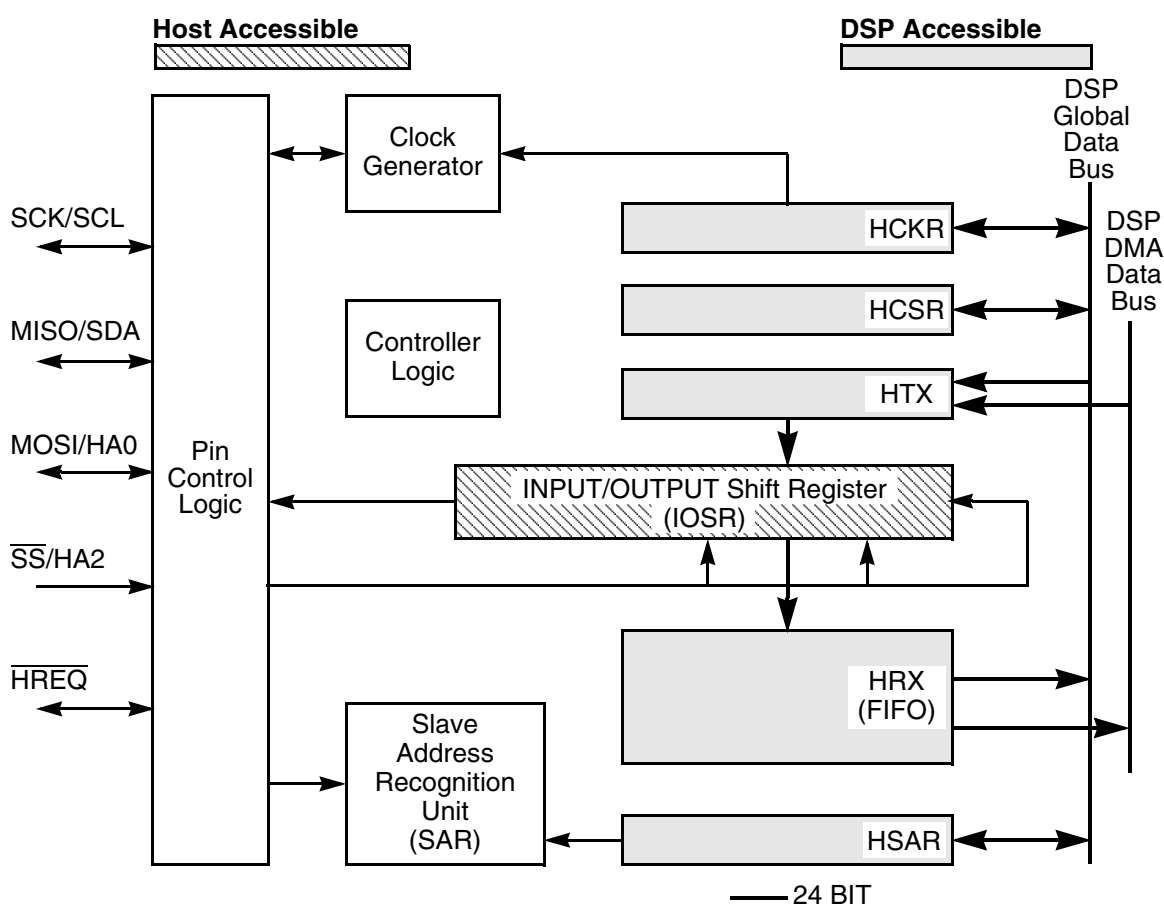


Figure 7-1 Serial Host Interface Block Diagram

## 7.3 SHI Clock Generator

The SHI clock generator generates the SHI serial clock if the interface operates in the master mode. The clock generator is disabled if the interface operates in the slave mode, except in I<sup>2</sup>C mode when the HCKFR bit is set in the HCKR register. When the SHI operates in the slave mode, the clock is external and is input to the SHI (HMST = 0). Figure 7-2 illustrates the internal clock path connections. It is the user's responsibility to select the proper clock rate within the range as defined in the I<sup>2</sup>C and SPI bus specifications.

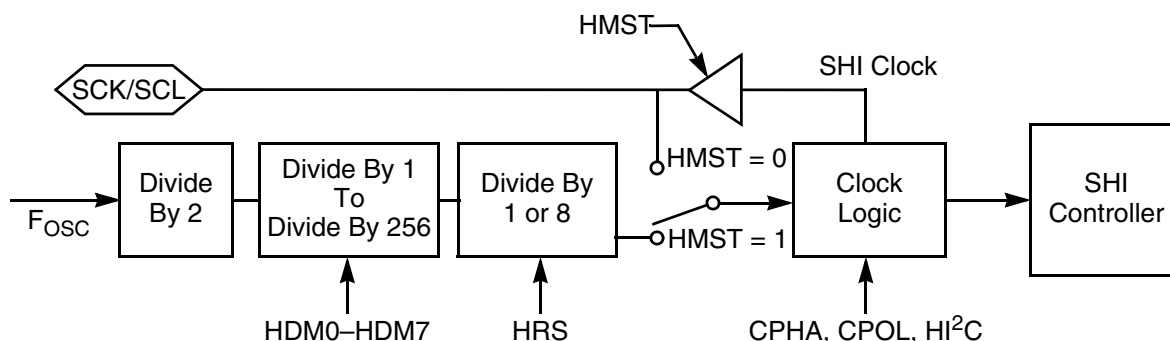
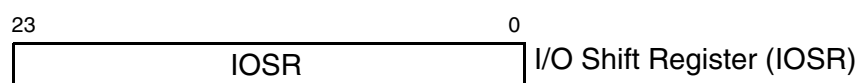


Figure 7-2 SHI Clock Generator

## 7.4 Serial Host Interface Programming Model

The Serial Host Interface programming model has two parts:

- **Host side**—see Figure 7-3 below and Section 7.4.1, "SHI Input/Output Shift Register (IOSR)—Host Side"
- **DSP side**—see Figure 7-4 and Section 7.4.2, "SHI Host Transmit Data Register (HTX)—DSP Side" through Section 7.4.6, "SHI Control/Status Register (HCSR)—DSP Side" for detailed information.



AA0418

Figure 7-3 SHI Programming Model—Host Side

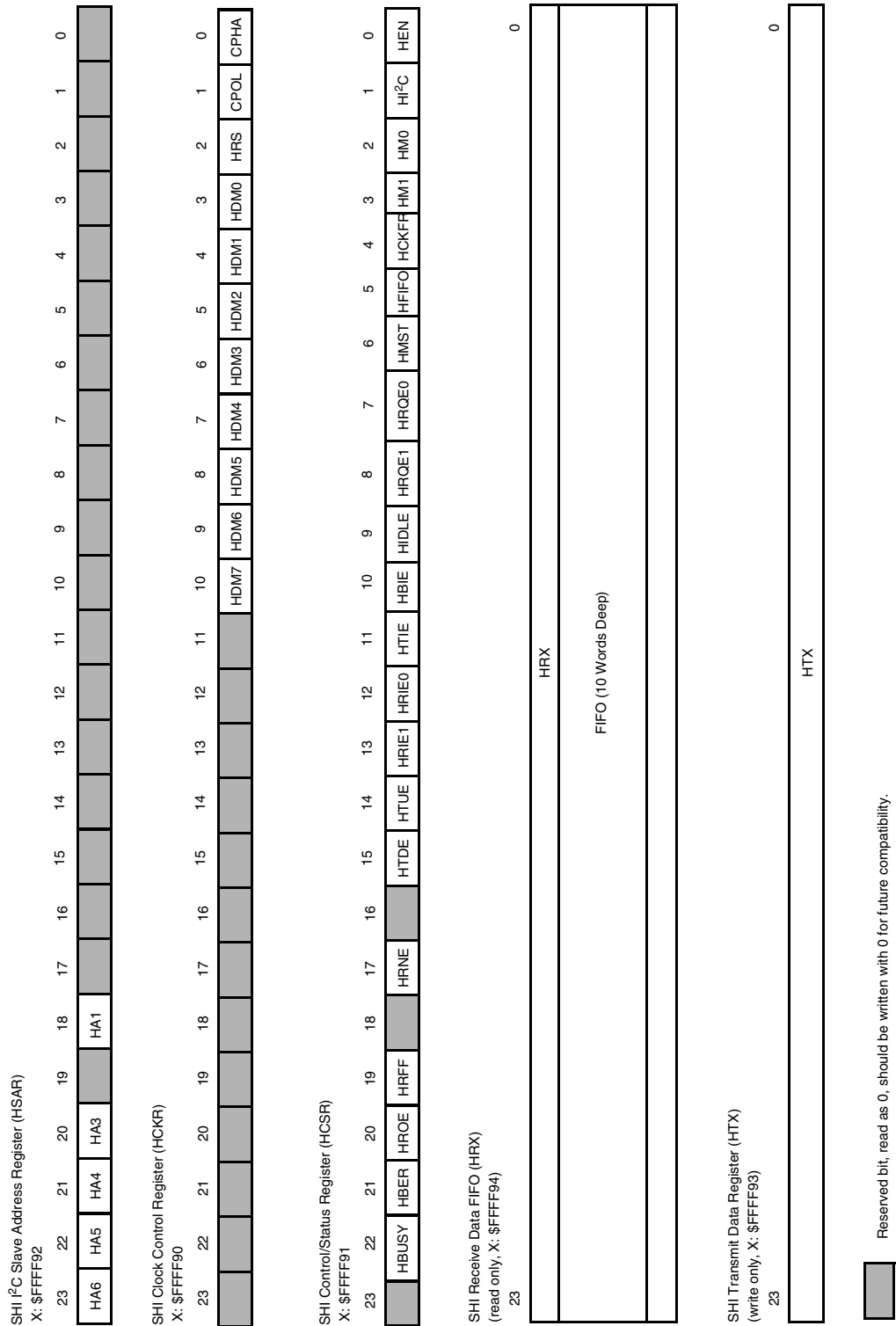


Figure 7-4 SHI Programming Model—DSP Side



The SHI interrupt vector table is shown in [Table 7-1](#) and the exception priorities generated by the SHI are shown in [Table 7-2](#).

**Table 7-1 SHI Interrupt Vectors**

Program Address	Interrupt Source
VBA:\$0040	SHI Transmit Data
VBA:\$0042	SHI Transmit Underrun Error
VBA:\$0044	SHI Receive FIFO Not Empty
VBA:\$0048	SHI Receive FIFO Full
VBA:\$004A	SHI Receive Overrun Error
VBA:\$004C	SHI Bus Error

**Table 7-2 SHI Internal Interrupt Priorities**

Priority	Interrupt
Highest	SHI Bus Error
	SHI Receive Overrun Error
	SHI Transmit Underrun Error
	SHI Receive FIFO Full
	SHI Transmit Data
Lowest	SHI Receive FIFO Not Empty

### 7.4.1 SHI Input/Output Shift Register (IOSR)—Host Side

The variable length Input/Output Shift Register (IOSR) can be viewed as a serial-to-parallel and parallel-to-serial buffer in the SHI. The IOSR is involved with every data transfer in both directions (read and write). In compliance with the I<sup>2</sup>C and SPI bus protocols, data is shifted in and out MSB first. In 8-bit data transfer modes, the most significant byte of the IOSR is used as the shift register. In 16-bit data transfer modes, the two most significant bytes become the shift register. In 24-bit transfer modes, the shift register uses all three bytes of the IOSR (see [Figure 7-5](#)).

#### NOTE

The IOSR cannot be accessed directly either by the host processor or by the DSP. It is fully controlled by the SHI controller logic.

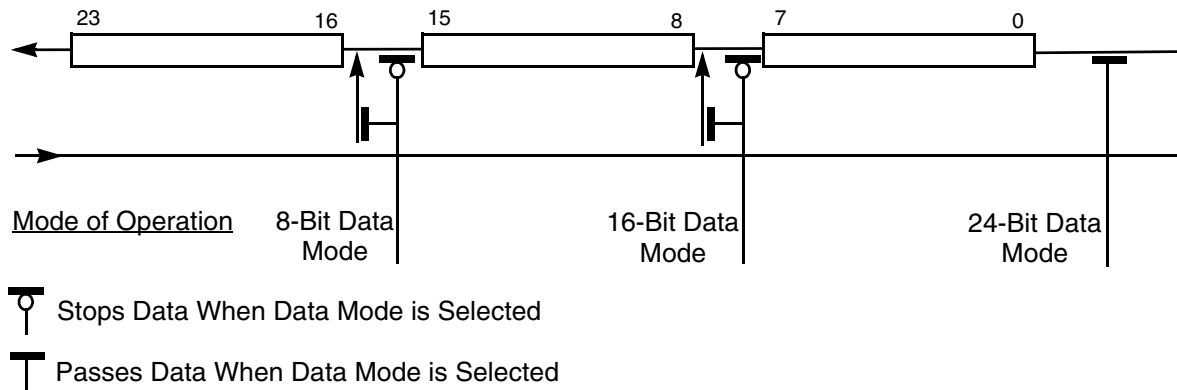


Figure 7-5 SHI I/O Shift Register (IOSR)

## 7.4.2 SHI Host Transmit Data Register (HTX)—DSP Side

The host transmit data register (HTX) is used for DSP-to-Host data transfers. The HTX register is 24 bits wide. Writing to the HTX register by DSP core instructions or by DMA transfers clears the HTDE flag. The DSP may program the HTIE bit to cause a host transmit data interrupt when HTDE is set (see [Section 7.4.6.10, "HCSR Transmit-Interrupt Enable \(HTIE\)—Bit 11"](#)). Data should not be written to the HTX until HTDE is set in order to prevent overwriting the previous data. HTX is reset to the empty state when in stop mode and during hardware reset, software reset and individual reset.

In the 8-bit data transfer mode, the most significant byte of the HTX is transmitted; in the 16-bit mode, the two most significant bytes are transmitted, and, in the 24-bit mode, all the contents of HTX are transferred.

## 7.4.3 SHI Host Receive Data FIFO (HRX)—DSP Side

The 24-bit host receive data FIFO (HRX) is a 10-word deep, First-In-First-Out (FIFO) register used for Host-to-DSP data transfers. The serial data is received via the shift register and then loaded into the HRX. In the 8-bit data transfer mode, the most significant byte of the shift register is transferred to the HRX (the other bits are cleared); in the 16-bit mode the two most significant bytes are transferred (the least significant byte is cleared), and, in the 24-bit mode, all 24 bits are transferred to the HRX. The HRX may be read by the DSP while the FIFO is being loaded from the shift register. Reading all data from HRX clears the HRNE flag. The HRX may be read by DSP core instructions or by DMA transfers. The HRX FIFO is reset to the empty state when the chip is in stop mode, as well as during hardware reset, software reset and individual reset.

## 7.4.4 SHI Slave Address Register (HSAR)—DSP Side

The 24-bit slave address register (HSAR) is used when the SHI operates in the I<sup>2</sup>C slave mode and is ignored in the other operational modes. HSAR holds five bits of the 7-bit slave device address. The SHI also acknowledges the general call address specified by the I<sup>2</sup>C protocol (eight zeroes comprising a 7-bit address and a R/W bit), but treats any following data bytes as regular data. That is, the SHI does not differentiate between its dedicated address and the general call address. HSAR cannot be accessed by the host processor.

#### 7.4.4.1 HSAR Reserved Bits—Bits 19, 17–0

These bits are reserved. They read as zero and should be written with zero for future compatibility.

#### 7.4.4.2 HSAR I<sup>2</sup>C Slave Address (HA[6:3], HA1)—Bits 23–20,18

Part of the I<sup>2</sup>C slave device address is stored in the read/write HA[6:3], HA1 bits of HSAR. The full 7-bit slave device address is formed by combining the HA[6:3], HA1 bits with the HA0 and HA2 pins to obtain the HA[6:0] slave device address. The full 7-bit slave device address is compared to the received address byte whenever an I<sup>2</sup>C master device initiates an I<sup>2</sup>C bus transfer. During hardware reset or software reset, HA[6:3] = 1011 and HA1 is cleared; this results in a default slave device address of 1011[HA2]0[HA0].

### 7.4.5 SHI Clock Control Register (HCKR)—DSP Side

The HCKR is a 24-bit read/write register that controls SHI clock generator operation. The HCKR bits should be modified only while the SHI is in the individual reset state (HEN = 0 in the HCSR).

For proper SHI clock setup, please consult the data sheet. The programmer should not use the combination HRS = 1 and HDM[7:0] = 00000000, since it may cause synchronization problems and improper operation (it is an illegal combination).

The HCKR bits are cleared during hardware reset or software reset, except for CPHA, which is set. The HCKR is not affected by the stop state.

The HCKR bits are described in the following paragraphs.

#### 7.4.5.1 Clock Phase and Polarity (CPHA and CPOL)—Bits 1–0

The Clock Phase (CPHA) bit controls the relationship between the data on the master-in-slave-out (MISO) and master-out-slave-in (MOSI) pins and the clock produced or received at the SCK pin. The CPOL bit determines the clock polarity (1 = active-high, 0 = active-low).

The clock phase and polarity should be identical for both the master and slave SPI devices. CPHA and CPOL are functional only when the SHI operates in the SPI mode and are ignored in the I<sup>2</sup>C mode. The CPHA bit is set and the CPOL bit is cleared during hardware reset and software reset.

The programmer may select any of four combinations of serial clock (SCK) phase and polarity when operating in the SPI mode (See [Figure 7-6](#)).

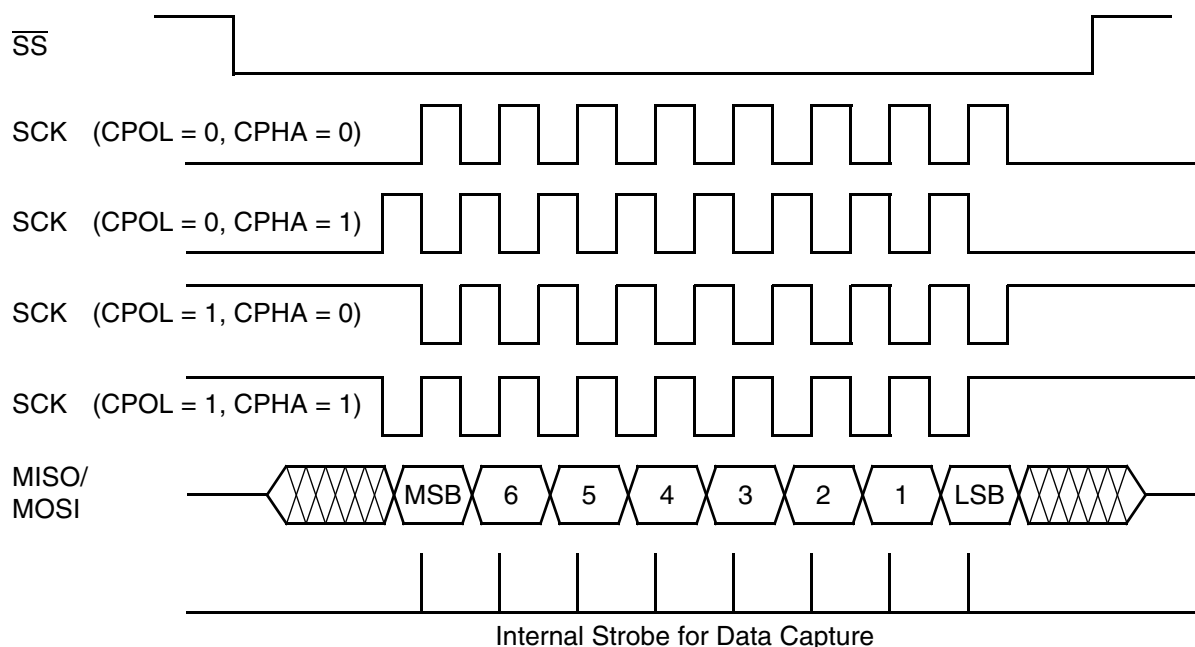


Figure 7-6 SPI Data-To-Clock Timing Diagram

If CPOL is cleared, it produces a steady-state low value at the SCK pin of the master device whenever data is not being transferred. If the CPOL bit is set, it produces a high value at the SCK pin of the master device whenever data is not being transferred.

CPHA is used with the CPOL bit to select the desired clock-to-data relationship. The CPHA bit, in general, selects the clock edge that captures data and allows it to change states. It has its greatest impact on the first bit transmitted (MSB) in that it does or does not allow a clock transition before the data capture edge.

When the SHI is in slave mode and CPHA = 0, the  $\overline{SS}$  line must be deasserted and asserted by the external master between each successive word transfer.  $\overline{SS}$  must remain asserted between successive bytes within a word. The DSP core should write the next data word to HTX when HTDE = 1, clearing HTDE. However, the data is transferred to the shift register for transmission only when  $\overline{SS}$  is deasserted. HTDE is set when the data is transferred from HTX to the shift register.

When the SHI is in slave mode and CPHA = 1, the  $\overline{SS}$  line may remain asserted between successive word transfers. The  $\overline{SS}$  must remain asserted between successive bytes within a word. The DSP core should write the next data word to HTX when HTDE = 1, clearing HTDE. The HTX data is transferred to the shift register for transmission as soon as the shift register is empty. HTDE is set when the data is transferred from HTX to the shift register.

When the SHI is in master mode and CPHA = 0, the DSP core should write the next data word to HTX when HTDE = 1, clearing HTDE. The data is transferred immediately to the shift register for transmission. HTDE is set only at the end of the data word transmission.

#### NOTE

The master is responsible for deasserting and asserting the slave device  $\overline{SS}$  line between word transmissions.

When the SHI is in master mode and  $CPHA = 1$ , the DSP core should write the next data word to HTX when  $HTDE = 1$ , clearing HTDE. The HTX data is transferred to the shift register for transmission as soon as the shift register is empty. HTDE is set when the data is transferred from HTX to the shift register.

#### 7.4.5.2 HCKR Prescaler Rate Select (HRS)—Bit 2

The HRS bit controls a prescaler in series with the clock generator divider. This bit is used to extend the range of the divider when slower clock rates are desired. When HRS is set, the prescaler is bypassed. When HRS is cleared, the fixed divide-by-eight prescaler is operational. HRS is ignored when the SHI operates in the slave mode, except for I<sup>2</sup>C when HCKFR is set. The HRS bit is cleared during hardware reset and software reset.

##### NOTE

Use the equations in the SHI data sheet to determine the value of HRS for the specific serial clock frequency required.

#### 7.4.5.3 HCKR Divider Modulus Select (HDM[7:0])—Bits 10–3

The HDM[7:0] bits specify the divide ratio of the clock generator divider. A divide ratio between 1 and 256 ( $HDM[7:0] = \$00$  to  $\$FF$ ) may be selected. When the SHI operates in the slave mode, the HDM[7:0] bits are ignored (except for I<sup>2</sup>C when HCKFR is set). The HDM[7:0] bits are cleared during hardware reset and software reset.

##### NOTE

Use the equations in the SHI data sheet to determine the value of HDM[7:0] for the specific serial clock frequency required.

#### 7.4.5.4 HCKR Reserved Bits—Bits 23–11

These bits in HCKR are reserved. They are read as zero and should be written with zero for future compatibility.

### 7.4.6 SHI Control/Status Register (HCSR)—DSP Side

The HCSR is a 24-bit register that controls the SHI operation and reflects its status. The control bits are read/write. The status bits are read-only. The bits are described in the following paragraphs. When in the stop state or during individual reset, the HCSR status bits are reset to their hardware-reset state, while the control bits are not affected.

#### 7.4.6.1 HCSR Host Enable (HEN)—Bit 0

The read/write control bit HEN, when set, enables the SHI. When HEN is cleared, the SHI is disabled (that is, it is in the individual reset state, see below). The HCKR and the HCSR control bits are not affected when HEN is cleared. When operating in master mode, HEN should be cleared only when the SHI is idle ( $HBUSY = 0$ ). HEN is cleared during hardware reset and software reset.

#### 7.4.6.1.1 SHI Individual Reset

While the SHI is in the individual reset state, SHI input pins are inhibited, output and bidirectional pins are disabled (high impedance), the HCSR status bits and the transmit/receive paths are reset to the same state produced by hardware reset or software reset. The individual reset state is entered following a one-instruction-cycle delay after clearing HEN.

#### 7.4.6.2 HCSR I<sup>2</sup>C/SPI Selection (HI<sup>2</sup>C)—Bit 1

The read/write control bit HI<sup>2</sup>C selects whether the SHI operates in the I<sup>2</sup>C or SPI modes. When HI<sup>2</sup>C is cleared, the SHI operates in the SPI mode. When HI<sup>2</sup>C is set, the SHI operates in the I<sup>2</sup>C mode. HI<sup>2</sup>C affects the functionality of the SHI pins as described in [Section 2, "Signal/Connection Descriptions"](#). It is recommended that an SHI individual reset be generated (HEN cleared) before changing HI<sup>2</sup>C. HI<sup>2</sup>C is cleared during hardware reset and software reset.

#### 7.4.6.3 HCSR Serial Host Interface Mode (HM[1:0])—Bits 3–2

The read/write control bits HM[1:0] select the size of the data words to be transferred, as shown in [Table 7-3](#). HM[1:0] should be modified only when the SHI is idle (HBUSY = 0). HM[1:0] are cleared during hardware reset and software reset.

**Table 7-3 SHI Data Size**

HM1	HMO	Description
0	0	8-bit data
0	1	16-bit data
1	0	24-bit data
1	1	Reserved

#### 7.4.6.4 HCSR I<sup>2</sup>C Clock Freeze (HCKFR)—Bit 4

The read/write control bit HCKFR determines the behavior of the SHI when the SHI is unable to service the master request, when operating in the I<sup>2</sup>C slave mode. The HCKFR bit is used only in the I<sup>2</sup>C slave mode; it is ignored otherwise.

If HCKFR is set, the SHI holds the clock line to GND if it is not ready to send data to the master during a read transfer or if the input FIFO is full when the master attempts to execute a write transfer. In this way, the master may detect that the slave is not ready for the requested transfer, without causing an error condition in the slave. When HCKFR is set for transmit sessions, the SHI clock generator must be programmed as if to generate the same serial clock as produced by the external master, otherwise erroneous operation may result. The programmed frequency should be in the range of 1 to 0.75 times the external clock frequency.

If HCKFR is cleared, any attempt from the master to execute a transfer when the slave is not ready results in an overrun or underrun error condition.

It is recommended that an SHI individual reset be generated (HEN cleared) before changing HCKFR. HCKFR is cleared during hardware reset and software reset.

#### 7.4.6.5 HCSR FIFO-Enable Control (HFIFO)—Bit 5

The read/write control bit HFIFO selects the receive FIFO size. When HFIFO is cleared, the FIFO has one level. When HFIFO is set, the FIFO has 10 levels. It is recommended that an SHI individual reset be generated (HEN cleared) before changing HFIFO. HFIFO is cleared during hardware reset and software reset.

#### 7.4.6.6 HCSR Master Mode (HMST)—Bit 6

The read/write control bit HMST determines the SHI operating mode. If HMST is set, the interface operates in the master mode. If HMST is cleared, the interface operates in the slave mode. The SHI supports a single-master configuration in both I<sup>2</sup>C and SPI modes.

When configured as an SPI master, the SHI drives the SCK line and controls the direction of the data lines MOSI and MISO. The  $\overline{SS}$  line must be held deasserted in the SPI master mode; if the  $\overline{SS}$  line is asserted when the SHI is in SPI master mode, a bus error is generated (the HCSR HBER bit is set—see [Section 7.4.6.18, "Host Bus Error \(HBER\)—Bit 21"](#)).

When configured as an I<sup>2</sup>C master, the SHI controls the I<sup>2</sup>C bus by generating start events, clock pulses and stop events for transmission and reception of serial data.

It is recommended that an SHI individual reset be generated (HEN cleared) before changing HMST. HMST is cleared during hardware reset and software reset.

#### 7.4.6.7 HCSR Host-Request Enable (HRQE[1:0])—Bits 8–7

The read/write control bits HRQE[1:0] are used to control the  $\overline{HREQ}$  pin. When HRQE[1:0] are cleared, the  $\overline{HREQ}$  pin is disabled and held in the high impedance state. If either of HRQE[1:0] are set and the SHI is in a master mode, the  $\overline{HREQ}$  pin becomes an input controlling SCK: deasserting  $\overline{HREQ}$  suspends SCK. If either of HRQE[1:0] are set and the SHI is in SPI slave mode,  $\overline{HREQ}$  becomes an output and its operation is defined in [Table 7-4](#). HRQE[1:0] should be changed only when the SHI is idle (HBUSY = 0). HRQE[1:0] are cleared during hardware reset and software reset.

**Table 7-4  $\overline{HREQ}$  Function In SPI Slave Mode**

HRQE1	HRQE0	$\overline{HREQ}$ Pin Operation
0	0	High impedance
0	1	Asserted if IOSR is ready to receive a new word
1	0	Asserted if IOSR is ready to transmit a new word
1	1	SPI: Asserted if IOSR is ready to transmit and receive

### 7.4.6.8 HCSR Idle (HIDLE)—Bit 9

The read/write control/status bit HIDLE is used only in the I<sup>2</sup>C master mode; it is ignored otherwise. It is only possible to set the HIDLE bit during writes to the HCSR. HIDLE is cleared by writing to HTX. To ensure correct transmission of the slave device address byte, HIDLE should be set only when HTX is empty (HTDE = 1). After HIDLE is set, a write to HTX clears HIDLE and causes the generation of a stop event, a start event, and then the transmission of the eight MSBs of the data as the slave device address byte. While HIDLE is cleared, data written to HTX is transmitted as is. If the SHI completes transmitting a word and there is no new data in HTX, the clock is suspended after sampling ACK. If HIDLE is set when the SHI completes transmitting a word with no new data in HTX, a stop event is generated.

HIDLE determines the acknowledge that the receiver sends after correct reception of a byte. If HIDLE is cleared, the reception is acknowledged by sending a 0 bit on the SDA line at the ACK clock tick. If HIDLE is set, the reception is not acknowledged (a 1 bit is sent). It is used to signal an end-of-data to a slave transmitter by not generating an ACK on the last byte. As a result, the slave transmitter must release the SDA line to allow the master to generate the stop event. If the SHI completes receiving a word and the HRX FIFO is full, the clock is suspended before transmitting an ACK. While HIDLE is cleared the bus is busy, that is, the start event was sent but no stop event was generated. Setting HIDLE causes a stop event after receiving the current word.

HIDLE is set while the SHI is not in the I<sup>2</sup>C master mode, while the chip is in the stop state, and during hardware reset, software reset and individual reset.

#### NOTE

Programmers should take care to ensure that all DMA channel service to HTX is disabled before setting HIDLE.

### 7.4.6.9 HCSR Bus-Error Interrupt Enable (HBIE)—Bit 10

The read/write control bit HBIE is used to enable the SHI bus-error interrupt. If HBIE is cleared, bus-error interrupts are disabled, and the HBER status bit must be polled to determine if an SHI bus error occurred. If both HBIE and HBER are set, the SHI requests an SHI bus-error interrupt service from the interrupt controller. HBIE is cleared by hardware reset and software reset.

#### NOTE

Clearing HBIE masks a pending bus-error interrupt only after a one instruction cycle delay. If HBIE is cleared in a long interrupt service routine, it is recommended that at least one other instruction separate the instruction that clears HBIE and the RTI instruction at the end of the interrupt service routine.

### 7.4.6.10 HCSR Transmit-Interrupt Enable (HTIE)—Bit 11

The read/write control bit HTIE is used to enable the SHI transmit data interrupts. If HTIE is cleared, transmit interrupts are disabled, and the HTDE status bit must be polled to determine if HTX is empty. If both HTIE and HTDE are set and HTUE is cleared, the SHI requests an SHI transmit-data interrupt service from the interrupt controller. If both HTIE and HTUE are set, the SHI requests an SHI



transmit-underrun-error interrupt service from the interrupt controller. HTIE is cleared by hardware reset and software reset.

#### NOTE

Clearing HTIE masks a pending transmit interrupt only after a one instruction cycle delay. If HTIE is cleared in a long interrupt service routine, it is recommended that at least one other instruction separate the instruction that clears HTIE and the RTI instruction at the end of the interrupt service routine.

#### 7.4.6.11 HCSR Receive Interrupt Enable (HRIE[1:0])—Bits 13–12

The read/write control bits HRIE[1:0] are used to enable the SHI receive-data interrupts. If HRIE[1:0] are cleared, receive interrupts are disabled, and the HRNE and HRFF (bits 17 and 19, see below) status bits must be polled to determine if there is data in the receive FIFO. If HRIE[1:0] are not cleared, receive interrupts are generated according to [Table 7-5](#). HRIE[1:0] are cleared by hardware and software reset.

**Table 7-5 HCSR Receive Interrupt Enable Bits**

HRIE[1:0]	Interrupt	Condition
00	Disabled	Not applicable
01	Receive FIFO not empty Receive Overrun Error	HRNE = 1 and HROE = 0 HROE = 1
10	Reserved	Not applicable
11	Receive FIFO full Receive Overrun Error	HRFF = 1 and HROE = 0 HROE = 1

#### NOTE

Clearing HRIE[1:0] masks a pending receive interrupt only after a one instruction cycle delay. If HRIE[1:0] are cleared in a long interrupt service routine, it is recommended that at least one other instruction separate the instruction that clears HRIE[1:0] and the RTI instruction at the end of the interrupt service routine.

#### 7.4.6.12 HCSR Host Transmit Underrun Error (HTUE)—Bit 14

The read-only status bit HTUE indicates whether a transmit-underrun error occurred. Transmit-underrun errors can occur only when operating in the SPI slave mode or the I<sup>2</sup>C slave mode when HCKFR is cleared. In a master mode, transmission takes place on demand and no underrun can occur. HTUE is set when both the shift register and the HTX register are empty and the external master begins reading the next word:

- When operating in the I<sup>2</sup>C mode, HTUE is set in the falling edge of the ACK bit. In this case, the SHI retransmits the previously transmitted word.
- When operating in the SPI mode, HTUE is set at the first clock edge if CPHA = 1; it is set at the assertion of SS if CPHA = 0.

If a transmit interrupt occurs with HTUE set, the transmit-underrun interrupt vector is generated. If a transmit interrupt occurs with HTUE cleared, the regular transmit-data interrupt vector is generated. HTUE is cleared by reading the HCSR and then writing to the HTX register. HTUE is cleared by hardware reset, software reset, SHI individual reset and during the stop state.

#### 7.4.6.13 HCSR Host Transmit Data Empty (HTDE)—Bit 15

The read-only status bit HTDE indicates whether the HTX register is empty and can be written by the DSP. HTDE is set when the data word is transferred from HTX to the shift register, except in SPI master mode when CPHA = 0 (see HCKR). When in the SPI master mode with CPHA = 0, HTDE is set after the end of the data word transmission. HTDE is cleared when the DSP writes the HTX either with write instructions or DMA transfers. HTDE is set by hardware reset, software reset, SHI individual reset and during the stop state.

#### 7.4.6.14 HCSR Reserved Bits—Bits 23, 18 and 16

These bits are reserved. They read as zero and should be written with zero for future compatibility.

#### 7.4.6.15 Host Receive FIFO Not Empty (HRNE)—Bit 17

The read-only status bit HRNE indicates that the Host Receive FIFO (HRX) contains at least one data word. HRNE is set when the FIFO is not empty. HRNE is cleared when HRX is read by the DSP (read instructions or DMA transfers), reducing the number of words in the FIFO to zero. HRNE is cleared during hardware reset, software reset, SHI individual reset and during the stop state.

#### 7.4.6.16 Host Receive FIFO Full (HRFF)—Bit 19

The read-only status bit HRFF indicates, when set, that the Host Receive FIFO (HRX) is full. HRFF is cleared when HRX is read by the DSP (read instructions or DMA transfers) and at least one place is available in the FIFO. HRFF is cleared by hardware reset, software reset, SHI individual reset and during the stop state.

#### 7.4.6.17 Host Receive Overrun Error (HROE)—Bit 20

The read-only status bit HROE indicates, when set, that a data-receive overrun error has occurred. Receive-overrun errors cannot occur when operating in the I<sup>2</sup>C master mode, because the clock is suspended if the receive FIFO is full; nor can they occur in the I<sup>2</sup>C slave mode when HCKFR is set.

HROE is set when the shift register (IOSR) is filled and ready to transfer the data word to the HRX FIFO and the FIFO is already full (HRFF is set). When a receive-overrun error occurs, the shift register is not transferred to the FIFO. If a receive interrupt occurs with HROE set, the receive-overrun interrupt vector is generated. If a receive interrupt occurs with HROE cleared, the regular receive-data interrupt vector is generated.

HROE is cleared by reading the HCSR with HROE set, followed by reading HRX. HROE is cleared by hardware reset, software reset, SHI individual reset and during the stop state.

#### 7.4.6.18 Host Bus Error (HBER)—Bit 21

The read-only status bit HBER indicates, when set, that an SHI bus error occurred when operating as a master (HMST set). In I<sup>2</sup>C mode, HBER is set if the transmitter does not receive an acknowledge after a byte is transferred; then a stop event is generated and transmission is suspended. In SPI mode, HBER is set if  $\overline{SS}$  is asserted; then transmission is suspended at the end of transmission of the current word. HBER is cleared only by hardware reset, software reset, SHI individual reset and during the stop state.

#### 7.4.6.19 HCSR Host Busy (HBUSY)—Bit 22

The read-only status bit HBUSY indicates that the I<sup>2</sup>C bus is busy (when in the I<sup>2</sup>C mode) or that the SHI itself is busy (when in the SPI mode). When operating in the I<sup>2</sup>C mode, HBUSY is set after the SHI detects a start event and remains set until a stop event is detected. When operating in the slave SPI mode, HBUSY is set while  $\overline{SS}$  is asserted. When operating in the master SPI mode, HBUSY is set if the HTX register is not empty or if the IOSR is not empty. HBUSY is cleared otherwise. HBUSY is cleared by hardware reset, software reset, SHI individual reset and during the stop state.

### 7.5 Characteristics Of The SPI Bus

The SPI bus consists of two serial data lines (MISO and MOSI), a clock line (SCK) and a Slave Select line ( $\overline{SS}$ ). During an SPI transfer, a byte is shifted out one data pin while a different byte is simultaneously shifted in through a second data pin. It can be viewed as two 8-bit shift registers connected together in a circular manner, with one shift register on the master side and the other on the slave side. Thus the data bytes in the master device and slave device are exchanged. The MISO and MOSI data pins are used for transmitting and receiving serial data. When the SPI is configured as a master, MISO is the master data input line, and MOSI is the master data output line. When the SPI is configured as a slave device, MISO is the slave data output line, and MOSI is the slave data input line.

Clock control logic allows a selection of clock polarity and a choice of two fundamentally different clocking protocols to accommodate most available synchronous serial peripheral devices. When the SPI is configured as a master, the control bits in the HCKR select the appropriate clock rate, as well as the desired clock polarity and phase format (see Figure 7-6).

The  $\overline{SS}$  line allows selection of an individual slave SPI device; slave devices that are not selected do not interfere with SPI bus activity, i.e., they keep their MISO output pin in the high-impedance state. When the SHI is configured as an SPI master device, the  $\overline{SS}$  line should be held high. If the  $\overline{SS}$  line is driven low when the SHI is in SPI master mode, a bus error is generated (the HCSR HBER bit is set).

### 7.6 Characteristics Of The I<sup>2</sup>C Bus

The I<sup>2</sup>C serial bus consists of two bidirectional lines, one for data signals (SDA) and one for clock signals (SCL). Both the SDA and SCL lines must be connected to a positive supply voltage via a pull-up resistor.

#### NOTE

In the I<sup>2</sup>C bus specifications, the standard mode (100 kHz clock rate) and a fast mode (400 kHz clock rate) are defined. The SHI can operate in either mode.

## 7.6.1 Overview

The I<sup>2</sup>C bus protocol must conform to the following rules:

- Data transfer may be initiated only when the bus is not busy.
- During data transfer, the data line must remain stable whenever the clock line is high. Changes in the data line when the clock line is high are interpreted as control signals (see Figure 7-7).

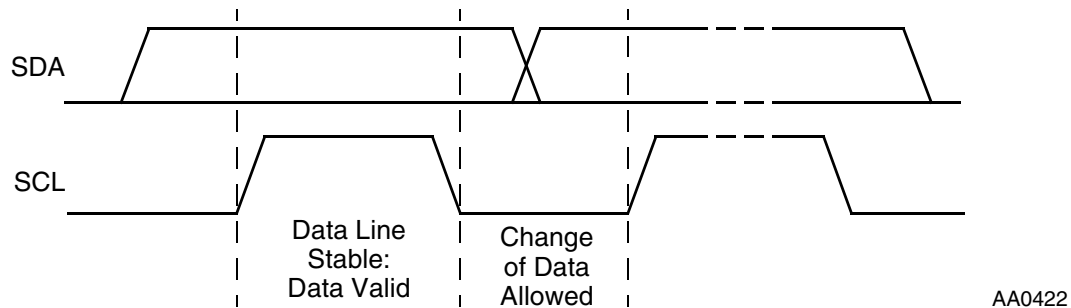


Figure 7-7 I<sup>2</sup>C Bit Transfer

Accordingly, the I<sup>2</sup>C bus protocol defines the following events:

- **Bus not busy**—Both data and clock lines remain high.
- **Start data transfer**—The start event is defined as a change in the state of the data line, from high to low, while the clock is high (see Figure 7-8).
- **Stop data transfer**—The stop event is defined as a change in the state of the data line, from low to high, while the clock is high (see Figure 7-8).
- **Data valid**—The state of the data line represents valid data when, after a start event, the data line is stable for the duration of the high period of the clock signal. The data on the line may be changed during the low period of the clock signal. There is one clock pulse per bit of data.

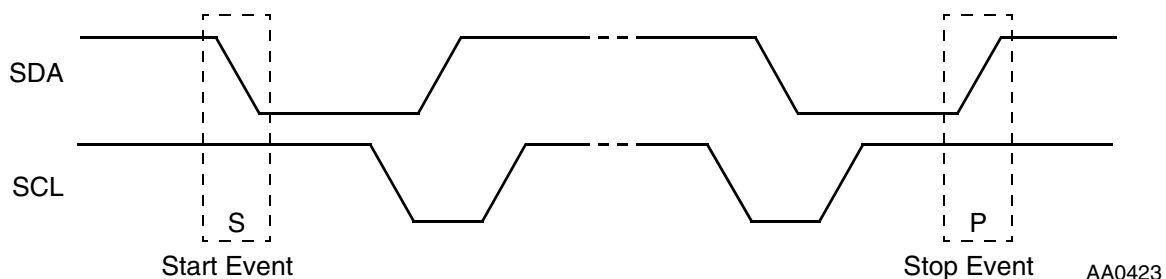


Figure 7-8 I<sup>2</sup>C Start and Stop Events

Each 8-bit word is followed by one acknowledge bit. This acknowledge bit is a high level put on the bus by the transmitter when the master device generates an extra acknowledge-related clock pulse. A slave receiver that is addressed must generate an acknowledge after each byte is received. Also, a master receiver must generate an acknowledge after the reception of each byte that has been clocked out of the slave transmitter. The acknowledging device must pull-down the SDA line during the acknowledge clock

pulse so that the SDA line is stable low during the high period of the acknowledge-related clock pulse (see Figure 7-9).

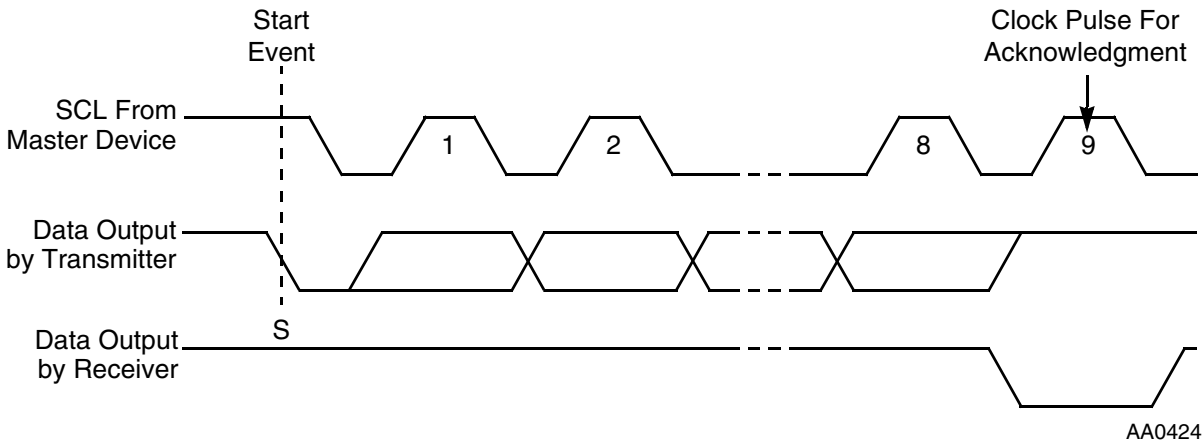


Figure 7-9 Acknowledgment on the I<sup>2</sup>C Bus

A device generating a signal is called a transmitter, and a device receiving a signal is called a receiver. A device controlling a signal is called a master and devices controlled by the master are called slaves. A master receiver must signal an end-of-data to the slave transmitter by not generating an acknowledge on the last byte clocked out of the slave device. In this case the transmitter must leave the data line high to enable the master to generate the stop event. Handshaking may also be accomplished by using the clock synchronizing mechanism. Slave devices can hold the SCL line low, after receiving and acknowledging a byte, to force the master into a wait state until the slave device is ready for the next byte transfer. The SHI supports this feature when operating as a master device and waits until the slave device releases the SCL line before proceeding with the data transfer.

## 7.6.2 I<sup>2</sup>C Data Transfer Formats

I<sup>2</sup>C bus data transfers follow the following process: after the start event, a slave device address is sent. The address consists of seven address bits and an eighth bit as a data direction bit (R/W). In the data direction bit, zero indicates a transmission (write), and one indicates a request for data (read). A data transfer is always terminated by a stop event generated by the master device. However, if the master device still wishes to communicate on the bus, it can generate another start event and address another slave device without first generating a stop event. (The SHI does not support this feature when operating as an I<sup>2</sup>C master device.) This method is also used to provide indivisible data transfers. Various combinations of read/write formats are illustrated in Figure 7-10 and Figure 7-11.

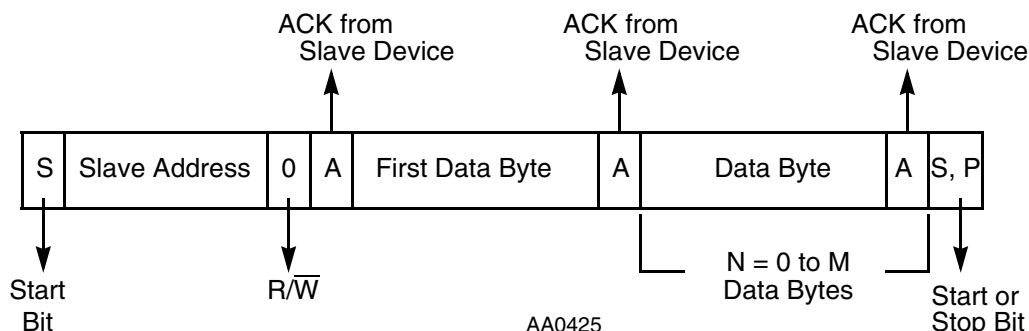


Figure 7-10 I²C Bus Protocol For Host Write Cycle

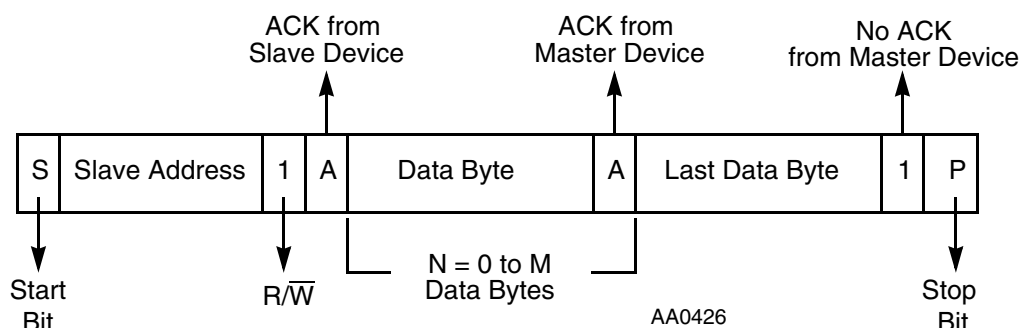


Figure 7-11 I²C Bus Protocol For Host Read Cycle

**NOTE**

The first data byte in a write-bus cycle can be used as a user-predefined control byte (e.g., to determine the location to which the forthcoming data bytes should be transferred).

## 7.7 SHI Programming Considerations

The SHI implements both SPI and I²C bus protocols and can be programmed to operate as a slave device or a single-master device. Once the operating mode is selected, the SHI may communicate with an external device by receiving and/or transmitting data. Before changing the SHI operational mode, an SHI individual reset should be generated by clearing the HEN bit. The following paragraphs describe programming considerations for each operational mode.

### 7.7.1 SPI Slave Mode

The SPI slave mode is entered by enabling the SHI (HEN=1), selecting the SPI mode (HI²C=0) and selecting the slave mode of operation (HMST=0). The programmer should verify that the CPHA and CPOL bits (in the HCKR) correspond to the external host clock phase and polarity. Other HCKR bits are ignored. When configured in the SPI slave mode, the SHI external pins operate as follows:

- SCK/SCL is the SCK serial clock input.
- MISO/SDA is the MISO serial data output.
- MOSI/HA0 is the MOSI serial data input.
- $\overline{SS}$ /HA2 is the  $\overline{SS}$  slave select input.
- $\overline{HREQ}$  is the Host Request output.

In the SPI slave mode, a receive, transmit, or full-duplex data transfer may be performed. Actually, the interface performs data receive and transmit simultaneously. The status bits of both receive and transmit paths are active; however, the programmer may disable undesired interrupts and ignore irrelevant status bits. It is recommended that an SHI individual reset (HEN cleared) be generated before beginning data reception in order to reset the HRX FIFO to its initial (empty) state (e.g., when switching from transmit to receive data).

If a write to HTX occurs, its contents are transferred to IOSR between data word transfers. The IOSR data is shifted out (via MISO) and received data is shifted in (via MOSI). The DSP may write HTX with either DSP instructions or DMA transfers if the HTDE status bit is set. If no writes to HTX occur, the contents of HTX are not transferred to IOSR, so the data shifted out when receiving is the data present in the IOSR at the time. The HRX FIFO contains valid receive data, which the DSP can read with either DSP instructions or DMA transfers (if the HRNE status bit is set).

The  $\overline{HREQ}$  output pin, if enabled for receive ( $HRQE[1:0] = 01$ ), is asserted when the IOSR is ready for receive and the HRX FIFO is not full; this operation guarantees that the next received data word is stored in the FIFO. The  $\overline{HREQ}$  output pin, if enabled for transmit ( $HRQE[1:0] = 10$ ), is asserted when the IOSR is loaded from HTX with a new data word to transfer. If  $\overline{HREQ}$  is enabled for both transmit and receive ( $HRQE[1:0] = 11$ ), it is asserted when the receive and transmit conditions are both true.  $\overline{HREQ}$  is deasserted at the first clock pulse of the next data word transfer. The  $\overline{HREQ}$  line may be used to interrupt the external master device. Connecting the  $\overline{HREQ}$  line between two SHI-equipped DSPs, one operating as an SPI master device and the other as an SPI slave device, enables full hardware handshaking if operating with  $CPHA = 1$ .

The  $\overline{SS}$  line should be kept asserted during a data word transfer. If the  $\overline{SS}$  line is deasserted before the end of the data word transfer, the transfer is aborted and the received data word is lost.

### 7.7.2 SPI Master Mode

The SPI master mode is initiated by enabling the SHI ( $HEN = 1$ ), selecting the SPI mode ( $HI^2C = 0$ ) and selecting the master mode of operation ( $HMST = 1$ ). Before enabling the SHI as an SPI master device, the programmer should program the proper clock rate, phase and polarity in HCKR. When configured in the SPI master mode, the SHI external pins operate as follows:

- SCK/SCL is the SCK serial clock output.
- MISO/SDA is the MISO serial data input.
- MOSI/HA0 is the MOSI serial data output.
- $\overline{SS}$ /HA2 is the  $\overline{SS}$  input. It should be kept deasserted (high) for proper operation.
- $\overline{HREQ}$  is the Host Request input.

The external slave device can be selected either by using external logic or by activating a GPIO pin connected to its  $\overline{SS}$  pin. However, the  $\overline{SS}$  input pin of the SPI master device should be held deasserted (high) for proper operation. If the SPI master device  $\overline{SS}$  pin is asserted, the host bus error status bit (HBER) is set. If the HBIE bit is also set, the SHI issues a request to the DSP interrupt controller to service the SHI bus error interrupt.

In the SPI master mode the DSP must write to HTX to receive, transmit or perform a full-duplex data transfer. Actually, the interface performs simultaneous data receive and transmit. The status bits of both receive and transmit paths are active; however, the programmer may disable undesired interrupts and ignore irrelevant status bits. In a data transfer, the HTX is transferred to IOSR, clock pulses are generated, the IOSR data is shifted out (via MOSI) and received data is shifted in (via MISO). The DSP programmer may write HTX (if the HTDE status bit is set) with either DSP instructions or DMA transfers to initiate the transfer of the next word. The HRX FIFO contains valid receive data, which the DSP can read with either DSP instructions or DMA transfers, if the HRNE status bit is set.

It is recommended that an SHI individual reset (HEN cleared) be generated before beginning data reception in order to reset the receive FIFO to its initial (empty) state (e.g., when switching from transmit to receive data).

The  $\overline{HREQ}$  input pin is ignored by the SPI master device if the HRQE[1:0] bits are cleared and considered if any of them is set. When asserted by the slave device,  $\overline{HREQ}$  indicates that the external slave device is ready for the next data transfer. As a result, the SPI master sends clock pulses for the full data word transfer.  $\overline{HREQ}$  is deasserted by the external slave device at the first clock pulse of the new data transfer. When deasserted,  $\overline{HREQ}$  prevents the clock generation of the next data word transfer until it is asserted again. Connecting the  $\overline{HREQ}$  line between two SHI-equipped DSPs, one operating as an SPI master device and the other as an SPI slave device, enables full hardware handshaking if CPHA = 1. For CPHA = 0,  $\overline{HREQ}$  should be disabled by clearing HRQE[1:0].

### 7.7.3 I<sup>2</sup>C Slave Mode

The I<sup>2</sup>C slave mode is entered by enabling the SHI (HEN=1), selecting the I<sup>2</sup>C mode (HI<sup>2</sup>C=1) and selecting the slave mode of operation (HMST=0). In this operational mode the contents of HCKR are ignored. When configured in the I<sup>2</sup>C slave mode, the SHI external pins operate as follows:

- SCK/SCL is the SCL serial clock input.
- MISO/SDA is the SDA open drain serial data line.
- MOSI/HA0 is the HA0 slave device address input.
- $\overline{SS}$ /HA2 is the HA2 slave device address input.
- $\overline{HREQ}$  is the Host Request output.

When the SHI is enabled and configured in the I<sup>2</sup>C slave mode, the SHI controller inspects the SDA and SCL lines to detect a start event. Upon detection of the start event, the SHI receives the slave device address byte and enables the slave device address recognition unit. If the slave device address byte was not identified as its personal address, the SHI controller fails to acknowledge this byte by not driving low the SDA line at the ninth clock pulse (ACK = 1). However, it continues to poll the SDA and SCL lines to detect a new start event. If the personal slave device address was correctly identified, the slave device address



byte is acknowledged (ACK = 0 is sent) and a receive/transmit session is initiated according to the eighth bit of the received slave device address byte, i.e., the  $R/\overline{W}$  bit.

### 7.7.3.1 Receive Data in I<sup>2</sup>C Slave Mode

A receive session is initiated when the personal slave device address has been correctly identified and the  $R/\overline{W}$  bit of the received slave device address byte has been cleared. Following a receive initiation, data in the SDA line is shifted into IOSR MSB first. Following each received byte, an acknowledge (ACK = 0) is sent at the ninth clock pulse via the SDA line. Data is acknowledged byte wise, as required by the I<sup>2</sup>C bus protocol, and is transferred to the HRX FIFO when the complete word (according to HM[1:0]) is filled into IOSR. It is the responsibility of the programmer to select the correct number of bytes in an I<sup>2</sup>C frame so that they fit in a complete number of words. For this purpose, the slave device address byte does not count as part of the data; therefore, it is treated separately.

In a receive session, only the receive path is enabled and HTX to IOSR transfers are inhibited. The HRX FIFO contains valid data, which may be read by the DSP with either DSP instructions or DMA transfers (if the HRNE status bit is set).

If HCKFR is cleared, when the HRX FIFO is full and IOSR is filled, an overrun error occurs and the HROE status bit is set. In this case, the last received byte is not acknowledged (ACK=1 is sent) and the word in the IOSR is not transferred to the HRX FIFO. This may inform the external I<sup>2</sup>C master device of the occurrence of an overrun error on the slave side. Consequently the I<sup>2</sup>C master device may terminate this session by generating a stop event.

If HCKFR is set, when the HRX FIFO is full the SHI holds the clock line to GND not letting the master device write to IOSR, which eliminates the possibility of reaching the overrun condition.

The  $\overline{\text{HREQ}}$  output pin, if enabled for receive (HRQE[1:0] = 01), is asserted when the IOSR is ready to receive and the HRX FIFO is not full; this operation guarantees that the next received data word is stored in the FIFO.  $\overline{\text{HREQ}}$  is deasserted at the first clock pulse of the next received word. The  $\overline{\text{HREQ}}$  line may be used to interrupt the external I<sup>2</sup>C master device. Connecting the  $\overline{\text{HREQ}}$  line between two SHI-equipped DSPs, one operating as an I<sup>2</sup>C master device and the other as an I<sup>2</sup>C slave device, enables full hardware handshaking.

### 7.7.3.2 Transmit Data In I<sup>2</sup>C Slave Mode

A transmit session is initiated when the personal slave device address has been correctly identified and the  $R/\overline{W}$  bit of the received slave device address byte has been set. Following a transmit initiation, the IOSR is loaded from HTX (assuming the latter was not empty) and its contents are shifted out, MSB first, on the SDA line. Following each transmitted byte, the SHI controller samples the SDA line at the ninth clock pulse and inspects the ACK status. If the transmitted byte was acknowledged (ACK = 0), the SHI controller continues and transmits the next byte. However, if it was not acknowledged (ACK = 1), the transmit session is stopped and the SDA line is released. Consequently, the external master device may generate a stop event in order to terminate the session.

HTX contents are transferred to IOSR when the complete word (according to HM[1:0]) has been shifted out. It is, therefore, the responsibility of the programmer to select the correct number of bytes in an I<sup>2</sup>C

frame so that they fit in a complete number of words. For this purpose, the slave device address byte does not count as part of the data; therefore, it is treated separately.

In a transmit session, only the transmit path is enabled and the IOSR-to-HRX FIFO transfers are inhibited. When the HTX transfers its valid data word to IOSR, the HTDE status bit is set and the DSP may write a new data word to HTX with either DSP instructions or DMA transfers.

If HCKFR is cleared and both IOSR and HTX are empty when the master device attempts a transmit session, an underrun condition occurs, setting the HTUE status bit, and the previous word is retransmitted.

If HCKFR is set and both IOSR and HTX are empty when the master device attempts a transmit session, the SHI holds the clock line to GND to avoid an underrun condition.

The  $\overline{\text{HREQ}}$  output pin, if enabled for transmit ( $\text{HRQE}[1:0] = 10$ ), is asserted when HTX is transferred to IOSR for transmission. When asserted,  $\overline{\text{HREQ}}$  indicates that the slave device is ready to transmit the next data word.  $\overline{\text{HREQ}}$  is deasserted at the first clock pulse of the next transmitted data word. The  $\overline{\text{HREQ}}$  line may be used to interrupt the external I<sup>2</sup>C master device. Connecting the  $\overline{\text{HREQ}}$  line between two SHI-equipped DSPs, one operating as an I<sup>2</sup>C master device and the other as an I<sup>2</sup>C slave device, enables full hardware handshaking.

#### 7.7.4 I<sup>2</sup>C Master Mode

The I<sup>2</sup>C master mode is entered by enabling the SHI ( $\text{HEN}=1$ ), selecting the I<sup>2</sup>C mode ( $\text{HI}^2\text{C}=1$ ) and selecting the master mode of operation ( $\text{HMST}=1$ ). Before enabling the SHI as an I<sup>2</sup>C master, the programmer should program the appropriate clock rate in HCKR.

When configured in the I<sup>2</sup>C master mode, the SHI external pins operate as follows:

- SCK/SCL is the SCL open drain serial clock output.
- MISO/SDA is the SDA open drain serial data line.
- MOSI/HA0 is the HA0 slave device address input.
- $\overline{\text{SS}}$ /HA2 is the HA2 slave device address input.
- $\overline{\text{HREQ}}$  is the Host Request input.

In the I<sup>2</sup>C master mode, a data transfer session is always initiated by the DSP by writing to the HTX register when HIDLE is set. This condition ensures that the data byte written to HTX is interpreted as being a slave address byte. This data byte must specify the slave device address to be selected and the requested data transfer direction.

#### NOTE

The slave address byte should be located in the high portion of the data word, whereas the middle and low portions are ignored. Only one byte (the slave address byte) is shifted out, independent of the word length defined by the  $\text{HM}[1:0]$  bits.

In order for the DSP to initiate a data transfer the following actions are to be performed:

- The DSP tests the  $\overline{\text{HIDLE}}$  status bit.
- If the  $\overline{\text{HIDLE}}$  status bit is set, the DSP writes the slave device address and the  $\text{R}/\overline{\text{W}}$  bit to the most significant byte of HTX.
- The SHI generates a start event.
- The SHI transmits one byte only, internally samples the  $\text{R}/\overline{\text{W}}$  direction bit (last bit) and accordingly initiates a receive or transmit session.
- The SHI inspects the SDA level at the ninth clock pulse to determine the ACK value. If acknowledged ( $\text{ACK} = 0$ ), it starts its receive or transmit session according to the sampled  $\text{R}/\overline{\text{W}}$  value. If not acknowledged ( $\text{ACK} = 1$ ), the HBER status bit in HCSR is set, which causes an SHI Bus Error interrupt request if HBIE is set, and a stop event is generated.

The  $\overline{\text{HREQ}}$  input pin is ignored by the  $\text{I}^2\text{C}$  master device if  $\text{HRQE}[1:0]$  are cleared, and it is considered if either of them is set. When asserted,  $\overline{\text{HREQ}}$  indicates that the external slave device is ready for the next data transfer. As a result, the  $\text{I}^2\text{C}$  master device sends clock pulses for the full data word transfer.  $\overline{\text{HREQ}}$  is deasserted by the external slave device at the first clock pulse of the next data transfer. When deasserted,  $\overline{\text{HREQ}}$  prevents the clock generation of the next data word transfer until it is asserted again. Connecting the  $\overline{\text{HREQ}}$  line between two SHI-equipped DSPs, one operating as an  $\text{I}^2\text{C}$  master device and the other as an  $\text{I}^2\text{C}$  slave device, enables full hardware handshaking.

#### 7.7.4.1 Receive Data in $\text{I}^2\text{C}$ Master Mode

A receive session is initiated if the  $\text{R}/\overline{\text{W}}$  direction bit of the transmitted slave device address byte is set. Following a receive initiation, data in the SDA line is shifted into IOSR MSB first. Following each received byte, an acknowledge ( $\text{ACK} = 0$ ) is sent at the ninth clock pulse via the SDA line if the  $\overline{\text{HIDLE}}$  control bit is cleared. Data is acknowledged byte-wise, as required by the  $\text{I}^2\text{C}$  bus protocol, and is transferred to the HRX FIFO when the complete word (according to  $\text{HM}[1:0]$ ) is filled into IOSR. It is the responsibility of the programmer to select the correct number of bytes in an  $\text{I}^2\text{C}$  frame so that they fit in a complete number of words. For this purpose, the slave device address byte does not count as part of the data; therefore, it is treated separately.

If the  $\text{I}^2\text{C}$  slave transmitter is acknowledged, it should transmit the next data byte. In order to terminate the receive session, the programmer should set the  $\overline{\text{HIDLE}}$  bit at the last required data word. As a result, the last byte of the next received data word is not acknowledged, the slave transmitter releases the SDA line, and the SHI generates the stop event and terminates the session.

In a receive session, only the receive path is enabled and the HTX-to-IOSR transfers are inhibited. If the HRNE status bit is set, the HRX FIFO contains valid data, which may be read by the DSP with either DSP instructions or DMA transfers. When the HRX FIFO is full, the SHI suspends the serial clock just before acknowledge. In this case, the clock is reactivated when the FIFO is read (the SHI gives an  $\text{ACK} = 0$  and proceeds receiving).

#### 7.7.4.2 Transmit Data In $\text{I}^2\text{C}$ Master Mode

A transmit session is initiated if the  $\text{R}/\overline{\text{W}}$  direction bit of the transmitted slave device address byte is cleared. Following a transmit initiation, the IOSR is loaded from HTX (assuming HTX is not empty) and

its contents are shifted out, MSB-first, on the SDA line. Following each transmitted byte, the SHI controller samples the SDA line at the ninth clock pulse and inspects the ACK status. If the transmitted byte was acknowledged (ACK=0), the SHI controller continues transmitting the next byte. However, if it was not acknowledged (ACK=1), the HBER status bit is set to inform the DSP side that a bus error (or overrun, or any other exception in the slave device) has occurred. Consequently, the I<sup>2</sup>C master device generates a stop event and terminates the session.

HTX contents are transferred to the IOSR when the complete word (according to HM[1:0]) has been shifted out. It is, therefore, the responsibility of the programmer to select the right number of bytes in an I<sup>2</sup>C frame so that they fit in a complete number of words. Remember that for this purpose, the slave device address byte does not count as part of the data.

In a transmit session, only the transmit path is enabled and the IOSR-to-HRX FIFO transfers are inhibited. When the HTX transfers its valid data word to the IOSR, the HTDE status bit is set and the DSP may write a new data word to HTX with either DSP instructions or DMA transfers. If both IOSR and HTX are empty, the SHI suspends the serial clock until new data is written into HTX (when the SHI proceeds with the transmit session) or HIDLE is set (the SHI reactivates the clock to generate the stop event and terminate the transmit session).

### 7.7.5 SHI Operation During DSP Stop

The SHI operation cannot continue when the DSP is in the stop state, because no DSP clocks are active. While the DSP is in the stop state, the SHI remains in the individual reset state.

While in the individual reset state the following is true:

- If the SHI was operating in the I<sup>2</sup>C mode, the SHI signals are disabled (high impedance state).
- If the SHI was operating in the SPI mode, the SHI signals are not affected.
- The HCSR status bits and the transmit/receive paths are reset to the same state produced by hardware reset or software reset.
- The HCSR and HCKR control bits are not affected.

#### NOTE

It is recommended that the SHI be disabled before entering the stop state.

## 8 Enhanced Serial Audio Interface (ESAI)

### 8.1 Introduction

The Enhanced Serial Audio Interface (ESAI) provides a full-duplex serial port for serial communication with a variety of serial devices, including industry-standard codecs, SPDIF transceivers, and other DSPs. The ESAI consists of independent transmitter and receiver sections, each section with its own clock generator. It is a superset of the 56300 Family ESSI peripheral and of the 56000 Family SAI peripheral.

#### NOTE

The DSP56371 has two ESAI modules. This section describes the ESAI, and Section 9 describes the ESAI\_1.

The ESAI block diagram is shown in [Figure 8-1](#). The ESAI is named synchronous because all serial transfers are synchronized to a clock. Additional synchronization signals are used to delineate the word frames. The normal mode of operation is used to transfer data at a periodic rate, one word per period. The network mode is similar in that it is also intended for periodic transfers; however, it supports up to 32 words (time slots) per period. This mode can be used to build time division multiplexed (TDM) networks. In contrast, the on-demand mode is intended for non-periodic transfers of data and to transfer data serially at high speed when the data becomes available.

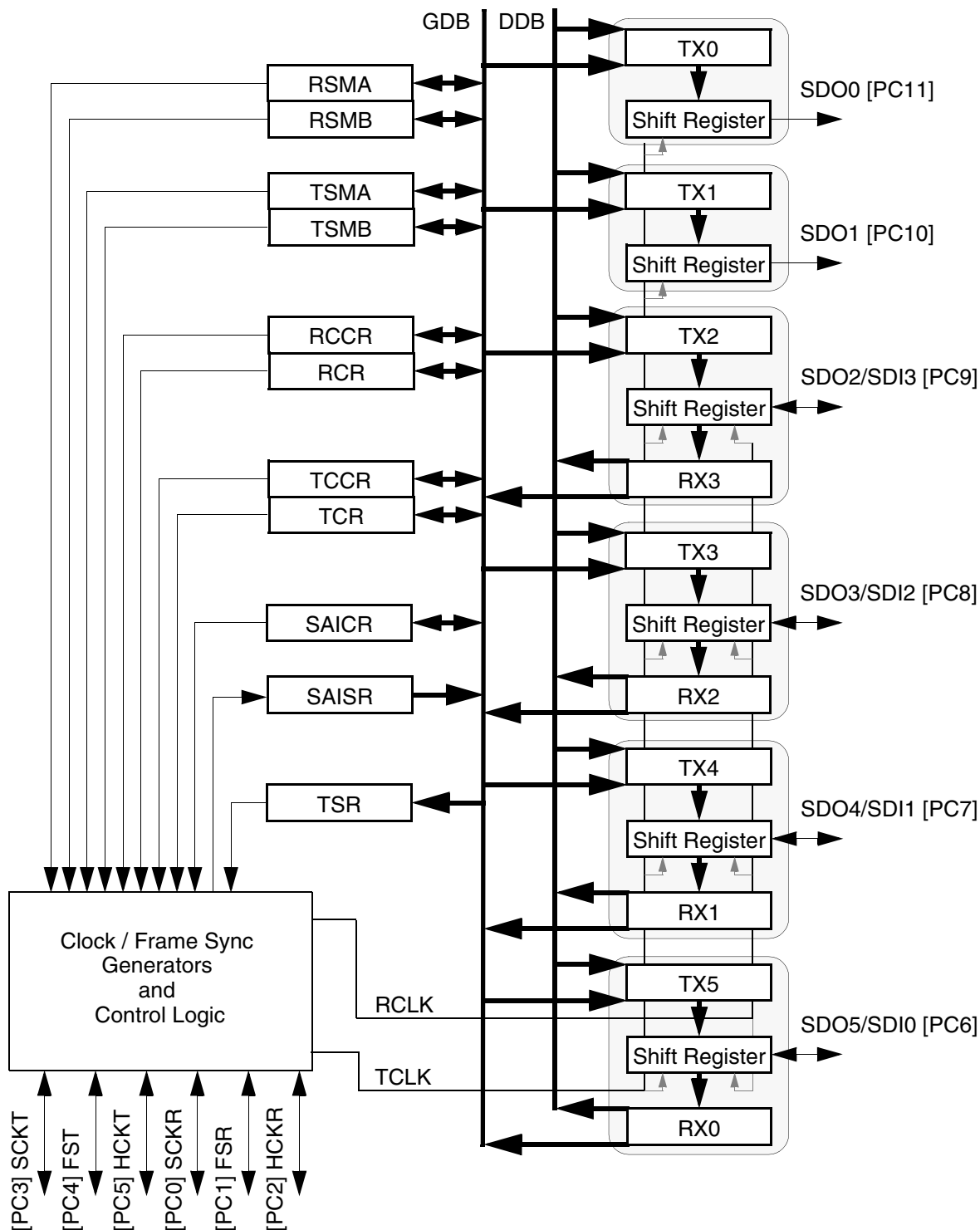


Figure 8-1 ESAI Block Diagram

## 8.2 ESAI Data and Control Pins

Three to twelve pins are required for operation, depending on the operating mode selected and the number of transmitters and receivers enabled. The SDO0 and SDO1 pins are used by transmitters 0 and 1 only. The SDO2/SDI3, SDO3/SDI2, SDO4/SDI1 and SDO5/SDI0 pins are shared by transmitters 2 to 5 with receivers 0 to 3. The actual mode of operation is selected under software control. All transmitters operate fully synchronized under control of the same transmitter clock signals. All receivers operate fully synchronized under control of the same receiver clock signals.

### 8.2.1 Serial Transmit 0 Data Pin (SDO0)

SDO0 is used for transmitting data from the TX0 serial transmit shift register. SDO0 is an output when data is being transmitted from the TX0 shift register. In the on-demand mode with an internally generated bit clock, the SDO0 pin becomes high impedance for a full clock period after the last data bit has been transmitted, assuming another data word does not follow immediately. If a data word follows immediately, there is no high-impedance interval.

SDO0 may be programmed as a general-purpose I/O pin (PC11) when the ESAI SDO0 function is not being used.

### 8.2.2 Serial Transmit 1 Data Pin (SDO1)

SDO1 is used for transmitting data from the TX1 serial transmit shift register. SDO1 is an output when data is being transmitted from the TX1 shift register. In the on-demand mode with an internally generated bit clock, the SDO1 pin becomes high impedance for a full clock period after the last data bit has been transmitted, assuming another data word does not follow immediately. If a data word follows immediately, there is no high-impedance interval.

SDO1 may be programmed as a general-purpose I/O pin (PC10) when the ESAI SDO1 function is not being used.

### 8.2.3 Serial Transmit 2/Receive 3 Data Pin (SDO2/SDI3)

SDO2/SDI3 is used as the SDO2 for transmitting data from the TX2 serial transmit shift register when programmed as a transmitter pin, or as the SDI3 signal for receiving serial data to the RX3 serial receive shift register when programmed as a receiver pin. SDO2/SDI3 is an input when data is being received by the RX3 shift register. SDO2/SDI3 is an output when data is being transmitted from the TX2 shift register. In the on-demand mode with an internally generated bit clock, the SDO2/SDI3 pin becomes high impedance for a full clock period after the last data bit has been transmitted, assuming another data word does not follow immediately. If a data word follows immediately, there is no high-impedance interval.

SDO2/SDI3 may be programmed as a general-purpose I/O pin (PC9) when the ESAI SDO2 and SDI3 functions are not being used.

### 8.2.4 Serial Transmit 3/Receive 2 Data Pin (SDO3/SDI2)

SDO3/SDI2 is used as the SDO3 signal for transmitting data from the TX3 serial transmit shift register when programmed as a transmitter pin, or as the SDI2 signal for receiving serial data to the RX2 serial receive shift register when programmed as a receiver pin. SDO3/SDI2 is an input when data is being received by the RX2 shift register. SDO3/SDI2 is an output when data is being transmitted from the TX3 shift register. In the on-demand mode with an internally generated bit clock, the SDO3/SDI2 pin becomes high impedance for a full clock period after the last data bit has been transmitted, assuming another data word does not follow immediately. If a data word follows immediately, there is no high-impedance interval.

SDO3/SDI2 may be programmed as a general-purpose I/O pin (PC8) when the ESAI SDO3 and SDI2 functions are not being used.

### 8.2.5 Serial Transmit 4/Receive 1 Data Pin (SDO4/SDI1)

SDO4/SDI1 is used as the SDO4 signal for transmitting data from the TX4 serial transmit shift register when programmed as transmitter pin, or as the SDI1 signal for receiving serial data to the RX1 serial receive shift register when programmed as a receiver pin. SDO4/SDI1 is an input when data is being received by the RX1 shift register. SDO4/SDI1 is an output when data is being transmitted from the TX4 shift register. In the on-demand mode with an internally generated bit clock, the SDO4/SDI1 pin becomes high impedance for a full clock period after the last data bit has been transmitted, assuming another data word does not follow immediately. If a data word follows immediately, there is no high-impedance interval.

SDO4/SDI1 may be programmed as a general-purpose I/O pin (PC7) when the ESAI SDO4 and SDI1 functions are not being used.

### 8.2.6 Serial Transmit 5/Receive 0 Data Pin (SDO5/SDI0)

SDO5/SDI0 is used as the SDO5 signal for transmitting data from the TX5 serial transmit shift register when programmed as transmitter pin, or as the SDI0 signal for receiving serial data to the RX0 serial shift register when programmed as a receiver pin. SDO5/SDI0 is an input when data is being received by the RX0 shift register. SDO5/SDI0 is an output when data is being transmitted from the TX5 shift register. In the on-demand mode with an internally generated bit clock, the SDO5/SDI0 pin becomes high impedance for a full clock period after the last data bit has been transmitted, assuming another data word does not follow immediately. If a data word follows immediately, there is no high-impedance interval.

SDO5/SDI0 may be programmed as a general-purpose I/O pin (PC6) when the ESAI SDO5 and SDI0 functions are not being used.

### 8.2.7 Receiver Serial Clock (SCKR)

SCKR is a bidirectional pin providing the receivers serial bit clock for the ESAI interface. The direction of this pin is determined by the RCKD bit in the RCCR register. The SCKR operates as a clock input or output used by all the enabled receivers in the asynchronous mode (SYN=0), or as serial flag 0 pin in the synchronous mode (SYN=1).



When this pin is configured as serial flag pin, its direction is determined by the RCKD bit in the RCCR register. When configured as the output flag OF0, this pin reflects the value of the OF0 bit in the SAICR register, and the data in the OF0 bit shows up at the pin synchronized to the frame sync being used by the transmitter and receiver sections. When this pin is configured as the input flag IF0, the data value at the pin is stored in the IF0 bit in the SAISR register, synchronized by the frame sync in normal mode or the slot in network mode.

SCKR may be programmed as a general-purpose I/O pin (PC0) when the ESAI SCKR function is not being used.

### NOTE

Although the external ESAI serial clock can be independent of and asynchronous to the DSP system clock, the DSP clock frequency must be at least three times the external ESAI serial clock frequency and each ESAI serial clock phase must exceed the minimum of 1.5 DSP clock periods.

For more information on pin mode and definition, see [Table 8-7](#) and on receiver clock signals see [Table 8-1](#).

**Table 8-1 Receiver Clock Sources (asynchronous mode only)**

RHCKD	RFSD	RCKD	Receiver Bit Clock Source	OUTPUTS		
0	0	0	SCKR			
0	0	1	HCKR			SCKR
0	1	0	SCKR		FSR	
0	1	1	HCKR		FSR	SCKR
1	0	0	SCKR	HCKR		
1	0	1	INT	HCKR		SCKR
1	1	0	SCKR	HCKR	FSR	
1	1	1	INT	HCKR	FSR	SCKR

## 8.2.8 Transmitter Serial Clock (SCKT)

SCKT is a bidirectional pin providing the transmitters serial bit clock for the ESAI interface. The direction of this pin is determined by the TCKD bit in the TCCR register. The SCKT is a clock input or output used by all the enabled transmitters in the asynchronous mode (SYN=0) or by all the enabled transmitters and receivers in the synchronous mode (SYN=1) (see [Table 8-2](#)).

Table 8-2 Transmitter Clock Sources

THCKD	TFSD	TCKD	Transmitter Bit Clock Source	OUTPUTS		
0	0	0	SCKT			
0	0	1	HCKT			SCKT
0	1	0	SCKT		FST	
0	1	1	HCKT		FST	SCKT
1	0	0	SCKT	HCKT		
1	0	1	INT	HCKT		SCKT
1	1	0	SCKT	HCKT	FST	
1	1	1	INT	HCKT	FST	SCKT

SCKT may be programmed as a general-purpose I/O pin (PC3) when the ESAI SCKT function is not being used.

#### NOTE

Although the external ESAI serial clock can be independent of and asynchronous to the DSP system clock, the DSP clock frequency must be at least three times the external ESAI serial clock frequency and each ESAI serial clock phase must exceed the minimum of 1.5 DSP clock periods.

### 8.2.9 Frame Sync for Receiver (FSR)

FSR is a bidirectional pin providing the receivers frame sync signal for the ESAI interface. The direction of this pin is determined by the RFSD bit in RCR register. In the asynchronous mode (SYN=0), the FSR pin operates as the frame sync input or output used by all the enabled receivers. In the synchronous mode (SYN=1), it operates as either the serial flag 1 pin (TEBE=0), or as the transmitter external buffer enable control (TEBE=1, RFSD=1). For further information on pin mode and definition, see [Table 8-8](#) and on receiver clock signals see [Table 8-1](#).

When this pin is configured as serial flag pin, its direction is determined by the RFSD bit in the RCCR register. When configured as the output flag OF1, this pin reflects the value of the OF1 bit in the SAICR register, and the data in the OF1 bit shows up at the pin synchronized to the frame sync being used by the transmitter and receiver sections. When configured as the input flag IF1, the data value at the pin is stored in the IF1 bit in the SAISR register, synchronized by the frame sync in normal mode or the slot in network mode.

FSR may be programmed as a general-purpose I/O pin (PC1) when the ESAI FSR function is not being used.

### 8.2.10 Frame Sync for Transmitter (FST)

FST is a bidirectional pin providing the frame sync for both the transmitters and receivers in the synchronous mode (SYN=1) and for the transmitters only in asynchronous mode (SYN=0) (see [Table 8-2](#)). The direction of this pin is determined by the TFSD bit in the TCR register. When configured as an output, this pin is the internally generated frame sync signal. When configured as an input, this pin receives an external frame sync signal for the transmitters (and the receivers in synchronous mode).

FST may be programmed as a general-purpose I/O pin (PC4) when the ESAI FST function is not being used.

### 8.2.11 High Frequency Clock for Transmitter (HCKT)

HCKT is a bidirectional pin providing the transmitters high frequency clock for the ESAI interface. The direction of this pin is determined by the THCKD bit in the TCCR register. In the asynchronous mode (SYN=0), the HCKT pin operates as the high frequency clock input or output used by all enabled transmitters. In the synchronous mode (SYN=1), it operates as the high frequency clock input or output used by all enabled transmitters and receivers. When programmed as input this pin is used as an alternative high frequency clock source to the ESAI transmitter rather than the DSP main clock. When programmed as output it can serve as a high frequency sample clock (to external DACs for example) or as an additional system clock. See [Table 8-2](#).

HCKT may be programmed as a general-purpose I/O pin (PC5) when the ESAI HCKT function is not being used.

### 8.2.12 High Frequency Clock for Receiver (HCKR)

HCKR is a bidirectional pin providing the receivers high frequency clock for the ESAI interface. The direction of this pin is determined by the RHCKD bit in the RCCR register. In the asynchronous mode (SYN=0), the HCKR pin operates as the high frequency clock input or output used by all the enabled receivers. In the synchronous mode (SYN=1), it operates as the serial flag 2 pin. For further information on pin mode and definition, see [Table 8-9](#) and on receiver clock signals see [Table 8-1](#).

When this pin is configured as serial flag pin, its direction is determined by the RHCKD bit in the RCCR register. When configured as the output flag OF2, this pin reflects the value of the OF2 bit in the SAICR register, and the data in the OF2 bit shows up at the pin synchronized to the frame sync being used by the transmitter and receiver sections. When configured as the input flag IF2, the data value at the pin is stored in the IF2 bit in the SAISR register, synchronized by the frame sync in normal mode or the slot in network mode.

HCKR may be programmed as a general-purpose I/O pin (PC2) when the ESAI HCKR function is not being used.

## 8.3 ESAI Programming Model

The ESAI can be viewed as five control registers, one status register, six transmit data registers, four receive data registers, two transmit slot mask registers, two receive slot mask registers and a special-purpose time slot register. The following paragraphs give detailed descriptions and operations of each bit in the ESAI registers.

The ESAI pins can also function as GPIO pins (Port C), described in [Section 8.5, "GPIO - Pins and Registers"](#).

### 8.3.1 ESAI Transmitter Clock Control Register (TCCR)

The read/write Transmitter Clock Control Register (TCCR) controls the ESAI transmitter clock generator bit and frame sync rates, the bit clock and high frequency clock sources and the directions of the HCKT, FST and SCKT signals. (See [Figure 8-2](#)). In the synchronous mode (SYN=1), the bit clock defined for the transmitter determines the receiver bit clock as well. TCCR also controls the number of words per frame for the serial data. Hardware and software reset clear all the bits of the TCCR register.

	11	10	9	8	7	6	5	4	3	2	1	0
X:\$FFFFB6	TDC2	TDC1	TDC0	TPSR	TPM7	TPM6	TPM5	TPM4	TPM3	TPM2	TPM1	TPM0
	23	22	21	20	19	18	17	16	15	14	13	12
	THCKD	TFSD	TCKD	THCKP	TFSP	TCKP	TFP3	TFP2	TFP1	TFP0	TDC4	TDC3

**Figure 8-2 TCCR Register**

Note that care should be taken in asynchronous mode whenever the framesync clock (FSR, FST) is not sourced directly from its associated bit clock (SCKR, SCKT). Proper phase relationships must be maintained between these clocks in order to guarantee proper operation of the ESAI.

The TCCR control bits are described in the following paragraphs.

#### 8.3.1.1 TCCR Transmit Prescale Modulus Select (TPM7–TPM0) - Bits 7–0

The TPM7–TPM0 bits specify the divide ratio of the prescale divider in the ESAI transmitter clock generator. A divide ratio from 1 to 256 (TPM[7:0]=\$00 to \$FF) may be selected. The bit clock output is available at the transmit serial bit clock (SCKT) pin of the DSP. The bit clock output is also available internally for use as the bit clock to shift the transmit and receive shift registers. The ESAI transmit clock generator functional diagram is shown in [Figure 8-3](#).

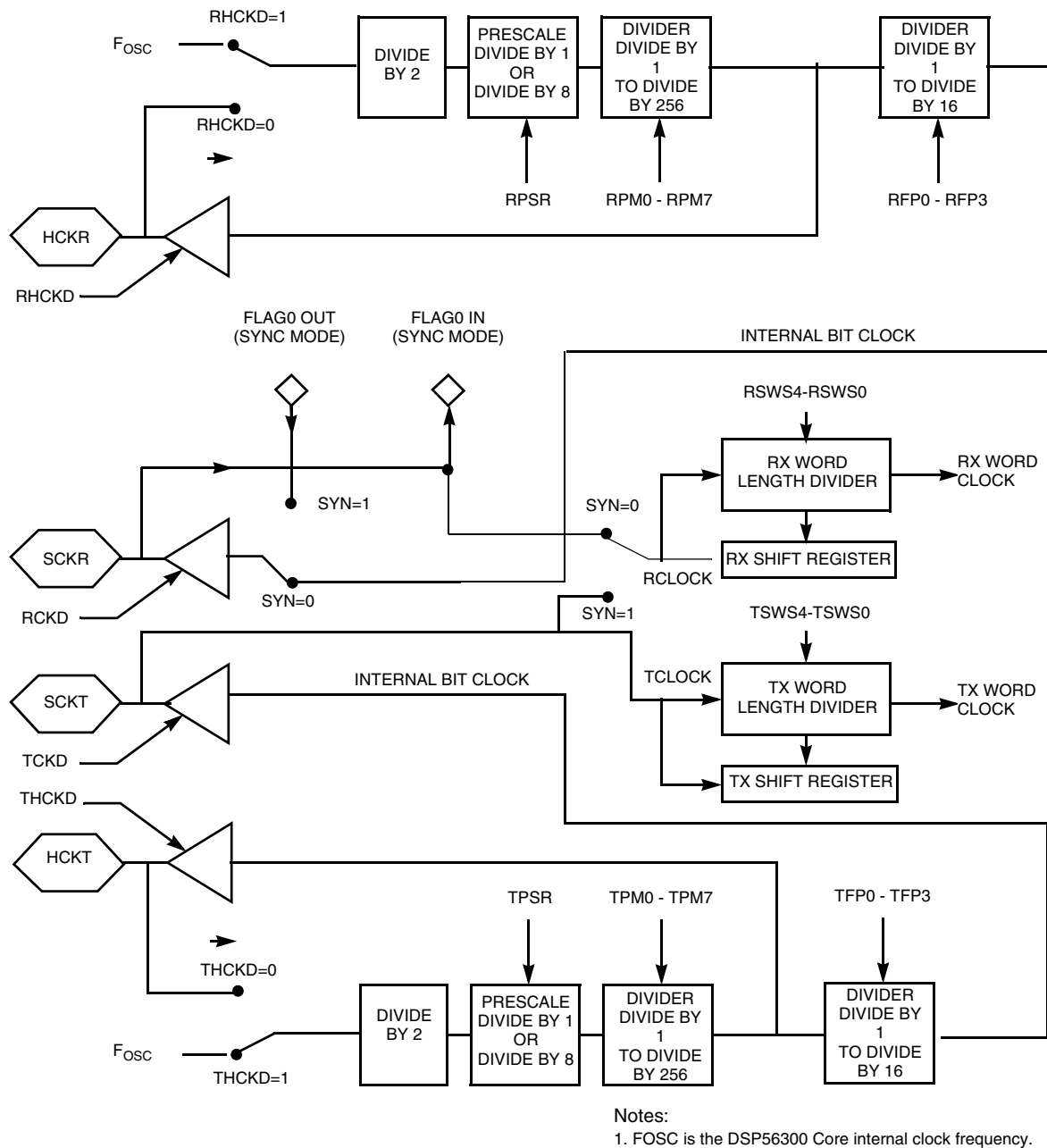


Figure 8-3 ESAI Clock Generator Functional Block Diagram

### 8.3.1.2 TCCR Transmit Prescaler Range (TPSR) - Bit 8

The TPSR bit controls a fixed divide-by-eight prescaler in series with the variable prescaler. This bit is used to extend the range of the prescaler for those cases where a slower bit clock is desired. When TPSR is set, the fixed prescaler is bypassed. When TPSR is cleared, the fixed divide-by-eight prescaler is

operational (see Figure 8-3). The maximum internally generated bit clock frequency is  $F_{osc}/4$ ; the minimum internally generated bit clock frequency is  $F_{osc}/(2 \times 8 \times 256) = F_{osc}/4096$ .

### NOTE

Do not use the combination  $TPSR=1$ ,  $TPM7-TPM0=\$00$ , and  $TFP3-TFP0=\$0$  which causes synchronization problems when using the internal DSP clock as source ( $TCKD=1$  or  $THCKD=1$ ).

### 8.3.1.3 TCCR Tx Frame Rate Divider Control (TDC4–TDC0) - Bits 13–9

The TDC4–TDC0 bits control the divide ratio for the programmable frame rate dividers used to generate the transmitter frame clocks.

In network mode, this ratio may be interpreted as the number of words per frame minus one. The divide ratio may range from 2 to 32 ( $TDC[4:0]=00001$  to  $11111$ ) for network mode. A divide ratio of one ( $TDC[4:0]=00000$ ) in network mode is a special case (on-demand mode).

In normal mode, this ratio determines the word transfer rate. The divide ratio may range from 1 to 32 ( $TDC[4:0]=00000$  to  $11111$ ) for normal mode. In normal mode, a divide ratio of 1 ( $TDC[4:0]=00000$ ) provides continuous periodic data word transfers. A bit-length frame sync ( $TFSL=1$ ) must be used in this case.

The ESAI frame sync generator functional diagram is shown in Figure 8-4.

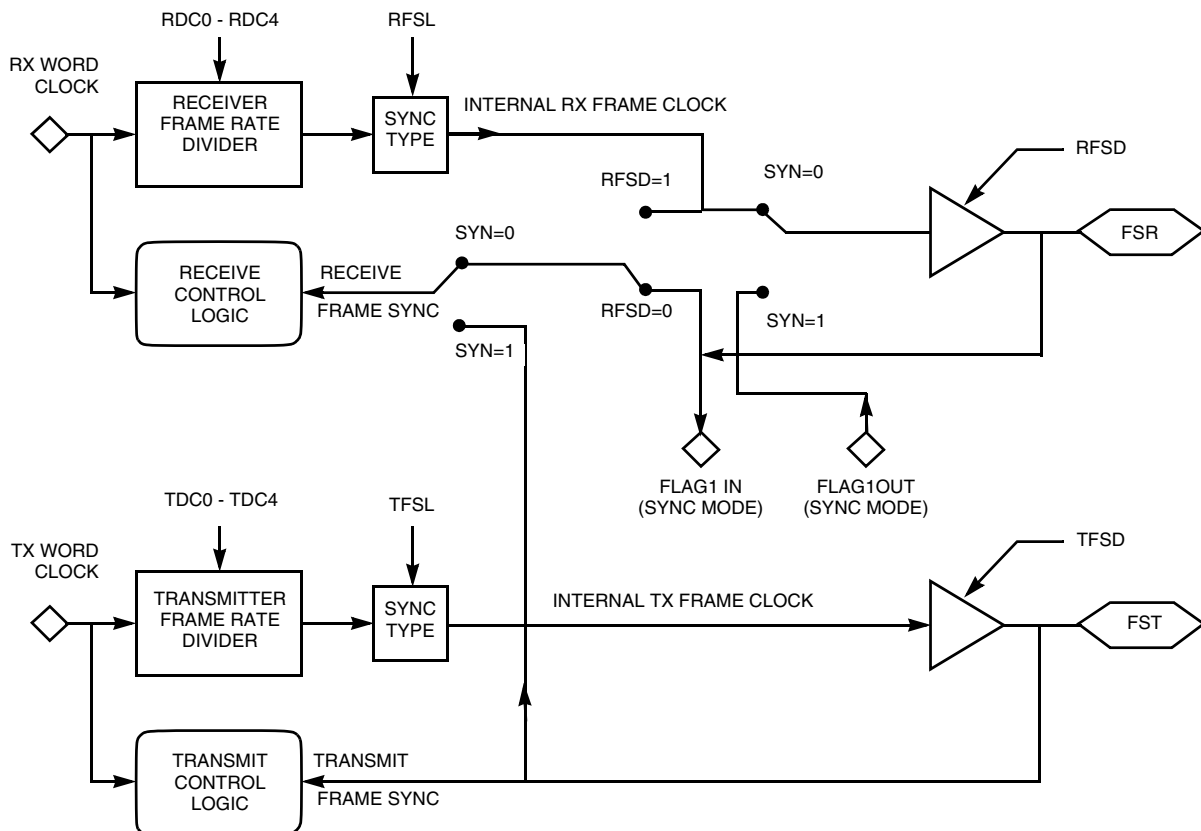


Figure 8-4 ESAI Frame Sync Generator Functional Block Diagram

### 8.3.1.4 TCCR Tx High Frequency Clock Divider (TFP3-TFP0) - Bits 17–14

The TFP3–TFP0 bits control the divide ratio of the transmitter high frequency clock to the transmitter serial bit clock when the source of the high frequency clock and the bit clock is the internal DSP clock. When the HCKT input is being driven from an external high frequency clock, the TFP3-TFP0 bits specify an additional division ratio in the clock divider chain. See [Table 8-3](#) for the specification of the divide ratio. The ESAI high frequency clock generator functional diagram is shown in [Figure 8-3](#).

**Table 8-3 Transmitter High Frequency Clock Divider**

TFP3-TFP0	Divide Ratio
\$0	1
\$1	2
\$2	3
\$3	4
...	...
\$F	16

### 8.3.1.5 TCCR Transmit Clock Polarity (TCKP) - Bit 18

The Transmitter Clock Polarity (TCKP) bit controls on which bit clock edge data and frame sync are clocked out and latched in. If TCKP is cleared the data and the frame sync are clocked out on the rising edge of the transmit bit clock and latched in on the falling edge of the transmit bit clock. If TCKP is set the falling edge of the transmit clock is used to clock the data out and frame sync and the rising edge of the transmit clock is used to latch the data and frame sync in.

### 8.3.1.6 TCCR Transmit Frame Sync Polarity (TFSP) - Bit 19

The Transmitter Frame Sync Polarity (TFSP) bit determines the polarity of the transmit frame sync signal. When TFSP is cleared, the frame sync signal polarity is positive, i.e., the frame start is indicated by a high level on the frame sync pin. When TFSP is set, the frame sync signal polarity is negative, i.e., the frame start is indicated by a low level on the frame sync pin.

### 8.3.1.7 TCCR Transmit High Frequency Clock Polarity (THCKP) - Bit 20

The Transmitter High Frequency Clock Polarity (THCKP) bit controls on which bit clock edge data and frame sync are clocked out and latched in. If THCKP is cleared the data and the frame sync are clocked out on the rising edge of the transmit high frequency bit clock and latched in on the falling edge of the transmit bit clock. If THCKP is set the falling edge of the transmit clock is used to clock the data out and frame sync and the rising edge of the transmit clock is used to latch the data and frame sync in.

### 8.3.1.8 TCCR Transmit Clock Source Direction (TCKD) - Bit 21

The Transmitter Clock Source Direction (TCKD) bit selects the source of the clock signal used to clock the transmit shift registers in the asynchronous mode (SYN=0) and the transmit shift registers and the receive shift registers in the synchronous mode (SYN=1). When TCKD is set, the internal clock source

becomes the bit clock for the transmit shift registers and word length divider and is the output on the SCKT pin. When TCKD is cleared, the clock source is external; the internal clock generator is disconnected from the SCKT pin, and an external clock source may drive this pin. See [Table 8-2](#).

### 8.3.1.9 TCCR Transmit Frame Sync Signal Direction (TFSD) - Bit 22

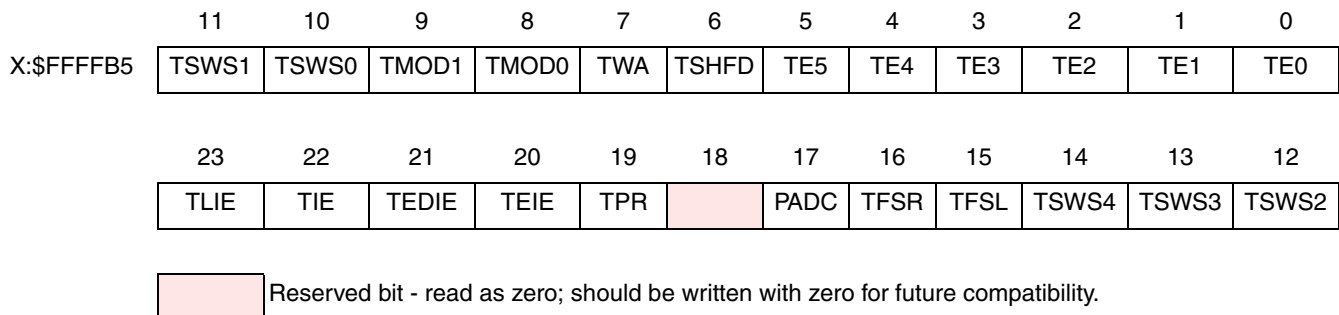
TFSD controls the direction of the FST pin. When TFSD is cleared, FST is an input; when TFSD is set, FST is an output. See [Table 8-2](#).

### 8.3.1.10 TCCR Transmit High Frequency Clock Direction (THCKD) - Bit 23

THCKD controls the direction of the HCKT pin. When THCKD is cleared, HCKT is an input; when THCKD is set, HCKT is an output. See [Table 8-2](#).

## 8.3.2 ESAI Transmit Control Register (TCR)

The read/write Transmit Control Register (TCR) controls the ESAI transmitter section. Interrupt enable bits for the transmitter section are provided in this control register. Operating modes are also selected in this register. See [Figure 8-5](#).



**Figure 8-5 TCR Register**

Hardware and software reset clear all the bits in the TCR register.

The TCR bits are described in the following paragraphs.

### 8.3.2.1 TCR ESAI Transmit 0 Enable (TE0) - Bit 0

TE0 enables the transfer of data from TX0 to the transmit shift register #0. When TE0 is set and a frame sync is detected, the transmit #0 portion of the ESAI is enabled for that frame. When TE0 is cleared, the transmitter #0 is disabled after completing transmission of data currently in the ESAI transmit shift register. The SDO0 output is tri-stated, and any data present in TX0 is not transmitted, i.e., data can be written to TX0 with TE0 cleared, but data is not transferred to the transmit shift register #0.

The normal mode transmit enable sequence is to write data to one or more transmit data registers before setting TEx. The normal transmit disable sequence is to clear TEx, TIE and TEIE after TDE equals one.

In the network mode, the operation of clearing TE0 and setting it again disables the transmitter #0 after completing transmission of the current data word until the beginning of the next frame. During that time



period, the SDO0 pin remains in the high-impedance state. The on-demand mode transmit enable sequence can be the same as the normal mode, or TE0 can be left enabled.

### 8.3.2.2 TCR ESAI Transmit 1 Enable (TE1) - Bit 1

TE1 enables the transfer of data from TX1 to the transmit shift register #1. When TE1 is set and a frame sync is detected, the transmit #1 portion of the ESAI is enabled for that frame. When TE1 is cleared, the transmitter #1 is disabled after completing transmission of data currently in the ESAI transmit shift register. The SDO1 output is tri-stated, and any data present in TX1 is not transmitted, i.e., data can be written to TX1 with TE1 cleared, but data is not transferred to the transmit shift register #1.

The normal mode transmit enable sequence is to write data to one or more transmit data registers before setting TEx. The normal transmit disable sequence is to clear TEx, TIE and TEIE after TDE equals one.

In the network mode, the operation of clearing TE1 and setting it again disables the transmitter #1 after completing transmission of the current data word until the beginning of the next frame. During that time period, the SDO1 pin remains in the high-impedance state. The on-demand mode transmit enable sequence can be the same as the normal mode, or TE1 can be left enabled.

### 8.3.2.3 TCR ESAI Transmit 2 Enable (TE2) - Bit 2

TE2 enables the transfer of data from TX2 to the transmit shift register #2. When TE2 is set and a frame sync is detected, the transmit #2 portion of the ESAI is enabled for that frame. When TE2 is cleared, the transmitter #2 is disabled after completing transmission of data currently in the ESAI transmit shift register. Data can be written to TX2 when TE2 is cleared but the data is not transferred to the transmit shift register #2.

The SDO2/SDI3 pin is the data input pin for RX3 if TE2 is cleared and RE3 in the RCR register is set. If both RE3 and TE2 are cleared, the transmitter and receiver are disabled, and the pin is tri-stated. Both RE3 and TE2 should not be set at the same time.

The normal mode transmit enable sequence is to write data to one or more transmit data registers before setting TEx. The normal transmit disable sequence is to clear TEx, TIE and TEIE after TDE equals one.

In the network mode, the operation of clearing TE2 and setting it again disables the transmitter #2 after completing transmission of the current data word until the beginning of the next frame. During that time period, the SDO2/SDI3 pin remains in the high-impedance state. The on-demand mode transmit enable sequence can be the same as the normal mode, or TE2 can be left enabled.

### 8.3.2.4 TCR ESAI Transmit 3 Enable (TE3) - Bit 3

TE3 enables the transfer of data from TX3 to the transmit shift register #3. When TE3 is set and a frame sync is detected, the transmit #3 portion of the ESAI is enabled for that frame. When TE3 is cleared, the transmitter #3 is disabled after completing transmission of data currently in the ESAI transmit shift register. Data can be written to TX3 when TE3 is cleared but the data is not transferred to the transmit shift register #3.

The SDO3/SDI2 pin is the data input pin for RX2 if TE3 is cleared and RE2 in the RCR register is set. If both RE2 and TE3 are cleared, the transmitter and receiver are disabled, and the pin is tri-stated. Both RE2 and TE3 should not be set at the same time.

The normal mode transmit enable sequence is to write data to one or more transmit data registers before setting TEx. The normal transmit disable sequence is to clear TEx, TIE and TEIE after TDE equals one.

In the network mode, the operation of clearing TE3 and setting it again disables the transmitter #3 after completing transmission of the current data word until the beginning of the next frame. During that time period, the SDO3/SDI2 pin remains in the high-impedance state. The on-demand mode transmit enable sequence can be the same as the normal mode, or TE3 can be left enabled.

### 8.3.2.5 TCR ESAI Transmit 4 Enable (TE4) - Bit 4

TE4 enables the transfer of data from TX4 to the transmit shift register #4. When TE4 is set and a frame sync is detected, the transmit #4 portion of the ESAI is enabled for that frame. When TE4 is cleared, the transmitter #4 is disabled after completing transmission of data currently in the ESAI transmit shift register. Data can be written to TX4 when TE4 is cleared but the data is not transferred to the transmit shift register #4.

The SDO4/SDI1 pin is the data input pin for RX1 if TE4 is cleared and RE1 in the RCR register is set. If both RE1 and TE4 are cleared, the transmitter and receiver are disabled, and the pin is tri-stated. Both RE1 and TE4 should not be set at the same time.

The normal mode transmit enable sequence is to write data to one or more transmit data registers before setting TEx. The normal transmit disable sequence is to clear TEx, TIE and TEIE after TDE equals one.

In the network mode, the operation of clearing TE4 and setting it again disables the transmitter #4 after completing transmission of the current data word until the beginning of the next frame. During that time period, the SDO4/SDI1 pin remains in the high-impedance state. The on-demand mode transmit enable sequence can be the same as the normal mode, or TE4 can be left enabled.

### 8.3.2.6 TCR ESAI Transmit 5 Enable (TE5) - Bit 5

TE5 enables the transfer of data from TX5 to the transmit shift register #5. When TE5 is set and a frame sync is detected, the transmit #5 portion of the ESAI is enabled for that frame. When TE5 is cleared, the transmitter #5 is disabled after completing transmission of data currently in the ESAI transmit shift register. Data can be written to TX5 when TE5 is cleared but the data is not transferred to the transmit shift register #5.

The SDO5/SDI0 pin is the data input pin for RX0 if TE5 is cleared and RE0 in the RCR register is set. If both RE0 and TE5 are cleared, the transmitter and receiver are disabled, and the pin is tri-stated. Both RE0 and TE5 should not be set at the same time.

The normal mode transmit enable sequence is to write data to one or more transmit data registers before setting TEx. The normal transmit disable sequence is to clear TEx, TIE and TEIE after TDE equals one.

In the network mode, the operation of clearing TE5 and setting it again disables the transmitter #5 after completing transmission of the current data word until the beginning of the next frame. During that time

period, the SDO5/SDI0 pin remains in the high-impedance state. The on-demand mode transmit enable sequence can be the same as the normal mode, or TE5 can be left enabled.

### 8.3.2.7 TCR Transmit Shift Direction (TSHFD) - Bit 6

The TSHFD bit causes the transmit shift registers to shift data out MSB first when TSHFD equals zero or LSB first when TSHFD equals one (see [Figure 8-13](#) and [Figure 8-14](#)).

### 8.3.2.8 TCR Transmit Word Alignment Control (TWA) - Bit 7

The Transmitter Word Alignment Control (TWA) bit defines the alignment of the data word in relation to the slot. This is relevant for the cases where the word length is shorter than the slot length. If TWA is cleared, the data word is left-aligned in the slot frame during transmission. If TWA is set, the data word is right-aligned in the slot frame during transmission.

Since the data word is shorter than the slot length, the data word is extended until achieving the slot length, according to the following rule:

1. If the data word is left-aligned (TWA=0), and zero padding is disabled (PADC=0), the last data bit is repeated after the data word has been transmitted. If zero padding is enabled (PADC=1), zeroes are transmitted after the data word has been transmitted.
2. If the data word is right-aligned (TWA=1), and zero padding is disabled (PADC=0), the first data bit is repeated before the transmission of the data word. If zero padding is enabled (PADC=1), zeroes are transmitted before the transmission of the data word.

### 8.3.2.9 TCR Transmit Network Mode Control (TMOD1-TMOD0) - Bits 9-8

The TMOD1 and TMOD0 bits are used to define the network mode of ESAI transmitters according to [Table 8-4](#). In the normal mode, the frame rate divider determines the word transfer rate – one word is transferred per frame sync during the frame sync time slot, as shown in [Figure 8-6](#). In network mode, it is possible to transfer a word for every time slot, as shown in [Figure 8-6](#). For more details, see [Section 8.4](#), "Operating Modes".

In order to comply with AC-97 specifications, TSW54-TSW50 should be set to 00011 (20-bit slot, 20-bit word length), TFSL and TFSR should be cleared, and TDC4-TDC0 should be set to \$0C (13 words in frame). If TMOD[1:0]=\$11 and the above recommendations are followed, the first slot and word will be 16 bits long, and the next 12 slots and words will be 20 bits long, as required by the AC97 protocol.

**Table 8-4 Transmit Network Mode Selection**

TMOD1	TMOD0	TDC4-TDC0	Transmitter Network Mode
0	0	\$0-\$1F	Normal Mode
0	1	\$0	On-Demand Mode
0	1	\$1-\$1F	Network Mode
1	0	X	Reserved
1	1	\$0C	AC97

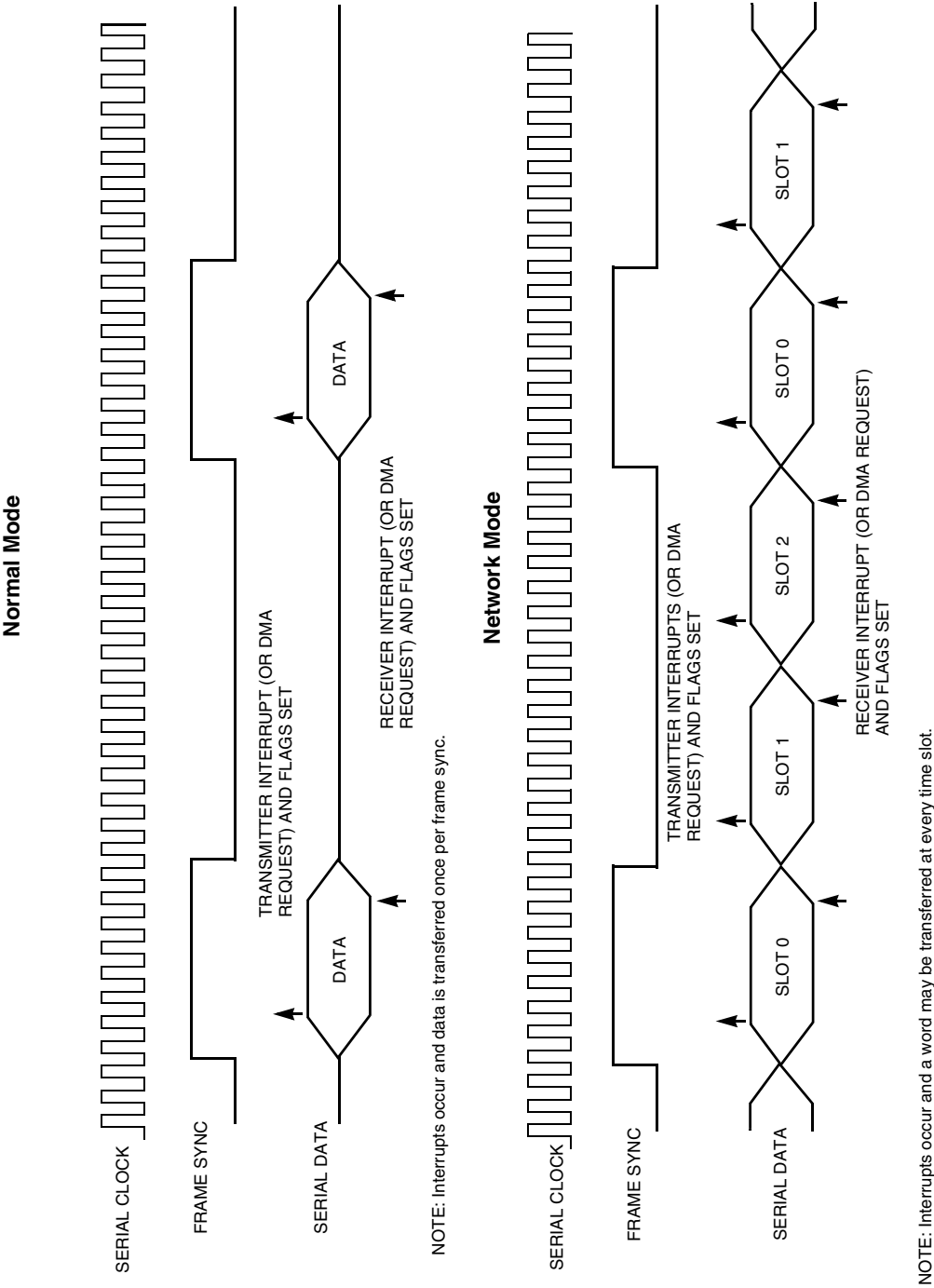


Figure 8-6 Normal and Network Operation

### 8.3.2.10 TCR Tx Slot and Word Length Select (TSWS4-TSWS0) - Bits 14-10

The TSWS4-TSWS0 bits are used to select the length of the slot and the length of the data words being transferred via the ESAI. The word length must be equal to or shorter than the slot length. The possible combinations are shown in [Table 8-5](#). See also the ESAI data path programming model in [Figure 8-13](#) and [Figure 8-14](#).

**Table 8-5 ESAI Transmit Slot and Word Length Selection**

TSWS4	TSWS3	TSWS2	TSWS1	TSWS0	SLOT LENGTH	WORD LENGTH
0	0	0	0	0	8	8
0	0	1	0	0	12	8
0	0	0	0	1		12
0	1	0	0	0	16	8
0	0	1	0	1		12
0	0	0	1	0		16
0	1	1	0	0	20	8
0	1	0	0	1		12
0	0	1	1	0		16
0	0	0	1	1		20
1	0	0	0	0	24	8
0	1	1	0	1		12
0	1	0	1	0		16
0	0	1	1	1		20
1	1	1	1	0		24
1	1	0	0	0	32	8
1	0	1	0	1		12
1	0	0	1	0		16
0	1	1	1	1		20
1	1	1	1	1		24

Table 8-5 ESAI Transmit Slot and Word Length Selection (continued)

TSWS4	TSWS3	TSWS2	TSWS1	TSWS0	SLOT LENGTH	WORD LENGTH
0	1	0	1	1	Reserved	
0	1	1	1	0		
1	0	0	0	1		
1	0	0	1	1		
1	0	1	0	0		
1	0	1	1	0		
1	0	1	1	1		
1	1	0	0	1		
1	1	0	1	0		
1	1	0	1	1		
1	1	1	0	0		
1	1	1	0	1		

### 8.3.2.11 TCR Transmit Frame Sync Length (TFSL) - Bit 15

The TFSL bit selects the length of frame sync to be generated or recognized. If TFSL is cleared, a word-length frame sync is selected. If TFSL is set, a 1-bit clock period frame sync is selected. See [Figure 8-7](#) for examples of frame length selection.

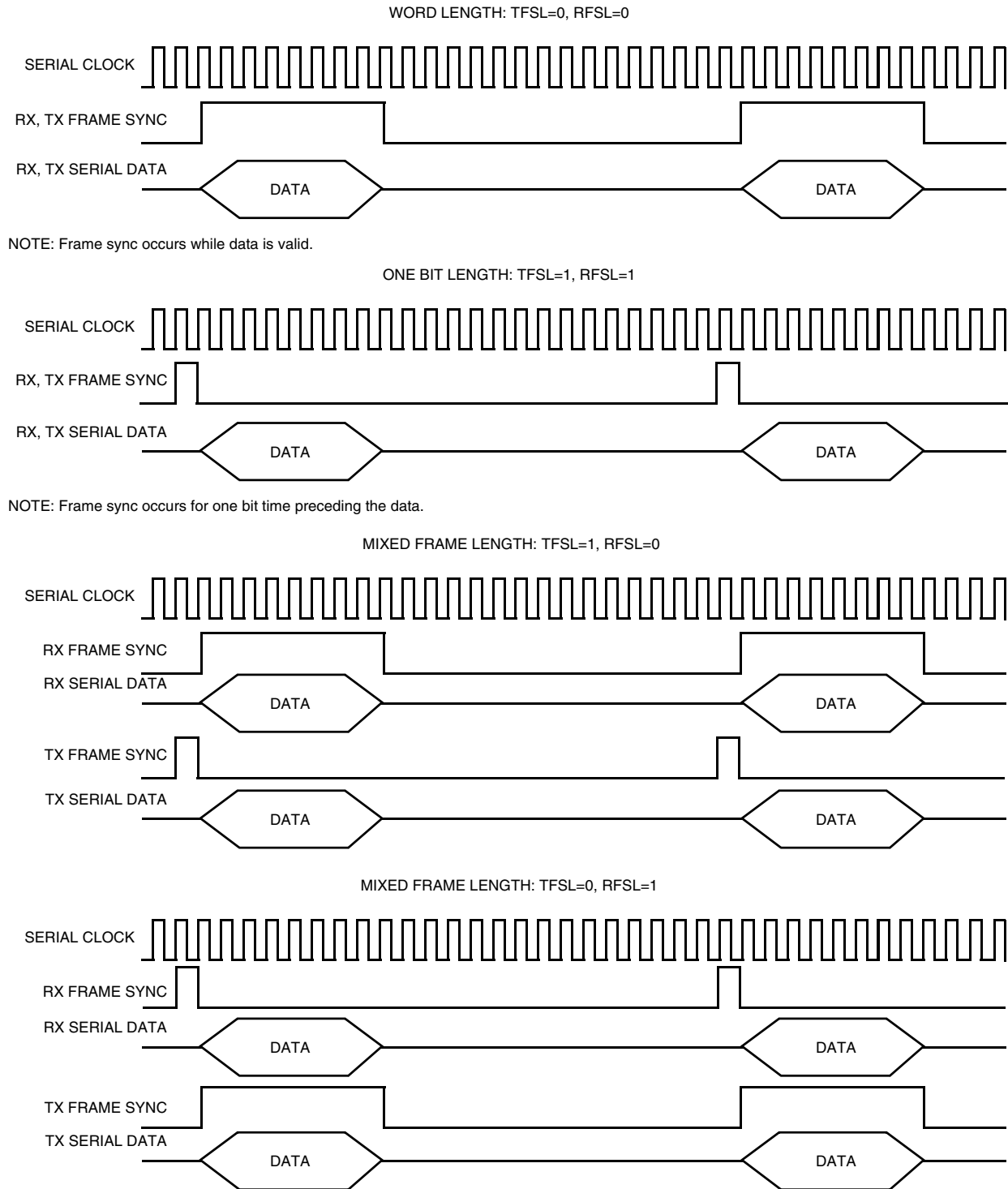


Figure 8-7 Frame Length Selection

### 8.3.2.12 TCR Transmit Frame Sync Relative Timing (TFSR) - Bit 16

TFSR determines the relative timing of the transmit frame sync signal as referred to the serial data lines, for a word length frame sync only (TFSL=0). When TFSR is cleared the word length frame sync occurs together with the first bit of the data word of the first slot. When TFSR is set the word length frame sync starts one serial clock cycle earlier, i.e., together with the last bit of the previous data word.

### 8.3.2.13 TCR Transmit Zero Padding Control (PADC) - Bit 17

When PADC is cleared, zero padding is disabled. When PADC is set, zero padding is enabled. PADC, in conjunction with the TWA control bit, determines the way that padding is done for operating modes where the word length is less than the slot length. See the TWA bit description in [Section 8.3.2.8, "TCR Transmit Word Alignment Control \(TWA\) - Bit 7"](#) for more details.

Since the data word is shorter than the slot length, the data word is extended until achieving the slot length, according to the following rule:

1. If the data word is left-aligned (TWA=0), and zero padding is disabled (PADC=0), the last data bit is repeated after the data word has been transmitted. If zero padding is enabled (PADC=1), zeroes are transmitted after the data word has been transmitted.
2. If the data word is right-aligned (TWA=1), and zero padding is disabled (PADC=0), the first data bit is repeated before the transmission of the data word. If zero padding is enabled (PADC=1), zeroes are transmitted before the transmission of the data word.

### 8.3.2.14 TCR Reserved Bit - Bits 18

This bit is reserved. It reads as zero, and it should be written with zero for future compatibility.

### 8.3.2.15 TCR Transmit Section Personal Reset (TPR) - Bit 19

The TPR control bit is used to put the transmitter section of the ESAI in the personal reset state. The receiver section is not affected. When TPR is cleared, the transmitter section may operate normally. When TPR is set, the transmitter section enters the personal reset state immediately. When in the personal reset state, the status bits are reset to the same state as after hardware reset. The control bits are not affected by the personal reset state. The transmitter data pins are tri-stated while in the personal reset state; if a stable logic level is desired, the transmitter data pins should be defined as GPIO outputs, or external pull-up or pull-down resistors should be used. The transmitter clock outputs drive zeroes while in the personal reset state. Note that to leave the personal reset state by clearing TPR, the procedure described in [Section 8.6, "ESAI Initialization Examples"](#) should be followed.

### 8.3.2.16 TCR Transmit Exception Interrupt Enable (TEIE) - Bit 20

When TEIE is set, the DSP is interrupted when both TDE and TUE in the SAISR status register are set. When TEIE is cleared, this interrupt is disabled. Reading the SAISR status register followed by writing to all the data registers of the enabled transmitters clears TUE, thus clearing the pending interrupt.



### 8.3.2.17 TCR Transmit Even Slot Data Interrupt Enable (TEDIE) - Bit 21

The TEDIE control bit is used to enable the transmit even slot data interrupts. If TEDIE is set, the transmit even slot data interrupts are enabled. If TEDIE is cleared, the transmit even slot data interrupts are disabled. A transmit even slot data interrupt request is generated if TEDIE is set and the TEDE status flag in the SAISR status register is set. Even time slots are all even-numbered time slots (0, 2, 4, etc.) when operating in network mode. The zero time slot in the frame is marked by the frame sync signal and is considered to be even. Writing data to all the data registers of the enabled transmitters or to TSR clears the TEDE flag, thus servicing the interrupt.

Transmit interrupts with exception have higher priority than transmit even slot data interrupts, therefore if exception occurs (TUE is set) and TEIE is set, the ESAI requests an ESAI transmit data with exception interrupt from the interrupt controller.

### 8.3.2.18 TCR Transmit Interrupt Enable (TIE) - Bit 22

The DSP is interrupted when TIE and the TDE flag in the SAISR status register are set. When TIE is cleared, this interrupt is disabled. Writing data to all the data registers of the enabled transmitters or to TSR clears TDE, thus clearing the interrupt.

Transmit interrupts with exception have higher priority than normal transmit data interrupts, therefore if exception occurs (TUE is set) and TEIE is set, the ESAI requests an ESAI transmit data with exception interrupt from the interrupt controller.

### 8.3.2.19 TCR Transmit Last Slot Interrupt Enable (TLIE) - Bit 23

TLIE enables an interrupt at the beginning of last slot of a frame in network mode. When TLIE is set the DSP is interrupted at the start of the last slot in a frame in network mode regardless of the transmit mask register setting. When TLIE is cleared the transmit last slot interrupt is disabled. TLIE is disabled when TDC[4:0]=\$00000 (on-demand mode). The use of the transmit last slot interrupt is described in [Section 8.4.3, "ESAI Interrupt Requests"](#).

## 8.3.3 ESAI Receive Clock Control Register (RCCR)

The read/write Receive Clock Control Register (RCCR) controls the ESAI receiver clock generator bit and frame sync rates, word length and number of words per frame for the serial data. The RCCR control bits are described in the following paragraphs (see [Figure 8-8](#)).

	11	10	9	8	7	6	5	4	3	2	1	0
X:\$FFFFB8	RDC2	RDC1	RDC0	RPSR	RPM7	RPM6	RPM5	RPM4	RPM3	RPM2	RPM1	RPM0
	23	22	21	20	19	18	17	16	15	14	13	12
	RHCKD	RFSD	RCKD	RHCKP	RFSP	RCKP	RFP3	RFP2	RFP1	RFP0	RDC4	RDC3

**Figure 8-8 RCCR Register**

Hardware and software reset clear all the bits of the RCCR register.

### 8.3.3.1 RCCR Receiver Prescale Modulus Select (RPM7–RPM0) - Bits 7–0

The RPM7–RPM0 bits specify the divide ratio of the prescale divider in the ESAI receiver clock generator. A divide ratio from 1 to 256 ( $RPM[7:0] = \$00$  to  $\$FF$ ) may be selected. The bit clock output is available at the receiver serial bit clock (SCKR) pin of the DSP. The bit clock output is also available internally for use as the bit clock to shift the receive shift registers. The ESAI receive clock generator functional diagram is shown in [Figure 8-3](#).

### 8.3.3.2 RCCR Receiver Prescaler Range (RPSR) - Bit 8

The RPSR controls a fixed divide-by-eight prescaler in series with the variable prescaler. This bit is used to extend the range of the prescaler for those cases where a slower bit clock is desired. When RPSR is set, the fixed prescaler is bypassed. When RPSR is cleared, the fixed divide-by-eight prescaler is operational (see [Figure 8-3](#)). The maximum internally generated bit clock frequency is  $F_{osc}/4$ , the minimum internally generated bit clock frequency is  $F_{osc}/(2 \times 8 \times 256) = F_{osc}/4096$ .

#### NOTE

Do not use the combination  $RPSR=1$  and  $RPM7-RPM0=\$00$ , which causes synchronization problems when using the internal DSP clock as source ( $RHCKD=1$  or  $RCKD=1$ ).

### 8.3.3.3 RCCR Rx Frame Rate Divider Control (RDC4–RDC0) - Bits 13–9

The RDC4–RDC0 bits control the divide ratio for the programmable frame rate dividers used to generate the receiver frame clocks.

In network mode, this ratio may be interpreted as the number of words per frame minus one. The divide ratio may range from 2 to 32 ( $RDC[4:0] = 00001$  to  $11111$ ) for network mode. A divide ratio of one ( $RDC[4:0] = 00000$ ) in network mode is a special case (on-demand mode).

In normal mode, this ratio determines the word transfer rate. The divide ratio may range from 1 to 32 ( $RDC[4:0] = 00000$  to  $11111$ ) for normal mode. In normal mode, a divide ratio of one ( $RDC[4:0] = 00000$ ) provides continuous periodic data word transfers. A bit-length frame sync ( $RFSL=1$ ) must be used in this case.

The ESAI frame sync generator functional diagram is shown in [Figure 8-4](#).

### 8.3.3.4 RCCR Rx High Frequency Clock Divider (RFP3–RFP0) - Bits 17–14

The RFP3–RFP0 bits control the divide ratio of the receiver high frequency clock to the receiver serial bit clock when the source of the receiver high frequency clock and the bit clock is the internal DSP clock. When the HCKR input is being driven from an external high frequency clock, the RFP3–RFP0 bits specify an additional division ration in the clock divider chain. See [Table 8-6](#) for the specification of the divide ratio. The ESAI high frequency generator functional diagram is shown in [Figure 8-3](#).

**Table 8-6 Receiver High Frequency Clock Divider**

RFP3-RFP0	Divide Ratio
\$0	1
\$1	2
\$2	3
\$3	4
...	...
\$F	16

### 8.3.3.5 RCCR Receiver Clock Polarity (RCKP) - Bit 18

The Receiver Clock Polarity (RCKP) bit controls on which bit clock edge data and frame sync are clocked out and latched in. If RCKP is cleared the data and the frame sync are clocked out on the rising edge of the receive bit clock and the frame sync is latched in on the falling edge of the receive bit clock. If RCKP is set the falling edge of the receive clock is used to clock the data and frame sync out and the rising edge of the receive clock is used to latch the frame sync in.

### 8.3.3.6 RCCR Receiver Frame Sync Polarity (RFSP) - Bit 19

The Receiver Frame Sync Polarity (RFSP) determines the polarity of the receive frame sync signal. When RFSP is cleared the frame sync signal polarity is positive, i.e., the frame start is indicated by a high level on the frame sync pin. When RFSP is set the frame sync signal polarity is negative, i.e., the frame start is indicated by a low level on the frame sync pin.

### 8.3.3.7 RCCR Receiver High Frequency Clock Polarity (RHCKP) - Bit 20

The Receiver High Frequency Clock Polarity (RHCKP) bit controls on which bit clock edge data and frame sync are clocked out and latched in. If RHCKP is cleared the data and the frame sync are clocked out on the rising edge of the receive high frequency bit clock and the frame sync is latched in on the falling edge of the receive bit clock. If RHCKP is set the falling edge of the receive clock is used to clock the data and frame sync out and the rising edge of the receive clock is used to latch the frame sync in.

### 8.3.3.8 RCCR Receiver Clock Source Direction (RCKD) - Bit 21

The Receiver Clock Source Direction (RCKD) bit selects the source of the clock signal used to clock the receive shift register in the asynchronous mode (SYN=0) and the IF0/OF0 flag direction in the synchronous mode (SYN=1).

In the asynchronous mode, when RCKD is set, the internal clock source becomes the bit clock for the receive shift registers and word length divider and is the output on the SCKR pin. In the asynchronous mode when RCKD is cleared, the clock source is external; the internal clock generator is disconnected from the SCKR pin, and an external clock source may drive this pin.

In the synchronous mode when RCKD is set, the SCKR pin becomes the OF0 output flag. If RCKD is cleared, the SCKR pin becomes the IF0 input flag. See [Table 8-1](#) and [Table 8-7](#).

**Table 8-7 SCKR Pin Definition Table**

Control Bits		SCKR PIN
SYN	RCKD	
0	0	SCKR input
0	1	SCKR output
1	0	IF0
1	1	OF0

### 8.3.3.9 RCCR Receiver Frame Sync Signal Direction (RFSD) - Bit 22

The Receiver Frame Sync Signal Direction (RFSD) bit selects the source of the receiver frame sync signal when in the asynchronous mode (SYN=0) and the IF1/OF1/Transmitter Buffer Enable flag direction in the synchronous mode (SYN=1).

In the asynchronous mode, when RFSD is set, the internal clock generator becomes the source of the receiver frame sync and is the output on the FSR pin. In the asynchronous mode, when RFSD is cleared, the receiver frame sync source is external; the internal clock generator is disconnected from the FSR pin, and an external clock source may drive this pin.

In the synchronous mode when RFSD is set, the FSR pin becomes the OF1 output flag or the Transmitter Buffer Enable, according to the TEBE control bit. If RFSD is cleared, the FSR pin becomes the IF1 input flag. See [Table 8-1](#) and [Table 8-8](#).

**Table 8-8 FSR Pin Definition Table**

Control Bits			FSR Pin
SYN	TEBE	RFSD	
0	X	0	FSR input
0	X	1	FSR output
1	0	0	IF1
1	0	1	OF1
1	1	0	Reserved
1	1	1	Transmitter Buffer Enable

### 8.3.3.10 RCCR Receiver High Frequency Clock Direction (RHCKD) - Bit 23

The Receiver High Frequency Clock Direction (RHCKD) bit selects the source of the receiver high frequency clock when in the asynchronous mode (SYN=0) and the IF2/OF2 flag direction in the synchronous mode (SYN=1).

In the asynchronous mode, when RHCKD is set, the internal clock generator becomes the source of the receiver high frequency clock and is the output on the HCKR pin. In the asynchronous mode, when RHCKD is cleared, the receiver high frequency clock source is external; the internal clock generator is disconnected from the HCKR pin, and an external clock source may drive this pin.

When RHCKD is cleared, HCKR is an input; when RHCKD is set, HCKR is an output.

In the synchronous mode when RHCKD is set, the HCKR pin becomes the OF2 output flag. If RHCKD is cleared, the HCKR pin becomes the IF2 input flag. See [Table 8-1](#) and [Table 8-9](#).

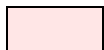
**Table 8-9 HCKR Pin Definition Table**

Control Bits		HCKR PIN
SYN	RHCKD	
0	0	HCKR input
0	1	HCKR output
1	0	IF2
1	1	OF2

### 8.3.4 ESAI Receive Control Register (RCR)

The read/write Receive Control Register (RCR) controls the ESAI receiver section. Interrupt enable bits for the receivers are provided in this control register. The receivers are enabled in this register (0,1,2 or 3 receivers can be enabled) if the input data pin is not used by a transmitter. Operating modes are also selected in this register.

	11	10	9	8	7	6	5	4	3	2	1	0
X:\$FFFFB7	RSWS1	RSWS0	RMOD1	RMOD0	RWA	RSHFD			RE3	RE2	RE1	RE0
	23	22	21	20	19	18	17	16	15	14	13	12
	RLIE	RIE	REDIE	REIE	RPR			RFSR	RFSL	RSWS4	RSWS3	RSWS2

 Reserved bit - read as zero; should be written with zero for future compatibility.

**Figure 8-9 RCR Register**

Hardware and software reset clear all the bits in the RCR register.

The ESAI RCR bits are described in the following paragraphs.

#### 8.3.4.1 RCR ESAI Receiver 0 Enable (RE0) - Bit 0

When RE0 is set and TE5 is cleared, the ESAI receiver 0 is enabled and samples data at the SDO5/SDIO pin. TX5 and RX0 should not be enabled at the same time (RE0=1 and TE5=1). When RE0 is cleared, receiver 0 is disabled by inhibiting data transfer into RX0. If this bit is cleared while receiving a data word, the remainder of the word is shifted in and transferred to the RX0 data register.

If RE0 is set while some of the other receivers are already in operation, the first data word received in RX0 will be invalid and must be discarded.

#### 8.3.4.2 RCR ESAI Receiver 1 Enable (RE1) - Bit 1

When RE1 is set and TE4 is cleared, the ESAI receiver 1 is enabled and samples data at the SDO4/SDI1 pin. TX4 and RX1 should not be enabled at the same time (RE1=1 and TE4=1). When RE1 is cleared, receiver 1 is disabled by inhibiting data transfer into RX1. If this bit is cleared while receiving a data word, the remainder of the word is shifted in and transferred to the RX1 data register.

If RE1 is set while some of the other receivers are already in operation, the first data word received in RX1 will be invalid and must be discarded.

#### 8.3.4.3 RCR ESAI Receiver 2 Enable (RE2) - Bit 2

When RE2 is set and TE3 is cleared, the ESAI receiver 2 is enabled and samples data at the SDO3/SDI2 pin. TX3 and RX2 should not be enabled at the same time (RE2=1 and TE3=1). When RE2 is cleared, receiver 2 is disabled by inhibiting data transfer into RX2. If this bit is cleared while receiving a data word, the remainder of the word is shifted in and transferred to the RX2 data register.

If RE2 is set while some of the other receivers are already in operation, the first data word received in RX2 will be invalid and must be discarded.

#### 8.3.4.4 RCR ESAI Receiver 3 Enable (RE3) - Bit 3

When RE3 is set and TE2 is cleared, the ESAI receiver 3 is enabled and samples data at the SDO2/SDI3 pin. TX2 and RX3 should not be enabled at the same time (RE3=1 and TE2=1). When RE3 is cleared, receiver 3 is disabled by inhibiting data transfer into RX3. If this bit is cleared while receiving a data word, the remainder of the word is shifted in and transferred to the RX3 data register.

If RE3 is set while some of the other receivers are already in operation, the first data word received in RX3 will be invalid and must be discarded.

#### 8.3.4.5 RCR Reserved Bits - Bits 5-4, 18-17

These bits are reserved. They read as zero, and they should be written with zero for future compatibility.

#### 8.3.4.6 RCR Receiver Shift Direction (RSHFD) - Bit 6

The RSHFD bit causes the receiver shift registers to shift data in MSB first when RSHFD is cleared or LSB first when RSHFD is set (see [Figure 8-13](#) and [Figure 8-14](#)).

#### 8.3.4.7 RCR Receiver Word Alignment Control (RWA) - Bit 7

The Receiver Word Alignment Control (RWA) bit defines the alignment of the data word in relation to the slot. This is relevant for the cases where the word length is shorter than the slot length. If RWA is cleared, the data word is assumed to be left-aligned in the slot frame. If RWA is set, the data word is assumed to be right-aligned in the slot frame.

If the data word is shorter than the slot length, the data bits which are not in the data word field are ignored. For data word lengths of less than 24 bits, the data word is right-extended with zeroes before being stored in the receive data registers.

### 8.3.4.8 RCR Receiver Network Mode Control (RMOD1-RMOD0) - Bits 9-8

The RMOD1 and RMOD0 bits are used to define the network mode of the ESAI receivers according to [Table 8-10](#). In the normal mode, the frame rate divider determines the word transfer rate – one word is transferred per frame sync during the frame sync time slot, as shown in [Figure 8-6](#). In network mode, it is possible to transfer a word for every time slot, as shown in [Figure 8-6](#). For more details, see [Section 8.4, "Operating Modes"](#).

In order to comply with AC-97 specifications, RSWS4-RSWS0 should be set to 00011 (20-bit slot, 20-bit word); RFSL and RFSR should be cleared, and RDC4-RDC0 should be set to \$0C (13 words in frame).

**Table 8-10 ESAI Receive Network Mode Selection**

RMOD1	RMOD0	RDC4-RDC0	Receiver Network Mode
0	0	\$0-\$1F	Normal Mode
0	1	\$0	On-Demand Mode
0	1	\$1-\$1F	Network Mode
1	0	X	Reserved
1	1	\$0C	AC97

### 8.3.4.9 RCR Receiver Slot and Word Select (RSWS4-RSWS0) - Bits 14-10

The RSWS4-RSWS0 bits are used to select the length of the slot and the length of the data words being received via the ESAI. The word length must be equal to or shorter than the slot length. The possible combinations are shown in [Table 8-11](#). See also the ESAI data path programming model in [Figure 8-13](#) and [Figure 8-14](#).

**Table 8-11 ESAI Receive Slot and Word Length Selection**

RSWS4	RSWS3	RSWS2	RSWS1	RSWS0	SLOT LENGTH	WORD LENGTH
0	0	0	0	0	8	8
0	0	1	0	0	12	8
0	0	0	0	1		12
0	1	0	0	0	16	8
0	0	1	0	1		12
0	0	0	1	0		16

Table 8-11 ESAI Receive Slot and Word Length Selection (continued)

RSWS4	RSWS3	RSWS2	RSWS1	RSWS0	SLOT LENGTH	WORD LENGTH
0	1	1	0	0	20	8
0	1	0	0	1		12
0	0	1	1	0		16
0	0	0	1	1		20
1	0	0	0	0	24	8
0	1	1	0	1		12
0	1	0	1	0		16
0	0	1	1	1		20
1	1	1	1	0		24
1	1	0	0	0	32	8
1	0	1	0	1		12
1	0	0	1	0		16
0	1	1	1	1		20
1	1	1	1	1		24
0	1	0	1	1	Reserved	
0	1	1	1	0		
1	0	0	0	1		
1	0	0	1	1		
1	0	1	0	0		
1	0	1	1	0		
1	0	1	1	1		
1	1	0	0	1		
1	1	0	1	0		
1	1	0	1	1		
1	1	1	0	0		
1	1	1	0	1		

#### 8.3.4.10 RCR Receiver Frame Sync Length (RFSL) - Bit 15

The RFSL bit selects the length of the receive frame sync to be generated or recognized. If RFSL is cleared, a word-length frame sync is selected. If RFSL is set, a 1-bit clock period frame sync is selected. See [Figure 8-7](#) for examples of frame length selection.



#### 8.3.4.11 RCR Receiver Frame Sync Relative Timing (RFSR) - Bit 16

RFSR determines the relative timing of the receive frame sync signal as referred to the serial data lines, for a word length frame sync only. When RFSR is cleared the word length frame sync occurs together with the first bit of the data word of the first slot. When RFSR is set the word length frame sync starts one serial clock cycle earlier, i.e., together with the last bit of the previous data word.

#### 8.3.4.12 RCR Receiver Section Personal Reset (RPR) - Bit 19

The RPR control bit is used to put the receiver section of the ESAI in the personal reset state. The transmitter section is not affected. When RPR is cleared, the receiver section may operate normally. When RPR is set, the receiver section enters the personal reset state immediately. When in the personal reset state, the status bits are reset to the same state as after hardware reset. The control bits are not affected by the personal reset state. The receiver data pins are disconnected while in the personal reset state. Note that to leave the personal reset state by clearing RPR, the procedure described in [Section 8.6, "ESAI Initialization Examples"](#) should be followed.

#### 8.3.4.13 RCR Receive Exception Interrupt Enable (REIE) - Bit 20

When REIE is set, the DSP is interrupted when both RDF and ROE in the SAISR status register are set. When REIE is cleared, this interrupt is disabled. Reading the SAISR status register followed by reading the enabled receivers data registers clears ROE, thus clearing the pending interrupt.

#### 8.3.4.14 RCR Receive Even Slot Data Interrupt Enable (REDIE) - Bit 21

The REDIE control bit is used to enable the receive even slot data interrupts. If REDIE is set, the receive even slot data interrupts are enabled. If REDIE is cleared, the receive even slot data interrupts are disabled. A receive even slot data interrupt request is generated if REDIE is set and the REDF status flag in the SAISR status register is set. Even time slots are all even-numbered time slots (0, 2, 4, etc.) when operating in network mode. The zero time slot is marked by the frame sync signal and is considered to be even. Reading all the data registers of the enabled receivers clears the REDF flag, thus servicing the interrupt.

Receive interrupts with exception have higher priority than receive even slot data interrupts, therefore if exception occurs (ROE is set) and REIE is set, the ESAI requests an ESAI receive data with exception interrupt from the interrupt controller.

#### 8.3.4.15 RCR Receive Interrupt Enable (RIE) - Bit 22

The DSP is interrupted when RIE and the RDF flag in the SAISR status register are set. When RIE is cleared, this interrupt is disabled. Reading the receive data registers of the enabled receivers clears RDF, thus clearing the interrupt.

Receive interrupts with exception have higher priority than normal receive data interrupts, therefore if exception occurs (ROE is set) and REIE is set, the ESAI requests an ESAI receive data with exception interrupt from the interrupt controller.

### 8.3.4.16 RCR Receive Last Slot Interrupt Enable (RLIE) - Bit 23

RLIE enables an interrupt after the last slot of a frame ended in network mode only. When RLIE is set the DSP is interrupted after the last slot in a frame ended regardless of the receive mask register setting. When RLIE is cleared the receive last slot interrupt is disabled. Hardware and software reset clear RLIE. RLIE is disabled when RDC[4:0]=00000 (on-demand mode). The use of the receive last slot interrupt is described in [Section 8.4.3, "ESAI Interrupt Requests"](#).

## 8.3.5 ESAI Common Control Register (SAICR)

The read/write Common Control Register (SAICR) contains control bits for functions that affect both the receive and transmit sections of the ESAI. See [Figure 8-10](#).

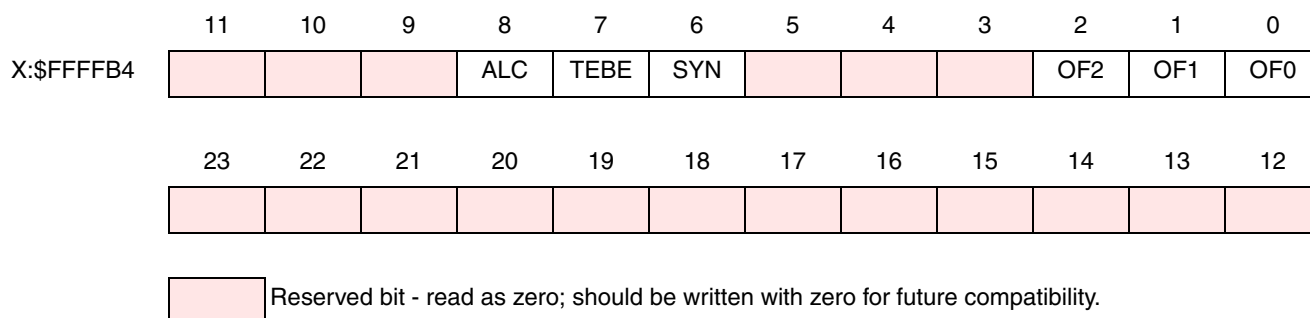


Figure 8-10 SAICR Register

Hardware and software reset clear all the bits in the SAICR register.

### 8.3.5.1 SAICR Serial Output Flag 0 (OF0) - Bit 0

The Serial Output Flag 0 (OF0) is a data bit used to hold data to be send to the OF0 pin. When the ESAI is in the synchronous clock mode (SYN=1), the SCKR pin is configured as the ESAI flag 0. If the receiver serial clock direction bit (RCKD) is set, the SCKR pin is the output flag OF0, and data present in the OF0 bit is written to the OF0 pin at the beginning of the frame in normal mode or at the beginning of the next time slot in network mode.

### 8.3.5.2 SAICR Serial Output Flag 1 (OF1) - Bit 1

The Serial Output Flag 1 (OF1) is a data bit used to hold data to be send to the OF1 pin. When the ESAI is in the synchronous clock mode (SYN=1), the FSR pin is configured as the ESAI flag 1. If the receiver frame sync direction bit (RFSD) is set and the TEBE bit is cleared, the FSR pin is the output flag OF1, and data present in the OF1 bit is written to the OF1 pin at the beginning of the frame in normal mode or at the beginning of the next time slot in network mode.

### 8.3.5.3 SAICR Serial Output Flag 2 (OF2) - Bit 2

The Serial Output Flag 2 (OF2) is a data bit used to hold data to be send to the OF2 pin. When the ESAI is in the synchronous clock mode (SYN=1), the HCKR pin is configured as the ESAI flag 2. If the receiver high frequency clock direction bit (RHCKD) is set, the HCKR pin is the output flag OF2, and data present

in the OF2 bit is written to the OF2 pin at the beginning of the frame in normal mode or at the beginning of the next time slot in network mode.

#### 8.3.5.4 SAICR Reserved Bits - Bits 5-3, 23-9

These bits are reserved. They read as zero, and they should be written with zero for future compatibility.

#### 8.3.5.5 SAICR Synchronous Mode Selection (SYN) - Bit 6

The Synchronous Mode Selection (SYN) bit controls whether the receiver and transmitter sections of the ESAI operate synchronously or asynchronously with respect to each other (see [Figure 8-11](#)). When SYN is cleared, the asynchronous mode is chosen and independent clock and frame sync signals are used for the transmit and receive sections. When SYN is set, the synchronous mode is chosen and the transmit and receive sections use common clock and frame sync signals.

When in the synchronous mode (SYN=1), the transmit and receive sections use the transmitter section clock generator as the source of the clock and frame sync for both sections. Also, the receiver clock pins SCKR, FSR and HCKR now operate as I/O flags. See [Table 8-7](#), [Table 8-8](#), and [Table 8-9](#) for the effects of SYN on the receiver clock pins.

#### 8.3.5.6 SAICR Transmit External Buffer Enable (TEBE) - Bit 7

The Transmitter External Buffer Enable (TEBE) bit controls the function of the FSR pin when in the synchronous mode. If the ESAI is configured for operation in the synchronous mode (SYN=1), and TEBE is set while FSR pin is configured as an output (RFSD=1), the FSR pin functions as the transmitter external buffer enable control to enable the use of an external buffers on the transmitter outputs. If TEBE is cleared, the FSR pin functions as the serial I/O flag 1. See [Table 8-8](#) for a summary of the effects of TEBE on the FSR pin.

#### 8.3.5.7 SAICR Alignment Control (ALC) - Bit 8

The ESAI is designed for 24-bit fractional data, thus shorter data words are left aligned to the MSB (bit 23). Some applications use 16-bit fractional data. In those cases, shorter data words may be left aligned to bit 15. The Alignment Control (ALC) bit supports these applications.

If ALC is set, transmitted and received words are left aligned to bit 15 in the transmit and receive shift registers. If ALC is cleared, transmitted and received word are left aligned to bit 23 in the transmit and receive shift registers.

#### NOTE

While ALC is set, 20-bit and 24-bit words may not be used, and word length control should specify 8-, 12- or 16-bit words; otherwise, results are unpredictable.

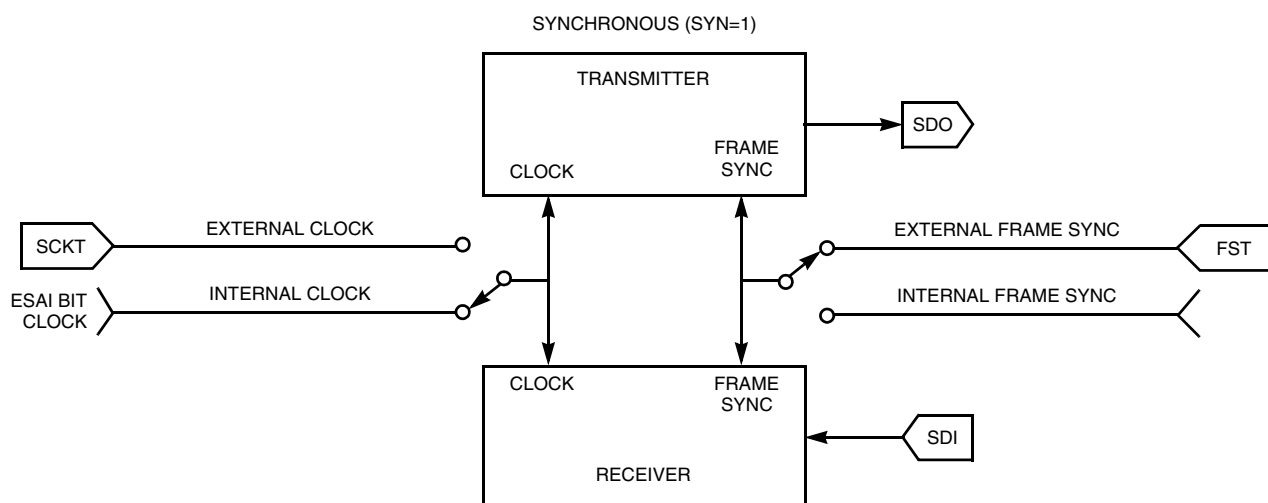
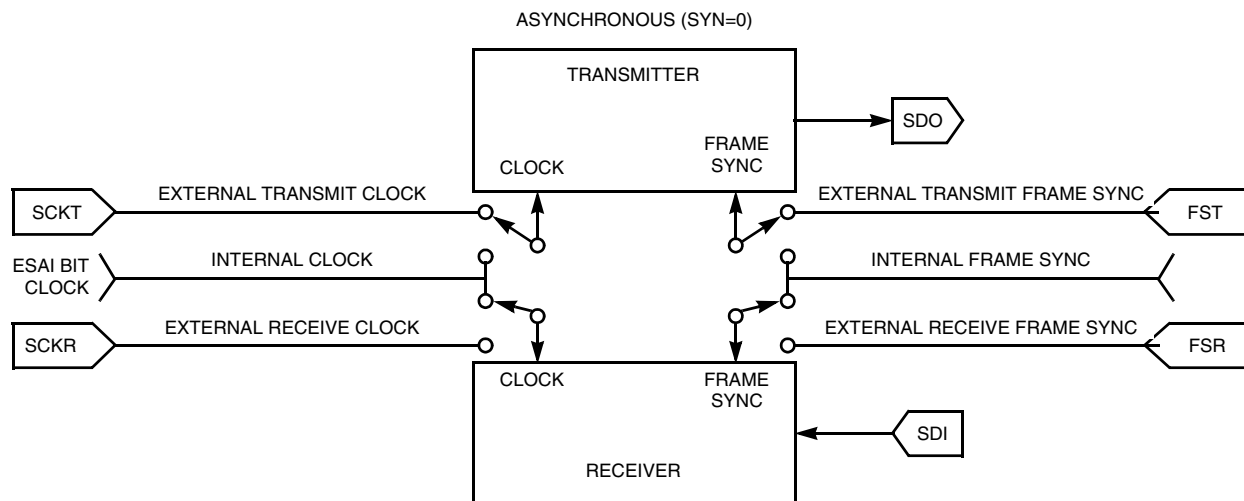


Figure 8-11 SAICR SYN Bit Operation

### 8.3.6 ESAI Status Register (SAISR)

The Status Register (SAISR) is a read-only status register used by the DSP to read the status and serial input flags of the ESAI. See [Figure 8-12](#). The status bits are described in the following paragraphs.

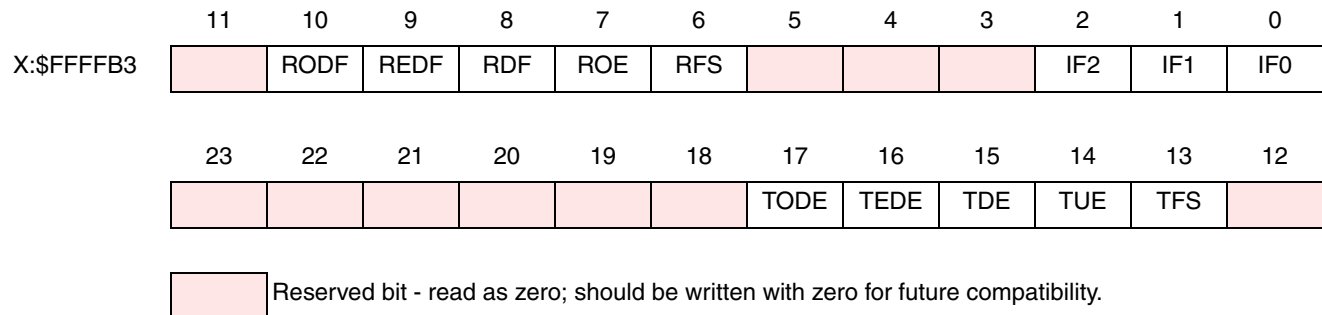


Figure 8-12 SAISR Register

### 8.3.6.1 SAISR Serial Input Flag 0 (IF0) - Bit 0

The IF0 bit is enabled only when the SCKR pin is defined as ESAI in the Port Control Register, SYN=1 and RCKD=0, indicating that SCKR is an input flag and the synchronous mode is selected. Data present on the SCKR pin is latched during reception of the first received data bit after frame sync is detected. The IF0 bit is updated with this data when the receiver shift registers are transferred into the receiver data registers. IF0 reads as a zero when it is not enabled. Hardware, software, ESAI individual and STOP reset clear IF0.

### 8.3.6.2 SAISR Serial Input Flag 1 (IF1) - Bit 1

The IF1 bit is enabled only when the FSR pin is defined as ESAI in the Port Control Register, SYN =1, RFSD=0 and TEBE=0, indicating that FSR is an input flag and the synchronous mode is selected. Data present on the FSR pin is latched during reception of the first received data bit after frame sync is detected. The IF1 bit is updated with this data when the receiver shift registers are transferred into the receiver data registers. IF1 reads as a zero when it is not enabled. Hardware, software, ESAI individual and STOP reset clear IF1.

### 8.3.6.3 SAISR Serial Input Flag 2 (IF2) - Bit 2

The IF2 bit is enabled only when the HCKR pin is defined as ESAI in the Port Control Register, SYN=1 and RHCKD=0, indicating that HCKR is an input flag and the synchronous mode is selected. Data present on the HCKR pin is latched during reception of the first received data bit after frame sync is detected. The IF2 bit is updated with this data when the receive shift registers are transferred into the receiver data registers. IF2 reads as a zero when it is not enabled. Hardware, software, ESAI individual and STOP reset clear IF2.

### 8.3.6.4 SAISR Reserved Bits - Bits 5-3, 12-11, 23-18

These bits are reserved for future use. They read as zero.

### 8.3.6.5 SAISR Receive Frame Sync Flag (RFS) - Bit 6

When set, RFS indicates that a receive frame sync occurred during reception of the words in the receiver data registers. This indicates that the data words are from the first slot in the frame. When RFS is clear and

a word is received, it indicates (only in the network mode) that the frame sync did not occur during reception of that word. RFS is cleared by hardware, software, ESAI individual, or STOP reset. RFS is valid only if at least one of the receivers is enabled (REx=1).

#### NOTE

In normal mode, RFS always reads as a one when reading data because there is only one time slot per frame – the “frame sync” time slot.

### 8.3.6.6 SAISR Receiver Overrun Error Flag (ROE) - Bit 7

The ROE flag is set when the serial receive shift register of an enabled receiver is full and ready to transfer to its receiver data register (RXx) and the register is already full (RDF=1). If REIE is set, an ESAI receive data with exception (overrun error) interrupt request is issued when ROE is set. Hardware, software, ESAI individual and STOP reset clear ROE. ROE is also cleared by reading the SAISR with ROE set, followed by reading all the enabled receive data registers.

### 8.3.6.7 SAISR Receive Data Register Full (RDF) - Bit 8

RDF is set when the contents of the receive shift register of an enabled receiver is transferred to the respective receive data register. RDF is cleared when the DSP reads the receive data register of all enabled receivers or cleared by hardware, software, ESAI individual, or STOP reset. If RIE is set, an ESAI receive data interrupt request is issued when RDF is set.

### 8.3.6.8 SAISR Receive Even-Data Register Full (REDF) - Bit 9

When set, REDF indicates that the received data in the receive data registers of the enabled receivers have arrived during an even time slot when operating in the network mode. Even time slots are all even-numbered slots (0, 2, 4, 6, etc.). Time slots are numbered from zero to N-1, where N is the number of time slots in the frame. The zero time slot is considered even. REDF is set when the contents of the receive shift registers are transferred to the receive data registers. REDF is cleared when the DSP reads all the enabled receive data registers or cleared by hardware, software, ESAI individual, or STOP resets. If REDIE is set, an ESAI receive even slot data interrupt request is issued when REDF is set.

### 8.3.6.9 SAISR Receive Odd-Data Register Full (RODF) - Bit 10

When set, RODF indicates that the received data in the receive data registers of the enabled receivers have arrived during an odd time slot when operating in the network mode. Odd time slots are all odd-numbered slots (1, 3, 5, etc.). Time slots are numbered from zero to N-1, where N is the number of time slots in the frame. RODF is set when the contents of the receive shift registers are transferred to the receive data registers. RODF is cleared when the DSP reads all the enabled receive data registers or cleared by hardware, software, ESAI individual, or STOP resets.

### 8.3.6.10 SAISR Transmit Frame Sync Flag (TFS) - Bit 13

When set, TFS indicates that a transmit frame sync occurred in the current time slot. TFS is set at the start of the first time slot in the frame and cleared during all other time slots. Data written to a transmit data register during the time slot when TFS is set is transmitted (in network mode), if the transmitter is enabled,

during the second time slot in the frame. TFS is useful in network mode to identify the start of a frame. TFS is cleared by hardware, software, ESAI individual, or STOP reset. TFS is valid only if at least one transmitter is enabled, i.e., one or more of TE0, TE1, TE2, TE3, TE4 and TE5 are set.

#### NOTE

In normal mode, TFS always reads as a one when transmitting data because there is only one time slot per frame – the “frame sync” time slot.

#### 8.3.6.11 SAISR Transmit Underrun Error Flag (TUE) - Bit 14

TUE is set when at least one of the enabled serial transmit shift registers is empty (no new data to be transmitted) and a transmit time slot occurs. When a transmit underrun error occurs, the previous data (which is still present in the TX registers that were not written) is retransmitted. If TEIE is set, an ESAI transmit data with exception (underrun error) interrupt request is issued when TUE is set. Hardware, software, ESAI individual and STOP reset clear TUE. TUE is also cleared by reading the SAISR with TUE set, followed by writing to all the enabled transmit data registers or to TSR.

#### 8.3.6.12 SAISR Transmit Data Register Empty (TDE) - Bit 15

TDE is set when the contents of the transmit data register of all the enabled transmitters are transferred to the transmit shift registers; it is also set for a TSR disabled time slot period in network mode (as if data were being transmitted after the TSR was written). When set, TDE indicates that data should be written to all the TX registers of the enabled transmitters or to the time slot register (TSR). TDE is cleared when the DSP writes to all the transmit data registers of the enabled transmitters, or when the DSP writes to the TSR to disable transmission of the next time slot. If TIE is set, an ESAI transmit data interrupt request is issued when TDE is set. Hardware, software, ESAI individual and STOP reset clear TDE.

#### 8.3.6.13 SAISR Transmit Even-Data Register Empty (TEDE) - Bit 16

When set, TEDE indicates that the enabled transmitter data registers became empty at the beginning of an even time slot. Even time slots are all even-numbered slots (0, 2, 4, 6, etc.). Time slots are numbered from zero to N-1, where N is the number of time slots in the frame. The zero time slot is considered even. This flag is set when the contents of the transmit data register of all the enabled transmitters are transferred to the transmit shift registers; it is also set for a TSR disabled time slot period in network mode (as if data were being transmitted after the TSR was written). When set, TEDE indicates that data should be written to all the TX registers of the enabled transmitters or to the time slot register (TSR). TEDE is cleared when the DSP writes to all the transmit data registers of the enabled transmitters, or when the DSP writes to the TSR to disable transmission of the next time slot. If TIE is set, an ESAI transmit data interrupt request is issued when TEDE is set. Hardware, software, ESAI individual and STOP reset clear TEDE.

#### 8.3.6.14 SAISR Transmit Odd-Data Register Empty (TODE) - Bit 17

When set, TODE indicates that the enabled transmitter data registers became empty at the beginning of an odd time slot. Odd time slots are all odd-numbered slots (1, 3, 5, etc.). Time slots are numbered from zero to N-1, where N is the number of time slots in the frame. This flag is set when the contents of the transmit data register of all the enabled transmitters are transferred to the transmit shift registers; it is also set for a

## ESAI Programming Model

TSR disabled time slot period in network mode (as if data were being transmitted after the TSR was written). When set, TODE indicates that data should be written to all the TX registers of the enabled transmitters or to the time slot register (TSR). TODE is cleared when the DSP writes to all the transmit data registers of the enabled transmitters, or when the DSP writes to the TSR to disable transmission of the next time slot. If TIE is set, an ESAI transmit data interrupt request is issued when TODE is set. Hardware, software, ESAI individual and STOP reset clear TODE.



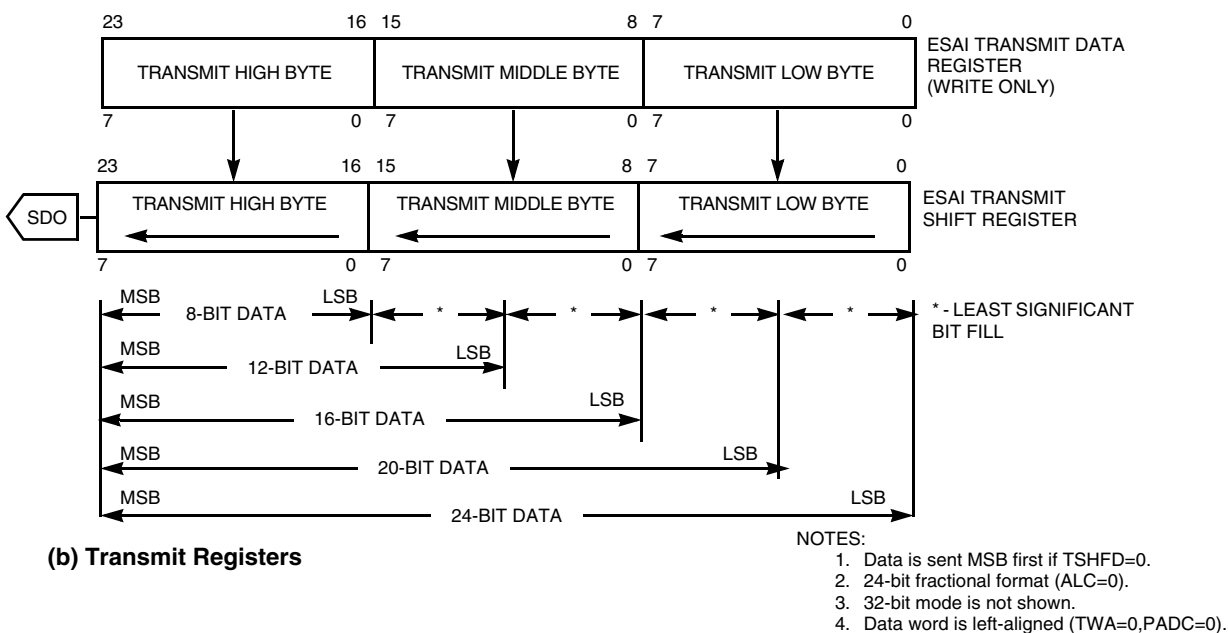
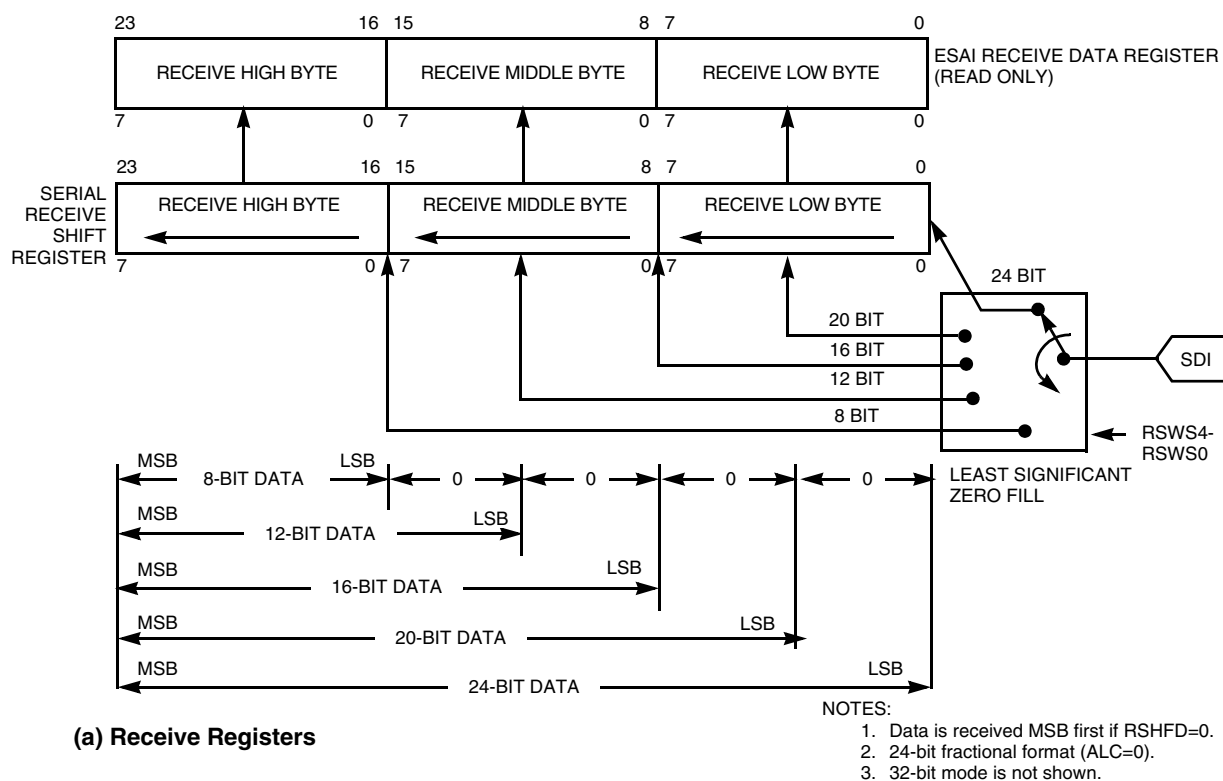
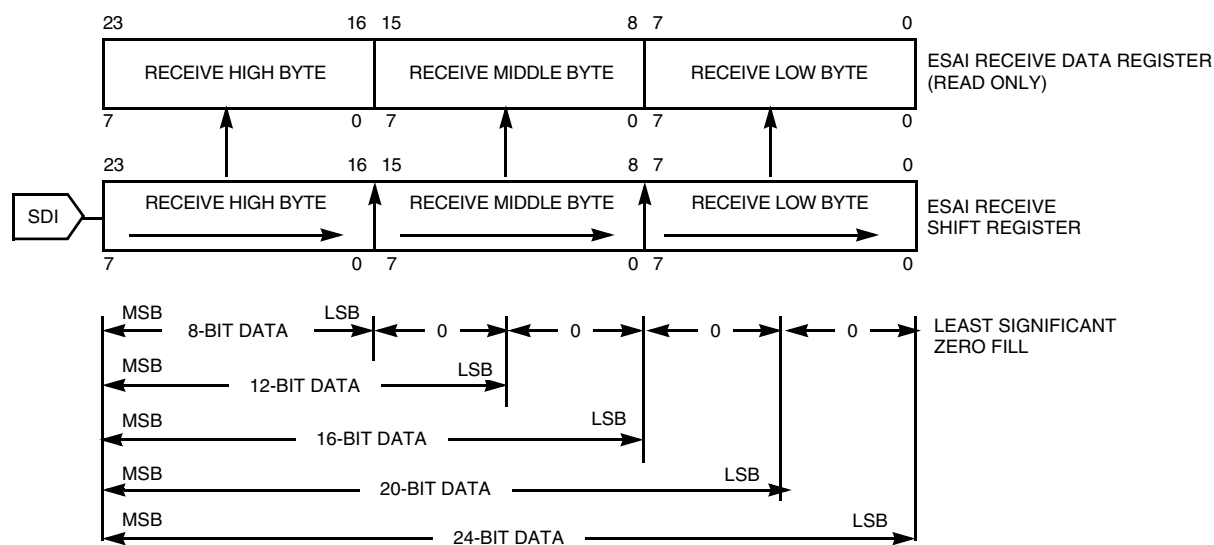
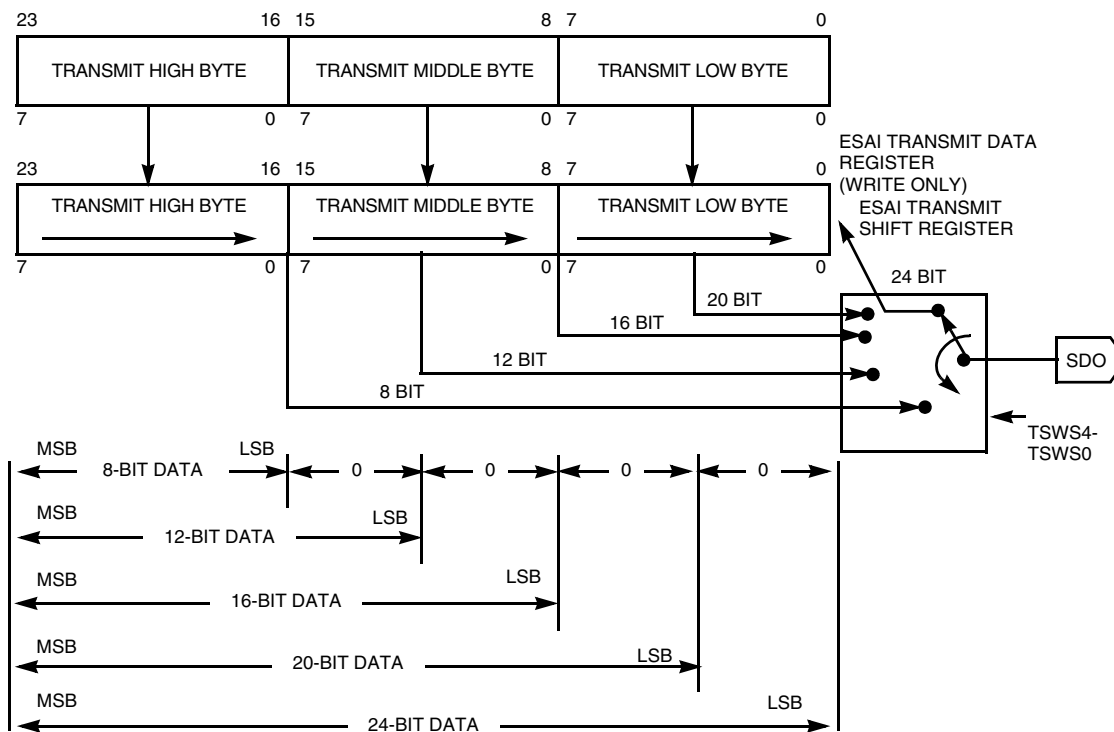


Figure 8-13 ESAI Data Path Programming Model ([R/T]SHFD=0)

## ESAI Programming Model



(a) Receive Registers



(b) Transmit Registers

Figure 8-14 ESAI Data Path Programming Model ([R/T]SHFD=1)

### 8.3.7 ESAI Receive Shift Registers

The receive shift registers (see [Figure 8-13](#) and [Figure 8-14](#)) receive the incoming data from the serial receive data pins. Data is shifted in by the selected (internal/external) bit clock when the associated frame sync I/O is asserted. Data is assumed to be received MSB first if RSHFD=0 and LSB first if RSHFD=1. Data is transferred to the ESAI receive data registers after 8, 12, 16, 20, 24, or 32 serial clock cycles were counted, depending on the slot length control bits in the RCR register.

### 8.3.8 ESAI Receive Data Registers (RX3, RX2, RX1, RX0)

RX3, RX2, RX1 and RX0 are 24-bit read-only registers that accept data from the receive shift registers when they become full (see [Figure 8-13](#) and [Figure 8-14](#)). The data occupies the most significant portion of the receive data registers, according to the ALC control bit setting. The unused bits (least significant portion and 8 most significant bits when ALC=1) read as zeros. The DSP is interrupted whenever RXx becomes full if the associated interrupt is enabled.

### 8.3.9 ESAI Transmit Shift Registers

The transmit shift registers contain the data being transmitted (see [Figure 8-13](#) and [Figure 8-14](#)). Data is shifted out to the serial transmit data pins by the selected (internal/external) bit clock when the associated frame sync I/O is asserted. The number of bits shifted out before the shift registers are considered empty and may be written to again can be 8, 12, 16, 20, 24 or 32 bits (determined by the slot length control bits in the TCR register). Data is shifted out of these registers MSB first if TSHFD=0 and LSB first if TSHFD=1.

### 8.3.10 ESAI Transmit Data Registers (TX5, TX4, TX3, TX2, TX1, TX0)

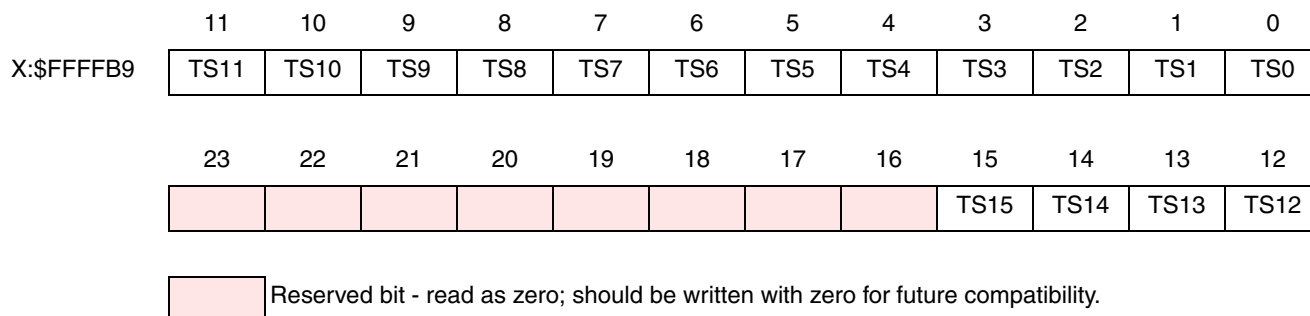
TX5, TX4, TX3, TX2, TX1 and TX0 are 24-bit write-only registers. Data to be transmitted is written into these registers and is automatically transferred to the transmit shift registers (see [Figure 8-13](#) and [Figure 8-14](#)). The data written (8, 12, 16, 20 or 24 bits) should occupy the most significant portion of the TXx according to the ALC control bit setting. The unused bits (least significant portion and the 8 most significant bits when ALC=1) of the TXx are don't care bits. The DSP is interrupted whenever the TXx becomes empty if the transmit data register empty interrupt has been enabled.

### 8.3.11 ESAI Time Slot Register (TSR)

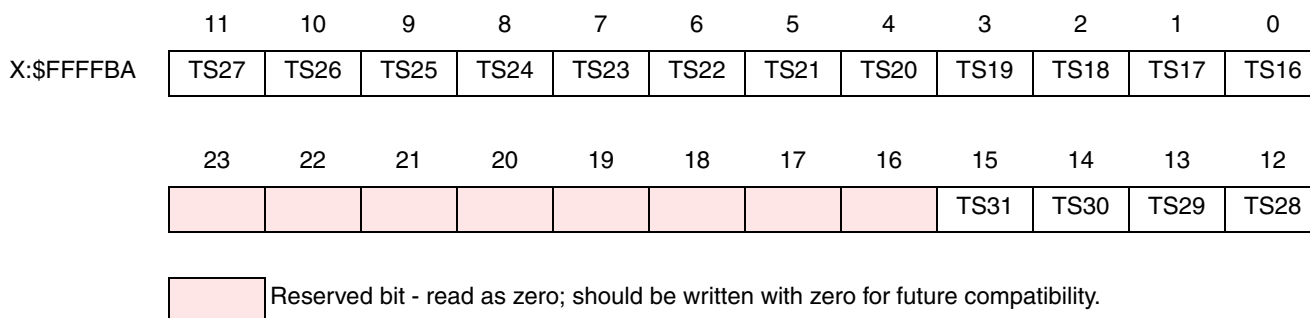
The write-only Time Slot Register (TSR) is effectively a null data register that is used when the data is not to be transmitted in the available transmit time slot. The transmit data pins of all the enabled transmitters are in the high-impedance state for the respective time slot where TSR has been written. The Transmitter External Buffer Enable pin (FSR pin when SYN=1, TEBE=1, RFSD=1) disables the external buffers during the slot when the TSR register has been written.

### 8.3.12 Transmit Slot Mask Registers (TSMA, TSMB)

The Transmit Slot Mask Registers (TSMA and TSMB) are two read/write registers used by the transmitters in network mode to determine for each slot whether to transmit a data word and generate a transmitter empty condition (TDE=1), or to tri-state the transmitter data pins. TSMA and TSMB should each be considered as containing half a 32-bit register TSM. See Figure 8-15 and Figure 8-16. Bit number N in TSM (TS\*\*) is the enable/disable control bit for transmission in slot number N.



**Figure 8-15 TSMA Register**



**Figure 8-16 TSMB Register**

When bit number N in TSM is cleared, all the transmit data pins of the enabled transmitters are tri-stated during transmit time slot number N. The data is still transferred from the transmit data registers to the transmit shift registers but neither the TDE nor the TUE flags are set. This means that during a disabled slot, no transmitter empty interrupt is generated. The DSP is interrupted only for enabled slots. Data that is written to the transmit data registers when servicing this request is transmitted in the next enabled transmit time slot.

When bit number N in TSM register is set, the transmit sequence is as usual: data is transferred from the TX registers to the shift registers and transmitted during slot number N, and the TDE flag is set.

Using the slot mask in TSM does not conflict with using TSR. Even if a slot is enabled in TSM, the user may choose to write to TSR instead of writing to the transmit data registers TXx. This causes all the transmit data pins of the enabled transmitters to be tri-stated during the next slot.

Data written to the TSM affects the next frame transmission. The frame being transmitted is not affected by this data and would comply to the last TSM setting. Data read from TSM returns the last written data.

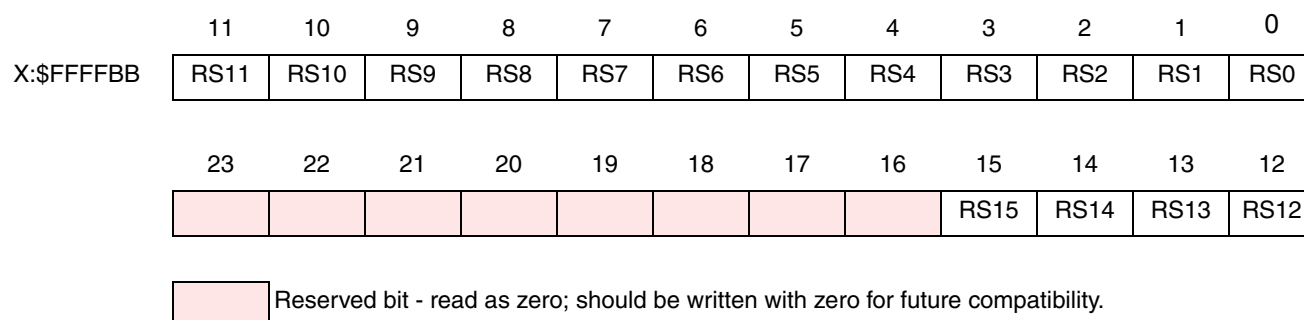
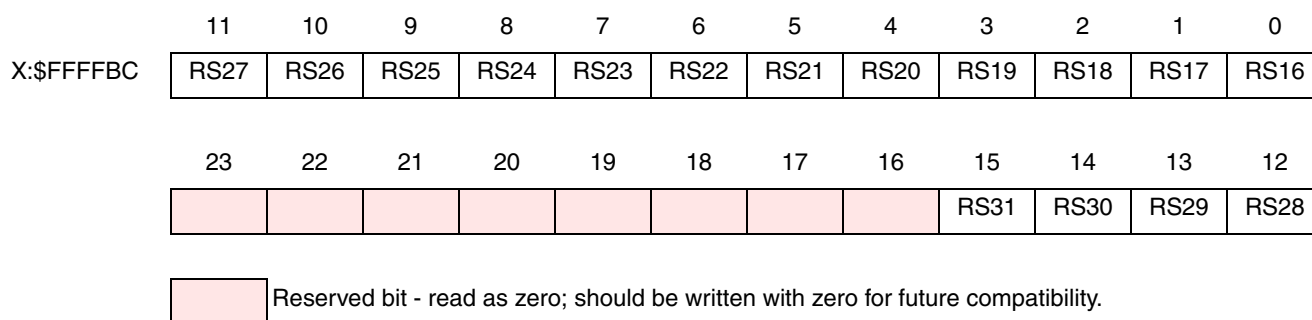
After hardware or software reset, the TSM register is preset to \$FFFFFFFF, which means that all 32 possible slots are enabled for data transmission.

**NOTE**

When operating in normal mode, bit 0 of the mask register must be set, otherwise no output is generated.

**8.3.13 Receive Slot Mask Registers (RSMA, RSMB)**

The Receive Slot Mask Registers (RSMA and RSMB) are two read/write registers used by the receiver in network mode to determine for each slot whether to receive a data word and generate a receiver full condition (RDF=1), or to ignore the received data. RSMA and RSMB should be considered as each containing half of a 32-bit register RSM. See [Figure 8-17](#) and [Figure 8-18](#). Bit number N in RSM (RS\*\*) is an enable/disable control bit for receiving data in slot number N.

**Figure 8-17 RSMA Register****Figure 8-18 RSMB Register**

When bit number N in the RSM register is cleared, the data from the enabled receivers input pins are shifted into their receive shift registers during slot number N. The data is not transferred from the receive shift registers to the receive data registers, and neither the RDF nor the ROE flag is set. This means that during a disabled slot, no receiver full interrupt is generated. The DSP is interrupted only for enabled slots.

When bit number N in the RSM is set, the receive sequence is as usual: data which is shifted into the enabled receivers shift registers is transferred to the receive data registers and the RDF flag is set.

Data written to the RSM affects the next received frame. The frame being received is not affected by this data and would comply to the last RSM setting. Data read from RSM returns the last written data.

After hardware or software reset, the RSM register is preset to \$FFFFFFFF, which means that all 32 possible slots are enabled for data reception.

**NOTE**

When operating in normal mode, bit 0 of the mask register must be set to one, otherwise no input is received.

## 8.4 Operating Modes

ESAI operating mode are selected by the ESAI control registers (TCCR, TCR, RCCR, RCR and SAICR). The main operating mode are described in the following paragraphs.

### 8.4.1 ESAI After Reset

Hardware or software reset clears the port control register bits and the port direction control register bits, which configure all ESAI I/O pins as disconnected. The ESAI is in the individual reset state while all ESAI pins are programmed as GPIO or disconnected, and it is active only if at least one of the ESAI I/O pins is programmed as an ESAI pin.

### 8.4.2 ESAI Initialization

The correct way to initialize the ESAI is as follows:

1. Hardware, software, ESAI individual, or STOP reset.
2. Program ESAI control and time slot registers.
3. Write data to all the enabled transmitters.
4. Configure at least one pin as ESAI pin.

During program execution, all ESAI pins may be defined as GPIO or disconnected, causing the ESAI to stop serial activity and enter the individual reset state. All status bits of the interface are set to their reset state; however, the control bits are not affected. This procedure allows the DSP programmer to reset the ESAI separately from the other internal peripherals. During individual reset, internal DMA accesses to the data registers of the ESAI are not valid and data read is undefined.

The DSP programmer must use an individual ESAI reset when changing the ESAI control registers (except for TEIE, REIE, TLIE, RLIE, TIE, RIE, TE0-TE5, RE0-RE3) to ensure proper operation of the interface.

**NOTE**

If the ESAI receiver section is already operating with some of the receivers, enabling additional receivers on the fly, i.e., without first putting the ESAI receiver in the personal reset state, by setting their REx control bits will result in erroneous data being received as the first data word for the newly enabled receivers.

### 8.4.3 ESAI Interrupt Requests

The ESAI can generate eight different interrupt requests (ordered from the highest to the lowest priority):

1. ESAI Receive Data with Exception Status  
Occurs when the receive exception interrupt is enabled (REIE=1 in the RCR register), at least one of the enabled receive data registers is full (RDF=1) and a receiver overrun error has occurred (ROE=1 in the SAISR register). ROE is cleared by first reading the SAISR and then reading all the enabled receive data registers.
2. ESAI Receive Even Data  
Occurs when the receive even slot data interrupt is enabled (REDIE=1), at least one of the enabled receive data registers is full (RDF=1), the data is from an even slot (REDF=1) and no exception has occurred (ROE=0 or REIE=0).  
Reading all enabled receiver data registers clears RDF and REDF.
3. ESAI Receive Data  
Occurs when the receive interrupt is enabled (RIE=1), at least one of the enabled receive data registers is full (RDF=1), no exception has occurred (ROE=0 or REIE=0) and no even slot interrupt has occurred (REDF=0 or REDIE=0).  
Reading all enabled receiver data registers clears RDF.
4. ESAI Receive Last Slot Interrupt  
Occurs, if enabled (RLIE=1), after the last slot of the frame ended (in network mode only) regardless of the receive mask register setting. The receive last slot interrupt may be used for resetting the receive mask slot register, reconfiguring the DMA channels and reassigning data memory pointers. Using the receive last slot interrupt guarantees that the previous frame was serviced with the previous setting and the new frame is serviced with the new setting without synchronization problems. Note that the maximum receive last slot interrupt service time should not exceed N-1 ESAI bits service time (where N is the number of bits in a slot).
5. ESAI Transmit Data with Exception Status  
Occurs when the transmit exception interrupt is enabled (TEIE=1), at least one transmit data register of the enabled transmitters is empty (TDE=1) and a transmitter underrun error has occurred (TUE=1). TUE is cleared by first reading the SAISR and then writing to all the enabled transmit data registers, or to the TSR register.
6. ESAI Transmit Last Slot Interrupt  
Occurs, if enabled (TLIE=1), at the start of the last slot of the frame in network mode regardless of the transmit mask register setting. The transmit last slot interrupt may be used for resetting the transmit mask slot register, reconfiguring the DMA channels and reassigning data memory pointers. Using the transmit last slot interrupt guarantees that the previous frame was serviced with the previous setting and the new frame is serviced with the new setting without synchronization problems. Note that the maximum transmit last slot interrupt service time should not exceed N-1 ESAI bits service time (where N is the number of bits in a slot).
7. ESAI Transmit Even Data  
Occurs when the transmit even slot data interrupt is enabled (TEDIE=1), at least one of the enabled transmit data registers is empty (TDE=1), the slot is an even slot (TEDE=1) and no exception has occurred (TUE=0 or TEIE=0).  
Writing to all the TX registers of the enabled transmitters or to TSR clears this interrupt request.

### 8. ESAI Transmit Data

Occurs when the transmit interrupt is enabled (TIE=1), at least one of the enabled transmit data registers is empty (TDE=1), no exception has occurred (TUE=0 or TEIE=0) and no even slot interrupt has occurred (TEDE=0 or TEDIE=0).

Writing to all the TX registers of the enabled transmitters, or to the TSR clears this interrupt request.

## 8.4.4 Operating Modes – Normal, Network and On-Demand

The ESAI has three basic operating modes and many data/operation formats.

### 8.4.4.1 Normal/Network/On-Demand Mode Selection

Selecting between the normal mode and network mode is accomplished by clearing or setting the TMOD0-TMOD1 bits in the TCR register for the transmitter section, as well as in the RMOD0-RMOD1 bits in the RCR register for the receiver section.

For normal mode, the ESAI functions with one data word of I/O per frame (per enabled transmitter or receiver). The normal mode is typically used to transfer data to/from a single device.

For the network mode, 2 to 32 time slots per frame may be selected. During each frame, 0 to 32 data words of I/O may be received/transmitted. In either case, the transfers are periodic. The frame sync signal indicates the first time slot in the frame. Network mode is typically used in time division multiplexed (TDM) networks of codecs, DSPs with multiple words per frame, or multi-channel devices.

Selecting the network mode and setting the frame rate divider to zero (DC=00000) selects the on-demand mode. This special case does not generate a periodic frame sync. A frame sync pulse is generated only when data is available to transmit. The on-demand mode requires that the transmit frame sync be internal (output) and the receive frame sync be external (input). Therefore, for simplex operation, the synchronous mode could be used; however, for full-duplex operation, the asynchronous mode must be used. Data transmission that is data driven is enabled by writing data into each TX. Although the ESAI is double buffered, only one word can be written to each TX, even if the transmit shift register is empty. The receive and transmit interrupts function as usual using TDE and RDF; however, transmit underruns are impossible for on-demand transmission and are disabled.

### 8.4.4.2 Synchronous/Asynchronous Operating Modes

The transmit and receive sections of the ESAI may be synchronous or asynchronous, i.e., the transmitter and receiver sections may use common clock and synchronization signals (synchronous operating mode), or they may have their own separate clock and sync signals (asynchronous operating mode). The SYN bit in the SAICR register selects synchronous or asynchronous operation. Since the ESAI is designed to operate either synchronously or asynchronously, separate receive and transmit interrupts are provided.

When SYN is cleared, the ESAI transmitter and receiver clocks and frame sync sources are independent. If SYN is set, the ESAI transmitter and receiver clocks and frame sync come from the transmitter section (either external or internal sources).



Data clock and frame sync signals can be generated internally by the DSP or may be obtained from external sources. If internally generated, the ESAI clock generator is used to derive high frequency clock, bit clock and frame sync signals from the DSP internal system clock.

### 8.4.4.3 Frame Sync Selection

The frame sync can be either a bit-long or word-long signal. The transmitter frame format is defined by the TFSL bit in the TCR register. The receiver frame format is defined by the RFSL bit in the RCR register.

1. In the word-long frame sync format, the frame sync signal is asserted during the entire word data transfer period. This frame sync length is compatible with Freescale codecs, SPI serial peripherals, serial A/D and D/A converters, shift registers and telecommunication PCM serial I/O.
2. In the bit-long frame sync format, the frame sync signal is asserted for one bit clock immediately before the data transfer period. This frame sync length is compatible with Intel and National components, codecs and telecommunication PCM serial I/O.

The relative timing of the word length frame sync as referred to the data word is specified by the TFSR bit in the TCR register for the transmitter section and by the RFSR bit in the RCR register for the receive section. The word length frame sync may be generated (or expected) with the first bit of the data word, or with the last bit of the previous word. TFSR and RFSR are ignored when a bit length frame sync is selected.

Polarity of the frame sync signal may be defined as positive (asserted high) or negative (asserted low). The TFSP bit in the TCCR register specifies the polarity of the frame sync for the transmitter section. The RFSP bit in the RCCR register specifies the polarity of the frame sync for the receiver section.

The ESAI receiver looks for a receive frame sync leading edge (trailing edge if RFSP is set) only when the previous frame is completed. If the frame sync goes high before the frame is completed (or before the last bit of the frame is received in the case of a bit frame sync or a word length frame sync with RFSR set), the current frame sync is not recognized, and the receiver is internally disabled until the next frame sync. Frames do not have to be adjacent, i.e., a new frame sync does not have to immediately follow the previous frame. Gaps of arbitrary periods can occur between frames. Enabled transmitters are tri-stated during these gaps.

When operating in the synchronous mode (SYN=1), all clocks including the frame sync are generated by the transmitter section.

### 8.4.4.4 Shift Direction Selection

Some data formats, such as those used by codecs, specify MSB first while other data formats, such as the AES-EBU digital audio interface, specify LSB first. The MSB/LSB first selection is made by programming RSHFD bit in the RCR register for the receiver section and by programming the TSHFD bit in the TCR register for the transmitter section.

### 8.4.5 Serial I/O Flags

Three ESAI pins (FSR, SCKR and HCKR) are available as serial I/O flags when the ESAI is operating in the synchronous mode (SYN=1). Their operation is controlled by RCKD, RFSD, TEBE bits in the RCR,

RCCR and SAICR registers. The output data bits (OF2, OF1 and OF0) and the input data bits (IF2, IF1 and IF0) are double buffered to/from the HCKR, FSR and SCKR pins. Double buffering the flags keeps them in sync with the TX and RX data lines.

Each flag can be separately programmed. Flag 0 (SCKR pin) direction is selected by RCKD, RCKD=1 for output and RCKD=0 for input. Flag 1 (FSR pin) is enabled when the pin is not configured as external transmitter buffer enable (TEBE=0) and its direction is selected by RFSD, RFSD=1 for output and RFSD=0 for input. Flag 2 (HCKR pin) direction is selected by RHCKD, RHCKD=1 for output and RHCKD=0 for input.

When programmed as input flags, the SCKR, FSR and HCKR logic values, respectively, are latched at the same time as the first bit of the receive data word is sampled. Because the input was latched, the signal on the input flag pin (SCKR, FSR or HCKR) can change without affecting the input flag until the first bit of the next receive data word. When the received data words are transferred to the receive data registers, the input flag latched values are then transferred to the IF0, IF1 and IF2 bits in the SAISR register, where they may be read by software.

When programmed as output flags, the SCKR, FSR and HCKR logic values are driven by the contents of the OF0, OF1 and OF2 bits in the SAICR register respectively, and they are driven when the transmit data registers are transferred to the transmit shift registers. The value on SCKR, FSR and HCKR is stable from the time the first bit of the transmit data word is transmitted until the first bit of the next transmit data word is transmitted. Software may change the OF0-OF2 values thus controlling the SCKR, FSR and HCKR pin values for each transmitted word. The normal sequence for setting output flags when transmitting data is as follows: wait for TDE (transmitter empty) to be set; first write the flags, and then write the transmit data to the transmit registers. OF0, OF1 and OF2 are double buffered so that the flag states appear on the pins when the transmit data is transferred to the transmit shift register, i.e., the flags are synchronous with the data.

## 8.5 GPIO - Pins and Registers

The GPIO functionality of the ESAI port is controlled by three registers: Port C control register (PCRC), Port C direction register (PRRC) and Port C data register (PDRC).

### 8.5.1 Port C Control Register (PCRC)

The read/write 24-bit Port C Control Register (PCRC) in conjunction with the Port C Direction Register (PRRC) controls the functionality of the ESAI GPIO pins. Each of the PC(11:0) bits controls the functionality of the corresponding port pin. See [Table 8-12](#) for the port pin configurations. Hardware and software reset clear all PCRC bits.

### 8.5.2 Port C Direction Register (PRRC)

The read/write 24-bit Port C Direction Register (PRRC) in conjunction with the Port C Control Register (PCRC) controls the functionality of the ESAI GPIO pins. [Table 8-12](#) describes the port pin configurations. Hardware and software reset clear all PRR bits.

Table 8-12 PCRC and PRRC Bits Functionality

PDC[i]	PC[i]	Port Pin[i] Function
0	0	disconnected
0	1	GPIO input
1	0	GPIO output
1	1	ESAI

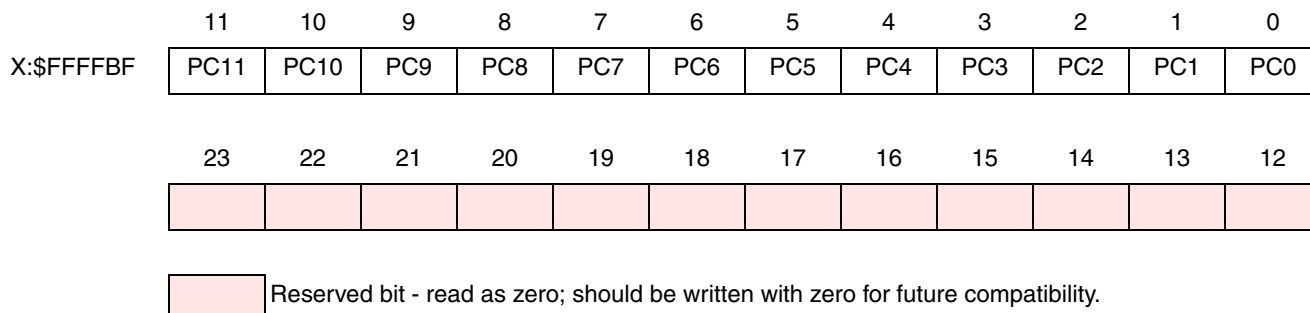


Figure 8-19 PCRC Register

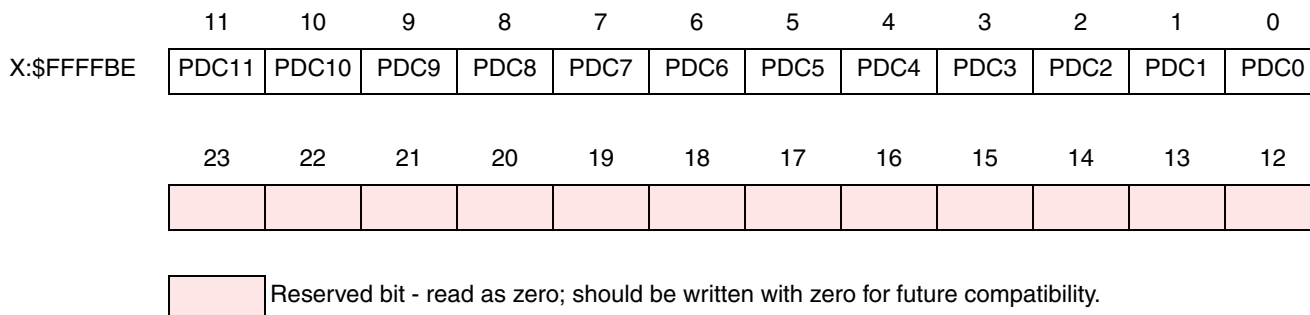


Figure 8-20 PRRC Register

### 8.5.3 Port C Data register (PDRC)

The read/write 24-bit Port C Data Register (see [Figure 8-21](#)) is used to read or write data to/from ESAI GPIO pins. Bits PD(11:0) are used to read or write data from/to the corresponding port pins if they are configured as GPIO. If a port pin [i] is configured as a GPIO input, the corresponding PD[i] bit reflects the value present on this pin. If a port pin [i] is configured as a GPIO output, the value written into the corresponding PD[i] bit is reflected on this pin. If a port pin [i] is configured as disconnected, the corresponding PD[i] bit is not reset and contains undefined data.

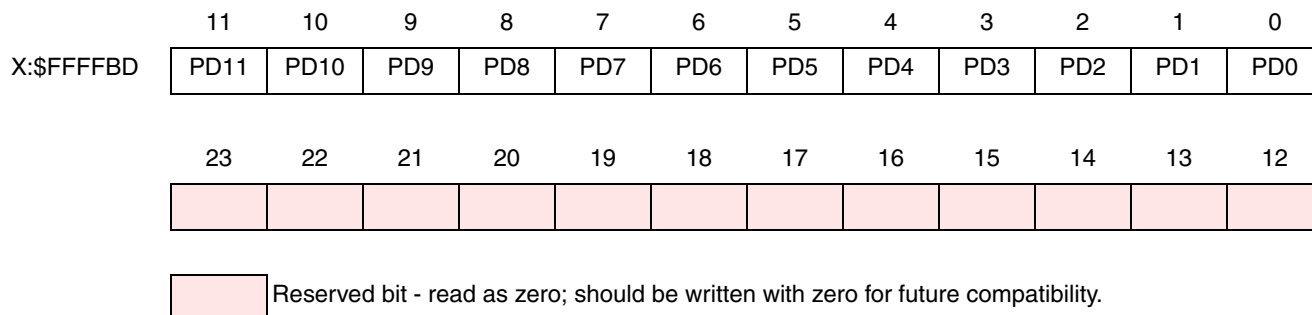


Figure 8-21 PDRC Register

## 8.6 ESAI Initialization Examples

### 8.6.1 Initializing the ESAI Using Individual Reset

- The ESAI should be in its individual reset state (PCRC = \$000 and PRRC = \$000). In the individual reset state, both the transmitter and receiver sections of the ESAI are simultaneously reset. The TPR bit in the TCR register may be used to reset just the transmitter section. The RPR bit in the RCR register may be used to reset just the receiver section.
- Configure the control registers (TCCR, TCR, RCCR, RCR) according to the operating mode, but do not enable transmitters (TE5–TE0 = \$0) or receivers (RE3–RE0 = \$0). It is possible to set the interrupt enable bits which are in use during the operation (no interrupt occurs).
- Enable the ESAI by setting the PCRC register and PRRC register bits according to pins which are in use during operation.
- Write the first data to be transmitted to the transmitters which are in use during operation. This step is needed even if DMA is used to service the transmitters.
- Enable the transmitters and receivers.
- From now on ESAI can be serviced either by polling, interrupts, or DMA.

Operation proceeds as follows:

- For internally generated clock and frame sync, these signals are active immediately after ESAI is enabled (step 3 above).
- Data is received only when one of the receive enable (REx) bits is set and after the occurrence of frame sync signal (either internally or externally generated).
- Data is transmitted only when the transmitter enable (TE<sub>x</sub>) bit is set and after the occurrence of frame sync signal (either internally or externally generated). The transmitter outputs remain tri-stated after TE<sub>x</sub> bit is set until the frame sync occurs.

## 8.6.2 Initializing Just the ESAI Transmitter Section

- It is assumed that the ESAI is operational; that is, at least one pin is defined as an ESAI pin.
- The transmitter section should be in its personal reset state (TPR = 1).
- Configure the control registers TCCR and TCR according to the operating mode, making sure to clear the transmitter enable bits (TE0 - TE5). TPR must remain set.
- Take the transmitter section out of the personal reset state by clearing TPR.
- Write first data to the transmitters which will be used during operation. This step is needed even if DMA is used to service the transmitters.
- Enable the transmitters by setting their TE bits.
- Data is transmitted only when the transmitter enable (TE<sub>x</sub>) bit is set and after the occurrence of frame sync signal (either internally or externally generated). The transmitter outputs remain tri-stated after TE<sub>x</sub> bit is set until the frame sync occurs.
- From now on the transmitters are operating and can be serviced either by polling, interrupts, or DMA.

## 8.6.3 Initializing Just the ESAI Receiver Section

- It is assumed that the ESAI is operational; that is, at least one pin is defined as an ESAI pin.
- The receiver section should be in its personal reset state (RPR = 1).
- Configure the control registers RCCR and RCR according to the operating mode, making sure to clear the receiver enable bits (RE0 - RE3). RPR must remain set.
- Take the receiver section out of the personal reset state by clearing RPR.
- Enable the receivers by setting their RE bits.
- From now on the receivers are operating and can be serviced either by polling, interrupts, or DMA.

## NOTES

## 9 Enhanced Serial Audio Interface 1 (ESAI\_1)

### 9.1 Introduction

The Enhanced Serial Audio Interface I (ESAI\_1) is the second ESAI peripheral in the DSP56371. It is functionally identical to the ESAI peripheral described in [Section 8, "Enhanced Serial Audio Interface \(ESAI\)"](#). The ESAI\_1 block diagram is shown in [Figure 9-1](#).

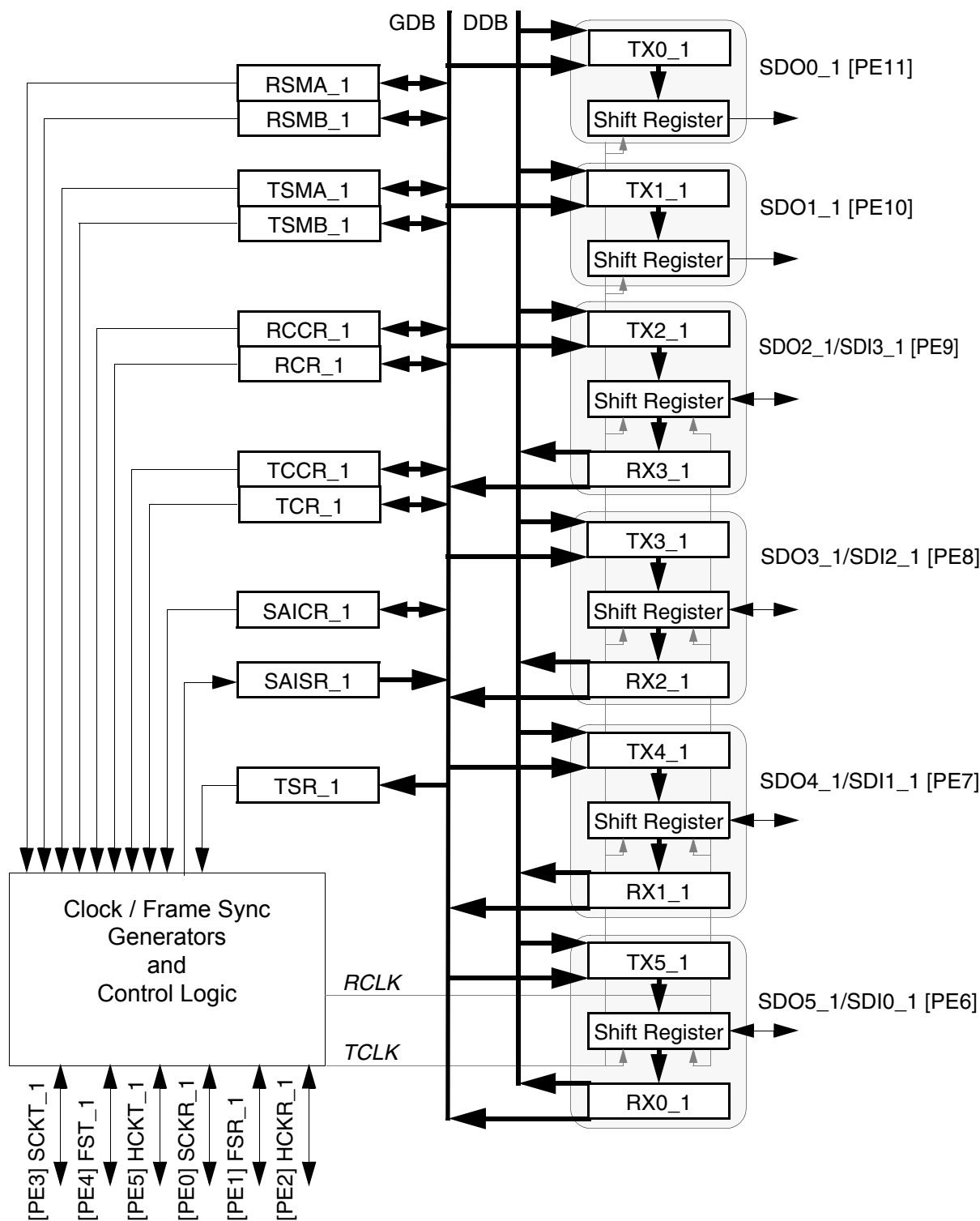


Figure 9-1 ESAI\_1 Block Diagram



## 9.2 ESAI\_1 Data and Control Pins

Three to twelve pins are required for operation, depending on the operating mode selected and the number of transmitters and receivers enabled. The SDO0\_1 and SDO1\_1 pins are used by transmitters 0 and 1 only. The SDO2\_1/SDI3\_1, SDO3\_1/SDI2\_1, SDO4\_1/SDI1\_1 and SDO5\_1/SDI0\_1 pins are shared by transmitters 2 to 5 with receivers 0 to 3. The actual mode of operation is selected under software control. All transmitters operate fully synchronized under control of the same transmitter clock signals. All receivers operate fully synchronized under control of the same receiver clock signals.

### 9.2.1 Serial Transmit 0 Data Pin (SDO0\_1)

SDO0\_1 transmits data from the TX0\_1 serial transmit shift register. SDO0\_1 is an output when data is being transmitted from the TX0\_1 shift register. In the on-demand mode with an internally generated bit clock, the SDO0 pin becomes high impedance for a full clock period after the last data bit has been transmitted, assuming another data word does not follow immediately. If a data word follows immediately, there is no high-impedance interval.

SDO0\_1 may be programmed as a general-purpose I/O pin (PE11) when the ESAI SDO0\_1 function is not being used.

### 9.2.2 Serial Transmit 1 Data Pin (SDO1\_1)

SDO1\_1 transmits data from the TX1\_1 serial transmit shift register. SDO1\_1 is an output when data is being transmitted from the TX1\_1 shift register. In the on-demand mode with an internally generated bit clock, the SDO1 pin becomes high impedance for a full clock period after the last data bit has been transmitted, assuming another data word does not follow immediately. If a data word follows immediately, there is no high-impedance interval.

SDO1\_1 may be programmed as a general-purpose I/O pin (PE10) when the ESAI SDO1\_1 function is not being used.

### 9.2.3 Serial Transmit 2/Receive 3 Data Pin (SDO2\_1/SDI3\_1)

SDO2\_1/SDI3\_1 is used as the SDO2\_1 for transmitting data from the TX2\_1 serial transmit shift register when programmed as a transmitter pin, or as the SDI3\_1 signal for receiving serial data to the RX3\_1 serial receive shift register when programmed as a receiver pin. SDO2\_1/SDI3\_1 is an input when data is being received by the RX3\_1 shift register. SDO2\_1/SDI3\_1 is an output when data is being transmitted from the TX2\_1 shift register. In the on-demand mode with an internally generated bit clock, the SDO2\_1/SDI3\_1 pin becomes high impedance for a full clock period after the last data bit has been transmitted, assuming another data word does not follow immediately. If a data word follows immediately, there is no high-impedance interval.

SDO2\_1/SDI3\_1 may be programmed as a general-purpose I/O pin (PE9) when the ESAI SDO2\_1/SDI3\_1 function is not being used.

### 9.2.4 Serial Transmit 3/Receive 2 Data Pin (SDO3\_1/SDI2\_1)

SDO3\_1/SDI2\_1 is used as the SDO3\_1 for transmitting data from the TX3\_1 serial transmit shift register when programmed as a transmitter pin, or as the SDI2\_1 signal for receiving serial data to the RX2\_1 serial receive shift register when programmed as a receiver pin. SDO3\_1/SDI2\_1 is an input when data is being received by the RX2\_1 shift register. SDO3\_1/SDI2\_1 is an output when data is being transmitted from the TX3\_1 shift register. In the on-demand mode with an internally generated bit clock, the SDO3\_1/SDI2\_1 pin becomes high impedance for a full clock period after the last data bit has been transmitted, assuming another data word does not follow immediately. If a data word follows immediately, there is no high-impedance interval.

SDO3\_1/SDI2\_1 may be programmed as a general-purpose I/O pin (PE8) when the ESAI SDO3\_1/SDI2\_1 function is not being used.

### 9.2.5 Serial Transmit 4/Receive 1 Data Pin (SDO4\_1/SDI1\_1)

SDO4\_1/SDI1\_1 is used as the SDO4\_1 for transmitting data from the TX4\_1 serial transmit shift register when programmed as a transmitter pin, or as the SDI1\_1 signal for receiving serial data to the RX1\_1 serial receive shift register when programmed as a receiver pin. SDO4\_1/SDI1\_1 is an input when data is being received by the RX1\_1 shift register. SDO4\_1/SDI1\_1 is an output when data is being transmitted from the TX4\_1 shift register. In the on-demand mode with an internally generated bit clock, the SDO4\_1/SDI1\_1 pin becomes high impedance for a full clock period after the last data bit has been transmitted, assuming another data word does not follow immediately. If a data word follows immediately, there is no high-impedance interval.

SDO4\_1/SDI1\_1 may be programmed as a general-purpose pin (PE7) when the ESAI\_1 SDO4\_1 and SDI1\_1 functions are not being used.

### 9.2.6 Serial Transmit 5/Receive 0 Data Pin (SDO5\_1/SDI0\_1)

SDO5\_1/SDI0\_1 is used as the SDO5\_1 for transmitting data from the TX5\_1 serial transmit shift register when programmed as a transmitter pin, or as the SDI0\_1 signal for receiving serial data to the RX0\_1 serial receive shift register when programmed as a receiver pin. SDO5\_1/SDI0\_1 is an input when data is being received by the RX0\_1 shift register. SDO5\_1/SDI0\_1 is an output when data is being transmitted from the TX5\_1 shift register. In the on-demand mode with an internally generated bit clock, the SDO5\_1/SDI0\_1 pin becomes high impedance for a full clock period after the last data bit has been transmitted, assuming another data word does not follow immediately. If a data word follows immediately, there is no high-impedance interval.

SDO5\_1/SDI0\_1 may be programmed as a general-purpose pin (PE6) when the ESAI\_1 SDO5\_1 and SDI0\_1 functions are not being used.

### 9.2.7 Receiver Serial Clock (SCKR\_1)

SCKR\_1 is a bidirectional pin providing the receivers serial bit clock for the ESAI\_1 interface. The direction of this pin is determined by the RCKD bit in the RCCR\_1 register. The SCKR\_1 operates as a

clock input or output used by all the enabled receivers in the asynchronous mode (SYN=0), or as serial flag 0 pin in the synchronous mode (SYN=1).

When this pin is configured as serial flag pin, its direction is determined by the RCKD bit in the RCCR\_1 register. When configured as the output flag OF0, this pin reflects the value of the OF0 bit in the SAICR\_1 register, and the data in the OF0 bit shows up at the pin synchronized to the frame sync being used by the transmitter and receiver sections. When this pin is configured as the input flag IF0, the data value at the pin is stored in the IF0 bit in the SAISR\_1 register, synchronized by the frame sync in normal mode or the slot in network mode.

SCKR\_1 may be programmed as a general-purpose I/O pin (PE0) when the ESAI\_1 SCKR\_1 function is not being used.

### NOTE

Although the external ESAI\_1 serial clock can be independent of and asynchronous to the DSP system clock, the DSP clock frequency must be at least three times the external ESAI\_1 serial clock frequency and each ESAI\_1 serial clock phase must exceed the minimum of 1.5 DSP clock periods.

For more information on pin mode and definition, see [Table 9-7](#) and on receiver clock signals see [Table 9-1](#).

**Table 9-1 Receiver Clock Sources (asynchronous mode only)**

RHCKD	RFSD	RCKD	Receiver Bit Clock Source	OUTPUTS		
0	0	0	SCKR_1			
0	0	1	HCKR_1			SCKR_1
0	1	0	SCKR_1		FSR_1	
0	1	1	HCKR_1		FSR_1	SCKR_1
1	0	0	SCKR_1	HCKR_1		
1	0	1	INT	HCKR_1		SCKR_1
1	1	0	SCKR_1	HCKR_1	FSR_1	
1	1	1	INT	HCKR_1	FSR_1	SCKR_1

## 9.2.8 Transmitter Serial Clock (SCKT\_1)

SCKT\_1 is a bidirectional pin providing the transmitters serial bit clock for the ESAI\_1 interface. The direction of this pin is determined by the TCKD bit in the TCCR\_1 register. The SCKT\_1 is a clock input or output used by all the enabled transmitters in the asynchronous mode (SYN=0) or by all the enabled transmitters and receivers in the synchronous mode (SYN=1) (see [Table 9-2](#)).

Table 9-2 Transmitter Clock Sources

THCKD	TFSD	TCKD	Transmitter Bit Clock Source	OUTPUTS		
0	0	0	SCKT_1			
0	0	1	HCKT_1			SCKT_1
0	1	0	SCKT_1		FST_1	
0	1	1	HCKT_1		FST_1	SCKT_1
1	0	0	SCK_1T	HCKT_1		
1	0	1	INT	HCKT_1		SCKT_1
1	1	0	SCKT_1	HCKT_1	FST_1	
1	1	1	INT	HCKT_1	FST_1	SCKT_1

### 9.2.9 Frame Sync for Receiver (FSR\_1)

FSR\_1 is a bidirectional pin providing the receivers frame sync signal for the ESAI\_1 interface. The direction of this pin is determined by the RFSD bit in RCR\_1 register. In the asynchronous mode (SYN=0), the FSR\_1 pin operates as the frame sync input or output used by all the enabled receivers. In the synchronous mode (SYN=1), it operates as either the serial flag 1 pin (TEBE=0), or as the transmitter external buffer enable control (TEBE=1, RFSD=1). For further information on pin mode and definition, see [Table 9-8](#) and on receiver clock signals see [Table 9-1](#).

When this pin is configured as serial flag pin, its direction is determined by the RFSD bit in the RCCR\_1 register. When configured as the output flag OF1, this pin reflects the value of the OF1 bit in the SAICR\_1 register, and the data in the OF1 bit shows up at the pin synchronized to the frame sync being used by the transmitter and receiver sections. When configured as the input flag IF1, the data value at the pin is stored in the IF1 bit in the SAISR\_1 register, synchronized by the frame sync in normal mode or the slot in network mode.

FSR\_1 may be programmed as a general-purpose I/O pin (PE1) when the ESAI\_1 FSR\_1 function is not being used.

### 9.2.10 Frame Sync for Transmitter (FST\_1)

FST\_1 is a bidirectional pin providing the frame sync for both the transmitters and receivers in the synchronous mode (SYN=1) and for the transmitters only in asynchronous mode (SYN=0) (see [Table 9-2](#)). The direction of this pin is determined by the TFSD bit in the TCR\_1 register. When configured as an output, this pin is the internally generated frame sync signal. When configured as an input, this pin receives an external frame sync signal for the transmitters (and the receivers in synchronous mode).

FST\_1 may be programmed as a general-purpose I/O pin (PE4) when the ESAI\_1 FST\_1 function is not being used.

### 9.2.11 High Frequency Clock for Transmitter (HCKT\_1)

HCKT\_1 is a bidirectional pin providing the transmitters high frequency clock for the ESAI\_1 interface. The direction of this pin is determined by the THCKD bit in the TCCR\_1 register. In the asynchronous mode (SYN=0), the HCKT\_1 pin operates as the high frequency clock input or output used by all enabled transmitters. In the synchronous mode (SYN=1), it operates as the high frequency clock input or output used by all enabled transmitters and receivers. When programmed as input this pin is used as an alternative high frequency clock source to the ESAI\_1 transmitter rather than the DSP main clock or audio master clock. When programmed as output it can serve as a high frequency sample clock (to external DACs for example) or as an additional system clock. See [Table 9-2](#).

HCKT\_1 may be programmed as a general-purpose I/O pin (PE5) when the ESAI\_1 HCKT\_1 function is not being used.

### 9.2.12 High Frequency Clock for Receiver (HCKR\_1)

HCKR\_1 is a bidirectional pin providing the receivers high frequency clock for the ESAI\_1 interface. The direction of this pin is determined by the RHCKD bit in the RCCR\_1 register. In the asynchronous mode (SYN=0), the HCKR\_1 pin operates as the high frequency clock input or output used by all the enabled receivers. In the synchronous mode (SYN=1), it operates as the serial flag 2 pin. For further information on pin mode and definition, see [Table 9-9](#) and on receiver clock signals see [Table 9-1](#).

When this pin is configured as serial flag pin, its direction is determined by the RHCKD bit in the RCCR\_1 register. When configured as the output flag OF2, this pin reflects the value of the OF2 bit in the SAICR\_1 register, and the data in the OF2 bit shows up at the pin synchronized to the frame sync being used by the transmitter and receiver sections. When configured as the input flag IF2, the data value at the pin is stored in the IF2 bit in the SAISR\_1 register, synchronized by the frame sync in normal mode or the slot in network mode.

HCKR\_1 may be programmed as a general-purpose I/O pin (PE2) when the ESAI\_1 HCKR\_1 function is not being used.

## 9.3 ESAI\_1 Programming Model

The ESAI\_1 can be viewed as five control registers, one status register, six transmit data registers, four receive data registers, two transmit slot mask registers, two receive slot mask registers and a special-purpose time slot register. The following paragraphs give detailed descriptions and operations of each bit in the ESAI\_1 registers.

The ESAI\_1 also contains the GPIO Port E functionality, described in [Section 9.5, "GPIO - Pins and Registers"](#).

### 9.3.1 ESAI\_1 Transmitter Clock Control Register (TCCR\_1)

The read/write Transmitter Clock Control Register (TCCR\_1) controls the ESAI\_1 transmitter clock generator bit and frame sync rates, the bit rate and high frequency clock sources and the directions of the FST\_1 and SCKT\_1 signals. In synchronous mode, the bit clock defined for the transmitter determines the receiver bit clock as well. TCCR\_1 also controls the number of words per frame for the serial data.

Note that care should be taken in asynchronous mode whenever the framesync clock (FSR\_1, FST\_1) is not sourced directly from its associated bit clock (SCKR\_1, SCKT\_1). Proper phase relationships must be maintained between these clocks in order to guarantee proper operation of the ESAI.

Hardware and software reset clear all the bits of the TCCR\_1 register.

	11	10	9	8	7	6	5	4	3	2	1	0
Y:\$FFFF96	TDC2	TDC1	TDC0	TPSR	TPM7	TPM6	TPM5	TPM4	TPM3	TPM2	TPM1	TPM0
	23	22	21	20	19	18	17	16	15	14	13	12
	THCKD	TFSD	TCKD	THCKP	TFSP	TCKP	TFP3	TFP2	TFP1	TFP0	TDC4	TDC3

Figure 9-2 TCCR\_1 Register

### 9.3.1.1 TCCR\_1 Transmit Prescale Modulus Select (TPM7–TPM0) - Bits 7–0

The TPM7–TPM0 bits specify the divide ratio of the prescale divider in the ESAI\_1 transmitter clock generator. A divide ratio from 1 to 256 (TPM[7:0]=\$00 to \$FF) may be selected. The bit clock output is available at the transmit serial bit clock (SCKT\_1) pin of the DSP. The bit clock output is also available internally for use as the bit clock to shift the transmit and receive shift registers. The ESAI\_1 transmit clock generator functional diagram is shown in [Figure 9-3](#).

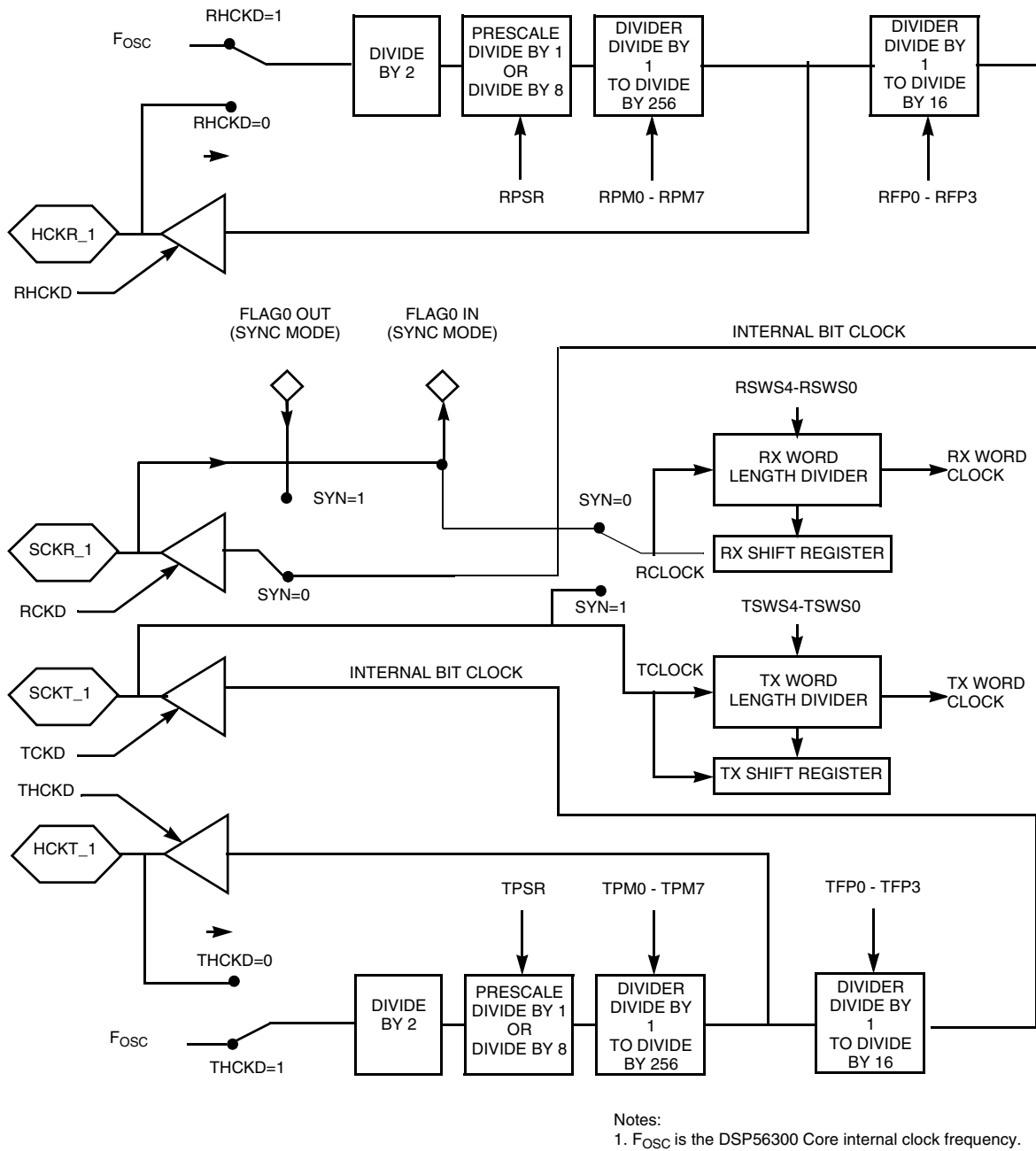


Figure 9-3 ESAI\_1 Clock Generator Functional Block Diagram

### 9.3.1.2 TCCR\_1 Transmit Prescaler Range (TPSR) - Bit 8

The TPSR bit controls a fixed divide-by-eight prescaler in series with the variable prescaler. This bit is used to extend the range of the prescaler for those cases where a slower bit clock is desired. When TPSR is set, the fixed prescaler is bypassed. When TPSR is cleared, the fixed divide-by-eight prescaler is operational (see [Figure 9-3](#)). The maximum internally generated bit clock frequency is  $F_{osc}/4$ ; the minimum internally generated bit clock frequency is  $F_{osc}/(2 \times 8 \times 256) = F_{osc}/4096$ .

#### NOTE

Do not use the combination  $TPSR=1$  and  $TPM7-TPM0=\$00$ , which causes synchronization problems when using the internal DSP clock as source ( $TCKD=1$  or  $THCKD=1$ ).

### 9.3.1.3 TCCR\_1 Tx Frame Rate Divider Control (TDC4–TDC0) - Bits 13–9

The TDC4–TDC0 bits control the divide ratio for the programmable frame rate dividers used to generate the transmitter frame clocks.

In network mode, this ratio may be interpreted as the number of words per frame minus one. The divide ratio may range from 2 to 32 ( $TDC[4:0]=00001$  to  $11111$ ) for network mode. A divide ratio of one ( $TDC[4:0]=00000$ ) in network mode is a special case (on-demand mode).

In normal mode, this ratio determines the word transfer rate. The divide ratio may range from 1 to 32 ( $TDC[4:0]=00000$  to  $11111$ ) for normal mode. In normal mode, a divide ratio of 1 ( $TDC[4:0]=00000$ ) provides continuous periodic data word transfers. A bit-length frame sync ( $TFSL=1$ ) must be used in this case.

The ESAI frame sync generator functional diagram is shown in [Figure 9-4](#).



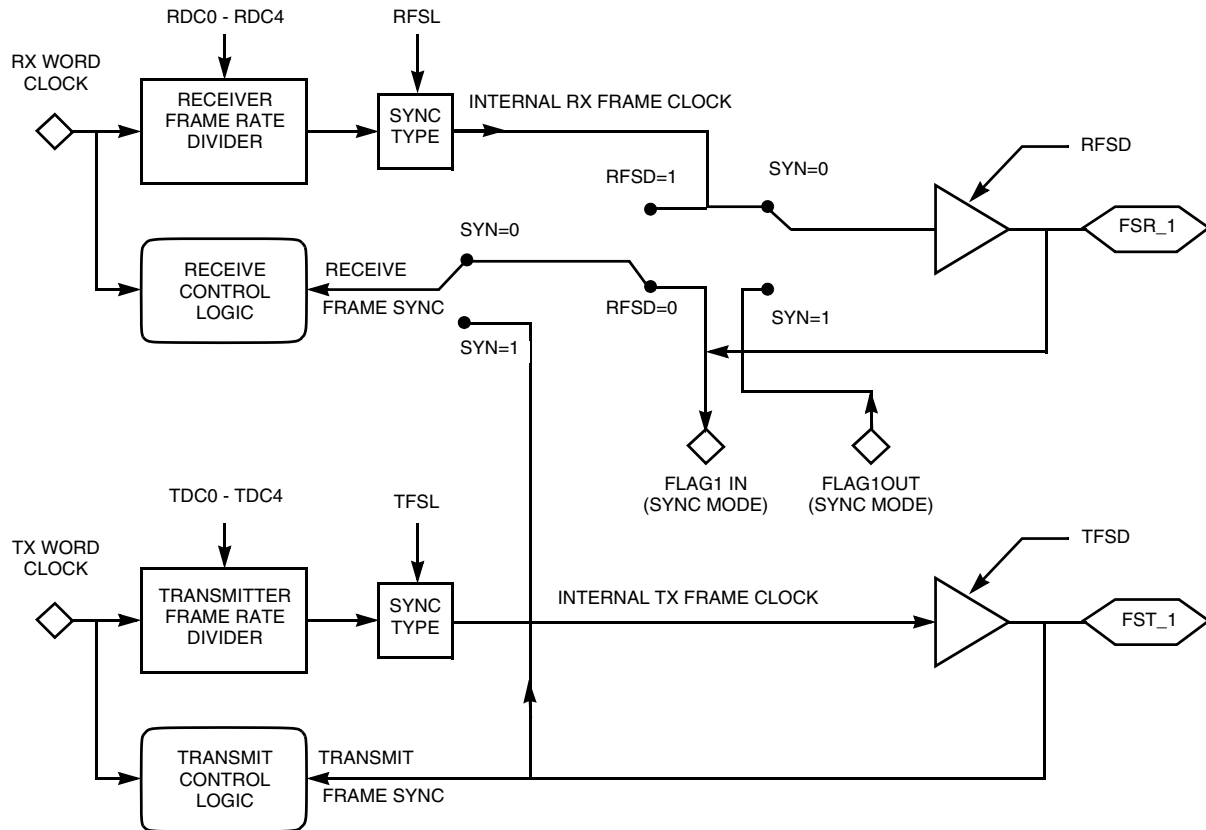


Figure 9-4 ESAI\_1 Frame Sync Generator Functional Block Diagram

### 9.3.1.4 TCCR\_1 Tx High Frequency Clock Divider (TFP3-TFP0) - Bits 17–14

The TFP3–TFP0 bits control the divide ratio of the transmitter high frequency clock to the transmitter serial bit clock when the source of the high frequency clock and the bit clock is the internal DSP clock. When the HCKT\_1 input is being driven from an external high frequency clock, the TFP3–TFP0 bits specify an additional division ratio in the clock divider chain. See [Table 9-3](#) for the specification of the divide ratio. The ESAI\_1 high frequency clock generator functional diagram is shown in [Figure 9-3](#).

Table 9-3 Transmitter High Frequency Clock Divider

TFP3-TFP0	Divide Ratio
\$0	1
\$1	2
\$2	3
\$3	4
...	...
\$F	16

### 9.3.1.5 TCCR\_1 Transmit Clock Polarity (TCKP) - Bit 18

The Transmitter Clock Polarity (TCKP) bit controls on which bit clock edge data and frame sync are clocked out and latched in. If TCKP is cleared the data and the frame sync are clocked out on the rising edge of the transmit bit clock and latched in on the falling edge of the transmit bit clock. If TCKP is set the falling edge of the transmit clock is used to clock the data out and frame sync and the rising edge of the transmit clock is used to latch the data and frame sync in.

### 9.3.1.6 TCCR\_1 Transmit Frame Sync Polarity (TFSP) - Bit 19

The Transmitter Frame Sync Polarity (TFSP) bit determines the polarity of the transmit frame sync signal. When TFSP is cleared, the frame sync signal polarity is positive, i.e., the frame start is indicated by a high level on the frame sync pin. When TFSP is set, the frame sync signal polarity is negative, i.e., the frame start is indicated by a low level on the frame sync pin.

### 9.3.1.7 TCCR\_1 Transmit High Frequency Clock Polarity (THCKP) - Bit 20

The Transmitter High Frequency Clock Polarity (THCKP) bit controls on which bit clock edge data and frame sync are clocked out and latched in. If THCKP is cleared the data and the frame sync are clocked out on the rising edge of the high frequency transmit bit clock and latched in on the falling edge of the transmit bit clock. If THCKP is set the falling edge of the transmit clock is used to clock the data out and frame sync and the rising edge of the transmit clock is used to latch the data and frame sync in.

### 9.3.1.8 TCCR\_1 Transmit Clock Source Direction (TCKD) - Bit 21

The Transmitter Clock Source Direction (TCKD) bit selects the source of the clock signal used to clock the transmit shift registers in the asynchronous mode (SYN=0) and the transmit shift registers and the receive shift registers in the synchronous mode (SYN=1). When TCKD is set, the internal clock source becomes the bit clock for the transmit shift registers and word length divider and is the output on the SCKT\_1 pin. When TCKD is cleared, the clock source is external; the internal clock generator is disconnected from the SCKT\_1 pin, and an external clock source may drive this pin. See [Table 9-2](#).

### 9.3.1.9 TCCR\_1 Transmit Frame Sync Signal Direction (TFSD) - Bit 22

TFSD controls the direction of the FST\_1 pin. When TFSD is cleared, FST\_1 is an input; when TFSD is set, FST\_1 is an output. See [Table 9-2](#).

### 9.3.1.10 TCCR\_1 Transmit High Frequency Clock Direction (THCKD) - Bit 23

THCKD controls the direction of the HCKT\_1 pin. When THCKD is cleared, HCKT\_1 is an input; when THCKD is set, HCKT\_1 is an output. See [Table 9-2](#).

## 9.3.2 ESAI\_1 Transmit Control Register (TCR\_1)

The read/write Transmit Control Register (TCR\_1) controls the ESAI\_1 transmitter section. Interrupt enable bits for the transmitter section are provided in this control register. Operating modes are also selected in this register. See [Figure 9-5](#).

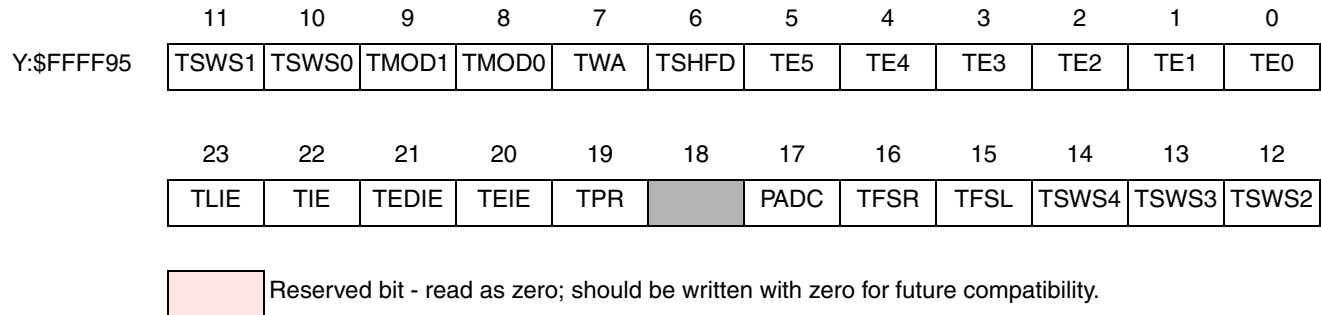


Figure 9-5 TCR\_1 Register

Hardware and software reset clear all the bits in the TCR\_1 register.

The TCR bits are described in the following paragraphs.

### 9.3.2.1 TCR\_1 ESAI\_1 Transmit 0 Enable (TE0) - Bit 0

TE0 enables the transfer of data from TX0\_1 to the transmit shift register #0. When TE0 is set and a frame sync is detected, the transmit #0 portion of the ESAI is enabled for that frame. When TE0 is cleared, the transmitter #0 is disabled after completing transmission of data currently in the ESAI\_1 transmit shift register. The SDO0\_1 output is tri-stated, and any data present in TX0\_1 is not transmitted, i.e., data can be written to TX0\_1 with TE0 cleared, but data is not transferred to the transmit shift register #0.

The normal mode transmit enable sequence is to write data to one or more transmit data registers before setting TEx. The normal transmit disable sequence is to clear TEx, TIE and TEIE after TDE equals one.

In the network mode, the operation of clearing TE0 and setting it again disables the transmitter #0 after completing transmission of the current data word until the beginning of the next frame. During that time period, the SDO0\_1 pin remains in the high-impedance state. The on-demand mode transmit enable sequence can be the same as the normal mode, or TE0 can be left enabled.

### 9.3.2.2 TCR\_1 ESAI\_1 Transmit 1 Enable (TE1) - Bit 1

TE1 enables the transfer of data from TX1\_1 to the transmit shift register #1. When TE1 is set and a frame sync is detected, the transmit #1 portion of the ESAI is enabled for that frame. When TE1 is cleared, the transmitter #1 is disabled after completing transmission of data currently in the ESAI transmit shift register. The SDO1\_1 output is tri-stated, and any data present in TX1\_1 is not transmitted, i.e., data can be written to TX1\_1 with TE1 cleared, but data is not transferred to the transmit shift register #1.

The normal mode transmit enable sequence is to write data to one or more transmit data registers before setting TEx. The normal transmit disable sequence is to clear TEx, TIE and TEIE after TDE equals one.

In the network mode, the operation of clearing TE1 and setting it again disables the transmitter #1 after completing transmission of the current data word until the beginning of the next frame. During that time period, the SDO1\_1 pin remains in the high-impedance state. The on-demand mode transmit enable sequence can be the same as the normal mode, or TE1 can be left enabled.

### 9.3.2.3 TCR\_1 ESAI\_1 Transmit 2 Enable (TE2) - Bit 2

TE2 enables the transfer of data from TX2\_1 to the transmit shift register #2. When TE2 is set and a frame sync is detected, the transmit #2 portion of the ESAI\_1 is enabled for that frame. When TE2 is cleared, the transmitter #2 is disabled after completing transmission of data currently in the ESAI\_1 transmit shift register. Data can be written to TX2\_1 when TE2 is cleared but the data is not transferred to the transmit shift register #2.

The SDO2\_1/SDI3\_1 pin is the data input pin for RX3\_1 if TE2 is cleared and RE3\_1 in the RCR\_1 register is set. If both RE3\_1 and TE2\_1 are cleared, the transmitter and receiver are disabled, and the pin is tri-stated. Both RE3\_1 and TE2\_1 should not be set at the same time.

The normal mode transmit enable sequence is to write data to one or more transmit data registers before setting TEx. The normal transmit disable sequence is to clear TEx, TIE and TEIE after TDE equals one.

In the network mode, the operation of clearing TE2 and setting it again disables the transmitter #2 after completing transmission of the current data word until the beginning of the next frame. During that time period, the SDO2\_1/SDI3\_1 pin remains in the high-impedance state. The on-demand mode transmit enable sequence can be the same as the normal mode, or TE2\_1 can be left enabled.

### 9.3.2.4 TCR\_1 ESAI\_1 Transmit 3 Enable (TE3) - Bit 3

TE3 enables the transfer of data from TX3\_1 to the transmit shift register #3. When TE3 is set and a frame sync is detected, the transmit #3 portion of the ESAI\_1 is enabled for that frame. When TE3 is cleared, the transmitter #3 is disabled after completing transmission of data currently in the ESAI\_1 transmit shift register. Data can be written to TX3\_1 when TE3 is cleared but the data is not transferred to the transmit shift register #3.

The SDO3\_1/SDI2\_1 pin is the data input pin for RX2\_1 if TE3 is cleared and RE2 in the RCR\_1 register is set. If both RE2 and TE3 are cleared, the transmitter and receiver are disabled, and the pin is tri-stated. Both RE2 and TE3 should not be set at the same time.

The normal mode transmit enable sequence is to write data to one or more transmit data registers before setting TEx. The normal transmit disable sequence is to clear TEx, TIE and TEIE after TDE equals one.

In the network mode, the operation of clearing TE3 and setting it again disables the transmitter #3 after completing transmission of the current data word until the beginning of the next frame. During that time period, the SDO3\_1/SDI2\_1 pin remains in the high-impedance state. The on-demand mode transmit enable sequence can be the same as the normal mode, or TE3 can be left enabled.

### 9.3.2.5 TCR\_1 ESAI\_1 Transmit 4 Enable (TE4) - Bit 4

TE4 enables the transfer of data from TX4\_1 to the transmit shift register #4. When TE4 is set and a frame sync is detected, the transmit #4 portion of the ESAI\_1 is enabled for that frame. When TE4 is cleared, the transmitter #4 is disabled after completing transmission of data currently in the ESAI\_1 transmit shift register. Data can be written to TX4\_1 when TE4 is cleared but the data is not transferred to the transmit shift register #4.

The SDO4\_1/SDI1\_1 pin is the data input pin for RX1\_1 if TE4 is cleared and RE1 in the RCR\_1 register is set. If both RE1 and TE4 are cleared, the transmitter and receiver are disabled, and the pin is tri-stated. Both RE1 and TE4 should not be set at the same time.

The normal mode transmit enable sequence is to write data to one or more transmit data registers before setting TEx. The normal transmit disable sequence is to clear TEx, TIE and TEIE after TDE equals one.

In the network mode, the operation of clearing TE4 and setting it again disables the transmitter #4 after completing transmission of the current data word until the beginning of the next frame. During that time period, the SDO4\_1/SDI1\_1 pin remains in the high-impedance state. The on-demand mode transmit enable sequence can be the same as the normal mode, or TE4 can be left enabled.

### 9.3.2.6 TCR\_1 ESAI\_1 Transmit 5 Enable (TE5) - Bit 5

TE5 enables the transfer of data from TX5\_1 to the transmit shift register #5. When TE5 is set and a frame sync is detected, the transmit #5 portion of the ESAI\_1 is enabled for that frame. When TE5 is cleared, the transmitter #5 is disabled after completing transmission of data currently in the ESAI\_1 transmit shift register. Data can be written to TX5\_1 when TE5 is cleared but the data is not transferred to the transmit shift register #5.

The SDO5\_1/SDI0\_1 pin is the data input pin for RX0\_1 if TE5 is cleared and RE0 in the RCR\_1 register is set. If both RE0 and TE5 are cleared, the transmitter and receiver are disabled, and the pin is tri-stated. Both RE0 and TE5 should not be set at the same time.

The normal mode transmit enable sequence is to write data to one or more transmit data registers before setting TEx. The normal transmit disable sequence is to clear TEx, TIE and TEIE after TDE equals one.

In the network mode, the operation of clearing TE5 and setting it again disables the transmitter #5 after completing transmission of the current data word until the beginning of the next frame. During that time period, the SDO5\_1/SDI0\_1 pin remains in the high-impedance state. The on-demand mode transmit enable sequence can be the same as the normal mode, or TE5 can be left enabled.

### 9.3.2.7 TCR\_1 Transmit Shift Direction (TSHFD) - Bit 6

The TSHFD bit causes the transmit shift registers to shift data out MSB first when TSHFD equals zero or LSB first when TSHFD equals one (see [Figure 9-13](#) and [Figure 9-14](#)).

### 9.3.2.8 TCR\_1 Transmit Word Alignment Control (TWA) - Bit 7

The Transmitter Word Alignment Control (TWA) bit defines the alignment of the data word in relation to the slot. This is relevant for the cases where the word length is shorter than the slot length. If TWA is cleared, the data word is left-aligned in the slot frame during transmission. If TWA is set, the data word is right-aligned in the slot frame during transmission.

Since the data word is shorter than the slot length, the data word is extended until achieving the slot length, according to the following rule:

1. If the data word is left-aligned (TWA=0), and zero padding is disabled (PADC=0), the last data bit is repeated after the data word has been transmitted. If zero padding is enabled (PADC=1), zeroes are transmitted after the data word has been transmitted.

2. If the data word is right-aligned (TWA=1), and zero padding is disabled (PADC=0), the first data bit is repeated before the transmission of the data word. If zero padding is enabled (PADC=1), zeroes are transmitted before the transmission of the data word.

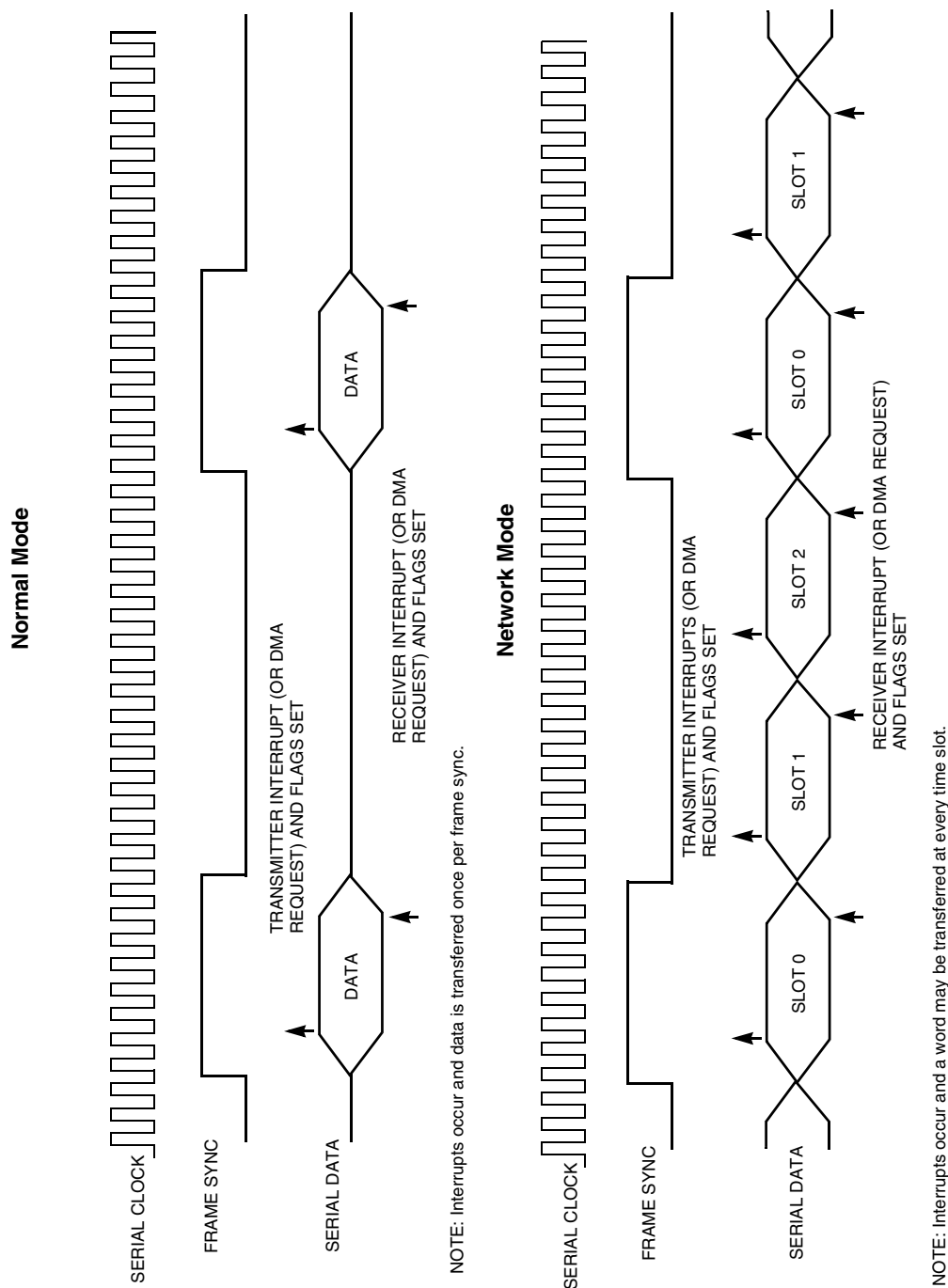
### 9.3.2.9 TCR\_1 Transmit Network Mode Control (TMOD1-TMOD0) - Bits 9-8

The TMOD1 and TMOD0 bits are used to define the network mode of ESAI\_1 transmitters according to [Table 9-4](#). In the normal mode, the frame rate divider determines the word transfer rate – one word is transferred per frame sync during the frame sync time slot, as shown in [Figure 9-6](#). In network mode, it is possible to transfer a word for every time slot, as shown in [Figure 9-6](#). For more details, see [Section 9.4](#), "Operating Modes".

In order to comply with AC-97 specifications, TSWS4-TSWS0 should be set to 00011 (20-bit slot, 20-bit word length), TFSL and TFSR should be cleared and TDC4-TDC0 should be set to \$0C (13 words in frame). If TMOD[1:0]=\$11 and the above recommendations are followed, the first slot and word will be 16 bits long, and the next 12 slots and words will be 20 bits long, as required by the AC97 protocol.

**Table 9-4 Transmit Network Mode Selection**

TMOD1	TMOD0	TDC4-TDC0	Transmitter Network Mode
0	0	\$0-\$1F	Normal Mode
0	1	\$0	On-Demand Mode
0	1	\$1-\$1F	Network Mode
1	0	X	Reserved
1	1	\$0C	AC97



### Figure 9-6 Normal and Network Operation

### 9.3.2.10 TCR\_1 Tx Slot and Word Length Select (TSWS4-TSWS0) - Bits 14-10

The TSWS4-TSWS0 bits are used to select the length of the slot and the length of the data words being transferred via the ESAI\_1. The word length must be equal to or shorter than the slot length. The possible combinations are shown in [Table 9-5](#). See also the ESAI\_1 data path programming model in [Figure 9-13](#) and [Figure 9-14](#).

**Table 9-5 ESAI Transmit Slot and Word Length Selection**

TSWS4	TSWS3	TSWS2	TSWS1	TSWS0	SLOT LENGTH	WORD LENGTH
0	0	0	0	0	8	8
0	0	1	0	0	12	8
0	0	0	0	1		12
0	1	0	0	0	16	8
0	0	1	0	1		12
0	0	0	1	0		16
0	1	1	0	0	20	8
0	1	0	0	1		12
0	0	1	1	0		16
0	0	0	1	1		20
1	0	0	0	0	24	8
0	1	1	0	1		12
0	1	0	1	0		16
0	0	1	1	1		20
1	1	1	1	0		24
1	1	0	0	0	32	8
1	0	1	0	1		12
1	0	0	1	0		16
0	1	1	1	1		20
1	1	1	1	1		24



Table 9-5 ESAI Transmit Slot and Word Length Selection (continued)

TSWS4	TSWS3	TSWS2	TSWS1	TSWS0	SLOT LENGTH	WORD LENGTH
0	1	0	1	1	Reserved	
0	1	1	1	0		
1	0	0	0	1		
1	0	0	1	1		
1	0	1	0	0		
1	0	1	1	0		
1	0	1	1	1		
1	1	0	0	1		
1	1	0	1	0		
1	1	0	1	1		
1	1	1	0	0		
1	1	1	0	1		

### 9.3.2.11 TCR\_1 Transmit Frame Sync Length (TFSL) - Bit 15

The TFSL bit selects the length of frame sync to be generated or recognized. If TFSL is cleared, a word-length frame sync is selected. If TFSL is set, a 1-bit clock period frame sync is selected. See [Figure 9-7](#) for examples of frame length selection.

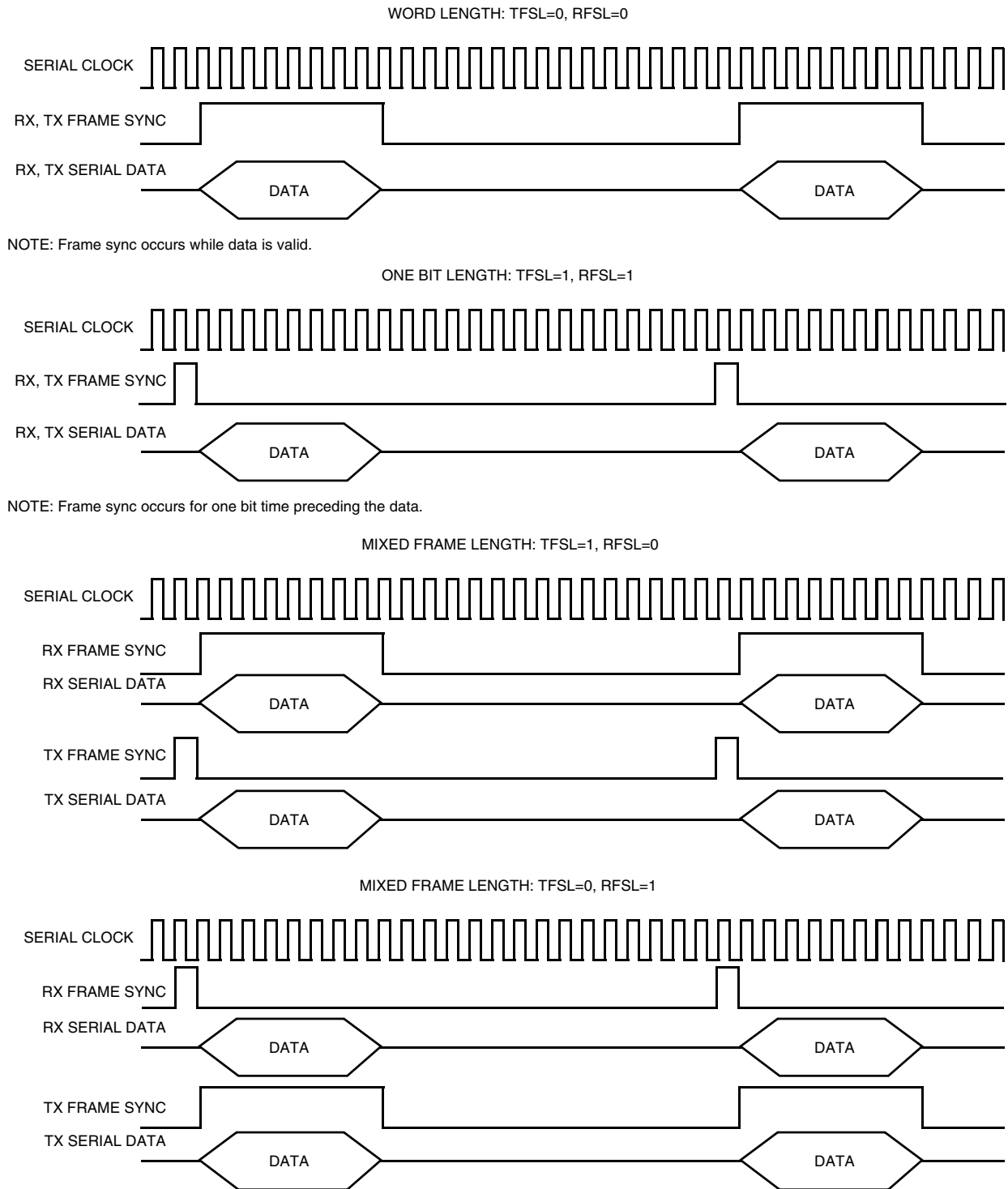


Figure 9-7 Frame Length Selection

### 9.3.2.12 TCR\_1 Transmit Frame Sync Relative Timing (TFSR) - Bit 16

TFSR determines the relative timing of the transmit frame sync signal as referred to the serial data lines, for a word length frame sync only (TFSL=0). When TFSR is cleared the word length frame sync occurs together with the first bit of the data word of the first slot. When TFSR is set the word length frame sync starts one serial clock cycle earlier, i.e., together with the last bit of the previous data word.

### 9.3.2.13 TCR\_1 Transmit Zero Padding Control (PADC) - Bit 17

When PADC is cleared, zero padding is disabled. When PADC is set, zero padding is enabled. PADC, in conjunction with the TWA control bit, determines the way that padding is done for operating modes where the word length is less than the slot length. See the TWA bit description in [Section 9.3.2.8, "TCR\\_1 Transmit Word Alignment Control \(TWA\) - Bit 7"](#) for more details.

Since the data word is shorter than the slot length, the data word is extended until achieving the slot length, according to the following rule:

1. If the data word is left-aligned (TWA=0), and zero padding is disabled (PADC=0), the last data bit is repeated after the data word has been transmitted. If zero padding is enabled (PADC=1), zeroes are transmitted after the data word has been transmitted.
2. If the data word is right-aligned (TWA=1), and zero padding is disabled (PADC=0), the first data bit is repeated before the transmission of the data word. If zero padding is enabled (PADC=1), zeroes are transmitted before the transmission of the data word.

### 9.3.2.14 Reserved - Bit 18

This bit is reserved. It is read as zero and should be written with zero for future compatibility.

### 9.3.2.15 TCR\_1 Transmit Section Personal Reset (TPR) - Bit 19

The TPR control bit is used to put the transmitter section of the ESAI\_1 in the personal reset state. The receiver section is not affected. When TPR is cleared, the transmitter section may operate normally. When TPR is set, the transmitter section enters the personal reset state immediately. When in the personal reset state, the status bits are reset to the same state as after hardware reset. The control bits are not affected by the personal reset state. The transmitter data pins are tri-stated while in the personal reset state; if a stable logic level is desired, the transmitter data pins should be defined as GPIO outputs, or external pull-up or pull-down resistors should be used. The transmitter clock outputs drive zeroes while in the personal reset state. Note that to leave the personal reset state by clearing TPR, the procedure described in [Section 9.6, "ESAI\\_1 Initialization Examples"](#) should be followed.

### 9.3.2.16 TCR\_1 Transmit Exception Interrupt Enable (TEIE) - Bit 20

When TEIE is set, the DSP is interrupted when both TDE and TUE in the SAISR\_1 status register are set. When TEIE is cleared, this interrupt is disabled. Reading the SAISR\_1 status register followed by writing to all the data registers of the enabled transmitters clears TUE, thus clearing the pending interrupt.

### 9.3.2.17 TCR\_1 Transmit Even Slot Data Interrupt Enable (TEDIE) - Bit 21

The TEDIE control bit is used to enable the transmit even slot data interrupts. If TEDIE is set, the transmit even slot data interrupts are enabled. If TEDIE is cleared, the transmit even slot data interrupts are disabled. A transmit even slot data interrupt request is generated if TEDIE is set and the TEDE status flag in the SAISR\_1 status register is set. Even time slots are all even-numbered time slots (0, 2, 4, etc.) when operating in network mode. The zero time slot in the frame is marked by the frame sync signal and is considered to be even. Writing data to all the data registers of the enabled transmitters or to TSR clears the TEDE flag, thus servicing the interrupt.

Transmit interrupts with exception have higher priority than transmit even slot data interrupts, therefore if exception occurs (TUE is set) and TEIE is set, the ESAI\_1 requests an ESAI\_1 transmit data with exception interrupt from the interrupt controller.

### 9.3.2.18 TCR\_1 Transmit Interrupt Enable (TIE) - Bit 22

The DSP is interrupted when TIE and the TDE flag in the SAISR\_1 status register are set. When TIE is cleared, this interrupt is disabled. Writing data to all the data registers of the enabled transmitters or to TSR clears TDE, thus clearing the interrupt.

Transmit interrupts with exception have higher priority than normal transmit data interrupts, therefore if exception occurs (TUE is set) and TEIE is set, the ESAI\_1 requests an ESAI\_1 transmit data with exception interrupt from the interrupt controller.

### 9.3.2.19 TCR\_1 Transmit Last Slot Interrupt Enable (TLIE) - Bit 23

TLIE enables an interrupt at the beginning of last slot of a frame in network mode. When TLIE is set the DSP is interrupted at the start of the last slot in a frame in network mode regardless of the transmit mask register setting. When TLIE is cleared the transmit last slot interrupt is disabled. TLIE is disabled when TDC[4:0]=\$00000 (on-demand mode). The use of the transmit last slot interrupt is described in [Section 9.4.3, "ESAI\\_1 Interrupt Requests"](#).

## 9.3.3 ESAI\_1 Receive Clock Control Register (RCCR\_1)

The read/write Receive Clock Control Register (RCCR\_1) controls the ESAI\_1 receiver clock generator bit and frame sync rates, word length and number of words per frame for the serial data. The RCCR\_1 control bits are described in the following paragraphs (see [Figure 9-8](#)).

	11	10	9	8	7	6	5	4	3	2	1	0
Y:\$FFFF98	RDC2	RDC1	RDC0	RPSR	RPM7	RPM6	RPM5	RPM4	RPM3	RPM2	RPM1	RPM0
	23	22	21	20	19	18	17	16	15	14	13	12
	RHCKD	RFSD	RCKD	RHCKP	RFSP	RCKP	RFP3	RFP2	RFP1	RFP0	RDC4	RDC3

**Figure 9-8 RCCR\_1 Register**

Hardware and software reset clear all the bits of the RCCR\_1 register.

### 9.3.3.1 RCCR\_1 Receiver Prescale Modulus Select (RPM7–RPM0) - Bits 7–0

The RPM7–RPM0 bits specify the divide ratio of the prescale divider in the ESAI\_1 receiver clock generator. A divide ratio from 1 to 256 ( $RPM[7:0] = \$00$  to  $\$FF$ ) may be selected. The bit clock output is available at the receiver serial bit clock (SCKR\_1) pin of the DSP. The bit clock output is also available internally for use as the bit clock to shift the receive shift registers. The ESAI\_1 receive clock generator functional diagram is shown in [Figure 9-3](#).

### 9.3.3.2 RCCR\_1 Receiver Prescaler Range (RPSR) - Bit 8

The RPSR controls a fixed divide-by-eight prescaler in series with the variable prescaler. This bit is used to extend the range of the prescaler for those cases where a slower bit clock is desired. When RPSR is set, the fixed prescaler is bypassed. When RPSR is cleared, the fixed divide-by-eight prescaler is operational (see [Figure 9-3](#)). The maximum internally generated bit clock frequency is  $F_{osc}/4$ , the minimum internally generated bit clock frequency is  $F_{osc}/(2 \times 8 \times 256) = F_{osc}/4096$ .

#### NOTE

Do not use the combination  $RPSR=1$  and  $RPM7-RPM0=\$00$ , which causes synchronization problems when using the internal DSP clock as source ( $RHCKD=1$  or  $RCKD=1$ ).

### 9.3.3.3 RCCR\_1 Rx Frame Rate Divider Control (RDC4–RDC0) - Bits 13–9

The RDC4–RDC0 bits control the divide ratio for the programmable frame rate dividers used to generate the receiver frame clocks.

In network mode, this ratio may be interpreted as the number of words per frame minus one. The divide ratio may range from 2 to 32 ( $RDC[4:0] = 00001$  to  $11111$ ) for network mode. A divide ratio of one ( $RDC[4:0] = 00000$ ) in network mode is a special case (on-demand mode).

In normal mode, this ratio determines the word transfer rate. The divide ratio may range from 1 to 32 ( $RDC[4:0] = 00000$  to  $11111$ ) for normal mode. In normal mode, a divide ratio of one ( $RDC[4:0] = 00000$ ) provides continuous periodic data word transfers. A bit-length frame sync ( $RFSL=1$ ) must be used in this case.

The ESAI\_1 frame sync generator functional diagram is shown in [Figure 9-4](#).

### 9.3.3.4 RCCR\_1 Rx High Frequency Clock Divider (RFP3–RFP0) - Bits 14–17

The RFP3–RFP0 bits control the divide ratio of the receiver high frequency clock to the receiver serial bit clock when the source of the receiver high frequency clock and the bit clock is the internal DSP clock. When the HCKR\_1 input is being driven from an external high frequency clock, the RFP3–RFP0 bits specify an additional division ration in the clock divider chain. See [Table 9-6](#) for the specification of the divide ratio. The ESAI\_1 high frequency generator functional diagram is shown in [Figure 9-3](#).

**Table 9-6 Receiver High Frequency Clock Divider**

RFP3-RFP0	Divide Ratio
\$0	1
\$1	2
\$2	3
\$3	4
...	...
\$F	16

### 9.3.3.5 RCCR\_1 Receiver Clock Polarity (RCKP) - Bit 18

The Receiver Clock Polarity (RCKP) bit controls on which bit clock edge data and frame sync are clocked out and latched in. If RCKP is cleared the data and the frame sync are clocked out on the rising edge of the receive bit clock and the frame sync is latched in on the falling edge of the receive bit clock. If RCKP is set the falling edge of the receive clock is used to clock the data and frame sync out and the rising edge of the receive clock is used to latch the frame sync in.

### 9.3.3.6 RCCR\_1 Receiver Frame Sync Polarity (RFSP) - Bit 19

The Receiver Frame Sync Polarity (RFSP) determines the polarity of the receive frame sync signal. When RFSP is cleared the frame sync signal polarity is positive, i.e., the frame start is indicated by a high level on the frame sync pin. When RFSP is set the frame sync signal polarity is negative, i.e., the frame start is indicated by a low level on the frame sync pin.

### 9.3.3.7 RCCR\_1 Receiver High Frequency Clock Polarity (RHCKP) - Bit 20

The Receiver High Frequency Clock Polarity (RHCKP) bit controls on which bit clock edge data and frame sync are clocked out and latched in. If RHCKP is cleared the data and the frame sync are clocked out on the rising edge of the high frequency receive bit clock and the frame sync is latched in on the falling edge of the receive bit clock. If RHCKP is set the falling edge of the receive clock is used to clock the data and frame sync out and the rising edge of the receive clock is used to latch the frame sync in.

### 9.3.3.8 RCCR\_1 Receiver Clock Source Direction (RCKD) - Bit 21

The Receiver Clock Source Direction (RCKD) bit selects the source of the clock signal used to clock the receive shift register in the asynchronous mode (SYN=0) and the IF0/OF0 flag direction in the synchronous mode (SYN=1).

In the asynchronous mode, when RCKD is set, the internal clock source becomes the bit clock for the receive shift registers and word length divider and is the output on the SCKR\_1 pin. In the asynchronous mode when RCKD is cleared, the clock source is external; the internal clock generator is disconnected from the SCKR\_1 pin, and an external clock source may drive this pin.

In the synchronous mode when RCKD is set, the SCKR\_1 pin becomes the OF0 output flag. If RCKD is cleared, the SCKR\_1 pin becomes the IF0 input flag. See [Table 9-1](#) and [Table 9-7](#).

**Table 9-7 SCKR Pin Definition Table**

Control Bits		SCKR_1 PIN
SYN	RCKD	
0	0	SCKR_1 input
0	1	SCKR_1 output
1	0	IF0
1	1	OF0

### 9.3.3.9 RCCR\_1 Receiver Frame Sync Signal Direction (RFSD) - Bit 22

The Receiver Frame Sync Signal Direction (RFSD) bit selects the source of the receiver frame sync signal when in the asynchronous mode (SYN=0) and the IF1/OF1/Transmitter Buffer Enable flag direction in the synchronous mode (SYN=1).

In the asynchronous mode, when RFSD is set, the internal clock generator becomes the source of the receiver frame sync, and is the output on the FSR\_1 pin. In the asynchronous mode when RFSD is cleared, the receiver frame sync source is external; the internal clock generator is disconnected from the FSR\_1 pin, and an external clock source may drive this pin.

In the synchronous mode when RFSD is set, the FSR\_1 pin becomes the OF1 output flag or the Transmitter Buffer Enable, according to the TEBE control bit. If RFSD is cleared, the FSR\_1 pin becomes the IF1 input flag. See [Table 9-1](#) and [Table 9-8](#).

**Table 9-8 FSR\_1 Pin Definition Table**

Control Bits			FSR_1 Pin
SYN	TEBE	RFSD	
0	X	0	FSR_1 input
0	X	1	FSR_1 output
1	0	0	IF1
1	0	1	OF1
1	1	0	reserved
1	1	1	Transmitter Buffer Enable

### 9.3.3.10 RCCR\_1 Receiver High Frequency Clock Direction (RHCKD) - Bit 23

The Receiver High Frequency Clock Direction (RHCKD) bit selects the source of the receiver high frequency clock when in the asynchronous mode (SYN=0) and the IF2/OF2 flag direction in the synchronous mode (SYN=1).

In the asynchronous mode, when RHCKD is set, the internal clock generator becomes the source of the receiver high frequency clock and is the output on the HCKR\_1 pin. In the asynchronous mode when RHCKD is cleared, the receiver high frequency clock source is external; the internal clock generator is disconnected from the HCKR\_1 pin, and an external clock source may drive this pin.

When RHCKD is cleared, HCKR\_1 is an input; when RHCKD is set, HCKR\_1 is an output.

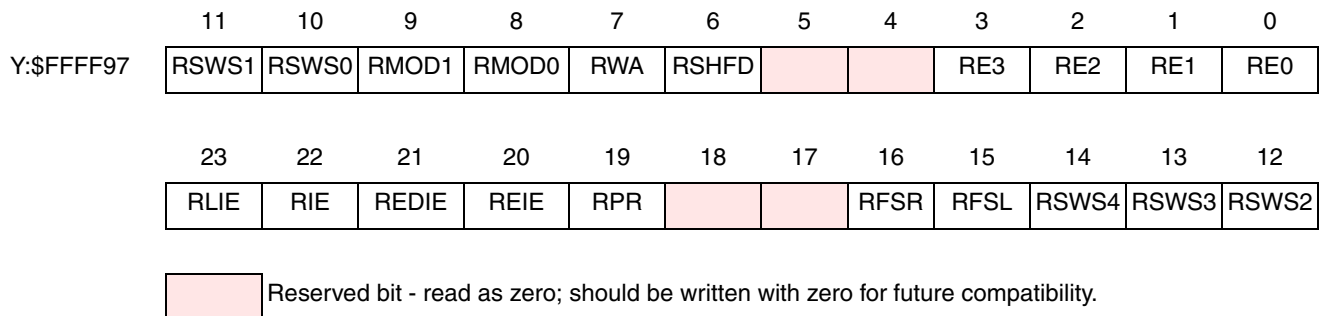
In the synchronous mode when RHCKD is set, the HCKR\_1 pin becomes the OF2 output flag. If RHCKD is cleared, the HCKR\_1 pin becomes the IF2 input flag. See [Table 9-1](#) and [Table 9-9](#).

**Table 9-9 HCKR\_1 Pin Definition Table**

Control Bits		HCKR_1 PIN
SYN	RHCKD	
0	0	HCKR_1 input
0	1	HCKR_1 output
1	0	IF2
1	1	OF2

### 9.3.4 ESAI\_1 Receive Control Register (RCR\_1)

The read/write Receive Control Register (RCR\_1) controls the ESAI\_1 receiver section. Interrupt enable bits for the receivers are provided in this control register. The receivers are enabled in this register (0,1,2 or 3 receivers can be enabled) if the input data pin is not used by a transmitter. Operating modes are also selected in this register.



**Figure 9-9 RCR\_1 Register**

Hardware and software reset clear all the bits in the RCR\_1 register.

The ESAI RCR bits are described in the following paragraphs.

#### 9.3.4.1 RCR\_1 ESAI\_1 Receiver 0 Enable (RE0) - Bit 0

When RE0 is set and TE5 is cleared, the ESAI\_1 receiver 0 is enabled and samples data at the SDO5\_1/SDIO\_1 pin. TX5\_1 and RX0\_1 should not be enabled at the same time (RE0=1 and TE5=1). When RE0 is cleared, receiver 0 is disabled by inhibiting data transfer into RX0\_1. If this bit is cleared while receiving a data word, the remainder of the word is shifted in and transferred to the RX0\_1 data register.



If RE0 is set while some of the other receivers are already in operation, the first data word received in RX0\_1 will be invalid and must be discarded.

#### 9.3.4.2 RCR\_1 ESAI\_1 Receiver 1 Enable (RE1) - Bit 1

When RE1 is set and TE4 is cleared, the ESAI\_1 receiver 1 is enabled and samples data at the SDO4\_1/SDI1\_1 pin. TX4\_1 and RX1\_1 should not be enabled at the same time (RE1=1 and TE4=1). When RE1 is cleared, receiver 1 is disabled by inhibiting data transfer into RX1\_1. If this bit is cleared while receiving a data word, the remainder of the word is shifted in and transferred to the RX1\_1 data register.

If RE1 is set while some of the other receivers are already in operation, the first data word received in RX1\_1 will be invalid and must be discarded.

#### 9.3.4.3 RCR\_1 ESAI\_1 Receiver 2 Enable (RE2) - Bit 2

When RE2 is set and TE3 is cleared, the ESAI\_1 receiver 2 is enabled and samples data at the SDO3\_1/SDI2\_1 pin. TX3\_1 and RX2\_1 should not be enabled at the same time (RE2=1 and TE3=1). When RE2 is cleared, receiver 2 is disabled by inhibiting data transfer into RX2\_1. If this bit is cleared while receiving a data word, the remainder of the word is shifted in and transferred to the RX2\_1 data register.

If RE2 is set while some of the other receivers are already in operation, the first data word received in RX2\_1 will be invalid and must be discarded.

#### 9.3.4.4 RCR\_1 ESAI\_1 Receiver 3 Enable (RE3) - Bit 3

When RE3 is set and TE2 is cleared, the ESAI\_1 receiver 3 is enabled and samples data at the SDO2\_1/SDI3\_1 pin. TX2\_1 and RX3\_1 should not be enabled at the same time (RE3=1 and TE2=1). When RE3 is cleared, receiver 3 is disabled by inhibiting data transfer into RX3\_1. If this bit is cleared while receiving a data word, the remainder of the word is shifted in and transferred to the RX3\_1 data register.

If RE3 is set while some of the other receivers are already in operation, the first data word received in RX3\_1 will be invalid and must be discarded.

#### 9.3.4.5 RCR\_1 Reserved Bits - Bits 5-4, 18-17

These bits are reserved. They read as zero, and they should be written with zero for future compatibility.

#### 9.3.4.6 RCR\_1 Receiver Shift Direction (RSHFD) - Bit 6

The RSHFD bit causes the receiver shift registers to shift data in MSB first when RSHFD is cleared or LSB first when RSHFD is set (see [Figure 9-13](#) and [Figure 9-14](#)).

### 9.3.4.7 RCR\_1 Receiver Word Alignment Control (RWA) - Bit 7

The Receiver Word Alignment Control (RWA) bit defines the alignment of the data word in relation to the slot. This is relevant for the cases where the word length is shorter than the slot length. If RWA is cleared, the data word is assumed to be left-aligned in the slot frame. If RWA is set, the data word is assumed to be right-aligned in the slot frame.

If the data word is shorter than the slot length, the data bits which are not in the data word field are ignored.

For data word lengths of less than 24 bits, the data word is right-extended with zeroes before being stored in the receive data registers.

### 9.3.4.8 RCR\_1 Receiver Network Mode Control (RMOD1-RMOD0) - Bits 9-8

The RMOD1 and RMOD0 bits are used to define the network mode of the ESAI receivers according to [Table 9-10](#). In the normal mode, the frame rate divider determines the word transfer rate – one word is transferred per frame sync during the frame sync time slot, as shown in [Figure 9-6](#). In network mode, it is possible to transfer a word for every time slot, as shown in [Figure 9-6](#). For more details, see [Section 9.4, "Operating Modes"](#).

In order to comply with AC-97 specifications, RSWS4-RSWS0 should be set to 00011 (20-bit slot, 20-bit word), RFSL and RFSR should be cleared, and RDC4-RDC0 should be set to \$0C (13 words in frame).

**Table 9-10 ESAI\_1 Receive Network Mode Selection**

RMOD1	RMOD0	RDC4-RDC0	Receiver Network Mode
0	0	\$0-\$1F	Normal Mode
0	1	\$0	On-Demand Mode
0	1	\$1-\$1F	Network Mode
1	0	X	Reserved
1	1	\$0C	AC97

### 9.3.4.9 RCR\_1 Receiver Slot and Word Select (RSWS4-RSWS0) - Bits 10-14

The RSWS4-RSWS0 bits are used to select the length of the slot and the length of the data words being received via the ESAI\_1. The word length must be equal to or shorter than the slot length. The possible combinations are shown in [Table 9-11](#). See also the ESAI\_1 data path programming model in [Figure 9-13](#) and [Figure 9-14](#).

**Table 9-11 ESAI\_1 Receive Slot and Word Length Selection**

RSWS4	RSWS3	RSWS2	RSWS1	RSWS0	SLOT LENGTH	WORD LENGTH
0	0	0	0	0	8	8
0	0	1	0	0	12	8
0	0	0	0	1		12

Table 9-11 ESAI\_1 Receive Slot and Word Length Selection (continued)

RSWS4	RSWS3	RSWS2	RSWS1	RSWS0	SLOT LENGTH	WORD LENGTH
0	1	0	0	0	16	8
0	0	1	0	1		12
0	0	0	1	0		16
0	1	1	0	0	20	8
0	1	0	0	1		12
0	0	1	1	0		16
0	0	0	1	1		20
1	0	0	0	0	24	8
0	1	1	0	1		12
0	1	0	1	0		16
0	0	1	1	1		20
1	1	1	1	0		24
1	1	0	0	0	32	8
1	0	1	0	1		12
1	0	0	1	0		16
0	1	1	1	1		20
1	1	1	1	1		24
0	1	0	1	1	Reserved	
0	1	1	1	0		
1	0	0	0	1		
1	0	0	1	1		
1	0	1	0	0		
1	0	1	1	0		
1	0	1	1	1		
1	1	0	0	1		
1	1	0	1	0		
1	1	0	1	1		
1	1	1	0	0		
1	1	1	0	1		

#### 9.3.4.10 RCR\_1 Receiver Frame Sync Length (RFSL) - Bit 15

The RFSL bit selects the length of the receive frame sync to be generated or recognized. If RFSL is cleared, a word-length frame sync is selected. If RFSL is set, a 1-bit clock period frame sync is selected. See [Figure 9-7](#) for examples of frame length selection.

#### 9.3.4.11 RCR\_1 Receiver Frame Sync Relative Timing (RFSR) - Bit 16

RFSR determines the relative timing of the receive frame sync signal as referred to the serial data lines, for a word length frame sync only. When RFSR is cleared the word length frame sync occurs together with the first bit of the data word of the first slot. When RFSR is set the word length frame sync starts one serial clock cycle earlier, i.e., together with the last bit of the previous data word.

#### 9.3.4.12 RCR\_1 Receiver Section Personal Reset (RPR) - Bit 19

The RPR control bit is used to put the receiver section of the ESAI\_1 in the personal reset state. The transmitter section is not affected. When RPR is cleared, the receiver section may operate normally. When RPR is set, the receiver section enters the personal reset state immediately. When in the personal reset state, the status bits are reset to the same state as after hardware reset. The control bits are not affected by the personal reset state. The receiver data pins are disconnected while in the personal reset state. Note that to leave the personal reset state by clearing RPR, the procedure described in [Section 9.6, "ESAI\\_1 Initialization Examples"](#) should be followed.

#### 9.3.4.13 RCR\_1 Receive Exception Interrupt Enable (REIE) - Bit 20

When REIE is set, the DSP is interrupted when both RDF and ROE in the SAISR status register are set. When REIE is cleared, this interrupt is disabled. Reading the SAISR status register followed by reading the enabled receivers data registers clears ROE, thus clearing the pending interrupt.

#### 9.3.4.14 RCR\_1 Receive Even Slot Data Interrupt Enable (REDIE) - Bit 21

The REDIE control bit is used to enable the receive even slot data interrupts. If REDIE is set, the receive even slot data interrupts are enabled. If REDIE is cleared, the receive even slot data interrupts are disabled. A receive even slot data interrupt request is generated if REDIE is set and the REDF status flag in the SAISR\_1 status register is set. Even time slots are all even-numbered time slots (0, 2, 4, etc.) when operating in network mode. The zero time slot is marked by the frame sync signal and is considered to be even. Reading all the data registers of the enabled receivers clears the REDF flag, thus servicing the interrupt.

Receive interrupts with exception have higher priority than receive even slot data interrupts, therefore if exception occurs (ROE is set) and REIE is set, the ESAI\_1 requests an ESAI\_1 receive data with exception interrupt from the interrupt controller.

### 9.3.4.15 RCR\_1 Receive Interrupt Enable (RIE) - Bit 22

The DSP is interrupted when RIE and the RDF flag in the SAISR\_1 status register are set. When RIE is cleared, this interrupt is disabled. Reading the receive data registers of the enabled receivers clears RDF, thus clearing the interrupt.

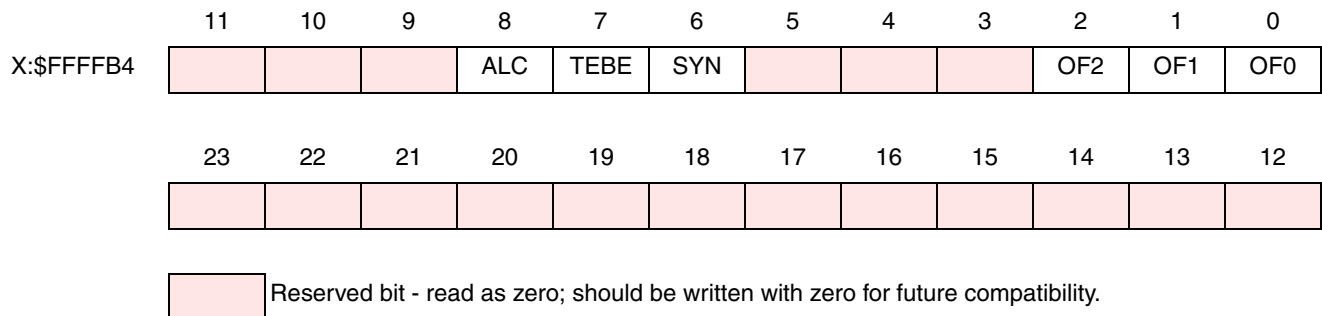
Receive interrupts with exception have higher priority than normal receive data interrupts, therefore if exception occurs (ROE is set) and REIE is set, the ESAI\_1 requests an ESAI\_1 receive data with exception interrupt from the interrupt controller.

### 9.3.4.16 RCR\_1 Receive Last Slot Interrupt Enable (RLIE) - Bit 23

RLIE enables an interrupt after the last slot of a frame ended in network mode only. When RLIE is set the DSP is interrupted after the last slot in a frame ended regardless of the receive mask register setting. When RLIE is cleared the receive last slot interrupt is disabled. Hardware and software reset clear RLIE. RLIE is disabled when RDC[4:0]=00000 (on-demand mode). The use of the receive last slot interrupt is described in [Section 9.4.3, "ESAI\\_1 Interrupt Requests"](#).

## 9.3.5 ESAI\_1 Common Control Register (SAICR\_1)

The read/write Common Control Register (SAICR\_1) contains control bits for functions that affect both the receive and transmit sections of the ESAI\_1. See [Figure 9-10](#).



**Figure 9-10 SAICR\_1 Register**

Hardware and software reset clear all the bits in the SAICR\_1 register.

### 9.3.5.1 SAICR\_1 Serial Output Flag 0 (OF0) - Bit 0

The Serial Output Flag 0 (OF0) is a data bit used to hold data to be send to the OF0 pin. When the ESAI is in the synchronous clock mode (SYN=1), the SCKR\_1 pin is configured as the ESAI flag 0. If the receiver serial clock direction bit (RCKD) is set, the SCKR\_1 pin is the output flag OF0, and data present in the OF0 bit is written to the OF0 pin at the beginning of the frame in normal mode or at the beginning of the next time slot in network mode.

### 9.3.5.2 SAICR\_1 Serial Output Flag 1 (OF1) - Bit 1

The Serial Output Flag 1 (OF1) is a data bit used to hold data to be send to the OF1 pin. When the ESAI\_1 is in the synchronous clock mode (SYN=1), the FSR\_1 pin is configured as the ESAI\_1 flag 1. If the receiver frame sync direction bit (RFSD) is set and the TEBE bit is cleared, the FSR\_1 pin is the output flag OF1, and data present in the OF1 bit is written to the OF1 pin at the beginning of the frame in normal mode or at the beginning of the next time slot in network mode.

### 9.3.5.3 SAICR\_1 Serial Output Flag 2 (OF2) - Bit 2

The Serial Output Flag 2 (OF2) is a data bit used to hold data to be send to the OF2 pin. When the ESAI\_1 is in the synchronous clock mode (SYN=1), the HCKR\_1 pin is configured as the ESAI\_1 flag 2. If the receiver high frequency clock direction bit (RHCKD) is set, the HCKR\_1 pin is the output flag OF2, and data present in the OF2 bit is written to the OF2 pin at the beginning of the frame in normal mode or at the beginning of the next time slot in network mode.

### 9.3.5.4 SAICR\_1 Reserved Bits - Bits 5-3, 23-9

These bits are reserved. They read as zero, and they should be written with zero for future compatibility.

### 9.3.5.5 SAICR\_1 Synchronous Mode Selection (SYN) - Bit 6

The Synchronous Mode Selection (SYN) bit controls whether the receiver and transmitter sections of the ESAI\_1 operate synchronously or asynchronously with respect to each other (see [Figure 9-11](#)). When SYN is cleared, the asynchronous mode is chosen and independent clock and frame sync signals are used for the transmit and receive sections. When SYN is set, the synchronous mode is chosen and the transmit and receive sections use common clock and frame sync signals.

When in the synchronous mode (SYN=1), the transmit and receive sections use the transmitter section clock generator as the source of the clock and frame sync for both sections. Also, the receiver clock pins SCKR\_1, FSR\_1 and HCKR\_1 now operate as I/O flags. See [Table 9-7](#), [Table 9-8](#) and [Table 9-9](#) for the effects of SYN on the receiver clock pins.

### 9.3.5.6 SAICR\_1 Transmit External Buffer Enable (TEBE) - Bit 7

The Transmitter External Buffer Enable (TEBE) bit controls the function of the FSR pin when in the synchronous mode. If the ESAI\_1 is configured for operation in the synchronous mode (SYN=1), and TEBE is set while FSR\_1 pin is configured as an output (RFSD=1), the FSR\_1 pin functions as the transmitter external buffer enable control to enable the use of an external buffers on the transmitter outputs. If TEBE is cleared then the FSR\_1 pin functions as the serial I/O flag 1. See [Table 9-8](#) for a summary of the effects of TEBE on the FSR\_1 pin.

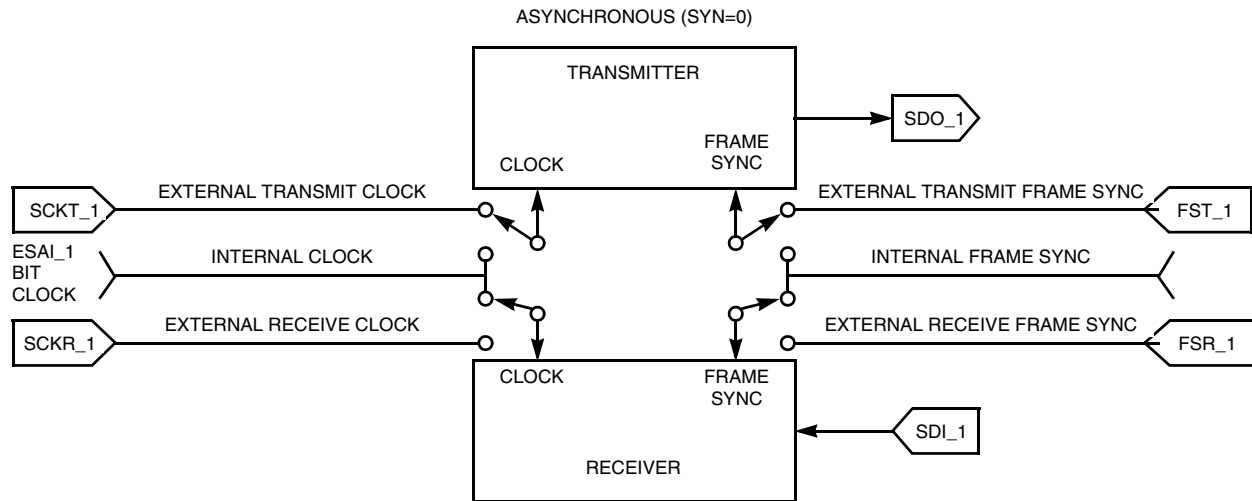
### 9.3.5.7 SAICR\_1 Alignment Control (ALC) - Bit 8

The ESAI\_1 is designed for 24-bit fractional data, thus shorter data words are left aligned to the MSB (bit 23). Some applications use 16-bit fractional data. In those cases, shorter data words may be left aligned to bit 15. The Alignment Control (ALC) bit supports these applications.

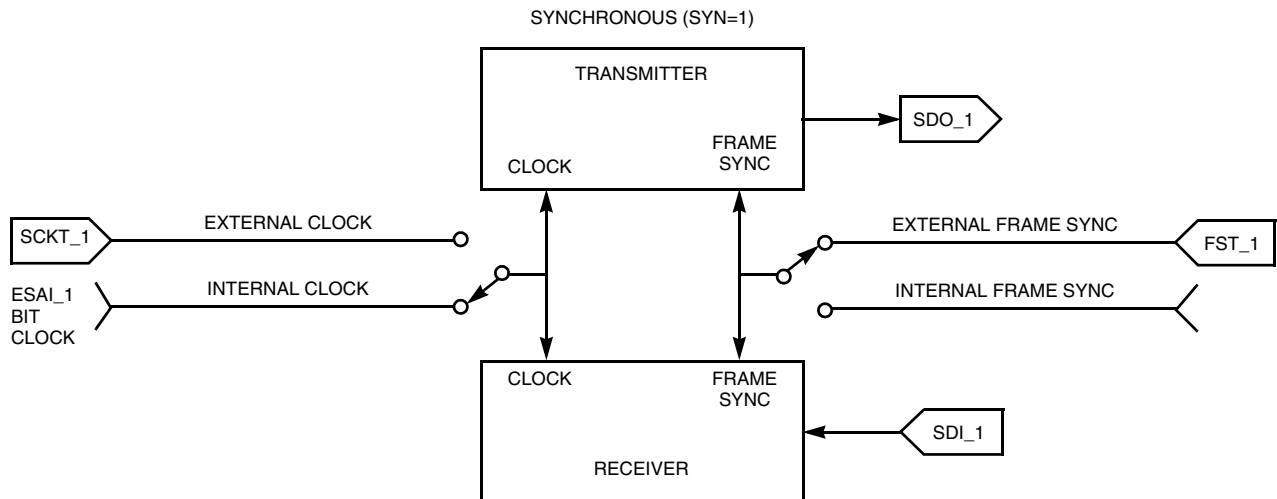
If ALC is set, transmitted and received words are left aligned to bit 15 in the transmit and receive shift registers. If ALC is cleared, transmitted and received word are left aligned to bit 23 in the transmit and receive shift registers.

### NOTE

While ALC is set, 20-bit and 24-bit words may not be used, and word length control should specify 8-, 12- or 16-bit words; otherwise, results are unpredictable.



NOTE: Transmitter and receiver may have different clocks and frame syncs.



NOTE: Transmitter and receiver have the same clocks and frame syncs.

**Figure 9-11 SAICR\_1 SYN Bit Operation**

### 9.3.6 ESAI\_1 Status Register (SAISR\_1)

The Status Register (SAISR\_1) is a read-only status register used by the DSP to read the status and serial input flags of the ESAI\_1. See Figure 9-12. The status bits are described in the following paragraphs.

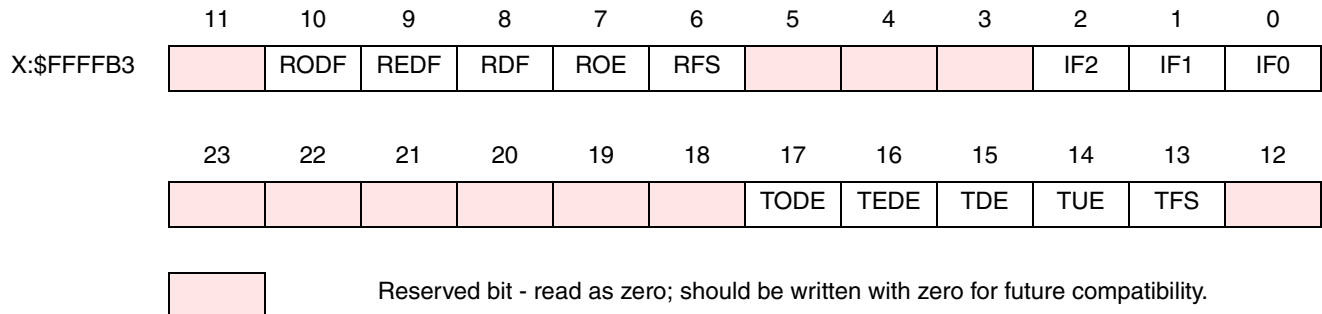


Figure 9-12 SAISR\_1 Register

#### 9.3.6.1 SAISR\_1 Serial Input Flag 0 (IF0) - Bit 0

The IF0 bit is enabled only when the SCKR\_1 pin is defined as ESAI\_1 in the Port Control Register, SYN=1 and RCKD=0, indicating that SCKR\_1 is an input flag and the synchronous mode is selected. Data present on the SCKR\_1 pin is latched during reception of the first received data bit after frame sync is detected. The IF0 bit is updated with this data when the receiver shift registers are transferred into the receiver data registers. IF0 reads as a zero when it is not enabled. Hardware, software, ESAI\_1 individual and STOP reset clear IF0.

#### 9.3.6.2 SAISR\_1 Serial Input Flag 1 (IF1) - Bit 1

The IF1 bit is enabled only when the FSR\_1 pin is defined as ESAI\_1 in the Port Control Register, SYN=1, RFSD=0 and TEBE=0, indicating that FSR\_1 is an input flag and the synchronous mode is selected. Data present on the FSR pin is latched during reception of the first received data bit after frame sync is detected. The IF1 bit is updated with this data when the receiver shift registers are transferred into the receiver data registers. IF1 reads as a zero when it is not enabled. Hardware, software, ESAI\_1 individual and STOP reset clear IF1.

#### 9.3.6.3 SAISR\_1 Serial Input Flag 2 (IF2) - Bit 2

The IF2 bit is enabled only when the HCKR\_1 pin is defined as ESAI\_1 in the Port Control Register, SYN=1 and RHCKD=0, indicating that HCKR\_1 is an input flag and the synchronous mode is selected. Data present on the HCKR\_1 pin is latched during reception of the first received data bit after frame sync is detected. The IF2 bit is updated with this data when the receive shift registers are transferred into the receiver data registers. IF2 reads as a zero when it is not enabled. Hardware, software, ESAI\_1 individual and STOP reset clear IF2.

#### 9.3.6.4 SAISR\_1 Reserved Bits - Bits 5-3, 12-11, 23-18

These bits are reserved for future use. They read as zero.



### 9.3.6.5 SAISR\_1 Receive Frame Sync Flag (RFS) - Bit 6

When set, RFS indicates that a receive frame sync occurred during reception of the words in the receiver data registers. This indicates that the data words are from the first slot in the frame. When RFS is clear and a word is received, it indicates (only in the network mode) that the frame sync did not occur during reception of that word. RFS is cleared by hardware, software, ESAI\_1 individual, or STOP reset. RFS is valid only if at least one of the receivers is enabled (REx=1).

#### NOTE

In normal mode, RFS always reads as a one when reading data because there is only one time slot per frame – the “frame sync” time slot.

### 9.3.6.6 SAISR\_1 Receiver Overrun Error Flag (ROE) - Bit 7

The ROE flag is set when the serial receive shift register of an enabled receiver is full and ready to transfer to its receiver data register (RXx\_1) and the register is already full (RDF=1). If REIE is set, an ESAI receive data with exception (overrun error) interrupt request is issued when ROE is set. Hardware, software, ESAI\_1 individual and STOP reset clear ROE. ROE is also cleared by reading the SAISR\_1 with ROE set, followed by reading all the enabled receive data registers.

### 9.3.6.7 SAISR\_1 Receive Data Register Full (RDF) - Bit 8

RDF is set when the contents of the receive shift register of an enabled receiver is transferred to the respective receive data register. RDF is cleared when the DSP reads the receive data register of all enabled receivers or cleared by hardware, software, ESAI\_1 individual, or STOP reset. If RIE is set, an ESAI\_1 receive data interrupt request is issued when RDF is set.

### 9.3.6.8 SAISR\_1 Receive Even-Data Register Full (REDF) - Bit 9

When set, REDF indicates that the received data in the receive data registers of the enabled receivers have arrived during an even time slot when operating in the network mode. Even time slots are all even-numbered slots (0, 2, 4, 6, etc.). Time slots are numbered from zero to N-1, where N is the number of time slots in the frame. The zero time slot is considered even. REDF is set when the contents of the receive shift registers are transferred to the receive data registers. REDF is cleared when the DSP reads all the enabled receive data registers or cleared by hardware, software, ESAI\_1 individual, or STOP resets. If REDIE is set, an ESAI\_1 receive even slot data interrupt request is issued when REDF is set.

### 9.3.6.9 SAISR\_1 Receive Odd-Data Register Full (RODF) - Bit 10

When set, RODF indicates that the received data in the receive data registers of the enabled receivers have arrived during an odd time slot when operating in the network mode. Odd time slots are all odd-numbered slots (1, 3, 5, etc.). Time slots are numbered from zero to N-1, where N is the number of time slots in the frame. RODF is set when the contents of the receive shift registers are transferred to the receive data registers. RODF is cleared when the DSP reads all the enabled receive data registers or cleared by hardware, software, ESAI\_1 individual, or STOP resets.

### 9.3.6.10 SAISR\_1 Transmit Frame Sync Flag (TFS) - Bit 13

When set, TFS indicates that a transmit frame sync occurred in the current time slot. TFS is set at the start of the first time slot in the frame and cleared during all other time slots. Data written to a transmit data register during the time slot when TFS is set is transmitted (in network mode), if the transmitter is enabled, during the second time slot in the frame. TFS is useful in network mode to identify the start of a frame. TFS is cleared by hardware, software, ESAI\_1 individual, or STOP reset. TFS is valid only if at least one transmitter is enabled, i.e., one or more of TE0, TE1, TE2, TE3, TE4 and TE5 are set.

#### NOTE

In normal mode, TFS always reads as a one when transmitting data because there is only one time slot per frame – the “frame sync” time slot.

### 9.3.6.11 SAISR\_1 Transmit Underrun Error Flag (TUE) - Bit 14

TUE is set when at least one of the enabled serial transmit shift registers is empty (no new data to be transmitted) and a transmit time slot occurs. When a transmit underrun error occurs, the previous data (which is still present in the TX registers that were not written) is retransmitted. If TEIE is set, an ESAI\_1 transmit data with exception (underrun error) interrupt request is issued when TUE is set. Hardware, software, ESAI\_1 individual and STOP reset clear TUE. TUE is also cleared by reading the SAISR\_1 with TUE set, followed by writing to all the enabled transmit data registers or to TSR.

### 9.3.6.12 SAISR\_1 Transmit Data Register Empty (TDE) - Bit 15

TDE is set when the contents of the transmit data register of all the enabled transmitters are transferred to the transmit shift registers; it is also set for a TSR\_1 disabled time slot period in network mode (as if data were being transmitted after the TSR\_1 was written). When set, TDE indicates that data should be written to all the TX registers of the enabled transmitters or to the time slot register (TSR\_1). TDE is cleared when the DSP writes to all the transmit data registers of the enabled transmitters, or when the DSP writes to the TSR\_1 to disable transmission of the next time slot. If TIE is set, an ESAI\_1 transmit data interrupt request is issued when TDE is set. Hardware, software, ESAI\_1 individual and STOP reset clear TDE.

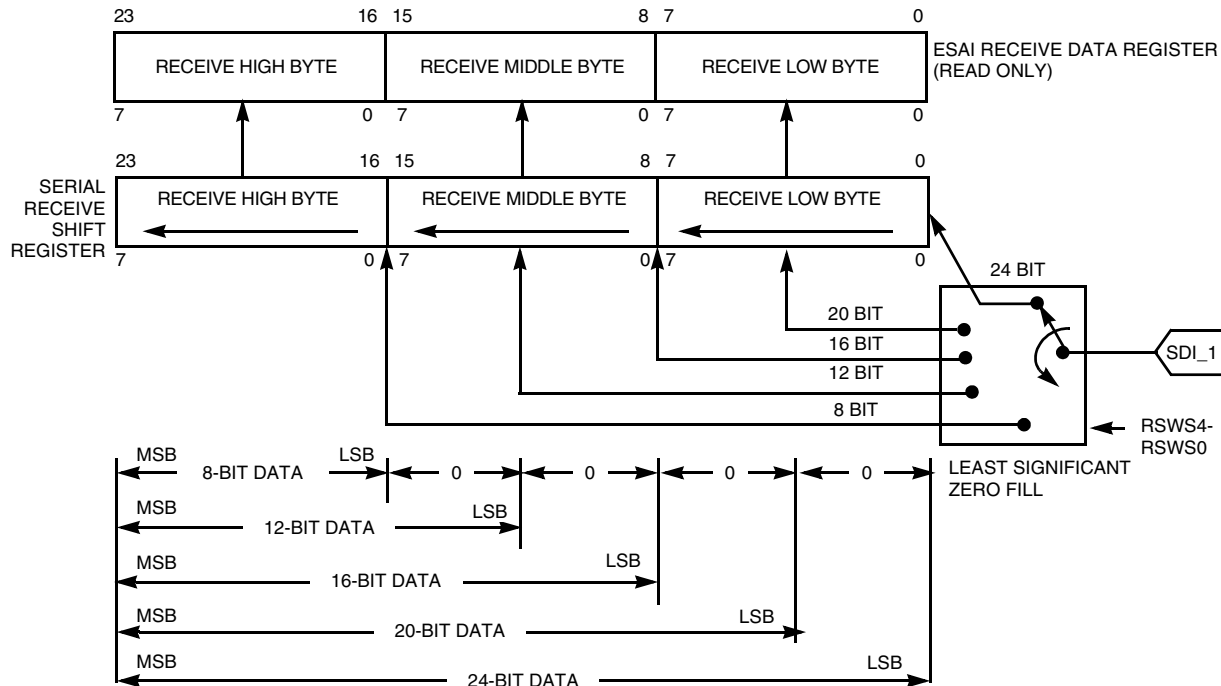
### 9.3.6.13 SAISR\_1 Transmit Even-Data Register Empty (TEDE) - Bit 16

When set, TEDE indicates that the enabled transmitter data registers became empty at the beginning of an even time slot. Even time slots are all even-numbered slots (0, 2, 4, 6, etc.). Time slots are numbered from zero to N-1, where N is the number of time slots in the frame. The zero time slot is considered even. This flag is set when the contents of the transmit data register of all the enabled transmitters are transferred to the transmit shift registers; it is also set for a TSR\_1 disabled time slot period in network mode (as if data were being transmitted after the TSR\_1 was written). When set, TEDE indicates that data should be written to all the TX registers of the enabled transmitters or to the time slot register (TSR\_1). TEDE is cleared when the DSP writes to all the transmit data registers of the enabled transmitters, or when the DSP writes to the TSR\_1 to disable transmission of the next time slot. If TIE is set, an ESAI\_1 transmit data interrupt request is issued when TEDE is set. Hardware, software, ESAI\_1 individual and STOP reset clear TEDE.

#### 9.3.6.14 SAISR\_1 Transmit Odd-Data Register Empty (TODE) - Bit 17

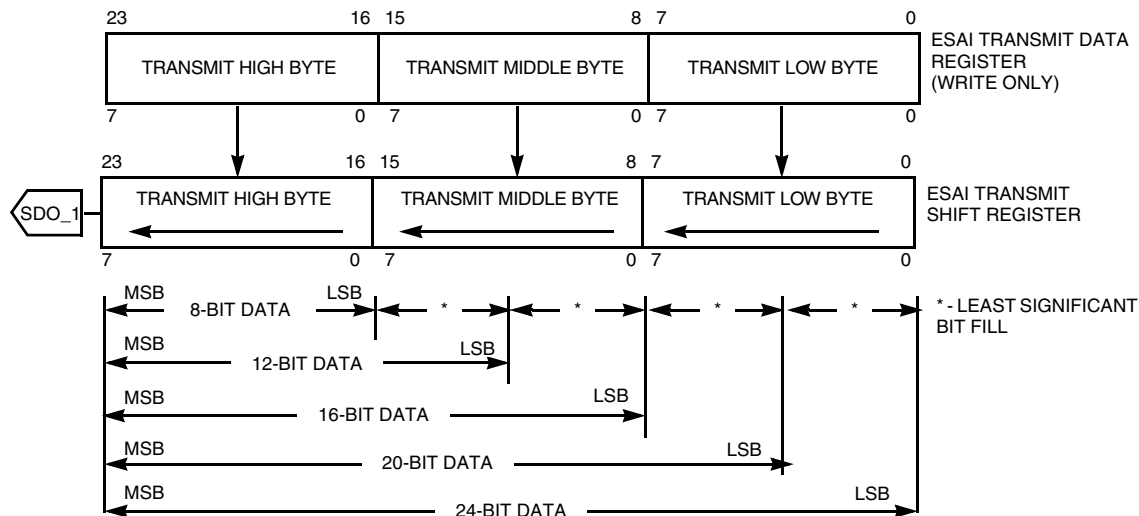
When set, TODE indicates that the enabled transmitter data registers became empty at the beginning of an odd time slot. Odd time slots are all odd-numbered slots (1, 3, 5, etc.). Time slots are numbered from zero to N-1, where N is the number of time slots in the frame. This flag is set when the contents of the transmit data register of all the enabled transmitters are transferred to the transmit shift registers; it is also set for a TSR\_1 disabled time slot period in network mode (as if data were being transmitted after the TSR\_1 was written). When set, TODE indicates that data should be written to all the TX\_1 registers of the enabled transmitters or to the time slot register (TSR\_1). TODE is cleared when the DSP writes to all the transmit data registers of the enabled transmitters, or when the DSP writes to the TSR\_1 to disable transmission of the next time slot. If TIE is set, an ESAI\_1 transmit data interrupt request is issued when TODE is set. Hardware, software, ESAI\_1 individual and STOP reset clear TODE.

## ESAI\_1 Programming Model



(a) Receive Registers

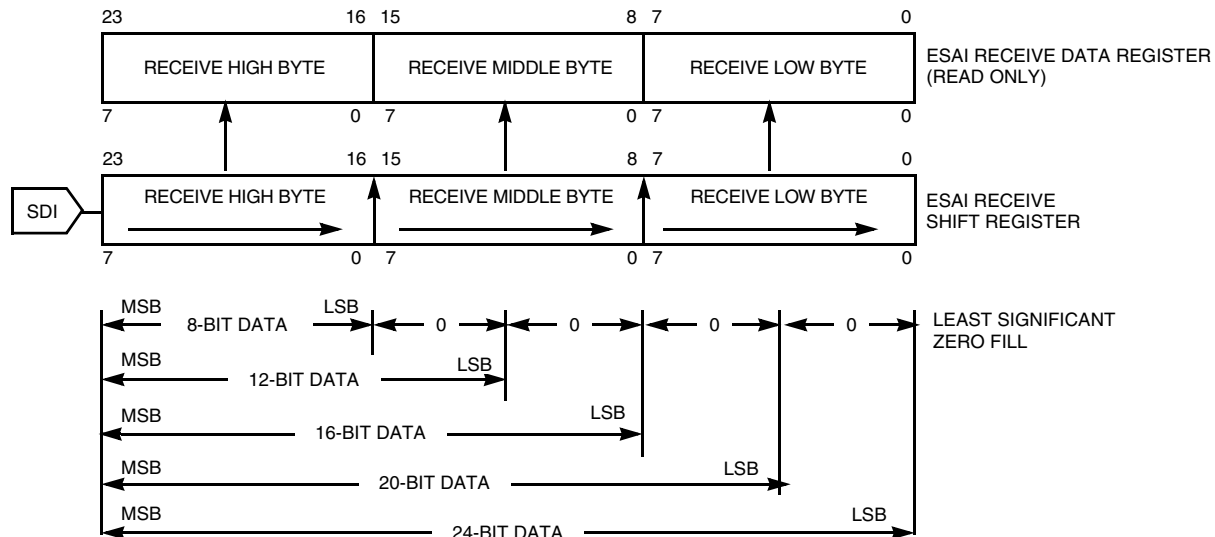
- NOTES:
1. Data is received MSB first if RSHFD=0.
  2. 24-bit fractional format (ALC=0).
  3. 32-bit mode is not shown.



(b) Transmit Registers

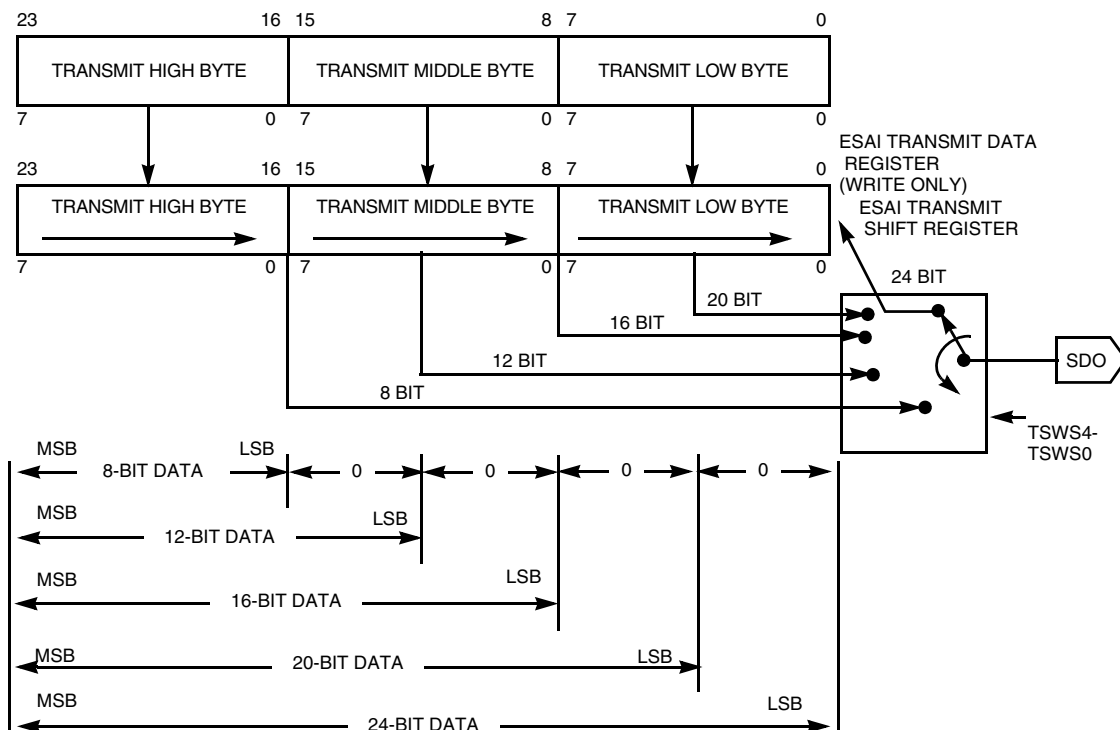
- NOTES:
1. Data is sent MSB first if TSHFD=0.
  2. 24-bit fractional format (ALC=0).
  3. 32-bit mode is not shown.
  4. Data word is left-aligned (TWA=0,PADC=0).

Figure 9-13 ESAI\_1 Data Path Programming Model ([R/T]SHFD=0)



(a) Receive Registers

- NOTES:
1. Data is received LSB first if RSHFD=1.
  2. 24-bit fractional format (ALC=0).
  3. 32-bit mode is not shown.



(b) Transmit Registers

- NOTES:
1. Data is sent LSB first if TSHFD=1.
  2. 24-bit fractional format (ALC=0).
  3. 32-bit mode is not shown.
  4. Data word is left aligned (TWA=0,PADC=1).

Figure 9-14 ESAI\_1 Data Path Programming Model ([R/T]SHFD=1)

### 9.3.7 ESAI\_1 Receive Shift Registers

The receive shift registers receive the incoming data from the serial receive data pins. Data is shifted in by the selected (internal/external) bit clock when the associated frame sync I/O is asserted. Data is assumed to be received MSB first if RSHFD=0 and LSB first if RSHFD=1. Data is transferred to the ESAI\_1 receive data registers after 8, 12, 16, 20, 24, or 32 serial clock cycles were counted, depending on the slot length control bits in the RCR\_1 register.

### 9.3.8 ESAI\_1 Receive Data Registers (RX3\_1, RX2\_1, RX1\_1, RX0\_1)

The Receive Data Registers RX3\_1, RX2\_1, RX1\_1 and RX0\_1 are 24-bit read-only registers that accept data from the receive shift registers when they become full. The data occupies the most significant portion of the receive data registers, according to the ALC control bit setting. The unused bits (least significant portion and eight most significant bits when ALC=1) read as zeros. The DSP is interrupted whenever RXx\_1 becomes full if the associated interrupt is enabled.

### 9.3.9 ESAI\_1 Transmit Shift Registers

The Transmit Shift Registers contain the data being transmitted. Data is shifted out to the serial transmit data pins by the selected (internal/external) bit clock when the associated frame sync I/O is asserted. The number of bits shifted out before the shift registers are considered empty and may be written to again can be 8, 12, 16, 20, 24 or 32 bits (determined by the slot length control bits in the TCR\_1 register). Data is shifted out of these registers MSB first if TSHFD=0 and LSB first if TSHFD=1.

### 9.3.10 ESAI\_1 Transmit Data Registers (TX5\_1, TX4\_1, TX3\_1, TX2\_1, TX1\_1, TX0\_1)

The Transmit Data registers TX5\_1, TX4\_1, TX3\_1, TX2\_1, TX1\_1 and TX0\_1 are 24-bit write-only registers. Data to be transmitted is written into these registers and is automatically transferred to the transmit shift registers. The data written (8, 12, 16, 20 or 24 bits) should occupy the most significant portion of the TXx\_1 according to the ALC control bit setting. The unused bits (least significant portion and the eight most significant bits when ALC=1) of the TXx\_1 are don't care bits. The DSP is interrupted whenever the TXx\_1 becomes empty if the transmit data register empty interrupt has been enabled.

### 9.3.11 ESAI\_1 Time Slot Register (TSR\_1)

The write-only Time Slot Register (TSR\_1) is effectively a null data register that is used when the data is not to be transmitted in the available transmit time slot. The transmit data pins of all the enabled transmitters are in the high-impedance state for the respective time slot where TSR\_1 has been written. The Transmitter External Buffer Enable pin (FSR\_1 pin when SYN=1, TEBE=1, RFSD=1) disables the external buffers during the slot when the TSR\_1 register has been written.

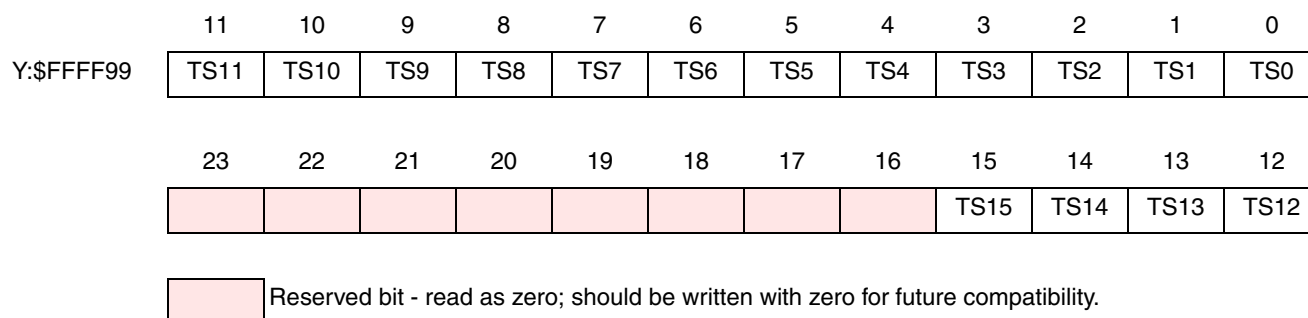
### 9.3.12 Transmit Slot Mask Registers (TSMA\_1, TSMB\_1)

The Transmit Slot Mask Registers (TSMA\_1 and TSMB\_1) are two read/write registers used by the transmitters in network mode to determine for each slot whether to transmit a data word and generate a

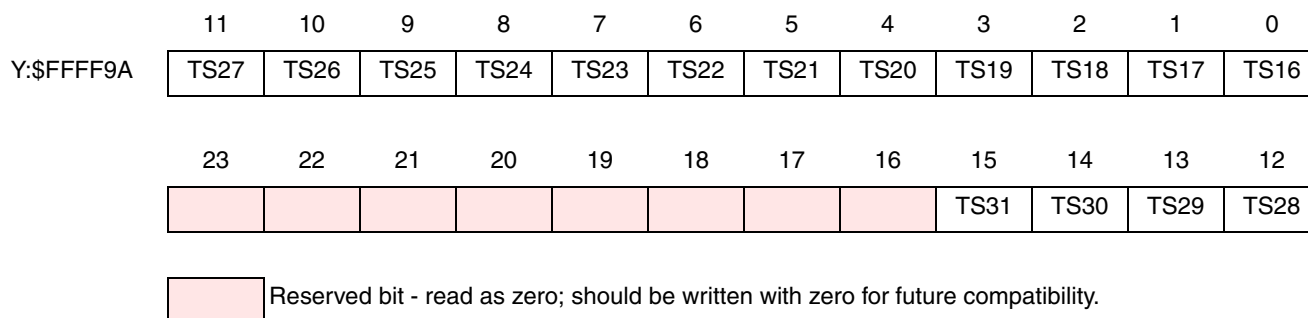
transmitter empty condition (TDE=1), or to tri-state the transmitter data pins. TSMA\_1 and TSMB\_1 should each be considered as containing half a 32-bit register TSM\_1. See Figure 9-15 and Figure 9-16. Bit number N in TSM\_1 (TS\*\*) is the enable/disable control bit for transmission in slot number N.

When bit number N in TSM is cleared, all the transmit data pins of the enabled transmitters are tri-stated during transmit time slot number N. The data is still transferred from the transmit data registers to the transmit shift registers but neither the TDE nor the TUE flags are set. This means that during a disabled slot, no transmitter empty interrupt is generated. The DSP is interrupted only for enabled slots. Data that is written to the transmit data registers when servicing this request is transmitted in the next enabled transmit time slot.

When bit number N in TSM register is set, the transmit sequence is as usual: data is transferred from the TX registers to the shift registers, transmitted during slot number N, and the TDE flag is set.



**Figure 9-15 TSMA\_1 Register**



**Figure 9-16 TSMB\_1 Register**

Using the slot mask in TSM does not conflict with using TSR\_1. Even if a slot is enabled in TSM, the user may choose to write to TSR\_1 instead of writing to the transmit data registers TXx. This causes all the transmit data pins of the enabled transmitters to be tri-stated during the next slot.

Data written to the TSM affects the next frame transmission. The frame being transmitted is not affected by this data and would comply to the last TSM setting. Data read from TSM returns the last written data.

After hardware or software reset, the TSM register is preset to \$FFFFFFFF, which means that all 32 possible slots are enabled for data transmission.

When operating in normal mode, bit 0 of the mask register must be set, otherwise no output is generated.

### 9.3.13 Receive Slot Mask Registers (RSMA\_1, RSMB\_1)

The Receive Slot Mask Registers (RSMA\_1 and RSMB\_1) are two read/write registers used by the receiver in network mode to determine for each slot whether to receive a data word and generate a receiver full condition (RDF=1), or to ignore the received data. RSMA\_1 and RSMB\_1 should be considered as each containing half of a 32-bit register RSM\_1. See Figure 9-17 and Figure 9-18. Bit number N in RSM\_1 (RS\*\*) is an enable/disable control bit for receiving data in slot number N.

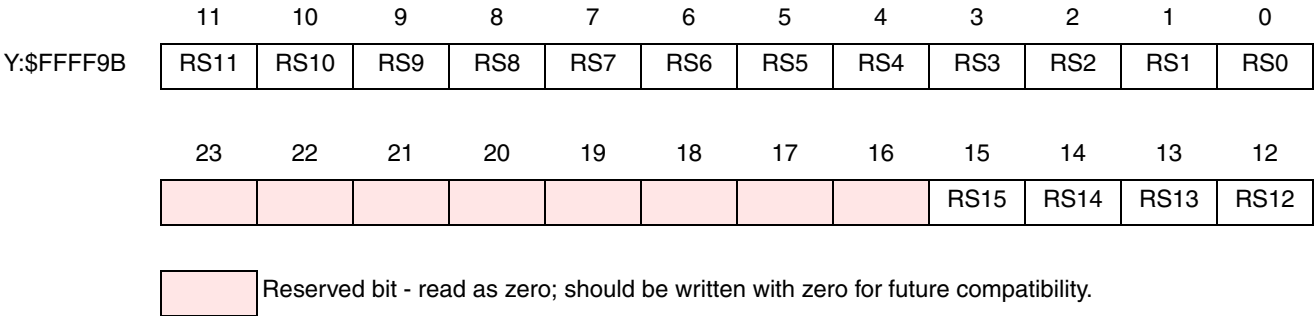


Figure 9-17 RSMA\_1 Register

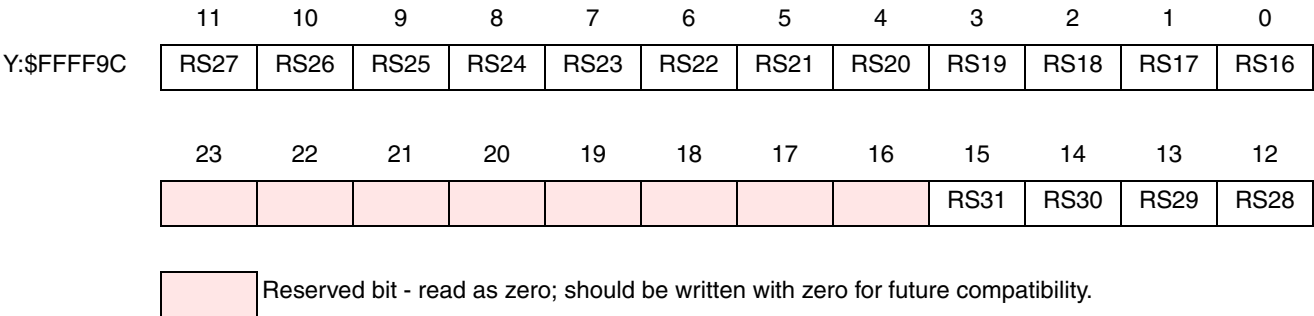


Figure 9-18 RSMB\_1 Register

When bit number N in the RSM register is cleared, the data from the enabled receivers input pins are shifted into their receive shift registers during slot number N. The data is not transferred from the receive shift registers to the receive data registers, and neither the RDF nor the ROE flag is set. This means that during a disabled slot, no receiver full interrupt is generated. The DSP is interrupted only for enabled slots.

When bit number N in the RSM is set, the receive sequence is as usual: data which is shifted into the enabled receivers shift registers is transferred to the receive data registers and the RDF flag is set.

Data written to the RSM affects the next received frame. The frame being received is not affected by this data and would comply to the last RSM setting. Data read from RSM returns the last written data.

After hardware or software reset, the RSM register is preset to \$FFFFFFFF, which means that all 32 possible slots are enabled for data reception.

**NOTE**

When operating in normal mode, bit 0 of the mask register must be set to one, otherwise no input is received.



## 9.4 Operating Modes

ESAI\_1 operating mode are selected by the ESAI\_1 control registers (TCCR\_1, TCR\_1, RCCR\_1, RCR\_1 and SAICR\_1). The main operating mode are described in the following paragraphs.

### 9.4.1 ESAI\_1 After Reset

Hardware or software reset clears the port control register bits and the port direction control register bits, which configure all ESAI\_1 I/O pins as disconnected. The ESAI\_1 is in the individual reset state while all ESAI\_1 pins are programmed as GPIO or disconnected and is active only if at least one of the ESAI\_1 I/O pins is programmed as an ESAI\_1 pin.

### 9.4.2 ESAI\_1 Initialization

The correct way to initialize the ESAI\_1 is as follows:

1. Hardware, software, ESAI\_1 individual, or STOP reset.
2. Program ESAI\_1 control and time slot registers.
3. Write data to all the enabled transmitters.
4. Configure at least one pin as ESAI\_1 pin.

During program execution, all ESAI\_1 pins may be defined as GPIO or disconnected, causing the ESAI\_1 to stop serial activity and enter the individual reset state. All status bits of the interface are set to their reset state; however, the control bits are not affected. This procedure allows the DSP programmer to reset the ESAI\_1 separately from the other internal peripherals. During individual reset, internal DMA accesses to the data registers of the ESAI\_1 are not valid and data read is undefined.

The DSP programmer must use an individual ESAI\_1 reset when changing the ESAI\_1 control registers (except for TEIE, REIE, TLIE, RLIE, TIE, RIE, TE0-TE5, RE0-RE3) to ensure proper operation of the interface.

#### NOTE

If the ESAI\_1 receiver section is already operating with some of the receivers, enabling additional receivers on the fly, i.e., without first putting the ESAI\_1 receiver in the personal reset state, by setting their REx control bits will result in erroneous data being received as the first data word for the newly enabled receivers.

### 9.4.3 ESAI\_1 Interrupt Requests

The ESAI\_1 can generate eight different interrupt requests (ordered from the highest to the lowest priority):

1. ESAI\_1 Receive Data with Exception Status  
Occurs when the receive exception interrupt is enabled (REIE=1 in the RCR register), at least one of the enabled receive data registers is full (RDF=1) and a receiver overrun error has occurred (ROE=1 in the SAISR\_1 register). ROE is cleared by first reading the SAISR\_1 and then reading all the enabled receive data registers.
2. ESAI\_1 Receive Even Data  
Occurs when the receive even slot data interrupt is enabled (REDIE=1), at least one of the enabled receive data registers is full (RDF=1), the data is from an even slot (REDF=1) and no exception has occurred (ROE=0 or REIE=0).  
Reading all enabled receiver data registers clears RDF and REDF.
3. ESAI\_1 Receive Data  
Occurs when the receive interrupt is enabled (RIE=1), at least one of the enabled receive data registers is full (RDF=1), no exception has occurred (ROE=0 or REIE=0) and no even-slot interrupt has occurred (REDF=0 or REDIE=0).  
Reading all enabled receiver data registers clears RDF.
4. ESAI\_1 Receive Last Slot Interrupt  
Occurs, if enabled (RLIE=1), after the last slot of the frame ended (in network mode only) regardless of the receive mask register setting. The receive last slot interrupt may be used for resetting the receive mask slot register, reconfiguring the DMA channels and reassigning data memory pointers. Using the receive last slot interrupt guarantees that the previous frame was serviced with the previous setting and the new frame is serviced with the new setting without synchronization problems. Note that the maximum receive last slot interrupt service time should not exceed N-1 ESAI\_1 bits service time (where N is the number of bits in a slot).
5. ESAI\_1 Transmit Data with Exception Status  
Occurs when the transmit exception interrupt is enabled (TEIE=1), at least one transmit data register of the enabled transmitters is empty (TDE=1) and a transmitter underrun error has occurred (TUE=1). TUE is cleared by first reading the SAISR\_1 and then writing to all the enabled transmit data registers, or to the TSR register.
6. ESAI\_1 Transmit Last Slot Interrupt  
Occurs, if enabled (TLIE=1), at the start of the last slot of the frame in network mode regardless of the transmit mask register setting. The transmit last slot interrupt may be used for resetting the transmit mask slot register, reconfiguring the DMA channels and reassigning data memory pointers. Using the transmit last slot interrupt guarantees that the previous frame was serviced with the previous setting and the new frame is serviced with the new setting without synchronization problems. Note that the maximum transmit last slot interrupt service time should not exceed N-1 ESAI\_1 bits service time (where N is the number of bits in a slot).

#### 7. ESAI\_1 Transmit Even Data

Occurs when the transmit even slot data interrupt is enabled (TEDIE=1), at least one of the enabled transmit data registers is empty (TDE=1), the slot is an even slot (TEDE=1) and no exception has occurred (TUE=0 or TEIE=0).

Writing to all the TX registers of the enabled transmitters or to TSR\_1 clears this interrupt request.

#### 8. ESAI\_1 Transmit Data

Occurs when the transmit interrupt is enabled (TIE=1), at least one of the enabled transmit data registers is empty (TDE=1), no exception has occurred (TUE=0 or TEIE=0) and no even-slot interrupt has occurred (TEDE=0 or TEDIE=0).

Writing to all the TX registers of the enabled transmitters, or to the TSR clears this interrupt request.

## 9.4.4 Operating Modes – Normal, Network and On-Demand

The ESAI has three basic operating modes and many data/operation formats.

### 9.4.4.1 Normal/Network/On-Demand Mode Selection

Selecting between the normal mode and network mode is accomplished by clearing or setting the TMOD0-TMOD1 bits in the TCR\_1 register for the transmitter section and in the RMOD0-RMOD1 bits in the RCR\_1 register for the receiver section.

For normal mode, the ESAI\_1 functions with one data word of I/O per frame (per enabled transmitter or receiver). The normal mode is typically used to transfer data to/from a single device.

For the network mode, 2 to 32 time slots per frame may be selected. During each frame, 0 to 32 data words of I/O may be received/transmitted. In either case, the transfers are periodic. The frame sync signal indicates the first time slot in the frame. Network mode is typically used in time division multiplexed (TDM) networks of codecs, DSPs with multiple words per frame, or multi-channel devices.

Selecting the network mode and setting the frame rate divider to zero (DC=00000) selects the on-demand mode. This special case does not generate a periodic frame sync. A frame sync pulse is generated only when data is available to transmit. The on-demand mode requires that the transmit frame sync be internal (output) and the receive frame sync be external (input). Therefore, for simplex operation, the synchronous mode could be used; however, for full-duplex operation, the asynchronous mode must be used. Data transmission that is data driven is enabled by writing data into each TX. Although the ESAI\_1 is double buffered, only one word can be written to each TX, even if the transmit shift register is empty. The receive and transmit interrupts function as usual using TDE and RDF; however, transmit underruns are impossible for on-demand transmission and are disabled.

### 9.4.4.2 Synchronous/Asynchronous Operating Modes

The transmit and receive sections of the ESAI\_1 may be synchronous or asynchronous, i.e., the transmitter and receiver sections may use common clock and synchronization signals (synchronous operating mode), or they may have their own separate clock and sync signals (asynchronous operating mode). The SYN bit in the SAICR\_1 register selects synchronous or asynchronous operation. Since the ESAI\_1 is designed to operate either synchronously or asynchronously, separate receive and transmit interrupts are provided.

When SYN is cleared, the ESAI\_1 transmitter and receiver clocks and frame sync sources are independent. If SYN is set, the ESAI\_1 transmitter and receiver clocks and frame sync come from the transmitter section (either external or internal sources).

Data clock and frame sync signals can be generated internally by the DSP or may be obtained from external sources. If internally generated, the ESAI\_1 clock generator is used to derive high frequency clock, bit clock and frame sync signals from the DSP internal system clock.

### 9.4.4.3 Frame Sync Selection

The frame sync can be either a bit-long or word-long signal. The transmitter frame format is defined by the TFSL bit in the TCR\_1 register. The receiver frame format is defined by the RFSL bit in the RCR\_1 register.

1. In the word-long frame sync format, the frame sync signal is asserted during the entire word data transfer period. This frame sync length is compatible with Freescale codecs, SPI serial peripherals, serial A/D and D/A converters, shift registers and telecommunication PCM serial I/O.
2. In the bit-long frame sync format, the frame sync signal is asserted for one bit clock immediately before the data transfer period. This frame sync length is compatible with Intel and National components, codecs and telecommunication PCM serial I/O.

The relative timing of the word length frame sync as referred to the data word is specified by the TFSR bit in the TCR\_1 register for the transmitter section and by the RFSR bit in the RCR\_1 register for the receive section. The word length frame sync may be generated (or expected) with the first bit of the data word or with the last bit of the previous word. TFSR and RFSR are ignored when a bit length frame sync is selected.

Polarity of the frame sync signal may be defined as positive (asserted high) or negative (asserted low). The TFSP bit in the TCCR\_1 register specifies the polarity of the frame sync for the transmitter section. The RFSP bit in the RCCR\_1 register specifies the polarity of the frame sync for the receiver section.

The ESAI\_1 receiver looks for a receive frame sync leading edge (trailing edge if RFSP is set) only when the previous frame is completed. If the frame sync goes high before the frame is completed (or before the last bit of the frame is received in the case of a bit frame sync or a word length frame sync with RFSR set), the current frame sync is not recognized, and the receiver is internally disabled until the next frame sync. Frames do not have to be adjacent, i.e., a new frame sync does not have to immediately follow the previous frame. Gaps of arbitrary periods can occur between frames. Enabled transmitters are tri-stated during these gaps.

When operating in the synchronous mode (SYN=1), all clocks including the frame sync are generated by the transmitter section.

### 9.4.4.4 Shift Direction Selection

Some data formats, such as those used by codecs, specify MSB first while other data formats, such as the AES-EBU digital audio interface, specify LSB first. The MSB/LSB first selection is made by programming RSHFD bit in the RCR\_1 register for the receiver section and by programming the TSHFD bit in the TCR\_1 register for the transmitter section.

### 9.4.5 Serial I/O Flags

Three ESAI\_1 pins (FSR\_1, SCKR\_1 and HCKR\_1) are available as serial I/O flags when the ESAI\_1 is operating in the synchronous mode (SYN=1). Their operation is controlled by RCKD, RFSD, TEBE bits in the RCR\_1, RCCR\_1 and SAICR\_1 registers. The output data bits (OF2, OF1 and OF0) and the input data bits (IF2, IF1 and IF0) are double buffered to/from the HCKR\_1, FSR\_1 and SCKR\_1 pins. Double buffering the flags keeps them in sync with the TX and RX data lines.

Each flag can be separately programmed. Flag 0 (SCKR\_1 pin) direction is selected by RCKD, RCKD=1 for output and RCKD=0 for input. Flag 1 (FSR\_1 pin) is enabled when the pin is not configured as external transmitter buffer enable (TEBE=0) and its direction is selected by RFSD, RFSD=1 for output and RFSD=0 for input. Flag 2 (HCKR\_1 pin) direction is selected by RHCKD, RHCKD=1 for output and RHCKD=0 for input.

When programmed as input flags, the SCKR\_1, FSR\_1 and HCKR\_1 logic values, respectively, are latched at the same time as the first bit of the receive data word is sampled. Because the input was latched, the signal on the input flag pin (SCKR\_1, FSR\_1 or HCKR\_1) can change without affecting the input flag until the first bit of the next receive data word. When the received data words are transferred to the receive data registers, the input flag latched values are then transferred to the IF0, IF1 and IF2 bits in the SAISR register, where they may be read by software.

When programmed as output flags, the SCKR\_1, FSR\_1 and HCKR\_1 logic values are driven by the contents of the OF0, OF1 and OF2 bits in the SAICR\_1 register, respectively, and are driven when the transmit data registers are transferred to the transmit shift registers. The value on SCKR\_1, FSR\_1 and HCKR\_1 is stable from the time the first bit of the transmit data word is transmitted until the first bit of the next transmit data word is transmitted. Software may change the OF0-OF2 values thus controlling the SCKR\_1, FSR\_1 and HCKR\_1 pin values for each transmitted word. The normal sequence for setting output flags when transmitting data is as follows: wait for TDE (transmitter empty) to be set, first write the flags, and then write the transmit data to the transmit registers. OF0, OF1 and OF2 are double buffered so that the flag states appear on the pins when the transmit data is transferred to the transmit shift register, i.e., the flags are synchronous with the data.

## 9.5 GPIO - Pins and Registers

The GPIO functionality of the ESAI\_1 port is controlled by three registers: Port E Control register (PCRE), Port E Direction register (PRRE) and Port E Data register (PDRE).

### 9.5.1 Port E Control Register (PCRE)

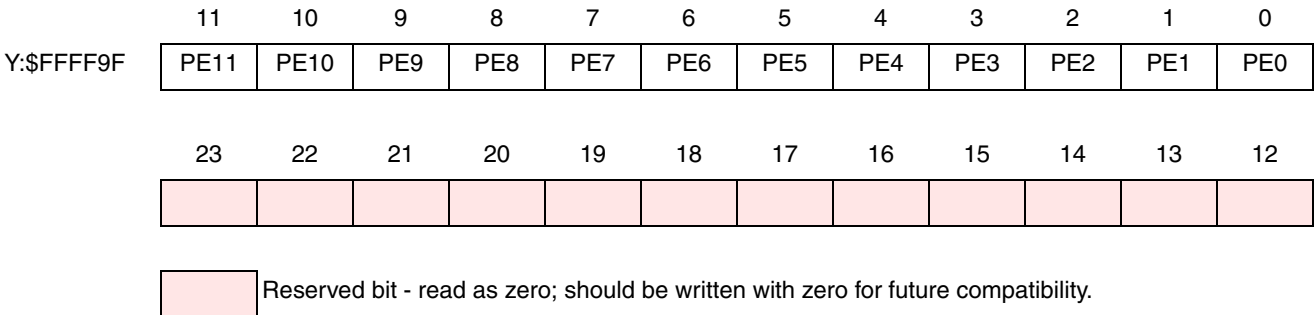
The read/write 24-bit Port E Control Register (PCRE) in conjunction with the Port E Direction Register (PRRE) controls the functionality of the ESAI\_1 GPIO pins. Each of the PE(11:0) bits controls the functionality of the corresponding port pin. See [Table 9-12](#) for the port pin configurations. Hardware and software reset clear all PCRE bits.

### 9.5.2 Port E Direction Register (PRRE)

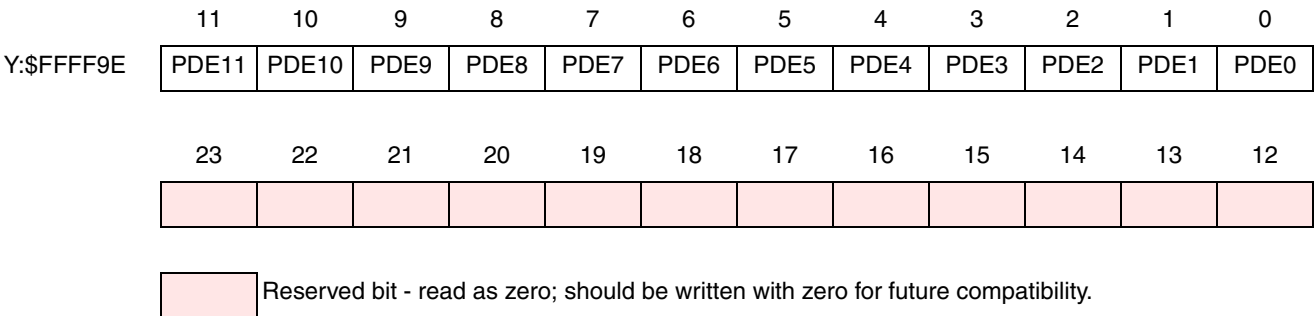
The read/write 24-bit Port E Direction Register (PRRE) in conjunction with the Port E Control Register (PCRE) controls the functionality of the ESAI\_1 GPIO pins. [Table 9-12](#) describes the port pin configurations. Hardware and software reset clear all PRRE bits.

**Table 9-12 PCRE and PRRE Bits Functionality**

PDE[i]	PE[i]	Port Pin[i] Function
0	0	disconnected
0	1	GPIO input
1	0	GPIO output
1	1	ESAI_1



**Figure 9-19 PCRE Register**



**Figure 9-20 PRRE Register**

### 9.5.3 Port E Data register (PDRE)

The read/write 24-bit Port E Data Register (see [Table 9-21](#)) is used to read or write data to/from ESAI\_1 GPIO pins. Bits PD(11:0) are used to read or write data from/to the corresponding port pins if they are configured as GPIO. If a port pin [i] is configured as a GPIO input, the corresponding PD[i] bit will reflect the value present on this pin. If a port pin [i] is configured as a GPIO output, the value written into the corresponding PD[i] bit will be reflected on this pin. If a port pin [i] is configured as disconnected, the corresponding PD[i] bit is not reset and contains undefined data.

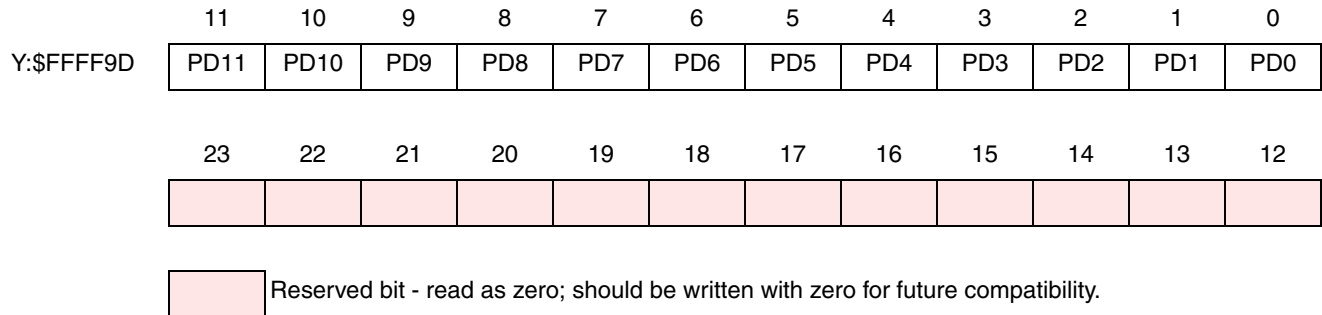


Figure 9-21 PDRE Register

## 9.6 ESAI\_1 Initialization Examples

### 9.6.1 Initializing the ESAI\_1 Using Individual Reset

- The ESAI\_1 should be in its individual reset state (PCRC = \$000 and PRRC = \$000). In the individual reset state, both the transmitter and receiver sections of the ESAI are simultaneously reset. The TPR\_1 bit in the TCR\_1 register may be used to reset just the transmitter section. The RPR\_1 bit in the RCR\_1 register may be used to reset just the receiver section.
- Configure the control registers (TCCR\_1, TCR\_1, RCCR\_1, RCR\_1) according to the operating mode, but do not enable transmitters (TE5–TE0 = \$0) or receivers (RE3–RE0 = \$0). It is possible to set the interrupt enable bits which are in use during the operation (no interrupt occurs).
- Enable the ESAI\_1 by setting the PCRC register and PRRC register bits according to pins which are in use during operation.
- Write the first data to be transmitted to the transmitters which are in use during operation. This step is needed even if DMA is used to service the transmitters.
- Enable the transmitters and receivers.
- From now on ESAI\_1 can be serviced either by polling, interrupts, or DMA.

Operation proceeds as follows:

- For internally generated clock and frame sync, these signals are active immediately after ESAI is enabled (step 3 above).
- Data is received only when one of the receive enable (REx) bits is set and after the occurrence of frame sync signal (either internally or externally generated).
- Data is transmitted only when the transmitter enable (TE<sub>x</sub>) bit is set and after the occurrence of frame sync signal (either internally or externally generated). The transmitter outputs remain tri-stated after TE<sub>x</sub> bit is set until the frame sync occurs.

### 9.6.2 Initializing Just the ESAI\_1 Transmitter Section

- It is assumed that the ESAI\_1 is operational; that is, at least one pin is defined as an ESAI\_1 pin.
- The transmitter section should be in its personal reset state (TPR = 1).

## ESAI\_1 Initialization Examples

- Configure the control registers TCCR\_1 and TCR\_1 according to the operating mode, making sure to clear the transmitter enable bits (TE0 - TE5). TPR must remain set.
- Take the transmitter section out of the personal reset state by clearing TPR.
- Write first data to the transmitters which will be used during operation. This step is needed even if DMA is used to service the transmitters.
- Enable the transmitters by setting their TE bits.
- Data is transmitted only when the transmitter enable (TE<sub>x</sub>) bit is set and after the occurrence of frame sync signal (either internally or externally generated). The transmitter outputs remain tri-stated after TE<sub>x</sub> bit is set until the frame sync occurs.
- From now on the transmitters are operating and can be serviced either by polling, interrupts, or DMA.

### 9.6.3 Initializing Just the ESAI\_1 Receiver Section

- It is assumed that the ESAI\_1 is operational; that is, at least one pin is defined as an ESAI\_1 pin.
- The receiver section should be in its personal reset state (RPR = 1).
- Configure the control registers RCCR\_1 and RCR\_1 according to the operating mode, making sure to clear the receiver enable bits (RE0 - RE3). RPR must remain set.
- Take the receiver section out of the personal reset state by clearing RPR.
- Enable the receivers by setting their RE bits.
- From now on the receivers are operating and can be serviced either by polling, interrupts, or DMA.



## 10 Digital Audio Transmitter

### 10.1 Introduction

The Digital Audio Transmitter (DAX) is a serial audio interface module that outputs digital audio data in the AES/EBU, CP-340 and IEC958 formats. Some of the key features of the DAX are listed below.

- **Operates on a frame basis**—The DAX can handle one frame (consisting of two subframes) of audio and non-audio data at a time.
- **Double-buffered audio and non-audio data**—The DAX data path is double-buffered so the next frame data can be stored in the DAX without affecting the frame currently being transmitted.
- **Direct Memory Access**—Audio data and non-audio data can be written to the DAX using DMA.
- **Programmable clock source**—Users can select the DAX clock source, and this selection configures the DAX to operate in slave or master mode.
- **Supports both master mode and slave mode in a digital audio network**—If the user selects a divided DSP core clock, the DAX will operate in the master mode. If the user selects an external clock source, the DAX will operate in the slave mode.
- **GPIO**—Each of the two DAX pins can be configured as either GPIO or as specific DAX pin. Each pin is independent of the other. However, at least one of the two pins must be selected as a DAX pin to release the DAX from reset.

The accessible DAX registers are all mapped in the X I/O memory space. This allows programmers to access the DAX using standard instructions and addressing modes. Interrupts generated by the DAX can be handled with a fast interrupt for cases in which the non-audio data does not change from frame to frame. When the DAX interrupts are disabled, they can still be served by DMA or by a “polling” technique. A block diagram of the DAX is shown in [Figure 10-1](#).

#### NOTE

The shaded registers in [Figure 10-1](#) are directly accessible by DSP instructions.

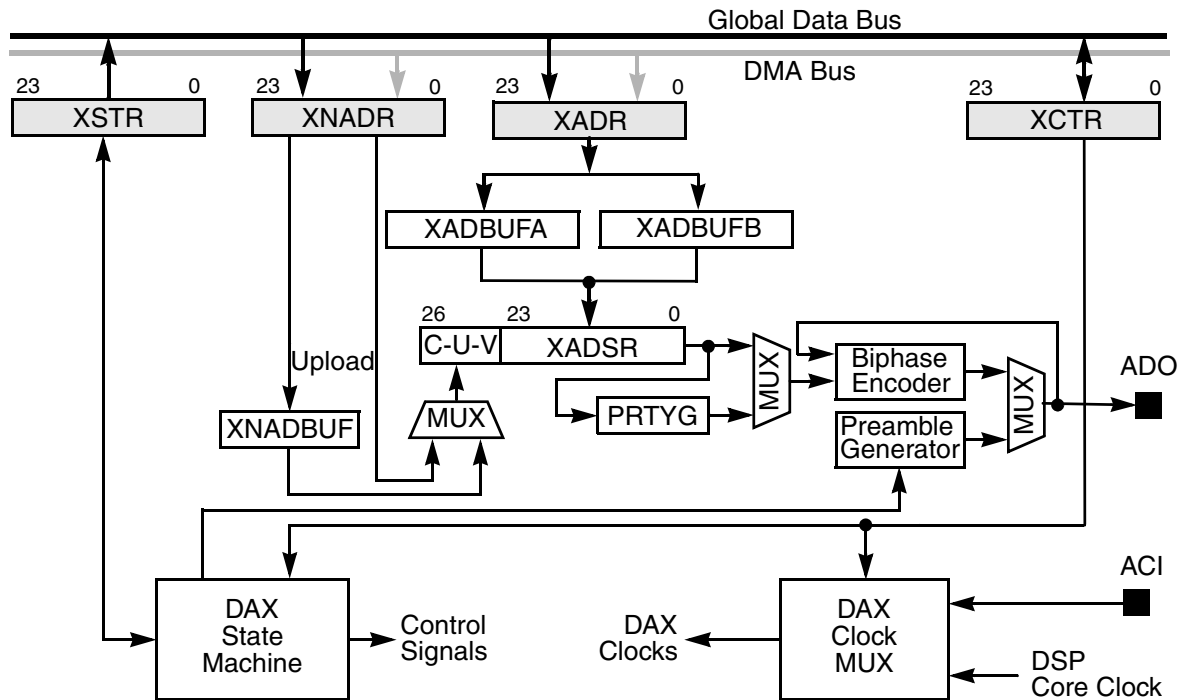


Figure 10-1 Digital Audio Transmitter (DAX) Block Diagram

## 10.2 DAX Signals

The DAX has two signal lines:

- **DAX Digital Audio Output (ADO/PD1)**—The ADO pin sends audio and non-audio data in the AES/EBU, CP340, and IEC958 formats in a biphase mark format. The ADO pin may also be used as a GPIO pin PD1 if the DAX is not operational.
- **DAX Clock Input (ACI/PD0)**—When the DAX clock is configured to be supplied externally, the external clock is applied to the ACI pin. The frequency of the external clock must be 256 times, 384 times, or 512 times the audio sampling frequency ( $256 \times F_s$ ,  $384 \times F_s$ , or  $512 \times F_s$ ). The ACI pin may also be used as a GPIO pin PD0 when the DAX is disabled or when operating from the internal DSP clock.

## 10.3 DAX Functional Overview

The DAX consists of the following:

- Audio data register (XADR)
- Two audio data buffers (XADBUFA and XADBUFB)
- Non-audio data register (XNADR)
- Non-audio data buffer (XNADBUF)
- Audio and non-audio data shift register (XADSR)
- Control register (XCTR)

- Status register (XSTR)
- Parity generator (PRTYG)
- Preamble generator
- Biphase encoder
- Clock multiplexer
- Control state machine

XADR, XADBUFA, XADBUFB and XADSR creates a FIFO-like data path. Channel A is written to XADR and moves to XADBUFA. Then channel B is written to XADR, and, when XADBUFB empties, XADR moves into it. XADBUFA moves to the shift register XADSR when XADSR has shifted out its last bit. After channel A audio and non-audio data has been shifted out, XADBUFB moves into XADSR, and channel B audio and non audio shift begins.

The frame non-audio data (stored in XNADR) is transferred to the XADSR (for channel A) and to the XNADBUF registers (for channel B) at the beginning of a frame transmission. This is called an “upload.” The DAX audio data register empty (XADE) flag is set when XADR and XADBUFA are empty, and, if the audio data register empty interrupt is enabled (XDIE=1), an interrupt request is sent to the DSP core. The interrupt handling routine then sends the non-audio data bits to XNADR and the next frame of audio data to XADR (two subframes).

At the beginning of a frame transmission, one of the 8-bit channel A preambles (Z-preamble for the first subframe in a block, or X-preamble otherwise) is generated in the preamble generator and then shifted out to the ADO pin in the first eight time slots. The preamble is generated in biphase mark format. The twenty-four audio and three non-audio data bits in the XADSR are shifted out to the biphase encoder, which shifts them out through the ADO pin in the biphase mark format in the next 54 time slots. The parity generator calculates an even parity over the 27 bits of audio and non-audio data; it then outputs the result through the biphase encoder to the ADO pin at the last two time slots. This is the end of the first (channel A) subframe transmission.

The second subframe transmission (channel B) starts with the preamble generator generating the channel B preamble (Y-preamble). At the same time, channel B audio and non-audio data is transferred to the XADSR shift-register from the XADBUFB and XNADBUF registers. The generated Y-preamble is output immediately after the channel A parity and is followed by the audio and non-audio data in the XADSR, which is in turn followed by the calculated parity for channel B. This completes a frame transmission. When the channel B parity is sent, the audio data for the next frame, stored in XADBUFA and the non-audio data bits from the XNADR, are uploaded to XADSR.

## 10.4 DAX Programming Model

The programmer-accessible DAX registers are shown in [Figure 10-2](#). The registers are described in the following subsections. The Interrupt Vector table for the DAX is shown in [Table 10-1](#). The internal interrupt priority is shown in [Table 10-2](#).

Table 10-1 DAX Interrupt Vectors

Condition	Address	Description
XAUR	VBA:\$28	DAX transmit underrun error
XADE & XBLK	VBA:\$2A	DAX block transferred
XADE	VBA:\$2E	DAX audio data register empty

Table 10-2 DAX Interrupt Priority

Priority	Interrupt
highest	DAX transmit underrun error
	DAX block transferred
lowest	DAX audio data register empty

# 10.5 DAX Internal Architecture

Hardware components shown in [Figure 10-1](#) are described in the following sections. The DAX programming model is illustrated in [Figure 10-2](#).

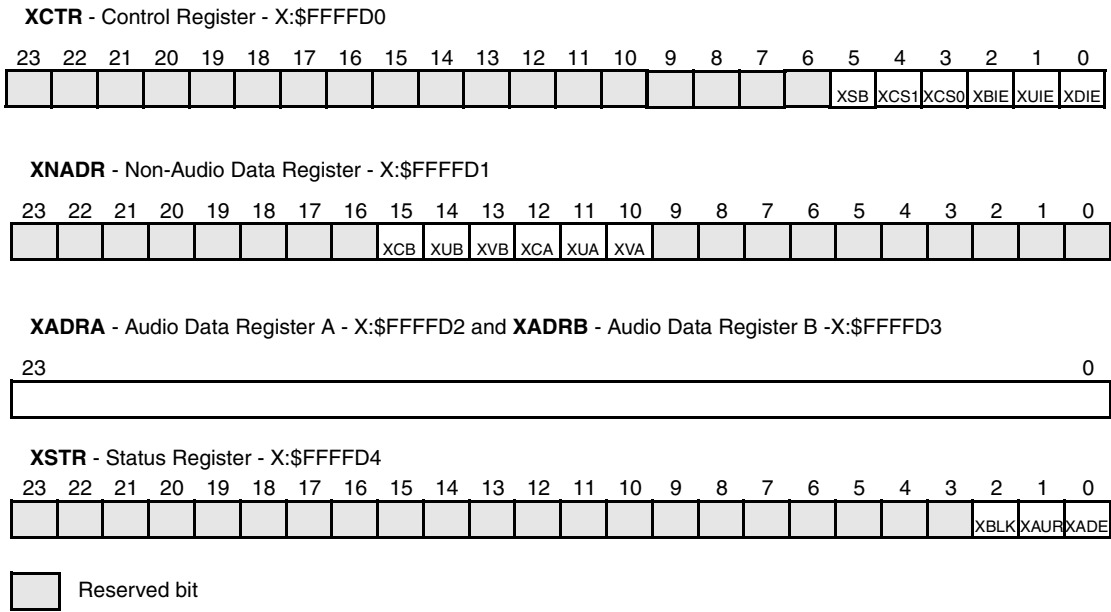


Figure 10-2 DAX Programming Model

### 10.5.1 DAX Audio Data Register (XADR)

XADR is a 24-bit write-only register. One frame of audio data, which is to be transmitted in the next frame slot, is transferred to this register. Successive write accesses to this register will store channel A and channel B alternately in XADBUFA and in XADBUFB respectively. When XADR and XADBUFA are empty, XADE bit in the XSTR is set, and, if the audio data register empty interrupt is enabled (XDIE=1), an interrupt request is sent to the DSP core. When channel B is transferred to XADR, the XADE bit in the XSTR is cleared. XADR can also be accessed by DMA. When XADR and XADBUFA are empty, the DAX sends a DMA request to the core. The DMA first transfers non-audio data bits to XNADR (optional), then transfers channel A and channel B to XADR. The XADR can be accessed with two different successive addresses. This feature supports sending non-audio data bits, channel A and channel B to the DAX in three successive DMA transfers.

### 10.5.2 DAX Audio Data Buffers (XADBUFA / XADBUFB)

XADBUFA and XADBUFB are 24-bit registers that buffer XADR from XADSR, creating a FIFO-like data path. These registers hold the next two subframes of audio data to be transmitted. Channel A audio data is transferred from XADR to XADBUFA if XADBUFA is empty. Channel B audio data is transferred from XADR to XADBUFB if XADBUFB is empty. Audio data is transferred from XADBUFA and XADBUFB alternately to XADSR provided that XADSR shifted out all the audio and non-audio bits of the currently transmitted channel. This buffering mechanism provides more cycles for writing the next audio data to XADR. These registers are not directly accessible by DSP instructions.

### 10.5.3 DAX Audio Data Shift Register (XADSR)

The XADSR is a 27-bit shift register that shifts the 24-bit audio data and the 3-bit non-audio data for one subframe. The contents of XADBUFA or XADBUFB are directly transferred to the XADSR at the beginning of the subframe transmission. The channel A subframe is transferred to XADSR at the same time that the three bits of non-audio data (V-bit, U-bit and C-bit) for channel A in the DAX non-audio data register (XNADR) are transferred to the three highest-order bits of the XADSR. At the beginning of the channel B transmission, audio and non-audio data for channel B are transferred from the XADBUFB and the XNADBUF to the XADSR for shifting. The data in the XADSR is shifted toward the lowest-order bit at the fifth to thirty-first bit slot of each subframe transmission. This register is not directly accessible by DSP instructions.

### 10.5.4 DAX Non-Audio Data Register (XNADR)

The XNADR is a 24-bit write-only register. It holds the three bits of non-audio data for each subframe. XNADR can be accessed by core instructions or by DMA. The contents of the XNADR are shown in [Figure 10-2](#). XNADR is not affected by any of the DAX reset states. The XNADR bits are described in the following paragraphs.

#### 10.5.4.1 DAX Channel A Validity (XVA)—Bit 10

The value of the XVA bit is transmitted as the twenty-ninth bit (Bit 28) of channel A subframe in the next frame.

#### 10.5.4.2 DAX Channel A User Data (XUA)—Bit 11

The value of the XUA bit is transmitted as the thirtieth bit (Bit 29) of the channel A subframe in the next frame.

#### 10.5.4.3 DAX Channel A Channel Status (XCA)—Bit 12

The value of the XCA bit is transmitted as the thirty-first bit (Bit 30) of the channel A subframe in the next frame.

#### 10.5.4.4 DAX Channel B Validity (XVB)—Bit 13

The value of the XVB bit is transmitted as the twenty-ninth bit (Bit 28) of the channel B subframe in the next frame.

#### 10.5.4.5 DAX Channel B User Data (XUB)—Bit 14

The value of the XUB bit is transmitted as the thirtieth bit (Bit 29) of the channel B subframe in the next frame.

#### 10.5.4.6 DAX Channel B Channel Status (XCB)—Bit 15

The value of the XCB bit is transmitted as the thirty-first bit (Bit 30) of the channel B subframe in the next frame.

#### 10.5.4.7 XNADR Reserved Bits—Bits 9-0, 23-16

These XNADR bits are reserved. They read as 0 and should be written with 0 to ensure compatibility with future device versions.

### 10.5.5 DAX Non-Audio Data Buffer (XNADBUF)

The XNADBUF is a 3-bit register that temporarily holds channel B non-audio data (XVB, XUB and XCB) for the current transmission while the channel A data is being transmitted. This mechanism provides programmers more instruction cycles to store the next frame's non-audio data to the XCB, XUB, XVB, XCA, XUA and XVA bits in the XNADR. The data in the XNADBUF register is transferred to the XADSR along with the contents of the XADBUF register at the beginning of channel B transmission.

#### NOTE

The XNADBUF register is not directly accessible by DSP instructions.

### 10.5.6 DAX Control Register (XCTR)

The XCTR is a 24-bit read/write register that controls the DAX operation. The contents of the XCTR are shown in [Figure 10-2](#). XCTR is cleared by software reset and hardware reset. The XCTR bits are described in the following paragraphs.

### 10.5.6.1 Audio Data Register Empty Interrupt Enable (XDIE)—Bit 0

When the XDIE bit is set, the audio data register empty interrupt is enabled and sends an interrupt request signal to the DSP if the XADE status bit is set. When XDIE bit is cleared, this interrupt is disabled.

### 10.5.6.2 Underrun Error Interrupt Enable (XUIE)—Bit 1

When the XUIE bit is set, the underrun error interrupt is enabled and sends an interrupt request signal to the DSP if the XAUR status bit is set. When XUIE bit is cleared, this interrupt is disabled.

### 10.5.6.3 Block Transferred Interrupt Enable (XBIE)—Bit 2

When the XBIE bit is set, the block transferred interrupt is enabled and sends an interrupt request signal to the DSP if the XBLK and XADE status bits are set. When XBIE bit is cleared, this interrupt is disabled.

### 10.5.6.4 DAX Clock Input Select (XCS[1:0])—Bits 4–3

The XCS[1:0] bits select the source of the DAX clock and/or its frequency. [Table 10-3](#) shows the configurations selected by these bits. These bits should be changed only when the DAX is disabled.

**Table 10-3 Clock Source Selection**

XCS1	XCS0	DAX Clock Source
0	0	DSP Core Clock ( $f = 1024 \times f_s$ )
0	1	ACI Pin, $f = 256 \times f_s$
1	0	ACI Pin, $f = 384 \times f_s$
1	1	ACI Pin, $f = 512 \times f_s$

### 10.5.6.5 DAX Start Block (XSB)—Bit 5

The XSB bit forces the DAX to start a new block. When this bit is set, the next frame will start with “Z” preamble and will start a new block even though the current block was not finished. This bit is cleared when the new block starts.

### 10.5.6.6 XCTR Reserved Bits—Bits 23-6

These XCTR bits are reserved. They read as 0 and should be written with 0 for future compatibility.

## 10.5.7 DAX Status Register (XSTR)

The XSTR is a 24-bit read-only register that contains the DAX status flags. The contents of the XSTR are shown in [Figure 10-2](#). XSTR is cleared by software reset, hardware reset and by the stop state. The XSTR bits are described in the following paragraphs.

### 10.5.7.1 DAX Audio Data Register Empty (XADE)—Bit 0

The XADE status flag indicates that the DAX audio data register XADR and the audio data buffer XADBUFA are empty (and ready to receive the next frame's audio data). This bit is set at the beginning of every frame transmission (more precisely, when channel A audio data is transferred from XADBUFA to XADSR). When XADE is set and the interrupt is enabled ( $XDIE = 1$ ), an audio data register empty interrupt request is sent to the DSP core. XADE is cleared by writing two channels of audio data to XADR.

### 10.5.7.2 DAX Transmit Underrun Error Flag (XAUR)—Bit 1

The XAUR status flag is set when the DAX audio data buffers XADBUFA or XADBUFB are empty and the respective audio data upload occurs. When a DAX underrun error occurs, the previous frame data will be retransmitted in both channels. When XAUR is set and the interrupt is enabled ( $XUIE = 1$ ), an underrun error interrupt request is sent to the DSP core. This allows programmers to write an exception handling routine for this special case. The XAUR bit is cleared by reading the XSTR register with XAUR set, followed by writing two channels of audio data to XADR.

### 10.5.7.3 DAX Block Transfer Flag (XBLK)—Bit 2

The XBLK flag indicates that the frame being transmitted is the last frame in a block. This bit is set at the beginning of the transmission of the last frame (the 191st frame). This bit does not cause any interrupt. However, if  $XBIE=1$  it causes a change in the interrupt vector sent to DSP core in the event of an audio data register empty interrupt, so that a different interrupt routine can be called (providing the next non-audio data structures for the next block as well as storing audio data for the next frame). Writing two channels of audio data to XADR clears this bit.

The relative timing of transmit frames and XADE and XBLK flags is shown in [Figure 10-3](#).

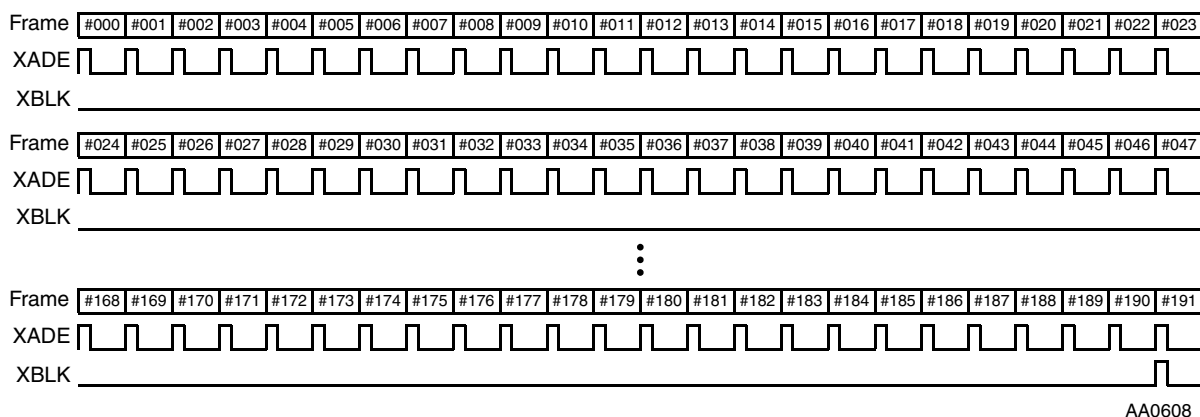


Figure 10-3 DAX Relative Timing



### 10.5.7.4 XSTR Reserved Bits—Bits 23–3

These XSTR bits are reserved. They read as 0 and should be written with 0 to ensure compatibility with future device versions.

### 10.5.8 DAX Parity Generator (PRTYG)

The PRTYG generates the parity bit for the subframe being transmitted. The generated parity bit ensures that subframe bits four to thirty-one will carry an even number of ones and zeroes.

### 10.5.9 DAX Biphase Encoder

The DAX biphase encoder encodes each audio and non-audio bit into its biphase mark format and shifts this encoded data out to the ADO output pin synchronously to the biphase clock.

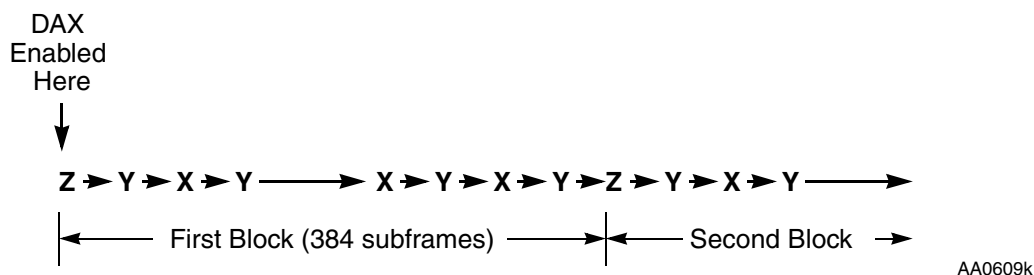
### 10.5.10 DAX Preamble Generator

The DAX preamble generator automatically generates one of three preambles in the 8-bit preamble shift register at the beginning of each subframe transmission and shifts it out. The generated preambles always start with “0”. Bit patterns of preambles generated in the preamble generator are shown in [Table 10-4](#). The preamble bits are already in the biphase mark format.

**Table 10-4 Preamble Bit Patterns**

Preamble	Bit Pattern	Channel
X	00011101	A
Y	00011011	B
Z	00010111	A (first in block)

There is no programmable control for the preamble selection. The first subframe to be transmitted (immediately after the DAX is enabled) is the beginning of a block, and, therefore, it has a “Z” preamble. This is followed by the second subframe, which has an “Y” preamble. After that, “X” and “Y” preambles are transmitted alternately until the end of the block transfer (192 frames transmitted). See [Figure 10-4](#) for an illustration of the preamble sequence.



**Figure 10-4 Preamble sequence**

### 10.5.11 DAX Clock Multiplexer

The DAX clock multiplexer selects one of the clock sources and generates the biphase clock ( $128 \times F_s$ ) and shift clock ( $64 \times F_s$ ). The clock source can be selected from the following options (see also Section 10.5.6.4, "DAX Clock Input Select (XCS[1:0])—Bits 4–3").

- The internal DSP core clock—assumes  $1024 \times F_s$
- DAX clock input pin (ACI)— $512 \times F_s$
- DAX clock input pin (ACI)— $384 \times F_s$
- DAX clock input pin (ACI)— $256 \times F_s$

Figure 10-5 shows how each clock is divided to generate the biphase and bit shift clocks

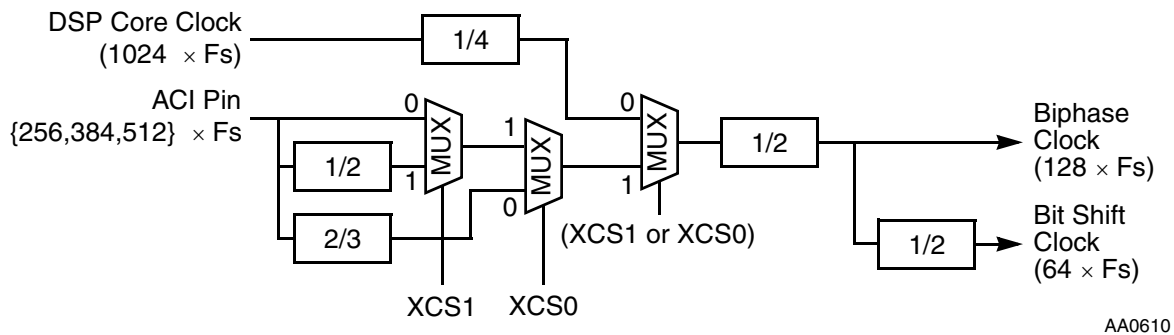


Figure 10-5 Clock Multiplexer Diagram

#### NOTE

For proper operation of the DAX, the DSP core clock frequency must be at least five times higher than the DAX bit shift clock frequency ( $64 \times F_s$ ).

### 10.5.12 DAX State Machine

The DAX state machine generates a set of sequencing signals used in the DAX.

## 10.6 DAX Programming Considerations

The following sections describe programming considerations for the DAX.

### 10.6.1 Initiating A Transmit Session

To initiate the DAX operation, follow this procedure:

1. Ensure that the DAX is disabled (PC1 and PC0 bits of port control register PCRD are cleared)
2. Write the non-audio data to the corresponding bits in the XNADR register
3. Write the channel A and channel B audio data in the XADR register
4. Write the transmit mode to the XCTR register
5. Enable DAX by setting PC1 bit (and by setting PC0 bit if in slave mode) in the port control register (PCRD); transmission begins.

## 10.6.2 Audio Data Register Empty Interrupt Handling

When the XDIE bit is set and the DAX is active, an audio data register empty interrupt (XADE = 1) is generated once at the beginning of every frame transmission. Typically, within an XADE interrupt, the non-audio data bits of the next frame are stored in XNADR and one frame of audio data to be transmitted in the next frame is stored in the FIFO by two consecutive MOVEP instructions to XADR. If the non-audio bits are not changed from frame to frame, this procedure can be handled within a fast interrupt routine. Storing the next frame's audio data in the FIFO clears the XADE bit in the XSTR.

## 10.6.3 Block Transferred Interrupt Handling

An interrupt with the XBLK vector indicates the end of a block transmission and may require some computation to provide the next non-audio data structures that are to be transmitted within the next block. Within the routine, the next audio data can be stored in the FIFO by two consecutive MOVEP instructions to XADR, and the next non-audio data can be stored in the XNADR. The XBLK interrupt occurs only if the XBIE bit in XCTR is set. If XBIE is cleared, a XADE interrupt vector will take place.

## 10.6.4 DAX operation with DMA

During DMA transfers, the XDIE bit of the XCTR must be cleared to avoid XADE interrupt services by the DSP core. The initialization appearing in [Section 10.6.1, "Initiating A Transmit Session"](#) is relevant for DMA operation. DMA transfers can be performed with or without changing non-audio bits from frame to frame. [Table 10-5](#) describes two examples of DMA configuration.

**Table 10-5 Examples of DMA configuration**

Register	Non-audio data bits change	Non-audio data bits do not change
DCR2	DE=1; Enable DMA channel. DIE=1; Enable DMA interrupt. DTM[2:0]=010; Line transfer mode. D3D=0; Not 3D. DAM[5:3]=000; 2D mode. DAM[2:0]=101; post increment by 1. DDS[1:0]=00; X memory space. DRS[4:0]=01010; DAX is DMA request source. Other bits are application dependent.	DE=1; Enable DMA channel. DIE=1; Enable DMA interrupt. DTM[2:0]=010; Line transfer mode. D3D=0; Not 3D. DAM[5:3]=000; 2D mode. DAM[2:0]=101; post increment by 1. DDS[1:0]=00; X memory space. DRS[4:0]=01010; DAX is DMA request source. Other bits are application dependent.
DCO2	DCOH=number of frames in block - 1 DCOL=\$002; 3 destination registers	DCOH=number of frames in block - 1 DCOL=\$001; 2 destination registers
DSR2	first memory address of the block	first memory address of the block
DDR2	XNADR address (base address + \$1)	XADR address (base address + \$2)
DOR0	\$FFFFFFE; offset=-2	\$FFFFFFF; offset=-1

## GPIO (PORT D) - Pins and Registers

The memory organization employed for DMA transfers depends on whether or not non-audio data changes from frame to frame as shown in Figure 10-6.

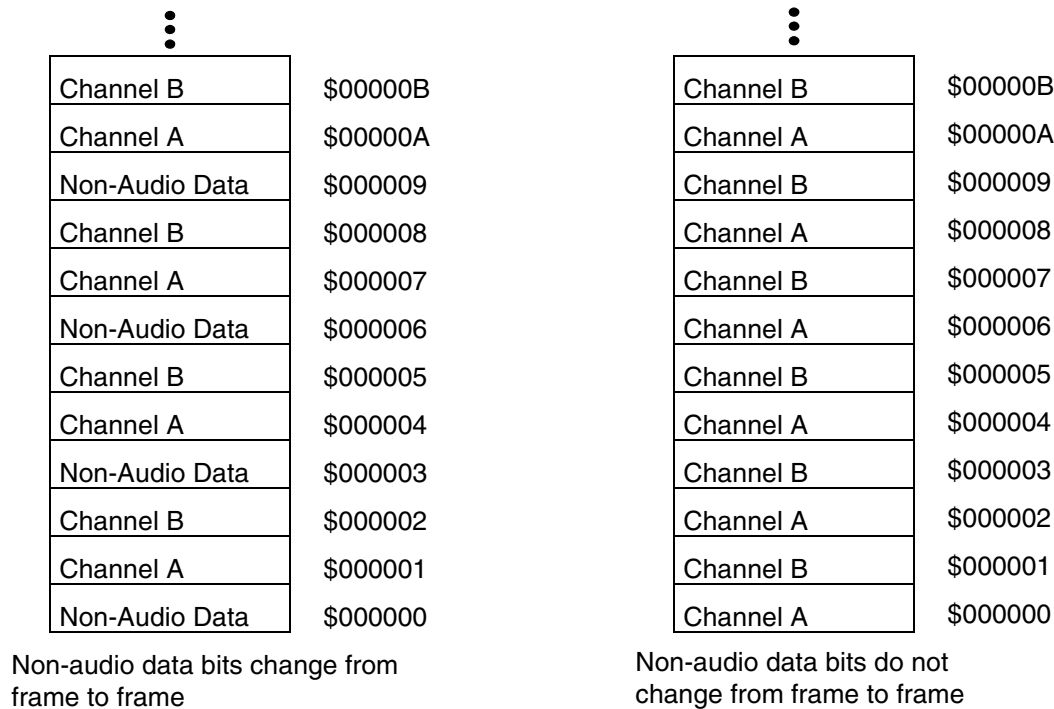


Figure 10-6 Examples of data organization in memory

### 10.6.5 DAX Operation During Stop

The DAX operation cannot continue when the DSP is in the stop state since no DSP clocks are active. While the DSP is in the stop state, the DAX will remain in the individual reset state and the status flags are initialized as described for resets. No DAX control bits are affected. The DAX should be disabled before the DSP enters the stop state.

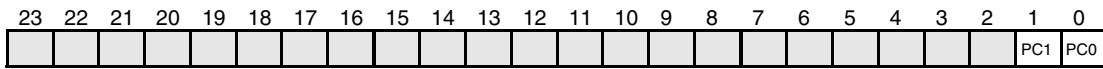
## 10.7 GPIO (PORT D) - Pins and Registers

The Port D GPIO functionality of the DAX is controlled by three registers: Port D Control Register (PCRD), Port D Direction Register (PRRD) and Port D Data Register (PDRD).

### 10.7.1 Port D Control Register (PCRD)

The read/write 24-bit DAX Port D Control Register controls the functionality of the DAX GPIO pins. Each of the PC[1:0] bits controls the functionality of the corresponding port pin. When a PC[i] bit is set, the corresponding port pin is configured as a DAX pin. When a PC[i] bit is cleared, the corresponding port pin is configured as GPIO pin. If both PC1 and PC0 are cleared, the DAX is disabled. Hardware and software reset clear all PCRD bits.

PCRD -Port D Control Register - X:\$FFFD7




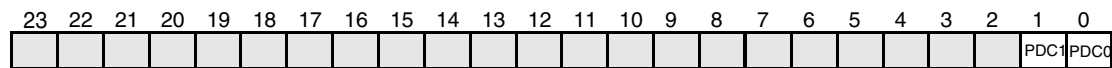
 read as zero, should be written with zero for future compatibility

Figure 10-7 Port D Control Register (PCRD)

## 10.7.2 Port D Direction Register (PRRD)

The read/write 24-bit Port D Direction Register controls the direction of the DAX GPIO pins. When port pin[i] is configured as GPIO, PDC[i] controls the port pin direction. When PDC[i] is set, the GPIO port pin[i] is configured as output. When PDC[i] is cleared the GPIO port pin[i] is configured as input. Hardware and software reset clear all PRRD bits. Table 10-6 describes the port pin configurations.

PRRD - Port D Direction Register - X:\$FFFD6



 read as zero, should be written with zero for future compatibility

Figure 10-8 Port D Direction Register (PRRD)

Table 10-6 DAX Port GPIO Control Register Functionality

PDC1	PC1	ADO/PD1 pin	PDC0	PC0	ACI/PD0 pin	DAX state
0	0	Disconnected	0	0	Disconnected	Personal Reset
0	0	Disconnected	0	1	PD0 Input	Personal Reset
0	0	Disconnected	1	0	PD0 Output	Personal Reset
0	0	Disconnected	1	1	ACI	Enabled
0	1	PD1 Input	0	0	Disconnected	Personal Reset
0	1	PD1 Input	0	1	PD0 Input	Personal Reset
0	1	PD1 Input	1	0	PD0 Output	Personal Reset
0	1	PD1 Input	1	1	ACI	Enabled
1	0	PD1 Output	0	0	Disconnected	Personal Reset
1	0	PD1 Output	0	1	PD0 Input	Personal Reset
1	0	PD1 Output	1	0	PD0 Output	Personal Reset
1	0	PD1 Output	1	1	ACI	Enabled
1	1	ADO	0	0	Disconnected	Enabled
1	1	ADO	0	1	PD0 Input	Enabled
1	1	ADO	1	0	PD0 Output	Enabled
1	1	ADO	1	1	ACI	Enabled

10.7.3 Port D Data Register (PDRD)

The read/write 24-bit Port D Data Register is used to read or write data to/from the DAX GPIO pins. Bits PD[1:0] are used to read or write data from/to the corresponding port pins if they are configured as GPIO. If a port pin [i] is configured as a GPIO input, the corresponding PD[i] bit will reflect the value present on this pin. If a port pin [i] is configured as a GPIO output, the value written into the corresponding PD[i] bit will be reflected on the this pin. Hardware and software reset clear all PDRD bits.

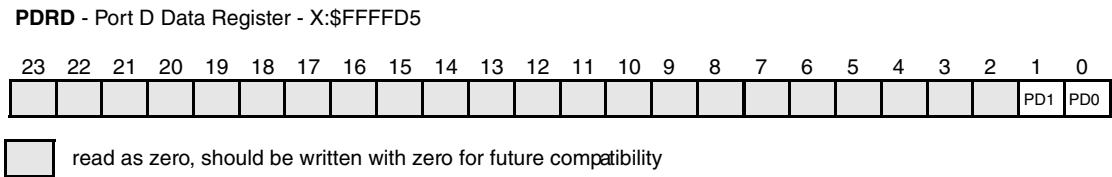


Figure 10-9 Port D Data Register (PDRD)

Because of an order from the United States International Trade Commission, BGA-packaged product lines and part numbers indicated here currently are not available from Freescale for import or sale in the United States prior to September 2010: DSP56303

## 11 Triple Timer Module

The timers in the DSP56371 internal triple timer module act as timed pulse generators or as pulse-width modulators. Two of the three timers (timer 0 and 1) each have a single signal that can function as a GPIO signal or as a timer signal. These two timers can also function as an event counter to capture an event or to measure the width or period of a signal.

### 11.1 Overview

The timer module contains a common 21-bit prescaler and three independent and identical general-purpose 24-bit timer/event counters, each with its own register set. Two of the timers (timer 0 and 1) have the following capabilities:

- Uses internal or external clocking
- Interrupts the DSP56371 after a specified number of events (clocks) or signals an external device after counting internal events
- Triggers DMA transfers after a specified number of events (clocks) occurs
- Connects to the external world through one bidirectional signal, designated TIO[0–1] for timers 0–1. Note that timer 2 does not interface externally via TIO pin.

When TIO is configured as an input, the timer functions as an external event counter or measures external pulse width/signal period. When TIO is configured as an output, the timer functions as a timer, a watchdog timer, or a pulse-width modulator. When the timer does not use TIO, it can be used as a GPIO signal (also called TIO[0–1]).

#### 11.1.1 Triple Timer Module Block Diagram

Figure 11-1 shows a block diagram of the triple timer module. This module includes a 24-bit Timer Prescaler Load Register (TPLR), a 24-bit Timer Prescaler Count Register (TPCR), and three timers. Each timer can use the prescaler clock as its clock source.

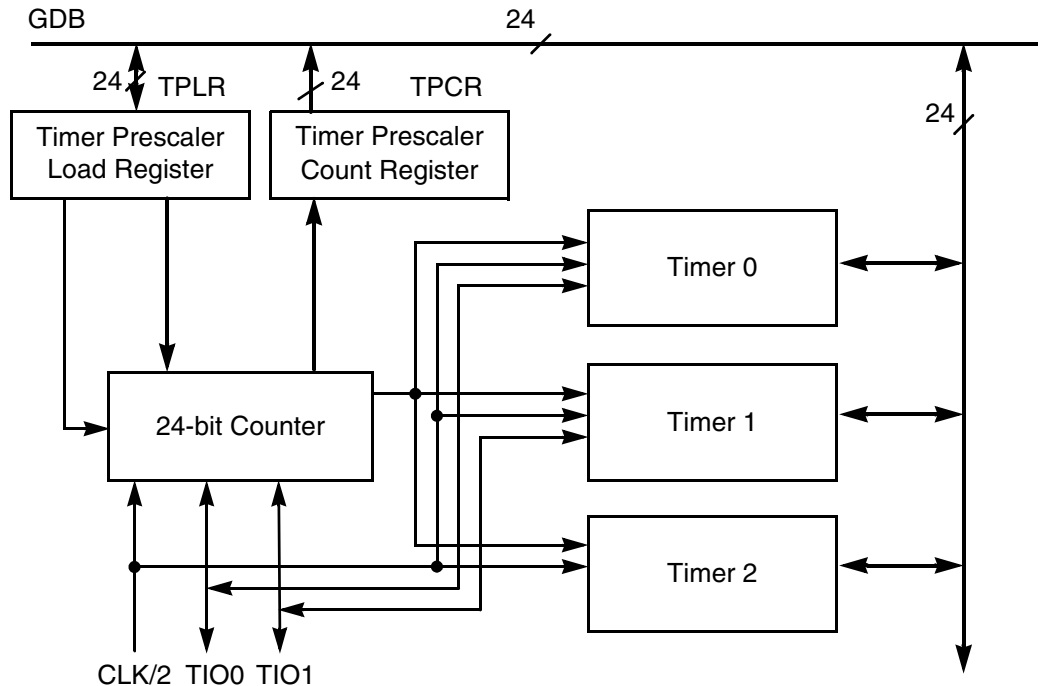


Figure 11-1 Triple Timer Module Block Diagram

### 11.1.2 Individual Timer Block Diagram

Figure 11-2 shows the structure of an individual timer block. The DSP56371 treats each timer as a memory-mapped peripheral with four registers occupying four 24-bit words in the X data memory space. The three timers are identical in structure and function with the exception that timer 2 does not interface to an external signal. Functions described in this section that requires interfacing to an external signal are only applicable to timers 0 and 1. Either standard polled or interrupt programming techniques can be used to service the timers. A single, generic timer is discussed in this chapter. Each timer includes the following:

- 24-bit counter
- 24-bit read/write Timer Control and Status Register (TCSR)
- 24-bit read-only Timer Count Register (TCR)
- 24-bit write-only Timer Load Register (TLR)
- 24-bit read/write Timer Compare Register (TCPR)
- Logic for clock selection and interrupt/DMA trigger generation.

The timer mode is controlled by the TC[3–0] bits which are TCSR[7–4]. For a listing of the timer modes and descriptions of their operations, see [Section 11.3, "Operating Modes"](#).



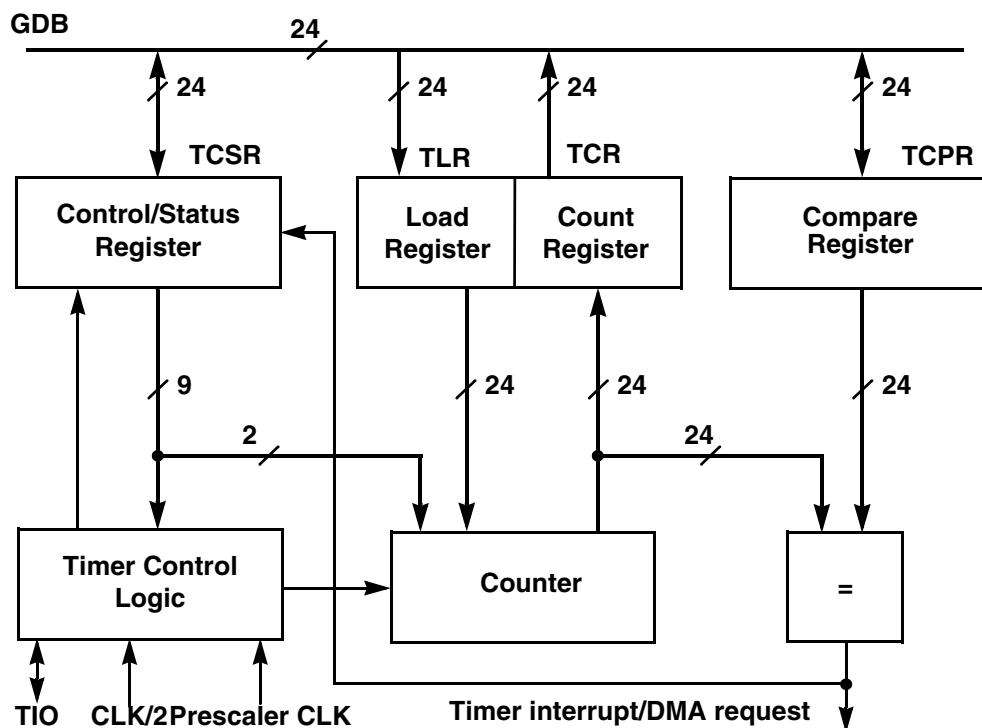


Figure 11-2 Timer Module Block Diagram

## 11.2 Operation

This section discusses the following timer basics:

- Reset
- Initialization
- Exceptions

### 11.2.1 Timer After Reset

A hardware  $\overline{\text{RESET}}$  signal or software RESET instruction clears the Timer Control and Status Register for each timer, thus configuring each timer as a GPIO. A timer is active only if the timer enable bit 0 (TCSR[TE]) in the specific timer TCSR is set.

### 11.2.2 Timer Initialization

To initialize a timer, do the following:

1. Ensure that the timer is not active either by sending a reset or clearing the TCSR[TE] bit.
2. Configure the control register (TCSR) to set the timer operating mode. Set the interrupt enable bits as needed for the application.
3. Configure other registers: Timer Prescaler Load Register (TPLR), Timer Load Register (TLR), and Timer Compare Register (TCPR) as needed for the application.
4. Enable the timer by setting the TCSR[TE] bit.

## 11.2.3 Timer Exceptions

Each timer can generate two different exceptions:

- **Timer Overflow (highest priority)** — Occurs when the timer counter reaches the overflow value. This exception sets the TOF bit. TOF is cleared when a value of one is written to it or when the timer overflow exception is serviced.
- **Timer Compare (lowest priority)** — Occurs when the timer counter reaches the value given in the Timer Compare Register (TCPR) for all modes except measurement modes. In measurement modes 4–6, a compare exception occurs when the appropriate transition occurs on the TIO signal. The Compare exception sets the TCF bit. TCF is cleared when a value of one is written to it or when the timer compare interrupt is serviced.

To configure a timer exception, perform the following steps. The example at the right of each step shows the register settings for configuring a Timer 0 compare interrupt. The order of the steps is optional except that the timer should not be enabled (step 2e) until all other exception configuration is complete:

1. Configure the interrupt service routine (ISR):
  - a) Load vector base address register VBA (b23–8)
  - b) Define I\_VEC to be equal to the VBA value (if that is nonzero).  
If it is defined, I\_VEC must be defined for the assembler before the interrupt equate file is included.
  - c) Load the exception vector table entry: two-word fast interrupt, or jump/branch to subroutine (long interrupt). p:TIM0C
2. Configure the interrupt trigger:
  - a) Enable and prioritize overall peripheral interrupt functionality. IPRP (TOL[1–0])
  - b) Enable a specific peripheral interrupt. TCSR0 (TCIE)
  - c) Unmask interrupts at the global level. SR (I[1–0])
  - d) Configure a peripheral interrupt-generating function. TCSR0 (TC[7–4])
  - e) Enable peripheral and associated signals. TCSR0 (TE)

## 11.3 Operating Modes

These timers have operating modes that meet a variety of system requirements, as follows:

- **Timer**
  - GPIO, mode 0: Internal timer interrupt generated by the internal clock
  - Pulse, mode 1: External timer pulse generated by the internal clock
  - Toggle, mode 2: Output timing signal toggled by the internal clock
  - Event counter, mode 3: Internal timer interrupt generated by an external clock

- Measurement
  - Input width, mode 4: Input pulse width measurement
  - Input period, mode 5: Input signal period measurement
  - Capture, mode 6: Capture external signal
- PWM, mode 7: Pulse width modulation
- Watchdog
  - Pulse, mode 9: Output pulse, internal clock
  - Toggle, mode 10: Output toggle, internal clock

**NOTE**

To ensure proper operation, the TCSR TC[3–0] bits should be changed only when the timer is disabled (that is, when TCSR[TE] is cleared).

### 11.3.1 Triple Timer Modes

For all triple timer modes, the following points are true:

- The TCSR[TE] bit is set to clear the counter and enable the timer. Clearing TCSR[TE] disables the timer.
- The value to which the timer is to count is loaded into the TCPR. (This is true for all modes except the measurement modes (modes 4 through 6).
- The counter is loaded with the TLR value on the first clock.
- If the counter overflows, TCSR[TOF] is set, and if TCSR[TOIE] is set, an overflow interrupt is generated.
- You can read the counter contents at any time from the Timer Count Register (TCR).

#### 11.3.1.1 Timer GPIO (Mode 0)

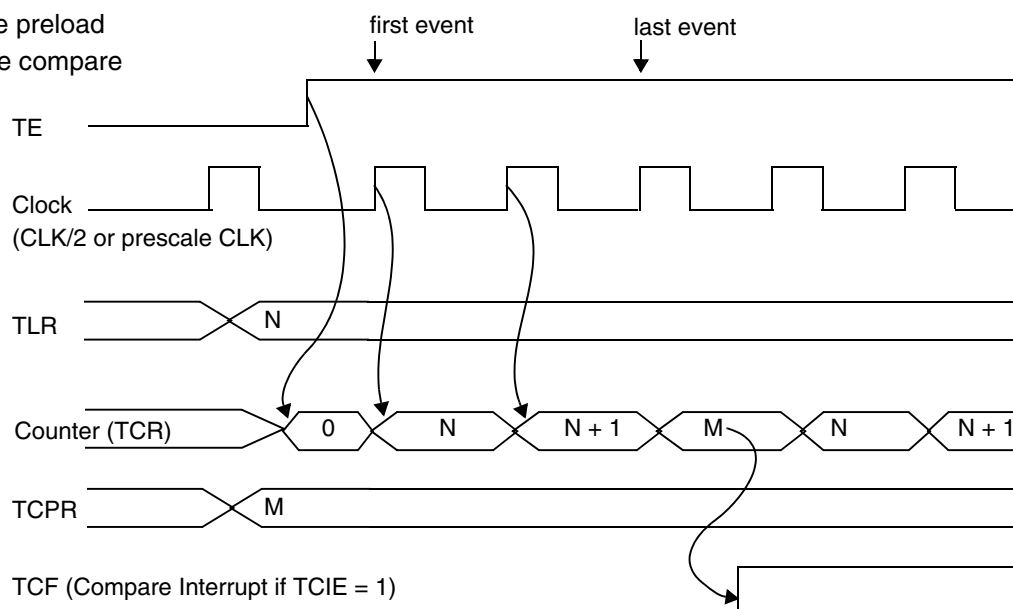
Bit Settings				Mode Characteristics				
TC3	TC2	TC1	TC0	Mode	Name	Function	TIO	Clock
0	0	0	0	0	GPIO	Timer	GPIO	Internal

In Mode 0, the timer generates an internal interrupt when a counter value is reached, if the timer compare interrupt is enabled (see [Figure 11-3](#) and [Figure 11-4](#)). When the counter equals the TCPR value, TCSR[TCF] is set and a compare interrupt is generated if the TCSR[TCIE] bit is set. If the TCSR[TRM] bit is set, the counter is reloaded with the TLR value at the next timer clock and the count is resumed. If TCSR[TRM] is cleared, the counter continues to increment on each timer clock signal. This process repeats until the timer is disabled.

**Mode 0 (internal clock, no timer output): TRM = 1**

N = write preload

M = write compare

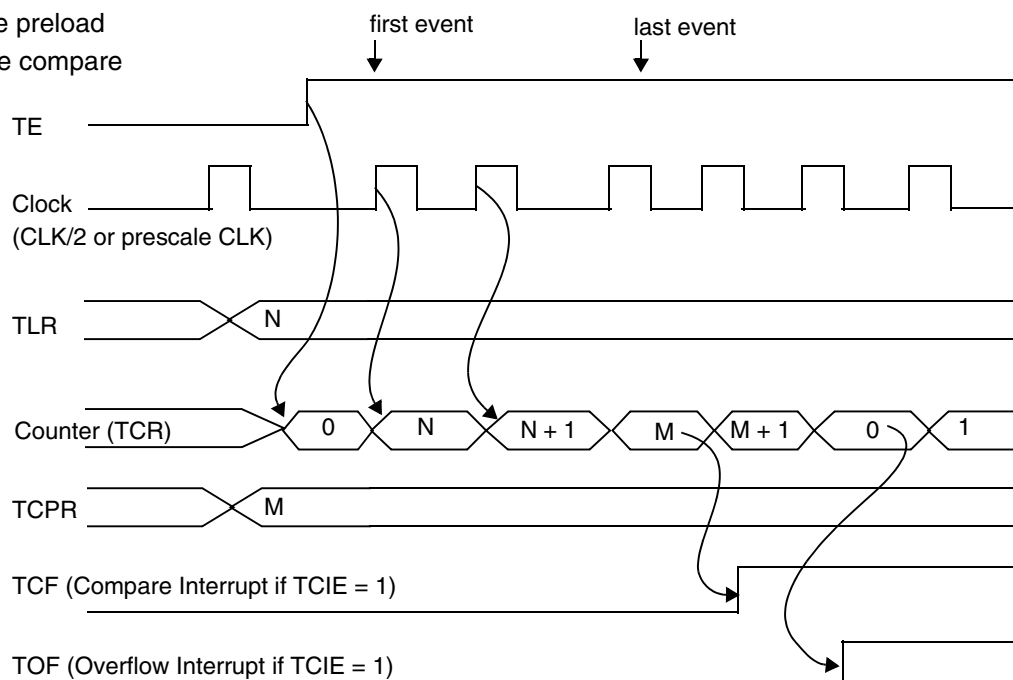


**Figure 11-3 Timer Mode (TRM = 1)**

**Mode 0 (internal clock, no timer output): TRM = 0**

N = write preload

M = write compare



**Figure 11-4 Timer Mode (TRM = 0)**

### 11.3.1.2 Timer Pulse (Mode 1)

Bit Settings				Mode Characteristics				
TC3	TC2	TC1	TC0	Mode	Name	Function	TIO	Clock
0	0	0	1	1	Timer Pulse	Timer	Output	Internal

In Mode 1, the timer generates an external pulse on its TIO signal when the timer count reaches a pre-set value. The TIO signal is loaded with the value of the TCSR[INV] bit. When the counter matches the TCPR value, TCSR[TCF] is set and a compare interrupt is generated if the TCSR[TCIE] bit is set. The polarity of the TIO signal is inverted for one timer clock period. If TCSR[TRM] is set, the counter is loaded with the TLR value on the next timer clock and the count is resumed. If TCSR[TRM] is cleared, the counter continues to increment on each timer clock. This process repeats until TCSR[TE] is cleared (disabling the timer).

The TLR value in the TCPR sets the delay between starting the timer and generating the output pulse. To generate successive output pulses with a delay of X clock cycles between signals, set the TLR value to X/2 and set the TCSR[TRM] bit. This process repeats until the timer is disabled.

#### Mode 1 (internal clock): TRM = 1

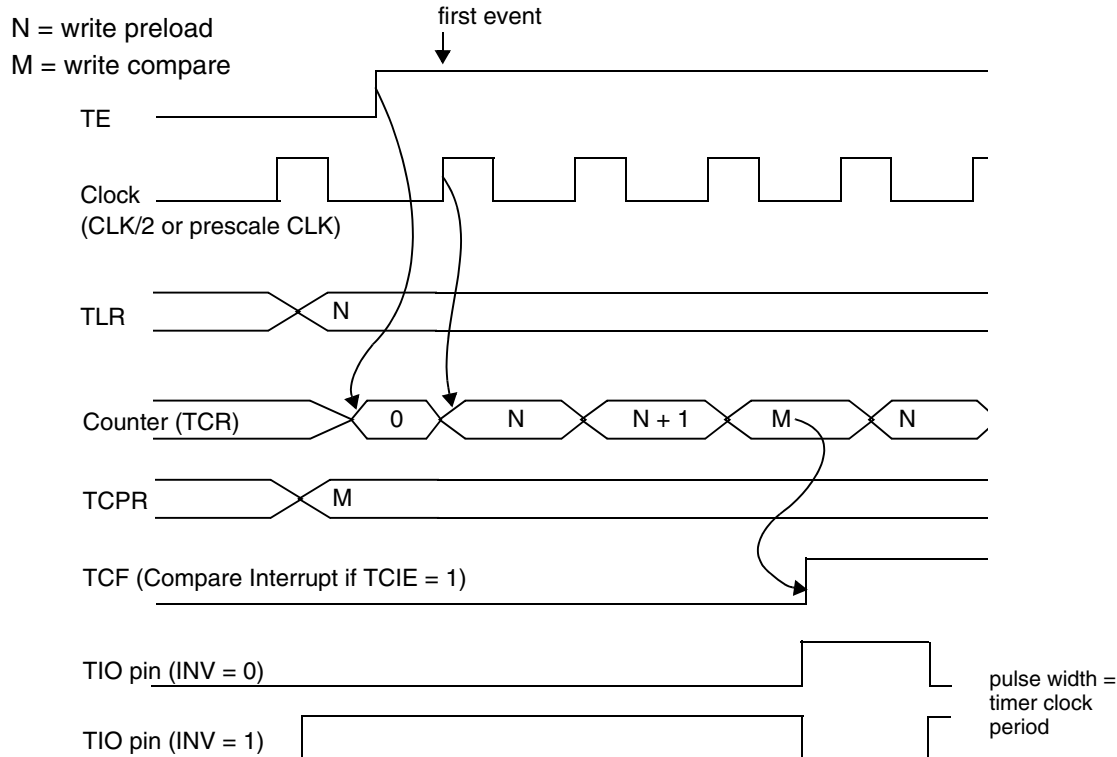
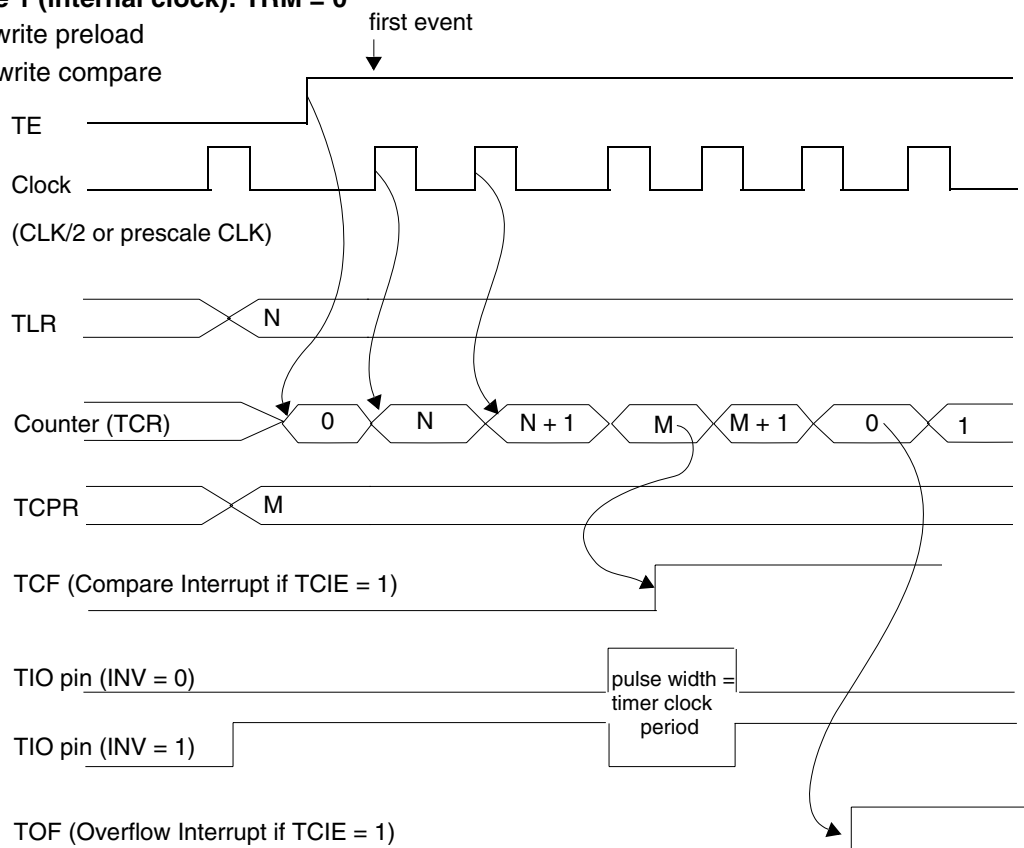


Figure 11-5 Pulse Mode (TRM = 1)

**Mode 1 (internal clock): TRM = 0**

N = write preload

M = write compare



**Figure 11-6 Pulse Mode (TRM = 0)**

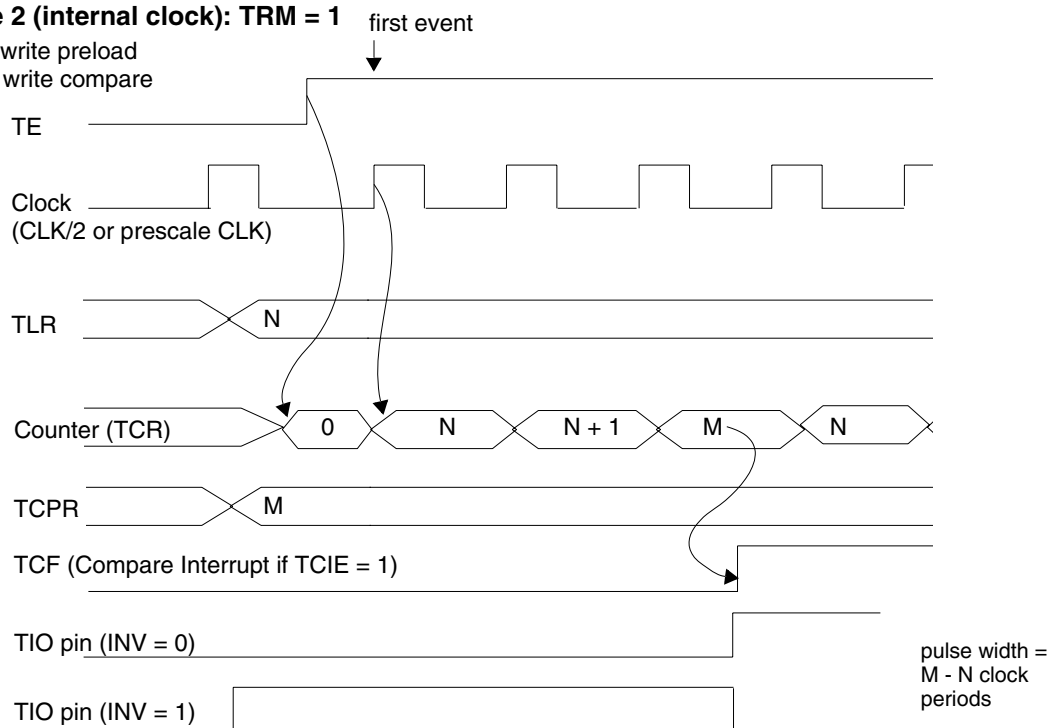
### 11.3.1.3 Timer Toggle (Mode 2)

Bit Settings				Mode Characteristics				
TC3	TC2	TC1	TC0	Mode	Name	Function	TIO	Clock
0	0	1	0	2	Toggle	Timer	Output	Internal

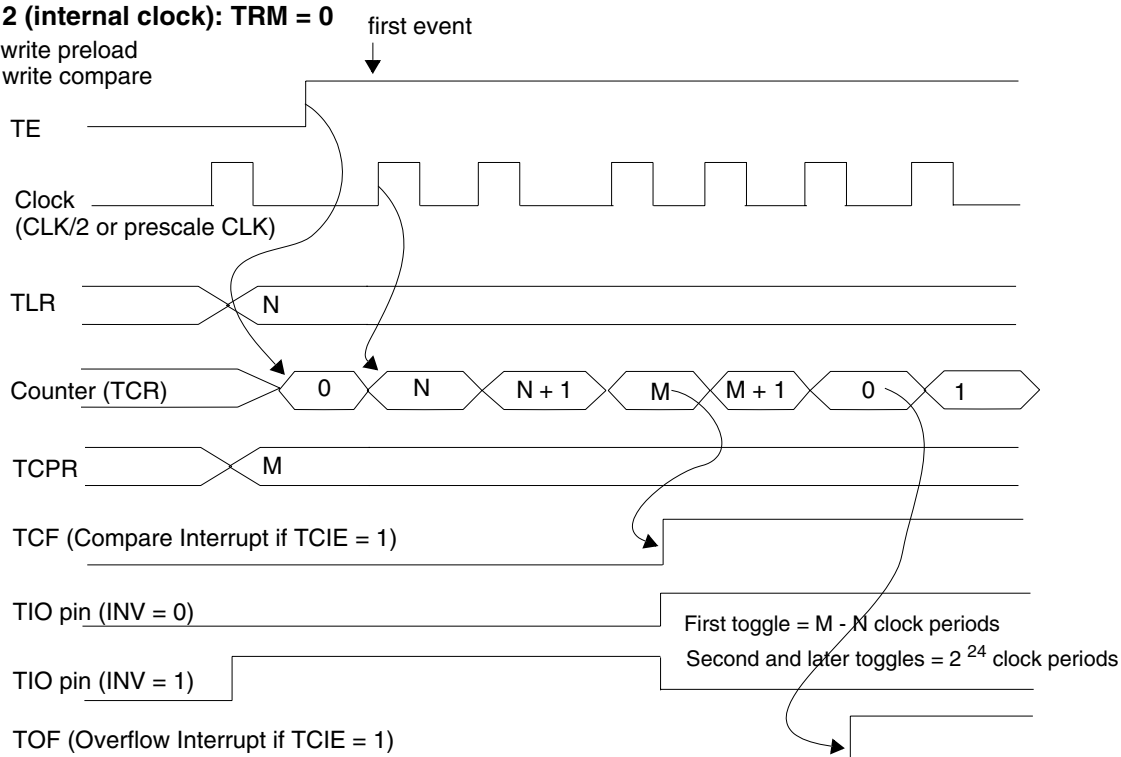
In Mode 2, the timer periodically toggles the polarity of the TIO signal. When the timer is enabled, the TIO signal is loaded with the value of the TCSR[INV] bit. When the counter value matches the value in the TCPR, the polarity of the TIO output signal is inverted. TCSR[TCF] is set, and a compare interrupt is generated if the TCSR[TCIE] bit is set. If the TCSR[TRM] bit is set, the counter is loaded with the value of the TLR when the next timer clock is received, and the count resumes. If the TRM bit is cleared, the counter continues to increment on each timer clock. This process repeats until the timer is cleared (disabling the timer). The TCPR[TLR] value sets the delay between starting the timer and toggling the TIO signal. To generate output signals with a delay of X clock cycles between toggles, set the TLR value to X/2, and set the TCSR[TRM] bit. This process repeats until the timer is disabled (that is, TCSR[TE] is cleared).

**Mode 2 (internal clock): TRM = 1**

N = write preload  
M = write compare

**Figure 11-7 Toggle Mode, TRM = 1****Mode 2 (internal clock): TRM = 0**

N = write preload  
M = write compare

**Figure 11-8 Toggle Mode, TRM = 0**

11.3.1.4 Timer Event Counter (Mode 3)

Bit Settings				Mode Characteristics				
TC3	TC2	TC1	TC0	Mode	Name	Function	TIO	Clock
0	0	1	1	3	Event Counter	Timer	Input	External

In Mode 3, the timer counts external events and issues an interrupt (if interrupt enable bits are set) when the timer counts a preset number of events. The timer clock signal can be taken from either the TIO input signal or the prescaler clock output. If an external clock is used, it is synchronized internally to the internal clock, and its frequency must be less than the DSP56371 internal operating frequency divided by 4. The value of the TCSR[INV] bit determines whether low-to-high (0 to 1) transitions or high-to-low (1 to 0) transitions increment the counter. If the INV bit is set, high-to-low transitions increment the counter. If the INV bit is cleared, low-to-high transitions increment the counter.

When the counter matches the value contained in the TCPR, TCSR[TCF] is set and a compare interrupt is generated if the TCSR[TCIE] bit is set. If the TCSR[TRM] bit is set, the counter is loaded with the value of the TLR when the next timer clock is received, and the count is resumed. If the TCSR[TRM] bit is cleared, the counter continues to increment on each timer clock. This process repeats until the timer is disabled.

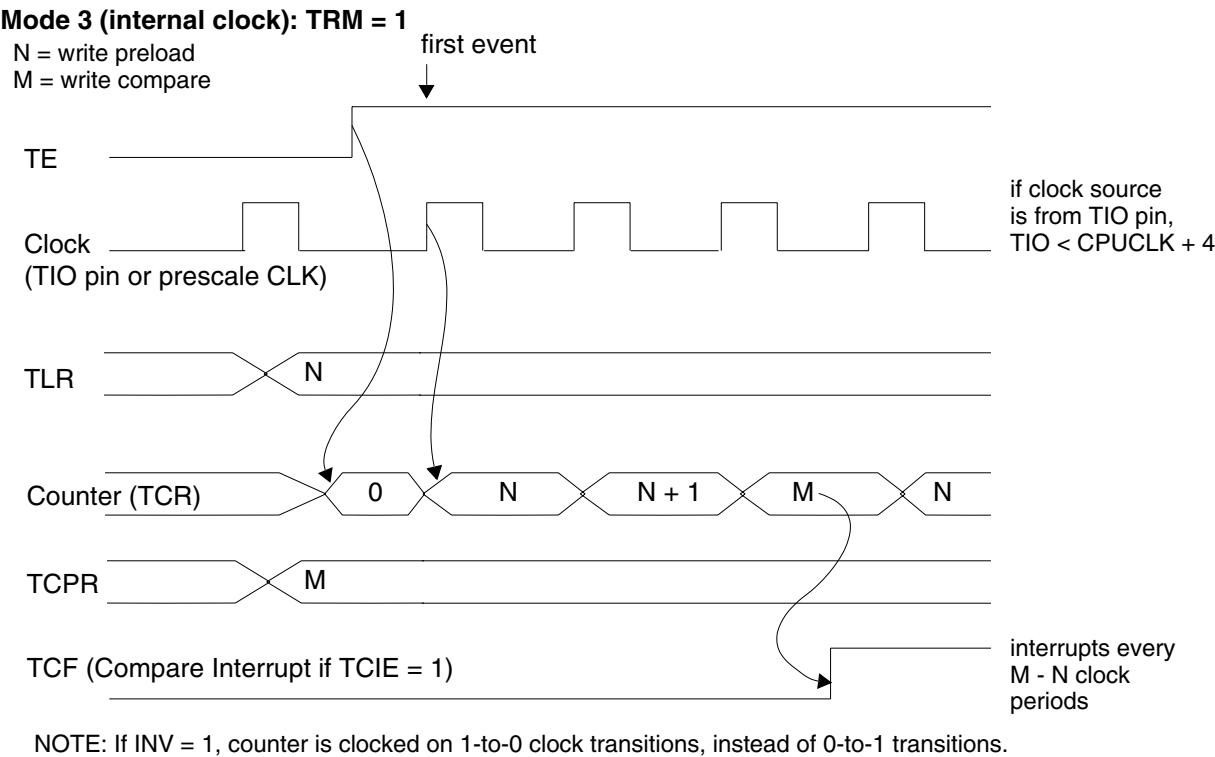


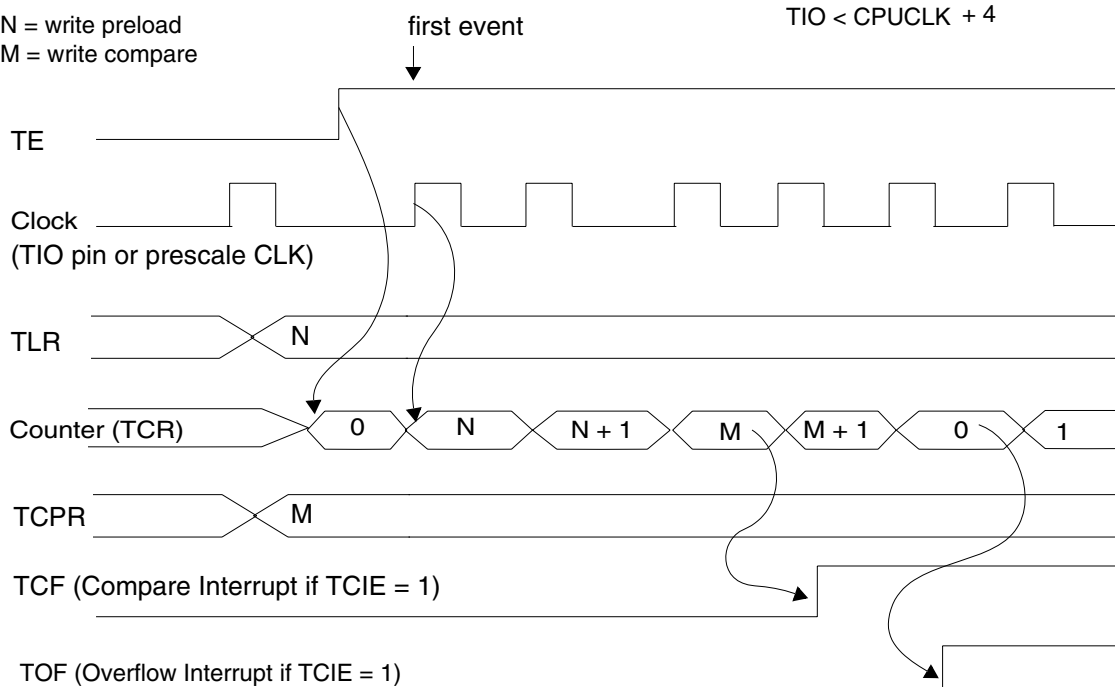
Figure 11-9 Event Counter Mode, TRM = 1



**Mode 3 (internal clock): TRM = 0**

N = write preload  
M = write compare

if clock source is from TIO pin,  
 $TIO < CPUCLK + 4$



NOTE: If INV = 1, counter is clocked on 1-to-0 clock transitions, instead of 0-to-1 transitions.

**Figure 11-10 Event Counter Mode, TRM = 0**

## 11.3.2 Signal Measurement Modes

The following signal measurement and pulse width modulation modes are provided:

- Measurement input width (Mode 4)
- Measurement input period (Mode 5)
- Measurement capture (Mode 6)
- Pulse width modulation (PWM) mode (Mode 7)

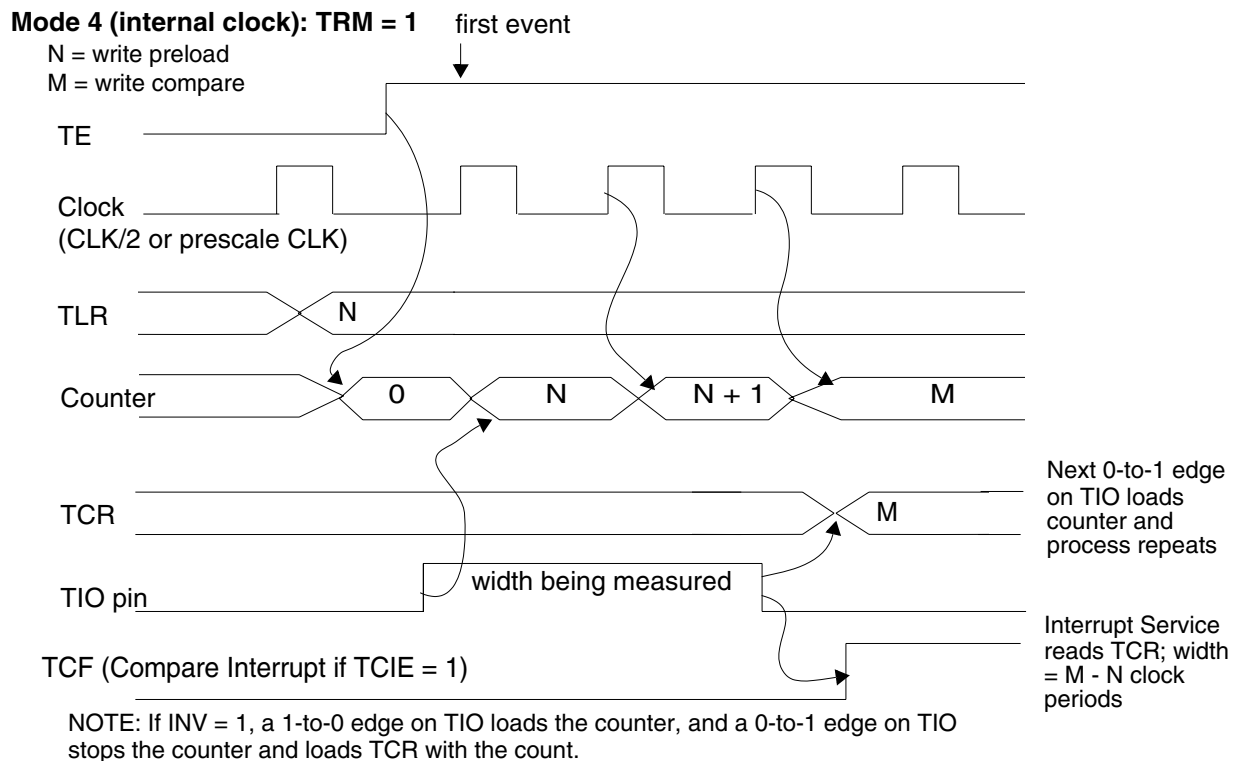
The external signal synchronizes with the internal clock that increments the counter. This synchronization process can cause the number of clocks measured for the selected signal value to vary from the actual signal value by plus or minus one counter clock cycle.

### 11.3.2.1 Measurement Input Width (Mode 4)

Bit Settings				Mode Characteristics				
TC3	TC2	TC1	TC0	Mode	Name	Function	TIO	Clock
0	1	0	0	4	Input width	Measurement	Input	Internal

## Operating Modes

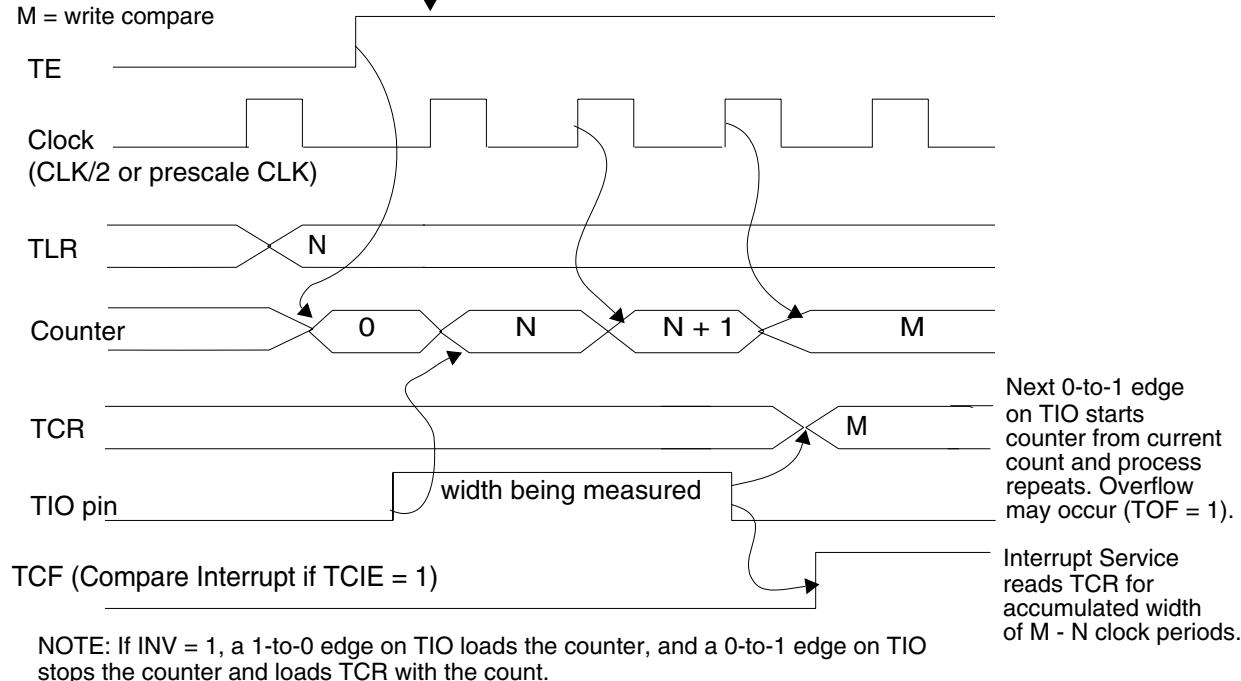
In Mode 4, the timer counts the number of clocks that occur between opposite edges of an input signal. After the first appropriate transition (as determined by the TCSR[INV] bit) occurs on the TIO input signal, the counter is loaded with the TLR value. If TCSR[INV] is set, the timer starts on the first high-to-low (1 to 0) signal transition on the TIO signal. If the INV bit is cleared, the timer starts on the first low-to-high (that is, 0 to 1) transition on the TIO signal. When the first transition opposite in polarity to the INV bit setting occurs on the TIO signal, the counter stops. TCSR[TCF] is set and a compare interrupt is generated if the TCSR[TCIE] bit is set. The value of the counter (which measures the width of the TIO pulse) is loaded into the TCR, which can be read to determine the external signal pulse width. If the TCSR[TRM] bit is set, the counter is loaded with the TLR value on the first timer clock received following the next valid transition on the TIO input signal, and the count resumes. If TCSR[TRM] is cleared, the counter continues to increment on each timer clock. This process repeats until the timer is disabled.



**Figure 11-11 Pulse Width Measurement Mode, TRM = 1**

**Mode 4 (internal clock): TRM = 1** first event

N = write preload  
M = write compare

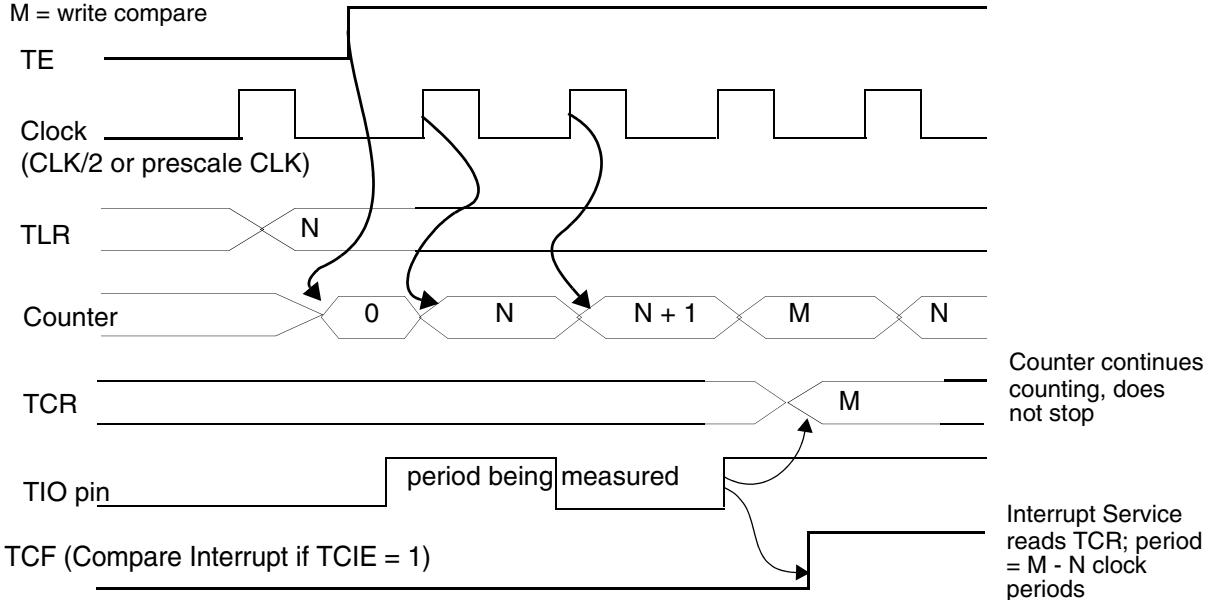
**Figure 11-12 Pulse Width Measurement Mode, TRM = 0****11.3.2.2 Measurement Input Period (Mode 5)**

Bit Settings				Mode Characteristics				
TC3	TC2	TC1	TC0	Mode	Name	Function	TIO	Clock
0	1	0	1	5	Input period	Measurement	Input	Internal

In Mode 5, the timer counts the period between the reception of signal edges of the same polarity across the TIO signal. The value of the INV bit determines whether the period is measured between consecutive low-to-high (0 to 1) transitions of TIO or between consecutive high-to-low (1 to 0) transitions of TIO. If INV is set, high-to-low signal transitions are selected. If INV is cleared, low-to-high signal transitions are selected. After the first appropriate transition occurs on the TIO input signal, the counter is loaded with the TLR value. On the next signal transition of the same polarity that occurs on TIO, TCSR[TCF] is set, and a compare interrupt is generated if the TCSR[TCIE] bit is set. The contents of the counter load into the TCR. The TCR then contains the value of the time that elapsed between the two signal transitions on the TIO signal. After the second signal transition, if the TCSR[TRM] bit is set, the TCSR[TE] bit is set to clear the counter and enable the timer. The counter is repeatedly loaded and incremented until the timer is disabled. If the TCSR[TRM] bit is cleared, the counter continues to increment until it overflows.

**Mode 5 (internal clock): TRM = 1** first event

N = write preload  
M = write compare

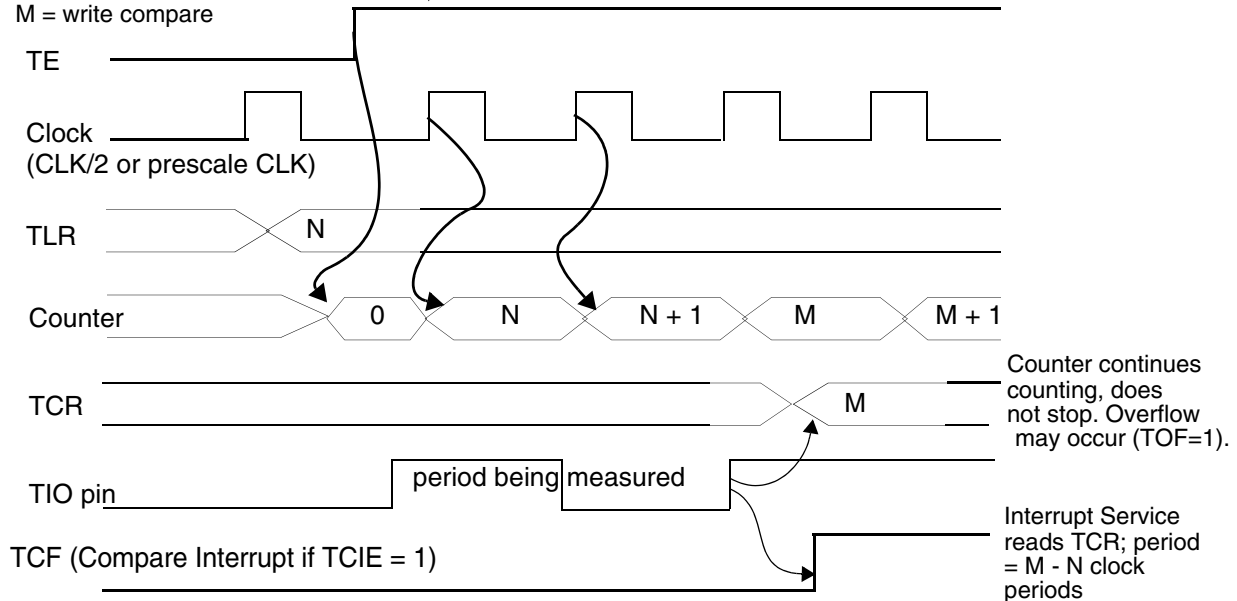


NOTE: If INV = 1, a 1-to-0 edge on TIO loads the counter, and a 0-to-1 edge on TIO loads TCR with count and the counter with N.

**Figure 11-13 Period Measurement Mode, TRM = 1**

**Mode 5 (internal clock): TRM = 0** first event

N = write preload  
M = write compare



NOTE: If INV = 1, a 1-to-0 edge on TIO loads the counter, and a 0-to-1 edge on TIO loads TCR with count and the counter with N.

**Figure 11-14 Period Measurement Mode, TRM = 0**

### 11.3.2.3 Measurement Capture (Mode 6)

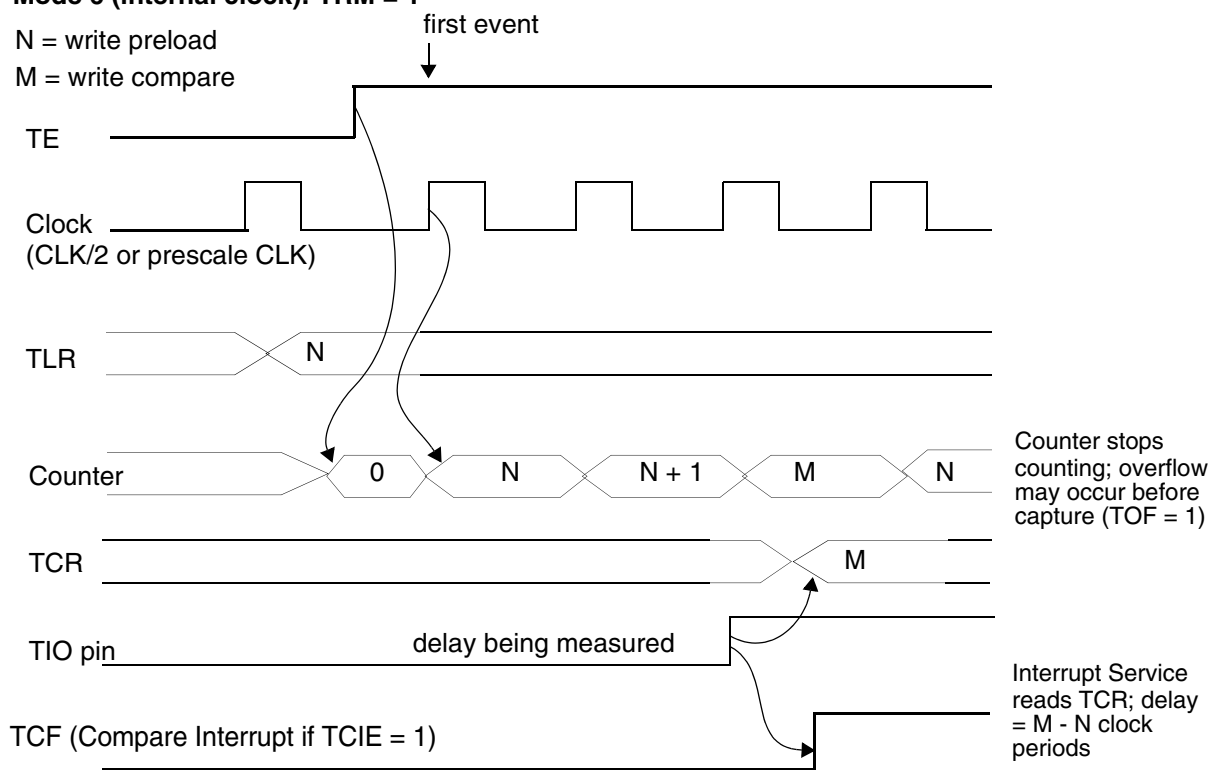
Bit Settings				Mode Characteristics				
TC3	TC2	TC1	TC0	Mode	Name	Function	TIO	Clock
0	1	1	0	6	Capture	Measurement	Input	Internal

In Mode 6, the timer counts the number of clocks that elapse between when the timer starts and when an external signal is received. At the first appropriate transition of the external clock detected on the TIO signal, TCSR[TCF] is set and, if the TCSR[TCIE] bit is set, a compare interrupt is generated. The counter halts. The contents of the counter are loaded into the TCR. The value of the TCR represents the delay between the setting of the TCSR[TE] bit and the detection of the first clock edge signal on the TIO signal. The value of the INV bit determines whether a high-to-low (1 to 0) or low-to-high (0 to 1) transition of the external clock signals the end of the timing period. If the INV bit is set, a high-to-low transition signals the end of the timing period. If INV is cleared, a low-to-high transition signals the end of the timing period.

#### Mode 6 (internal clock): TRM = 1

N = write preload

M = write compare



NOTE: If INV = 1, a 1-to-0 edge on TIO loads TCR with count and stops the counter.

Figure 11-15 Capture Measurement Mode, TRM = 0

### 11.3.3 Pulse Width Modulation (PWM, Mode 7)

Bit Settings				Mode Characteristics				
TC3	TC2	TC1	TC0	Mode	Name	Function	TIO	Clock
0	1	1	1	7	Pulse width modulation	PWM	Output	Internal

In Mode 7, the timer generates periodic pulses of a preset width. When the counter equals the value in the TCPR, the TIO output signal is toggled and TCSR[TCF] is set. The contents of the counter are placed into the TCR. If the TCSR[TCIE] bit is set, a compare interrupt is generated. The counter continues to increment on each timer clock.

If counter overflow occurs, the TIO output signal is toggled, TCSR[TOF] is set, and an overflow interrupt is generated if the TCSR[TOIE] bit is set. If the TCSR[TRM] bit is set, the counter is loaded with the TLR value on the next timer clock and the count resumes. If the TCSR[TRM] bit is cleared, the counter continues to increment on each timer clock. This process repeats until the timer is disabled.

When the TCSR[TE] bit is set and the counter starts, the TIO signal assumes the value of INV. On each subsequent toggle of the TIO signal, the polarity of the TIO signal is reversed. For example, if the INV bit is set, the TIO signal generates the following signal: 1010. If the INV bit is cleared, the TIO signal generates the following signal: 0101.

The value of the TLR determines the output period ( $\$FFFFFF - \text{TLR} + 1$ ). The timer counter increments the initial TLR value and toggles the TIO signal when the counter value exceeds  $\$FFFFFF$ . The duty cycle of the TIO signal is determined by the value in the TCPR. When the value in the TLR increments to a value equal to the value in the TCPR, the TIO signal is toggled. The duty cycle is equal to  $(\$FFFFFF - \text{TCPR})$  divided by  $(\$FFFFFF - \text{TLR} + 1)$ . For a 50 percent duty cycle, the value of TCPR is equal to  $(\$FFFFFF + \text{TLR} + 1)/2$ .

#### NOTE

The value in TCPR must be greater than the value in TLR.

$\text{Period} = \$\text{FFFFFF} - \text{TLR} + 1$   
 $\text{Duty cycle} = (\$\text{FFFFFF} - \text{TCPR})$   
 Ensure that  $\text{TCPR} > \text{TLR}$  for correct functionality

### Mode 7 (internal clock): TRM = 1

N = write preload  
 M = write compare

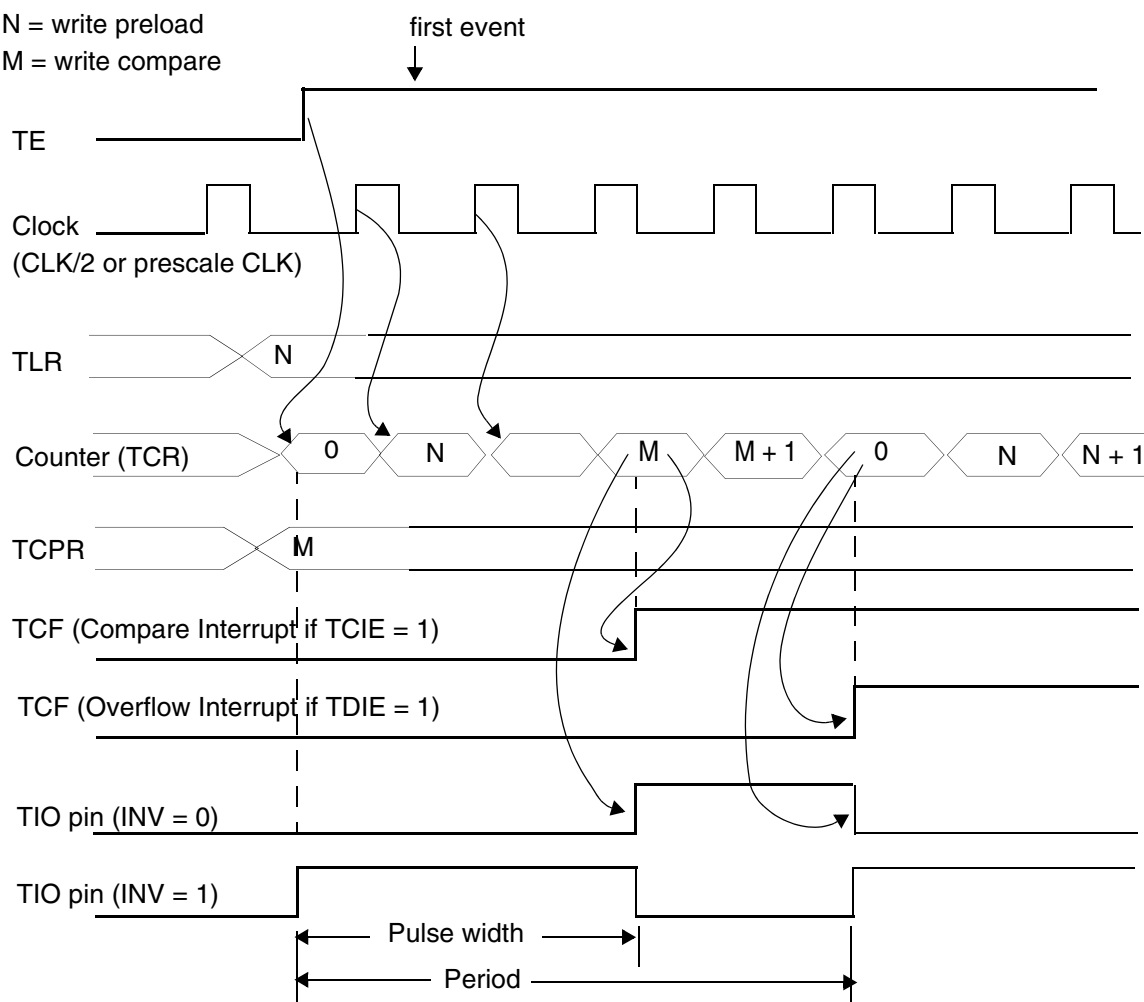
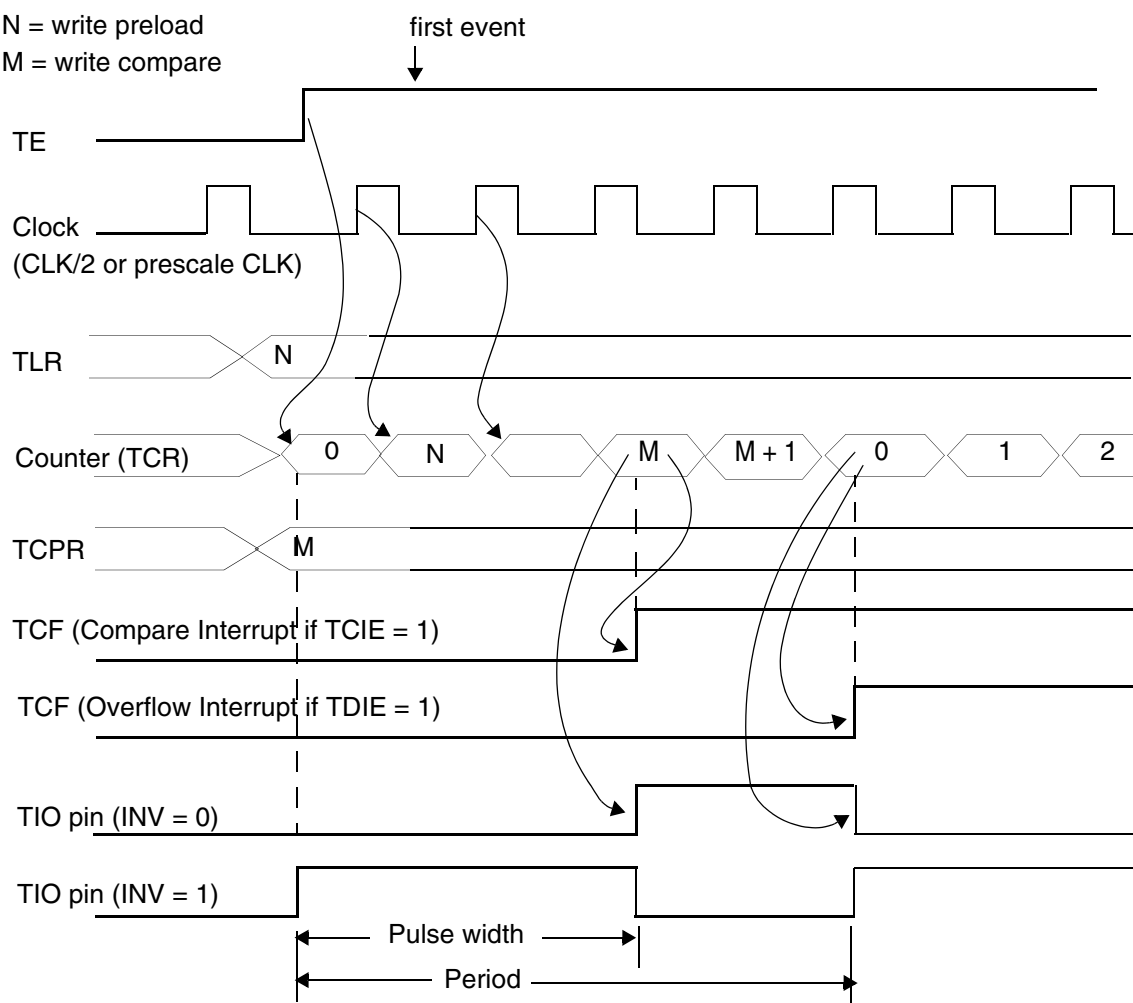


Figure 11-16 Pulse Width Modulation Toggle Mode, TRM = 1

**Mode 7 (internal clock): TRM = 0**

N = write preload  
M = write compare

Period =  $0xFFFF - TLR + 1$   
Duty cycle =  $(0xFFFF - TCPR)$   
Ensure that  $TCPR > TLR$  for correct functionality



NOTE: On overflow, TCR is loaded with the value of TLR.

**Figure 11-17 Pulse Width Modulation Toggle Mode, TRM = 0**



## 11.3.4 Watchdog Modes

The following watchdog timer modes are provided:

- Watchdog Pulse
- Watchdog Toggle

### 11.3.4.1 Watchdog Pulse (Mode 9)

Bit Settings				Mode Characteristics				
TC3	TC2	TC1	TC0	Mode	Name	Function	TIO	Clock
1	0	0	1	9	Pulse	Watchdog	Output	Internal

In Mode 9, the timer generates an external signal at a preset rate. The signal period is equal to the period of one timer clock. After the counter reaches the value in the TCPR, if the TCSR[TRM] bit is set, the counter is loaded with the TLR value on the next timer clock and the count resumes. Therefore TRM = 1 is not useful for watchdog functions. If the TCSR[TRM] bit is cleared, the counter continues to increment on each subsequent timer clock. This process repeats until the timer is disabled (that is, TCSR[TE] is cleared). If the counter overflows, a pulse is output on the TIO signal with a pulse width equal to the timer clock period. If the INV bit is set, the pulse polarity is high (logical 1). If INV is cleared, the pulse polarity is low (logical 0). The counter reloads when the TLR is written with a new value while the TCSR[TE] bit is set. In Mode 9, internal logic preserves the TIO value and direction for an additional 2.5 internal clock cycles after the hardware  $\overline{\text{RESET}}$  signal is asserted. This convention ensures that a valid  $\overline{\text{RESET}}$  signal is generated when the TIO signal resets the DSP56371.

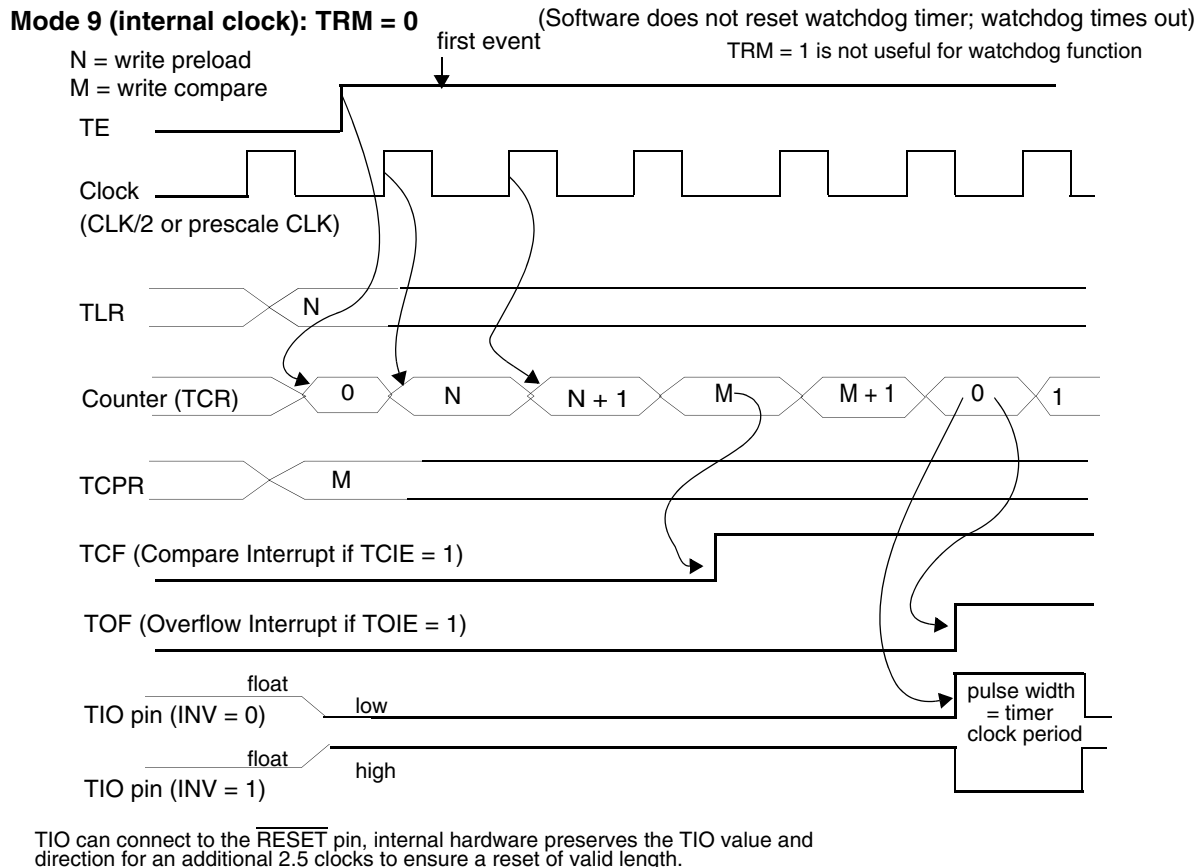


Figure 11-18 Watchdog Pulse Mode

### 11.3.4.2 Watchdog Toggle (Mode 10)

Bit Settings				Mode Characteristics				
TC3	TC2	TC1	TC0	Mode	Name	Function	TIO	Clock
1	0	1	0	10	Toggle	Watchdog	Output	Internal

In Mode 10, the timer toggles an external signal after a preset period. The TIO signal is set to the value of the INV bit. When the counter equals the value in the TCPR, TCSR[TCF] is set, and a compare interrupt is generated if the TCSR[TCIE] bit is also set. If the TCSR[TRM] bit is set, the counter loads with the TLR value on the next timer clock and the count resumes. Therefore, TRM = 1 is not useful for watchdog functions. If the TCSR[TRM] bit is cleared, the counter continues to increment on each subsequent timer clock. When a counter overflow occurs, the polarity of the TIO output signal is inverted. The counter is reloaded whenever the TLR is written with a new value while the TCSR[TE] bit is set. This process repeats until the timer is disabled. In Mode 10, internal logic preserves the TIO value and direction for an additional 2.5 internal clock cycles after the hardware RESET signal is asserted. This convention ensures that a valid reset signal is generated when the TIO signal resets the DSP56371.

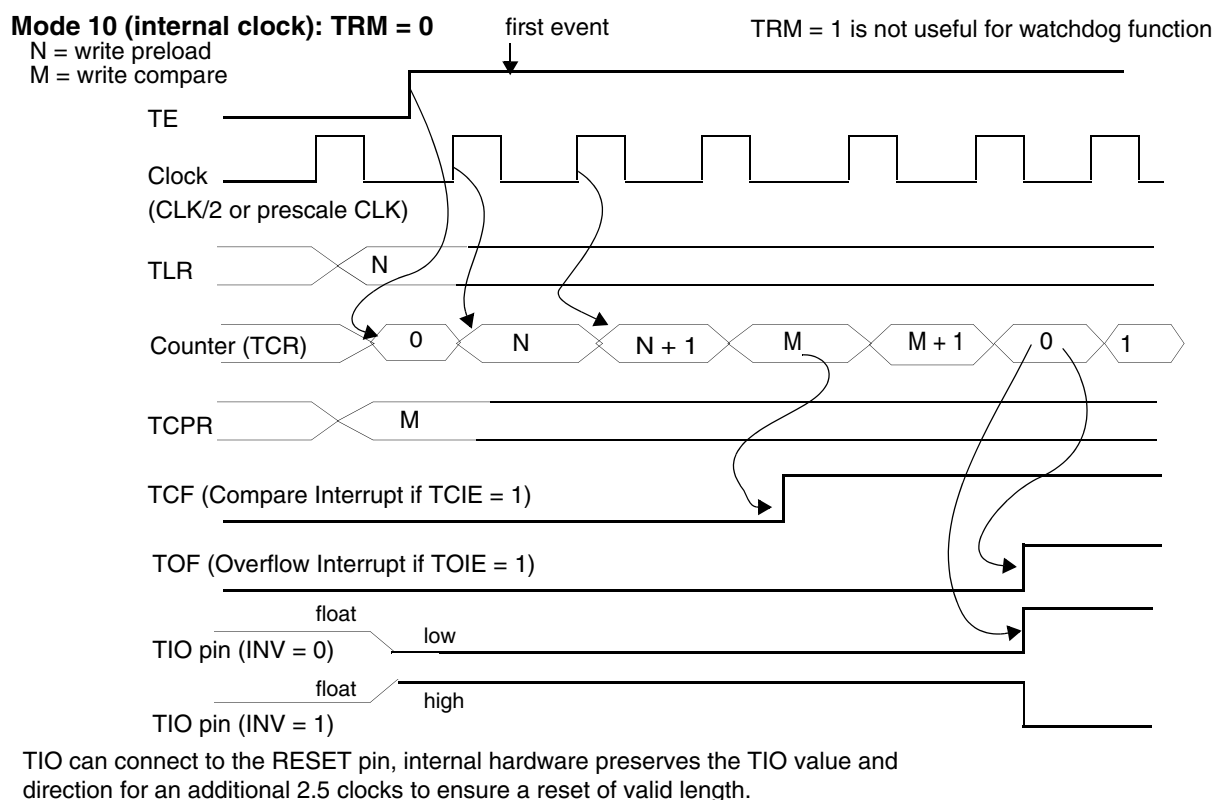


Figure 11-19 Watchdog Toggle Mode

### 11.3.4.3 Reserved Modes

Modes 8, 11, 12, 13, 14, and 15 are reserved.

### 11.3.5 Special Cases

The following special cases apply during wait and stop state.

- Timer behavior during wait — Timer clocks are active during the execution of the WAIT instruction and timer activity is undisturbed. If a timer interrupt is generated, the DSP56371 leaves the wait state and services the interrupt.
- Timer behavior during stop — During execution of the STOP instruction, the timer clocks are disabled, timer activity stops, and the TIO signals are disconnected. Any external changes that happen to the TIO signals are ignored when the DSP56371 is in stop state. To ensure correct operation, disable the timers before the DSP56371 is placed in stop state.

### 11.3.6 DMA Trigger

Each timer can also trigger DMA transfers if a DMA channel is programmed to be triggered by a timer event. The timer issues a DMA trigger on every event in all modes of operation. To ensure that all DMA triggers are serviced, provide for the preceding DMA trigger to be serviced before the DMA channel receives the next trigger.

## 11.4 Triple Timer Module Programming Model

The timer programmer's model in Figure 11-20 shows the structure of the timer registers.

### 11.4.1 Prescaler Counter

The prescaler counter is a 21-bit counter that decrements on the rising edge of the prescaler input clock. The counter is enabled when at least one of the three timers is enabled (that is, one or more of the timer enable bits are set) and is using the prescaler output as its source (that is, one or more of the PCE bits are set).

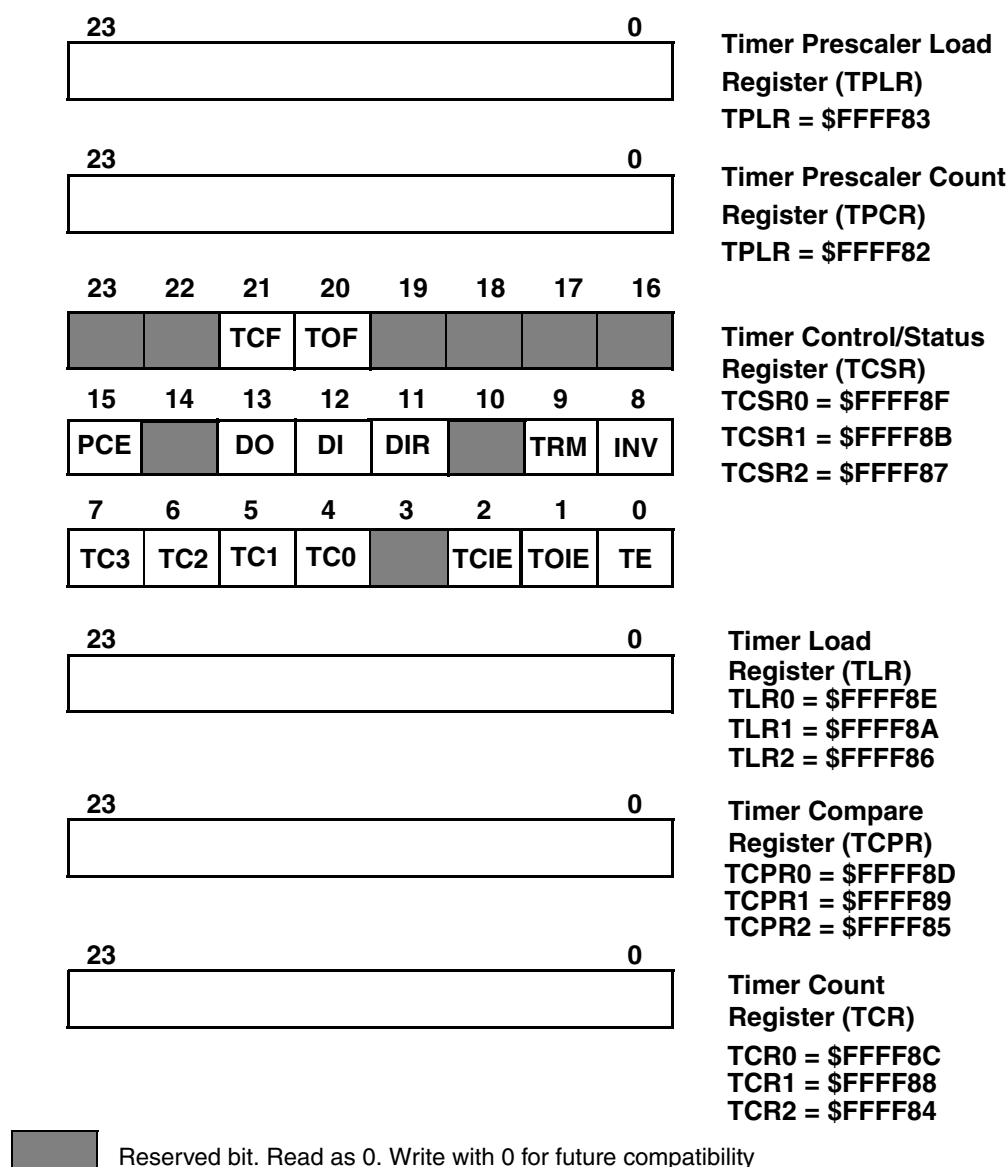


Figure 11-20 Timer Module Programmer's Model

## 11.4.2 Timer Prescaler Load Register (TPLR)

The TPLR is a read/write register that controls the prescaler divide factor (that is, the number that the prescaler counter loads and begins counting from) and the source for the prescaler input clock.

23	22	21	20	19	18	17	16	15	14	13	12
	PS1	PS0	PL20	PL19	PL18	PL17	PL16	PL15	PL14	PL13	PL12
11	10	9	8	7	6	5	4	3	2	1	0
PL11	PL10	PL9	PL8	PL7	PL6	PL5	PL4	PL3	PL2	PL1	PL0

— Reserved bit. Read as 0. Write to 0 for future compatibility

**Figure 11-21 Timer Prescaler Load Register (TPLR)**


**Table 11-1 Timer Prescaler Load Register (TPLR) Bit Definitions**

Bit Number	Bit Name	Reset Value	Description		
23		0	Reserved. Write to zero for future compatibility.		
22–21	PS[1–0]	0	<b>Prescaler Source</b> Control the source of the prescaler clock. The prescaler’s use of a TIO signal is not affected by the TCSR settings of the timer of the corresponding TIO signal. If the prescaler source clock is external, the prescaler counter is incremented by signal transitions on the TIO signal. The external clock is internally synchronized to the internal clock. The external clock frequency must be lower than the DSP56371 internal operating frequency divided by 4 (that is, CLK/4).  NOTE: To ensure proper operation, change the PS[1–0] bits only when the prescaler counter is disabled. Disable the prescaler counter by clearing TCSR[TE] of each of three timers.		
			<b>PS1</b>	<b>PS0</b>	<b>Prescaler Clock Source</b>
			0	0	Internal CLK/2
			0	1	TIO0
			1	0	TIO1
			1	1	Reserved
20–0	PL[20–0]	0	<b>Prescaler Preload Value</b> Contains the prescaler preload value, which is loaded into the prescaler counter when the counter value reaches 0 or the counter switches state from disabled to enabled. If PL[20–0] = N, then the prescaler counts N+1 source clock cycles before generating a prescaler clock pulse. Therefore, the prescaler divide factor = (preload value) + 1.		

### 11.4.3 Timer Prescaler Count Register (TPCR)

The TPCR is a read-only register that reflects the current value in the prescaler counter.

23	22	21	20	19	18	17	16	15	14	13	12
			PC20	PC19	PC18	PC17	PC16	PC15	PC14	PC13	PC12
11	10	9	8	7	6	5	4	3	2	1	0
PC11	PC10	PC9	PC8	PC7	PC6	PC5	PC4	PC3	PC2	PC1	PC0

 Reserved bit; read as 0; write to 0 for future compatibility

**Figure 11-22 Timer Prescaler Count Register (TPCR)**


**Table 11-2 Timer Prescaler Count Register (TPCR) Bit Definitions**

Bit Number	Bit Name	Reset Value	Description
23–21		0	Reserved. Write to zero for future compatibility.
20–0	PC[20–0]	0	<b>Prescaler Counter Value</b> Contain the current value of the prescaler counter.

### 11.4.4 Timer Control/Status Register (TCSR)

The TCSR is a read/write register controlling the timer and reflecting its status.

23	22	21	20	19	18	17	16	15	14	13	12
		TCF	TOF					PCE		DO	DI
11	10	9	8	7	6	5	4	3	2	1	0
DIR		TRM	INV	TC3	TC2	TC1	TC0		TCIE	TOIE	TE

 Reserved. Read as 0. Write to 0 for future compatibility

**Figure 11-23 Timer Control/Status Register (TCSR)**

Table 11-3 Timer Control/Status Register (TCSR) Bit Definitions

Bit Number	Bit Name	Reset Value	Description
23–22		0	Reserved. Write to zero for future compatibility.
21	TCF	0	<b>Timer Compare Flag</b> Indicate that the event count is complete. In timer, PWM, and watchdog modes, the TCF bit is set after $(M - N + 1)$ events are counted. (M is the value in the compare register and N is the TLR value.) In measurement modes, the TCF bit is set when the measurement completes. Writing a one to the TCF bit clears it. A zero written to the TCF bit has no effect. The bit is also cleared when the timer compare interrupt is serviced. The TCF bit is cleared by a hardware $\overline{\text{RESET}}$ signal, a software RESET instruction, the STOP instruction, or by clearing the TCSR[TE] bit to disable the timer.  NOTE: The TOF and TCF bits are cleared by a 1 written to the specific bit. To ensure that only the target bit is cleared, do not use the BSET command. The proper way to clear these bits is to write 1, using a MOVEP instruction, to the flag to be cleared and 0 to the other flag.
20	TOF	0	<b>Timer Overflow Flag</b> Indicates that a counter overflow has occurred. This bit is cleared by writing a one to the TOF bit. Writing a zero to TOF has no effect. The bit is also cleared when the timer overflow interrupt is serviced. The TOF bit is cleared by a hardware $\overline{\text{RESET}}$ signal, a software RESET instruction, the STOP instruction, or by clearing the TCSR[TE] bit to disable the timer.
19–16		0	Reserved. Write to zero for future compatibility.
15	PCE	0	<b>Prescaler Clock Enable</b> Selects the prescaler clock as the timer source clock. When PCE is cleared, the timer uses either an internal (CLK/2) signal or an external (TIO) signal as its source clock. When PCE is set, the prescaler output is the timer source clock for the counter, regardless of the timer operating mode. To ensure proper operation, the PCE bit is changed only when the timer is disabled. The PS[1–0] bits of the TPLR determine which source clock is used for the prescaler. A timer can be clocked by a prescaler clock that is derived from the TIO of another timer.
14		0	Reserved. Write to zero for future compatibility.
13	DO	0	<b>Data Output</b> The source of the TIO value when it is a data output signal. The TIO signal is a data output when the GPIO mode is enabled and DIR is set. A value written to the DO bit is written to the TIO signal. If the INV bit is set, the value of the DO bit is inverted when written to the TIO signal. When the INV bit is cleared, the value of the DO bit is written directly to the TIO signal. When GPIO mode is disabled, writing to the DO bit has no effect.
12	DI	0	<b>Data Input</b> Reflects the value of the TIO signal. If the INV bit is set, the value of the TIO signal is inverted before it is written to the DI bit. If the INV bit is cleared, the value of the TIO signal is written directly to the DI bit.

Table 11-3 Timer Control/Status Register (TCSR) Bit Definitions (continued)

Bit Number	Bit Name	Reset Value	Description
11	DIR	0	<b>Direction</b> Determines the behavior of the TIO signal when it functions as a GPIO signal. When DIR is set, the TIO signal is an output; when DIR is cleared, the TIO signal is an input. The TIO signal functions as a GPIO signal only when the TC[3–0] bits are cleared. If any of the TC[3–0] bits are set, then the GPIO function is disabled, and the DIR bit has no effect.
10		0	Reserved. Write to zero for future compatibility.
9	TRM	0	<b>Timer Reload Mode</b> Controls the counter preload operation. In timer (0–3) and watchdog (9–10) modes, the counter is preloaded with the TLR value after the TCSR[TE] bit is set and the first internal or external clock signal is received. If the TRM bit is set, the counter is reloaded each time after it reaches the value contained by the TCR. In PWM mode (7), the counter is reloaded each time counter overflow occurs. In measurement (4–5) modes, if the TRM and the TCSR[TE] bits are set, the counter is preloaded with the TLR value on each appropriate edge of the input signal. If the TRM bit is cleared, the counter operates as a free running counter and is incremented on each incoming event.
8	INV	0	<b>Inverter</b> Affects the polarity definition of the incoming signal on the TIO signal when TIO is programmed as input. It also affects the polarity of the output pulse generated on the TIO signal when TIO is programmed as output. See <a href="#">Table 11-4</a> . The INV bit does not affect the polarity of the prescaler source when the TIO is input to the prescaler.  NOTE: The INV bit affects both the timer and GPIO modes of operation. To ensure correct operation, change this bit only when one or both of the following conditions is true: the timer is disabled (the TCSR[TE] bit is cleared). The timer is in GPIO mode.



Table 11-3 Timer Control/Status Register (TCSR) Bit Definitions (continued)

Bit Number	Bit Name	Reset Value	Description							
7–4	TC[3–0]	0	<b>Timer Control</b> Control the source of the timer clock, the behavior of the TIO signal, and the Timer mode of operation. <a href="#">Section 11.3, "Operating Modes"</a> describes the timer operating modes in detail.  NOTE: To ensure proper operation, the TC[3–0] bits should be changed only when the timer is disabled (that is, when the TCSR[TE] bit is cleared)  NOTE: If the clock is external, the counter is incremented by the transitions on the TIO signal. The external clock is internally synchronized to the internal clock, and its frequency should be lower than the internal operating frequency divided by 4 (that is, CLK/4).							
			Bit Settings				Mode Characteristics			
			TC3	TC2	TC1	TC0	Mode Number	Mode Function	TIO	Clock
			0	0	0	0	0	Timer and GPIO	GPIO <sup>1</sup>	Internal
			0	0	0	1	1	Timer pulse	Output	Internal
			0	0	1	0	2	Timer toggle	Output	Internal
			0	0	1	1	3	Event counter	Input	External
			0	1	0	0	4	Input width measurement	Input	Internal
			0	1	0	1	5	Input period measurement	Input	Internal
			0	1	1	0	6	Capture event	Input	Internal
			0	1	1	1	7	Pulse width modulation	Output	Internal
			1	0	0	0	8	Reserved	—	—
			1	0	0	1	9	Watchdog pulse	Output	Internal
			1	0	1	0	10	Watchdog Toggle	Output	Internal
			1	0	1	1	11	Reserved	—	—
			1	1	0	0	12	Reserved	—	—
			1	1	0	1	13	Reserved	—	—
			1	1	1	0	14	Reserved	—	—
			1	1	1	1	15	Reserved	—	—
			Note 1: The GPIO function is enabled only if all of the TC[3–0] bits are 0.							

Table 11-3 Timer Control/Status Register (TCSR) Bit Definitions (continued)

Bit Number	Bit Name	Reset Value	Description
3		0	Reserved. Write to zero for future compatibility.
2	TCIE	0	<b>Timer Compare Interrupt Enable</b> Enables/disables the timer compare interrupts. When set, TCIE enables the compare interrupts. In the timer, pulse width modulation (PWM), or watchdog modes, a compare interrupt is generated after the counter value matches the value of the TCPR. The counter starts counting up from the number loaded from the TLR and if the TCPR value is M, an interrupt occurs after (M – N + 1) events, where N is the value of TLR. When cleared, the TCSR[TCIE] bit disables the compare interrupts.
1	TOIE	0	<b>Timer Overflow Interrupt Enable</b> Enables timer overflow interrupts. When set, TOIE enables overflow interrupt generation. The timer counter can hold a maximum value of \$FFFFFF. When the counter value is at the maximum value and a new event causes the counter to be incremented to \$000000, the timer generates an overflow interrupt. When cleared, the TOIE bit disables overflow interrupt generation.
0	TE	0	<b>Timer Enable</b> Enables/disables the timer. When set, TE enables the timer and clears the timer counter. The counter starts counting according to the mode selected by the timer control (TC[3–0]) bit values. When clear, TE bit disables the timer.  NOTE: When all three timers are disabled and the signals are not in GPIO mode, all three TIO signals are tri-stated. To prevent undesired spikes on the TIO signals when you switch from tri-state into active state, these signals should be tied to the high or low signal state by pull-up or pull-down resistors.

Table 11-4 Inverter (INV) Bit Operation

Mode	TIO Programmed as Input		TIO Programmed as Output	
	INV = 0	INV = 1	INV = 0	INV = 1
0	GPIO signal on the TIO signal read directly.	GPIO signal on the TIO signal inverted.	Bit written to GPIO put on TIO signal directly.	Bit written to GPIO inverted and put on TIO signal.
1	Counter is incremented on the <b>rising</b> edge of the signal from the TIO signal.	Counter is incremented on the <b>falling</b> edge of the signal from the TIO signal.	—	—
2	Counter is incremented on the <b>rising</b> edge of the signal from the TIO signal.	Counter is incremented on the <b>falling</b> edge of the signal from the TIO signal.	Initial output put on TIO signal directly.	Initial output inverted and put on TIO signal.
3	Counter is incremented on the <b>rising</b> edge of the signal from the TIO signal.	Counter is incremented on the <b>falling</b> edge of the signal from the TIO signal.	—	—

Table 11-4 Inverter (INV) Bit Operation (continued)

Mode	TIO Programmed as Input		TIO Programmed as Output	
	INV = 0	INV = 1	INV = 0	INV = 1
4	Width of the <b>high</b> input pulse is measured.	Width of the <b>low</b> input pulse is measured.	—	—
5	Period is measured between the <b>rising</b> edges of the input signal.	Period is measured between the <b>falling</b> edges of the input signal.	—	—
6	Event is captured on the <b>rising</b> edge of the signal from the TIO signal.	Event is captured on the <b>falling</b> edge of the signal from the TIO signal.	—	—
7	—	—	Pulse generated by the timer has <b>positive</b> polarity.	Pulse generated by the timer has <b>negative</b> polarity.
9	—	—	Pulse generated by the timer has <b>positive</b> polarity.	Pulse generated by the timer has <b>negative</b> polarity.
10	—	—	Pulse generated by the timer has <b>positive</b> polarity.	Pulse generated by the timer has <b>negative</b> polarity.

### 11.4.5 Timer Load Register (TLR)

The TLR is a 24-bit write-only register. In all modes, the counter is preloaded with the TLR value after the TCSR[TE] bit is set and a first event occurs.

- In timer modes, if the TCSR[TRM] bit is set, the counter is reloaded each time after it reaches the value contained by the timer compare register and the new event occurs.
- In measurement modes, if TCSR[TRM] and TCSR[TE] are set, the counter is reloaded with the value in the TLR on each appropriate edge of the input signal.
- In PWM modes, if TCSR[TRM] is set, the counter is reloaded each time after it overflows and the new event occurs.
- In watchdog modes, if TCSR[TRM] is set, the counter is reloaded each time after it reaches the value contained by the timer compare register and the new event occurs. In this mode, the counter is also reloaded whenever the TLR is written with a new value while TCSR[TE] is set.
- In all modes, if TCSR[TRM] is cleared (TRM = 0), the counter operates as a free-running counter.

### 11.4.6 Timer Compare Register (TCPR)

The TCPR is a 24-bit read/write register that contains the value to be compared to the counter value. These two values are compared every timer clock after TCSR[TE] is set. When the values match, the timer

compare flag bit is set and an interrupt is generated if interrupts are enabled (that is, the timer compare interrupt enable bit in the TCSR is set). The TCPR is ignored in measurement modes.

### 11.4.7 Timer Count Register (TCR)

The TCR is a 24-bit read-only register. In timer and watchdog modes, the contents of the counter can be read at any time from the TCR register. In measurement modes, the TCR is loaded with the current value of the counter on the appropriate edge of the input signal, and its value can be read to determine the width, period, or delay of the leading edge of the input signal. When the timer is in measurement mode, the TIO signal is used for the input signal.

## 12 Enhanced Filter Coprocessor (EFCOP)

The EFCOP peripheral module functions as a general-purpose, fully programmable filter. It has optimized modes of operation to perform real and complex finite impulse response (FIR) filtering, infinite impulse response (IIR) filtering, adaptive FIR filtering and multichannel FIR filtering. EFCOP filter operations complete concurrently with DSP56300 core operations, with minimal CPU intervention. For optimal performance, the EFCOP has one dedicated Filter Multiplier Accumulator (FMAC) unit. Thus, for filtering, the combination Core/EFCOP offers dual MAC capabilities. Its dedicated modes make the EFCOP a very flexible filter coprocessor. The EFCOP architecture also allows adaptive FIR filtering in which the filter coefficient update is performed using any fixed-point standard or non-standard adaptive algorithms—for example, the well-known Least Mean Square (LMS) algorithm, Normalized LMS and customized update algorithms. The EFCOP can perform complex matched filtering to maximize the signal-to-noise ratio (SNR) within an equalizer.

The first half of this chapter describes the structure and function of the EFCOP, examining its features, architecture and programming model. The remainder of the chapter covers programming topics, such as transferring data to and from the EFCOP, using it in different modes and examples of usage.

### 12.1 Features

- Fully programmable real/complex filter machine with 24-bit resolution
- FIR filter options
  - Four modes of operation with optimized performance:
    - Mode 0, FIR machine with real taps
    - Mode 1, FIR machine with complex taps
    - Mode 2, Complex FIR machine generating pure real/imaginary outputs alternately
    - Mode 3, Magnitude (calculate the square of each input sample)
  - 4-bit decimation factor in FIR filters providing up to 1:16 decimation ratio
  - Easy to use adaptive mode supporting true or delayed LMS-type algorithms
  - K-constant input register for coefficient updates (in adaptive mode)
- IIR filter options:
  - Direct form 1 (DFI) and direct form 2 (DFII) configurations<sup>1</sup>
  - Three optional output scaling factors (1, 8, or 16)
- Multichannel mode to process multiple, equal-length filter channels (up to 64) simultaneously with minimal core intervention
- Optional input scaling for both FIR and IIR filters

1. For details on DFI and DFII modes, refer to the Freescale application note entitled *Implementing IIR/FIR Filters with Freescale's DSP56000/DSP56001* (APR7/D).

- Two filter initialization modes
  - No initialization
  - Data initialization
- Sixteen-bit arithmetic mode support
- Three rounding options available:
  - No rounding
  - Convergent rounding
  - Two's complement rounding
- Arithmetic saturation mode support for bit-exact applications
- Sticky saturation status bit indication
- Sticky data/coefficient transfer contention status bit
- 4-word deep input data buffer for maximum performance
- EFCOP-shared and core-shared 16K-word filter data memory bank and 16K-word filter coefficient memory bank
- Two memory bank base address pointers, one for data memory (shared with X memory) and one for coefficient memory (shared with Y memory)
- I/O data transfers via core or DMA with minimal core intervention
- Core-concurrent operation with minimal core intervention

## 12.2 Architecture Overview

As [Figure 12-1](#) shows, the EFCOP comprises these main functional blocks:

- Peripheral module bus (PMB) interface, including:
  - Data input buffer
  - Constant input buffer
  - Output buffer
  - Filter counter
- Filter data memory (FDM) bank
- Filter coefficient memory (FCM) bank
- Filter multiplier accumulator (FMAC) machine
- Address generator
- Control logic



The PMB interface block contains control and status registers, buffers the internal bus from the PMB, decodes and generates addresses and controls the handshake signals required for DMA and interrupt operations. The block generates interrupt and DMA trigger signals for data transfers. The interface registers accessible to the DSP56300 core through the PMB are summarized in [Table 12-1](#).

### Table 12-1 EFCOP Registers Accessible Through the PMB

Register Name	Description
Filter Data Input Register (FDIR)	A 4-word-deep 24-bit-wide FIFO used for DSP-to-EFCOP data transfers. Data from the FDIR is transferred to the FDM for filter processing.
Filter Data Output Register (FDOR)	A 24-bit-wide register used for EFCOP-to-DSP data transfers. Data is transferred to FDOR after processing of all filter taps is completed for a specific set of input samples.
Filter K-Constant Input Register (FKIR)	A 24-bit register for DSP-to-EFCOP constant transfers.
Filter Count (FCNT) Register	A 24-bit register that specifies the number of filter taps. The count stored in the FCNT register is used by the EFCOP address generation logic to generate correct addressing to the FDM and FCM.
EFCOP Control Status Register (FCSR)	A 24-bit read/write register used by the DSP56300 core to program the EFCOP and to examine the status of the EFCOP module.

**Table 12-1 EFCOP Registers Accessible Through the PMB (continued)**

Register Name	Description
EFCOP ALU Control Register (FACR)	A 24-bit read/write register used by the DSP56300 core to program the EFCOP data ALU operating modes.
EFCOP Data Buffer Base Address (FDBA)	A 16-bit read/write register used by the DSP56300 core to indicate the EFCOP the data buffer base start address pointer in FDM RAM.
EFCOP Coefficient Buffer Base Address (FCBA)	A 16-bit read/write register by which the DSP56300 core indicates the EFCOP coefficient buffer base start address pointer in FCM RAM.
Decimation/ Channel Count Register (FDCH)	A 24-bit register that sets the number of channels in multichannel mode and the filter decimation ratio. The EFCOP address generation logic uses this information to supply the correct addressing to the FDM and FCM.

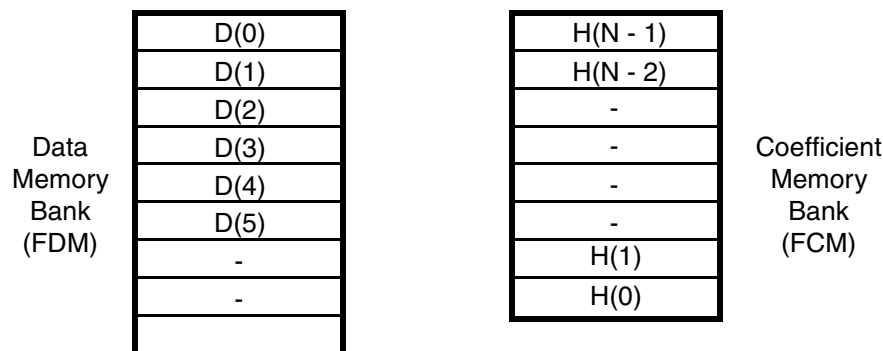
## 12.2.2 EFCOP Memory Banks

The EFCOP contains two memory banks:

- **Filter Data Memory (FDM)**—This 24-bit-wide memory bank is mapped as X memory and stores input data samples for EFCOP filter processing. The FDM is written via a four-word FIFO (FDIR), and its addressing is generated by the EFCOP address generation logic. The input data samples are read sequentially from the FDM into the MAC. The FDM is accessible for writes by the core and the DMA controller and is shared with 16K memory locations (\$c000–\$10000) of the on-chip internal X memory.
- **Filter Coefficient Memory (FCM)**—This 24-bit-wide memory bank is mapped as Y memory and stores filter coefficients for EFCOP filter processing. The FCM is written via the DSP56300 core, and the EFCOP address generation logic generates its addressing. The filter coefficients are read sequentially from the FCM into the MAC. The FCM is accessible for writes only by the core. The FCM is shared with the 16K memory locations (\$c000–\$10000) of the on-chip internal Y memory.

### NOTE

The filter coefficients,  $H(n)$ , are stored in “reverse order,” where  $H(N-1)$  is stored at the lowest address of the FCM register as shown in [Figure 12-2](#).



**Figure 12-2 Storage of Filter Coefficients**



The EFCOP connects to the shared memory in place of the DMA bus. Simultaneous core and EFCOP accesses to the same memory module block (8K locations) of shared memory are not permitted. It is your responsibility to prevent such simultaneous accesses. Figure 12-3 illustrates the memory shared between the core and the EFCOP.

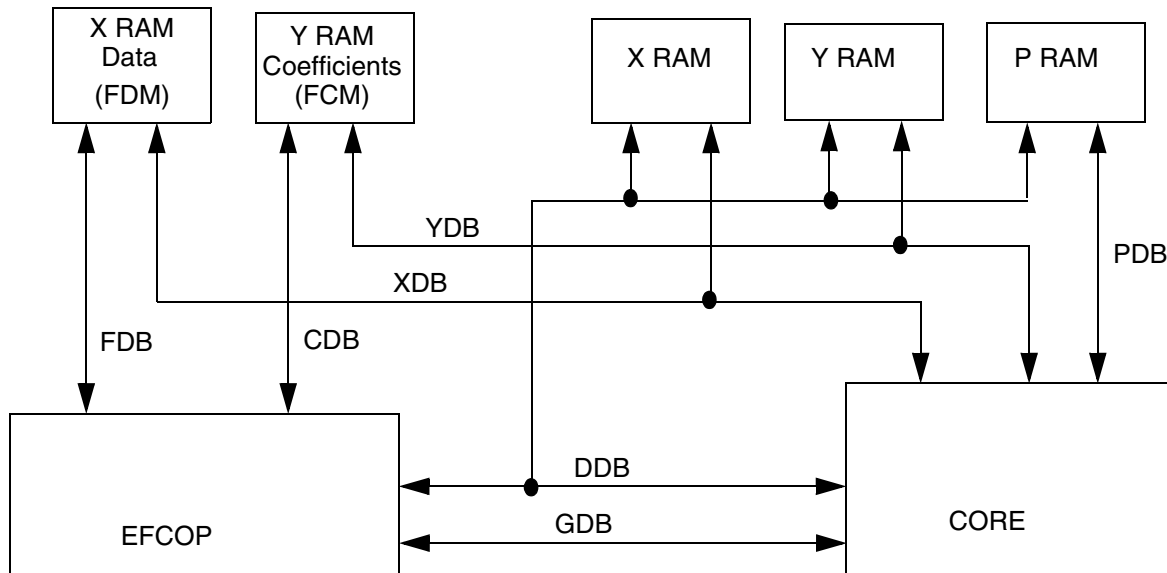


Figure 12-3 EFCOP Memory Organization

### 12.2.3 Filter Multiplier and Accumulator (FMAC)

The FMAC machine can perform a 24-bit  $\times$  24-bit multiplication with accumulation in a 56-bit accumulator. The FMAC operates a pipeline: the multiplication is performed in one clock cycle, and the accumulation occurs in the following clock cycle. Throughput is one MAC result per clock cycle. The two MAC operands are read from the FDM and from the FCM. The full 56-bit width of the accumulator is used for intermediate results during the filter calculations.

For operations in which saturation mode is disabled, the final result is rounded according to the selected rounding mode and limited to the most positive number (\$7FFFFFFF, if overflow occurred) or most negative number (\$8000000, if underflow occurred) after processing of all filter taps is completed. In saturation mode, the result is limited to the most positive number (\$7FFFFFFF, if overflow occurred), or the most negative number (\$8000000, if underflow occurred) after each MAC operation. The 24-bit result from the FMAC is stored in the EFCOP output buffer, FDOR.

Operating in sixteen-bit arithmetic mode, the FMAC performs a 16-bit  $\times$  16-bit multiplication with accumulation into a 40-bit accumulator. As with 24-bit operations, if saturation mode is disabled, the result is rounded according to the selected rounding mode and limited to the most positive number (\$7FFF, if overflow occurred) or the most negative number (\$8000, if underflow occurred) after processing of all filter taps is completed. In saturation mode, the result is limited to the most positive number (\$7FFF, if overflow occurred) or the most negative number (\$8000, if underflow occurred) after every MAC operation. The 16-bit result from the FMAC is stored in the EFCOP output buffer, FDOR.

## 12.3 EFCOP Programming Model

This section documents the registers for configuring and operating the EFCOP. The EFCOP registers available to the DSP programmer are listed in [Table 12-2](#). The following paragraphs describe these registers in detail.

**Table 12-2 EFCOP Registers and Base Addresses**

Address	EFCOP Register Name
Y:\$FFFFB0	Filter data input register (FDIR)
Y:\$FFFFB1	Filter data output register (FDOR)
Y:\$FFFFB2	Filter K-constant register (FKIR)
Y:\$FFFFB3	Filter count register (FCNT)
Y:\$FFFFB4	Filter control status register (FCSR)
Y:\$FFFFB5	Filter ALU control register (FACR)
Y:\$FFFFB6	Filter data buffer base address (FDBA)
Y:\$FFFFB7	Filter coefficient base address (FCBA)
Y:\$FFFFB8	Filter decimation/channel register (FDCH)
<b>Note:</b> The EFCOP registers are mapped onto Y data memory space.	

### 12.3.1 Filter Data Input Register (FDIR)

The FDIR is a 4-word deep, 24-bit wide FIFO for DSP-to-EFCOP data transfers. Up to four data samples can be written into the FDIR at the same address. Data from the FDIR is transferred to the FDM for filter processing. For proper operation, write data to the FDIR only if the FDIBE status bit is set, indicating that the FIFO is empty. A write to the FDIR clears the FDIBE bit. Data transfers can be triggered by an interrupt request (for core transfers) or a DMA request (for DMA transfers). The FDIR is accessible for writes by the DSP56300 core and the DMA controller.

### 12.3.2 Filter Data Output Register (FDOR)

The FDOR is a 24-bit read-only register for EFCOP-to-DSP data transfers. The result of the filter processing is transferred from the FMAC to the FDOR. For proper operation, read data from the FDOR only if the FDOBF status bit is set, indicating that the FDOR contains data. A read from the FDOR clears the FDOBF bit. Data transfers can be triggered by an interrupt request (for core transfers) or a DMA request (DMA transfers). The FDOR is accessible for reads by the DSP56300 core and the DMA controller.

### 12.3.3 Filter K-Constant Input Register (FKIR)

The Filter K-Constant Input Register (FKIR) is a 24-bit write-only register for DSP-to-EFCOP data transfers in adaptive mode where the value stored in FKIR represents the weight update multiplier. FKIR is accessible only to the DSP core for reads or writes. When adaptive mode is enabled, the EFCOP immediately starts the coefficient update if a K-Constant value is written to FKIR. If no value is written to FKIR for the current data sample, the EFCOP halts processing until the K-Constant is written to FKIR. After the weight update multiplier is written to FKIR, the EFCOP transfers it to the FMAC unit and starts updating the filter coefficients according to the following equation:

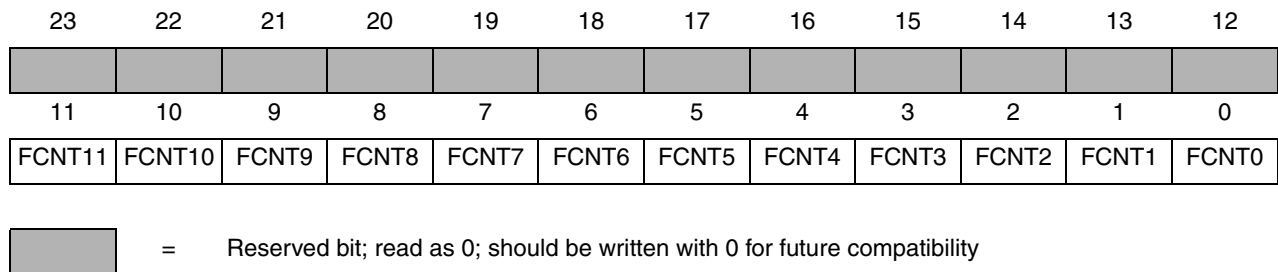
$$\text{New\_coefficients} = \text{Old\_coefficients} + \text{FKIR} * \text{Input\_buffer}$$

### 12.3.4 Filter Count (FCNT) Register

The FCNT register is a read/write register that selects the filter length (number of filter taps). Always write the initial count into the FCNT register before you enable the EFCOP (that is, before you set FEN). The number stored in FCNT is used to generate the correct addressing for the FDM and for the FCM.

#### NOTE

To ensure correct operation, never change the contents of the FCNT register unless the EFCOP is in the individual reset state (that is, FEN = 0). In the individual reset state (that is, FEN = 0), the EFCOP module is inactive, but the contents of the FCNT register are preserved.



**Figure 12-4 Filter Count (FCNT) Register**


**Table 12-3 Filter Count FCNT Register Bits**

Bit #	Abbr.	Description
23–12		These bits are reserved and unused. They are read as 0 and should be written with 0 for future compatibility.
11–0	FCNT	<b>Filter Count</b> —The actual value written to the FCNT register must be the number of coefficient values minus one. The number of coefficient values is the number of locations used in the FCM. For a real FIR filter, the number of coefficient values is identical to the number of filter taps. For a complex FIR filter, the number of coefficient values is twice the number of filter taps.

## 12.3.5 EFCOP Control Status Register (FCSR)

The FCSR is a 24-bit read/write register by which the DSP56300 core controls the main operation modes of the EFCOP and monitors the EFCOP status.

23	22	21	20	19	18	17	16	15	14	13	12
								FDOBF	FDIBE	FCONT	FSAT
11	10	9	8	7	6	5	4	3	2	1	0
FDOIE	FDIIE		FSCO	FPRC	FMLC	FOM1	FOM0	FUPD	FADP	FLT	FEN

 = Reserved bit; read as 0; should be written with 0 for future compatibility

**Table 12-4 FCSR Bits**

Bit Number	Bit Name	Reset Value	Description
23–16		0	These bits are reserved and unused. They are read as 0 and should be written with 0 for future compatibility.
15	FDOBF	0	<b>Filter Data Output Buffer Full</b> —When set, this read-only status bit indicates that the FDOR is full and the DSP can read data from the FDOR. The FDOBF bit is set when a result from FMAC is transferred to the FDOR. For proper operation, read data from the FDOR only if the FDOBF status bit is set. When FDOBF is set, the EFCOP generates an FDOBF interrupt request to the DSP56300 core if that interrupt is enabled (that is, FDOIE = 1). A DMA request is always generated when the FDOBF bit is set, but a DMA transfer takes place only if a DMA channel is activated and triggered by this event. A read from the FDOR clears the FDOBF bit.
14	FDIBE	0	<b>Filter Data Input Buffer Empty</b> —When set, this read-only status bit indicates that the FDIR is empty and the DSP can write data to the FDIR. The FDIBE bit is set when all four FDIR locations are empty. For proper operation, write data to the FDIR only if FDIBE is set. After the EFCOP is enabled by setting FEN, FDIBE is set, indicating that the FDIR is empty. When FDIBE is set, the EFCOP generates an FDIR empty interrupt request to the DSP56300 core, if enabled (that is, FDIIE = 1). A DMA request is always generated when the FDIBE bit is set, but a DMA transfer takes place only if a DMA channel is activated and triggered by this event. A write to the FDIR clears the FDIBE bit.
13	FCONT	0	<b>Filter Contention</b> —When set, this read-only status bit indicates an attempt by both the DSP56300 core and the EFCOP to access the same 8k-word bank in either the shared FDM or FCM. A dual access could result in faulty data output in the FDOR. Once set, the FCONT bit is a sticky bit that can only be cleared by a hardware $\overline{\text{RESET}}$ signal, a software RESET instruction, or an individual reset.
12	FSAT	0	<b>Filter Saturation</b> —When set, this read-only status bit indicates that an overflow or underflow occurred in the MAC result. When an overflow occurs, the FSAT bit is set, and the result is saturated to the most positive number (that is, \$7FFFFFFF). When an underflow occurs, the FSAT bit is set, and the result is saturated to the most negative number (that is, \$800000). FSAT is a sticky status bit that is set by hardware and can be cleared only by a hardware $\overline{\text{RESET}}$ signal, a software RESET instruction, or an individual reset.

Table 12-4 FCSR Bits (continued)

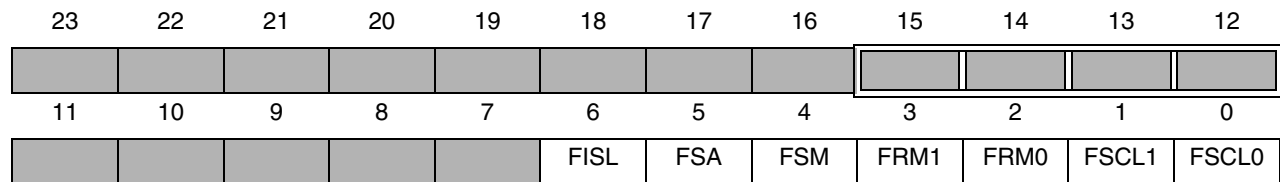
Bit Number	Bit Name	Reset Value	Description
11	FDOIE	0	<p><b>Filter Data Output Interrupt Enable</b>—This read/write control bit enables the filter data output interrupt. If FDOIE is cleared, the filter data output interrupt is disabled, and the FDOBF status bit should be polled to determine whether the FDOR is full. If both FDOIE and FDOBF are set, the EFCOP requests a data output buffer full interrupt service from the DSP56300 core. A DMA transfer is enabled if a DMA channel is activated and triggered by this event.</p> <p><b>Note:</b> For proper operation, enable the interrupt service routine and the corresponding interrupt for core processing <i>or</i> enable the DMA transfer and configure the proper trigger for the selected channel. <i>Never</i> enable both simultaneously.</p>
10	FDIIE	0	<p><b>Filter Data Input Interrupt Enable</b>—This read/write control bit enables the data input buffer empty interrupt. If FDIIE is cleared, the data input buffer empty interrupt is disabled, and the FDIBE status bit should be polled to determine whether the FDIR is empty. If both FDIIE and FDIBE are set, the EFCOP requests a data input buffer empty interrupt service from the DSP56300 core. DMA transfer is enabled if a DMA channel is activated and triggered by this event.</p> <p><b>Note:</b> For proper operation, enable the interrupt service routine and the corresponding interrupt for core processing <i>or</i> enable the DMA transfer and configure the proper trigger for the selected channel. <i>Never</i> enable both simultaneously.</p>
9		0	Reserved. It is read as 0 and should be written with 0 for future compatibility.
8	FSCO	0	<p><b>Filter Shared Coefficients Mode</b>—This read/write control bit is valid only when the EFCOP is operating in multichannel mode (that is, FMLC is set). When FSCO is set, the EFCOP uses the coefficients in the same memory area (that is, the same coefficients) to implement the filter for each channel. This mode is used when several channels are filtered through the same filter. When the FSCO bit is cleared, the EFCOP filter coefficients are stored sequentially in memory for each channel.</p> <p><b>Note:</b> To ensure proper operation, never change the FSCO bit unless the EFCOP is in individual reset state (that is, FEN = 0).</p>
7	FPRC	0	<p><b>Filter Processing (FPRC) State Initialization Mode</b>—This read/write control bit defines the EFCOP processing initialization mode. When this bit is cleared, the EFCOP starts processing after a state initialization. (The EFCOP machine starts computing once the FDM bank contains N input samples for an N tap filter). When this bit is set, the EFCOP starts processing with no state initialization. (The EFCOP machine starts computing as soon as the first data sample is available in the input buffer.)</p> <p><b>Note:</b> To ensure proper operation, never change the FPRC bit unless the EFCOP is in individual reset state (that is, FEN = 0).</p>
6	FMLC	0	<p><b>Filter Multichannel (FMLC) Mode</b>—This read/write control bit enables multichannel mode, allowing the EFCOP to process several filters (defined by FCHL[5:0] bits in FDCH register) concurrently by sequentially entering a different sample to each filter. If FMLC is cleared, multichannel mode is disabled, and the EFCOP operates in single filter mode.</p> <p><b>Note:</b> To ensure proper operation, never change the FMLC bit unless the EFCOP is in individual reset state (that is, FEN = 0).</p>


Table 12-4 FCSR Bits (continued)


Bit Number	Bit Name	Reset Value	Description
5–4	FOM	0	<p><b>Filter Operation Mode</b>—This pair of read/write control bits defines one of four operation modes if the FIR filter is selected (that is, FLT is cleared):</p> <p>FOM = 00—Mode 0: Real FIR filter</p> <p>FOM = 01—Mode 1: Full complex FIR filter</p> <p>FOM = 10—Mode 2: Complex FIR filter with alternate real and imaginary outputs</p> <p>FOM = 11—Mode 3: Magnitude</p> <p><b>Note:</b> To ensure proper operation, never change the FOM bits unless the EFCOP is in the individual reset state (that is, FEN = 0).</p>
3	FUPD	0	<p><b>Filter Update</b>—This read/write control/status bit enables the EFCOP to start a single coefficient update session. Upon completion of the session, the FUPD bit is automatically cleared. FUPD is automatically set when the EFCOP is in adaptive mode (that is, FADP = 1).</p>
2	FADP	0	<p><b>Filter Adaptive (FADP) Mode</b>—This read/write control bit enables adaptive mode. Adaptive mode is an efficient way to implement a LMS-type filter, and, therefore, it is used when the EFCOP operates in FIR filter mode (FLT = 0). In adaptive mode, processing of every input data sample consists of FIR processing followed by a coefficient update. When FADP is set, the EFCOP completes the FIR processing on the current data sample and immediately starts the coefficient update assuming that a K-constant value is written to the FKIR. If no value is written to the FKIR for the current data sample, the EFCOP halts processing until the K-constant is written to the FKIR. During the coefficient update, the FUPD bit is automatically set to indicate an update session. After completion of the update, the EFCOP starts processing the next data sample.</p>
1	FLT	0	<p><b>Filter (FLT) Type</b>—This read/write control bit selects one of two available filter types:</p> <p>FLT = 0—FIR filter</p> <p>FLT = 1—IIR filter</p> <p><b>Note:</b> To ensure proper operation, never change the FLT bit unless the EFCOP is in the individual reset state (that is, FEN = 0).</p>
0	FEN	0	<p><b>Filter Enable</b>—This read/write control bit enables the operation of the EFCOP. When FEN is cleared, operation is disabled and the EFCOP is in the individual reset state.</p> <p>In the individual reset state, the EFCOP is inactive; internal logic and status bits assume the same state as that produced by a hardware <math>\overline{\text{RESET}}</math> signal or a software RESET instruction; the contents of the FCNT, FDBA, and FCBA registers are preserved; and the control bits in FCSR and FACR remain unchanged.</p>

## 12.3.6 EFCOP ALU Control Register (FACR)

The FACR is a read/write register by which the DSP56300 core controls the main operation modes of the EFCOP ALU.



 = Reserved bit; read as 0; should be written with 0 for future compatibility

 = Reserved for internal use; read as 0; should be written with 0 for proper use.

**Figure 12-5 EFCOP ALU Control Register (FACR)**

**Table 12-5 EFCOP ALU Control Register (FACR) Bits**

Bit Number	Bit Name	Reset Value	Description
23–16		0	Reserved. They are read as 0 and should be written with 0 for future compatibility.
15–12		0	Reserved for internal use. Written as 0 for proper operation.
11–7		0	Reserved and unused. They are read as 0 and should be written with 0 for future compatibility.
6	FISL	0	<b>Filter Input Scale</b> —When set, this read/write control bit directs the EFCOP ALU to scale the IIR feedback terms but not the IIR input. When cleared, the EFCOP ALU scales both the IIR feedback terms and the IIR input. The scaling value in both cases is determined by the FSCL[1:0] bits.
5	FSA	0	<b>Filter Sixteen-bit Arithmetic (FSA) Mode</b> —When set, this read/write control bit enables FSA mode. In this mode, the rounding of the arithmetic operation is performed on Bit 31 of the 56-accumulator instead of the usual bit 23 of the 56-bit accumulator. The scaling of the EFCOP data ALU is affected accordingly.
4	FSM	0	<b>Filter Saturation Mode</b> —When set, this read/write control bit selects automatic saturation on 48 bits for the results going to the accumulator. A special circuit inside the EFCOP MAC unit then saturates those results. The purpose of this bit is to provide arithmetic saturation mode for algorithms that do not recognize or cannot take advantage of the extension accumulator.

Table 12-5 EFCOP ALU Control Register (FACR) Bits (continued)

Bit Number	Bit Name	Reset Value	Description
3–2	FRM	0	<b>Filter Rounding Mode</b> —These read/write control bits select the type of rounding performed by the EFCOP data ALU during arithmetic operation: FRM = 00—Convergent rounding FRM = 01—Two's complement rounding FRM = 10—Truncation (no rounding) FRM = 11—Reserved for future expansion These bits affect operation of the EFCOP data ALU.
1–0	FSCL	0	<b>Filter Scaling (FSCL)</b> —These read/write control bits select the scaling factor of the FMAC result: FSCL = 00—Scaling factor = 1 (no shift) FSCL = 01—Scaling factor = 8 (3-bit arithmetic left shift) FSCL = 10—Scaling factor = 16 (4-bit arithmetic left shift) FSCL = 11—Reserved for future expansion To ensure proper operation, never change the FSCL bits unless the EFCOP is in the individual reset state (that is, FEN = 0).

### 12.3.7 EFCOP Data Base Address (FDBA)

The FDBA is a 16-bit read/write counter register used as an address pointer to the EFCOP FDM bank. FDBA points to the location to write the next data sample. The FDBA points to a modulo delay buffer of size  $M$ , defined by the filter length ( $M = \text{FCNT}[11:0] + 1$ ). The address range of this modulo delay buffer is defined by lower and upper address boundaries. The lower address boundary is the FDBA value with 0 in the  $k$ -LSBs, where  $2^k \geq M \geq 2^{k-1}$ ; it, therefore, must be a multiple of  $2^k$ . The upper boundary is equal to the lower boundary plus  $(M - 1)$ . Since  $M \leq 2^k$ , once  $M$  has been chosen (that is, FCNT has been assigned), a sequential series of data memory blocks (each of length  $2^k$ ) will be created where multiple circular buffers for multichannel filtering can be located. If  $M < 2^k$ , there will be a space between sequential circular buffers of  $2^k - M$ . The address pointer is not required to start at the lower address boundary or to end on the upper address boundary. It can point anywhere within the defined modulo address range. If the data address pointer (FDBA) increments and reaches the upper boundary of the modulo buffer, it will wrap around to the lower boundary.

### 12.3.8 EFCOP Coefficient Base Address (FCBA)

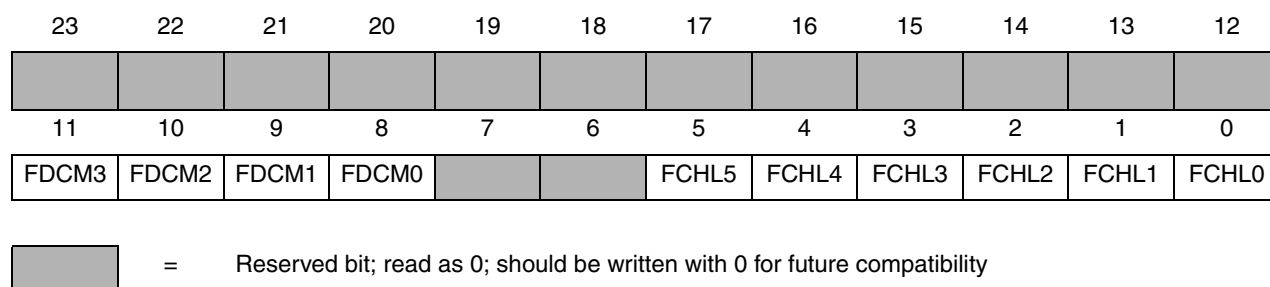
The FCBA is a 16-bit read/write counter register used as an address pointer to the EFCOP FCM bank. FCBA points to the first location of the coefficient table. The FCBA points to a modulo buffer of size  $M$ , defined by the filter length ( $M = \text{FCNT}[11:0] + 1$ ). The address range of this modulo buffer is defined by lower and upper address boundaries. The lower address boundary is the FCBA value with 0 in the  $k$ -LSBs, where  $2^k \geq M \geq 2^{k-1}$ ; it therefore must be a multiple of  $2^k$ . The upper boundary is equal to the lower boundary plus  $(M - 1)$ . Since  $M \leq 2^k$ , once  $M$  has been chosen (that is, FCNT has been assigned), a sequential series of coefficient memory blocks (each of length  $2^k$ ) is created where multiple circular



buffers for multichannel filtering can be located. If  $M < 2^k$ , there will be a space between sequential circular buffers of  $2^k - M$ . The FCBA address pointer must be assigned to the lower address boundary (that is, it must have 0 in its k-LSBs). In a compute session, the coefficient address pointer always starts at the lower boundary and ends at the upper address boundary. Therefore, a FCBA read always gives the value of the lower address boundary.

### 12.3.9 Decimation/Channel Count Register (FDCH)

The FDCH is a read/write register that sets the number of channels used in multichannel mode (FCHL) and sets the decimation ratio in FIR filter mode. FDCH must be written before the FEN enables the EFCOP. FDCH should be changed only when the EFCOP is in individual reset state ( $FEN = 0$ ); otherwise, improper operation may result. The number stored in FCHL is used by the EFCOP address generation logic to generate the correct address for the FDM bank and for the FCM bank in multichannel mode. When the EFCOP enable bit (FEN) is cleared, the EFCOP is in individual reset state. In this state, the EFCOP is inactive, and the contents of FDCH register are preserved.



**Figure 12-6 Decimation/Channel Count Register (FDCH)**

**Table 12-6 Decimation/Channel Count Register (FDCH) Bits**

Bit Number	Bit Name	Reset Value	Description
23–12		0	These bits are reserved and unused. They are read as 0 and should be written with 0 for future compatibility.
11–8	FDCM	0	<b>Filter Decimation</b> —These read/write control bits select the decimation function. There are 16 decimation factor options (from 1 to 16). <b>Note:</b> To ensure proper operation, never change the FDCM bits unless the EFCOP is in the individual reset state ( $FEN = 0$ ).
7–6		0	Reserved and unused. They are read as 0 and should be written with 0 for future compatibility.
5–0	FCHL	0	<b>Filter Channels</b> —These read/write control bits determine the number of filter channels to process simultaneously (from 1 to 64) in multichannel mode. The number represented by the FCHL bits is one less than the number of channels to be processed; that is, if $FCHL = 0$ , 1 channel is processed; if $FCHL = 1$ , 2 channels are processed, and so on. <b>Note:</b> To ensure proper operation, never change the FCHL bits unless the EFCOP is in the individual reset state ( $FEN = 0$ ).

## 12.3.10 EFCOP Interrupt Vectors

Table 12-7 shows the EFCOP interrupt vectors, and Table 12-8 shows the DMA request sources.

**Table 12-7 EFCOP Interrupt Vectors**

Interrupt Address	Interrupt Vector	Priority	Interrupt Enable	Interrupt Conditions
VBA : \$68	Data input buffer empty	Highest	FDIIE	FDIBE = 1
VBA : \$6A	Data output buffer full	Lowest	FDOIE	FDOBF = 1

**Table 12-8 EFCOP DMA Request Sources**

Requesting Device Number	Request Conditions	Peripheral Request MDRQ
EFCOP input buffer empty	FDIBE = 1	MDRQ11
EFCOP output buffer full	FDOBF = 1	MDRQ12

## 12.4 EFCOP Programming

The DSP56371 Enhanced Filter Coprocessor (EFCOP) supports both Finite Impulse Response (FIR) filters and Infinite Impulse Response (IIR) filters.<sup>1</sup> This section discusses the different ways data can be transferred in and out of the EFCOP and presents some programming examples in which such transfers are performed for FIR and IIR filters.

EFCOP operation is determined by the control bits in the EFCOP Control/Status Register (FCSR), described in [Section 12.3.5, "EFCOP Control Status Register \(FCSR\)"](#). Further filtering operations are enabled via the appropriate bits in the FACR and FDCH registers. After the FCSR is configured to the mode of choice, enable the EFCOP by setting FCSR[FEN]. To ensure proper EFCOP operation, most FCSR bits must not be changed while the EFCOP is enabled. [Table 12-9](#) summarizes the EFCOP operating modes.

1. For details on FIR and IIR filters, refer to the Freescale application note entitled *Implementing IIR/FIR Filters with Freescale's DSP56000/DSP56001* (APR7/D).

Table 12-9 EFCOP Operating Modes

Mode Description <sup>1</sup>	FCSR Bits					
	6 FMLC	5–4 FOM	3 FUPD <sup>2</sup>	2 FADP <sup>2</sup>	1 FLT	0 FEN
EFCOP Disabled <sup>3</sup>	x	x	x	x	x	0
FIR, Real, single channel	0	00	0	0	0	1
FIR, Real, adaptive, single channel	0	00	0	1	0	1
FIR, Real, coeff. update, single channel	0	00	1	0	0	1
FIR, Real, adaptive + coeff. update, single channel	0	00	1	1	0	1
FIR, Real, multichannel	1	00	0	0	0	1
FIR, Real, adaptive, multichannel	1	00	0	1	0	1
FIR, Real, coeff. update, multichannel	1	00	1	0	0	1
FIR, Real, adaptive + coeff. update, multichannel	1	00	1	1	0	1
FIR, Full Complex, single channel	0	01	0	0	0	1
FIR, Complex Alternating, single channel	0	10	0	0	0	1
FIR, Magnitude, single channel	0	11	0	0	0	1
IIR, Real, single channel	0	00	0	0	1	1
IIR, Real, multichannel	1	00	0	0	1	1

<sup>1</sup> All bit combinations not defined by this table are reserved for future development.

<sup>2</sup> If the user sets the FUPD bit, the EFCOP updates the coefficients and clears the FUPD bit. The adaptive mode (that is, FADP = 1) sets the FUPD bit, which causes the EFCOP to update the coefficients and then automatically clear the FUPD bit. Therefore, the value assigned to the FUPD bit in this table refers only to its initial setting and not its dynamic state during operation.

<sup>3</sup> An x indicates that the specified value can be 1 or 0.

## 12.5 Operation Summary

The EFCOP is very easy to use. To define the type of filtering to perform, you need only set the following registers (the settings in the FDCH and FACR are optional) and then enable the EFCOP by setting FCSR[FEN]:

- FCNT
- FDBA
- FCBA
- FCSR

Polling, DMA, or interrupts can then be used to write data to the FDIR and read data from the FDOR. As Table 12-9 shows, the EFCOP operates in many different modes based on the settings of the control registers. However, the EFCOP performs only two basic types of processing, FIR filter type and IIR filter type processing. Various sub-options are available with each filter type, as described in the following sections.

## 12.5.1 FIR Filter Type

To select the FIR filter type clear FCSR[FLT] and perform the processing shown in Figure 12-7 based on the equation shown below.

$$w(n) = \sum_{i=0}^N B_i x(n-i)$$

The EFCOP takes an input,  $x(n)$ , from the FDIR, saves the input while shifting the previous inputs down in the FDM, multiplies each input in the FDM by the corresponding coefficient,  $B_i$ , stored in the FCM, accumulates the multiplication results and places accumulation result,  $w(n)$ , in the FDOR. This is done for each sample input to the FDIR.

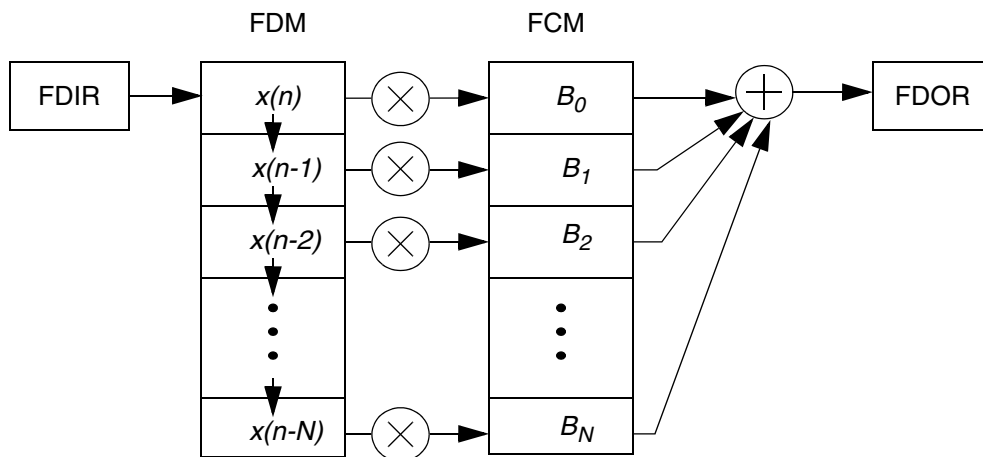


Figure 12-7 FIR Filter Type Processing

There are four operating modes available with the FIR filter type: real, complex, alternating complex and magnitude mode.

### 12.5.1.1 Real Mode

Real mode performs FIR type filtering with real data and is selected by clearing both FOM bits in the FCSR. One sample, the real input, is written to the FDIR, and the EFCOP processes the data. Then one sample, the real output, is read from the FDOR. Two other options are available with the real FIR filter type: adaptive and multichannel modes. These modes can be used individually or together.

### 12.5.1.2 Adaptive Mode

Adaptive mode provides a way to update the coefficients based on filter input,  $x(n)$ , using the following equation,

$$h_{n+1}(i) = h_n(i) + K_e(n)x(n-i)$$

where  $h_n(i)$  is the  $i$ th coefficient at time  $n$ . The coefficients are updated when FCSR[FUPD] is set. The EFCOP checks to see if a value has been written to the FKIR. If no value is written, the EFCOP halts processing until a value is written to the FKIR. When a value is written to the FKIR, the EFCOP updates all the coefficients based on the above equation using the value in the FKIR for  $K_e(n)$ . The EFCOP automatically clears FCSR[FUPD] when the coefficient update is complete.

If the coefficients are to be updated after every input sample, Adaptive mode is enabled by setting the FCSR[FADP]. In Adaptive mode, the EFCOP automatically sets the FUDP bit after each input sample is processed. This allows for continuous processing using interrupts that includes a filter session and a coefficient update session with minimal core intervention.

#### 12.5.1.2.1 Multichannel Mode

Multichannel mode allows several channels of data to be processed concurrently and is selected by setting the FCSR[FMLC]. The number of channels to process is one plus the number in the FDCH[FDCM] bits. For each time period, the EFCOP expects to receive the samples for each channel sequentially. This is repeated for consecutive time periods.

Filtering can be done with the same filter or different filters for each channel by using the FCSR[FSCO] bit. If FCSR[FSCO] is set, the same set of coefficients are used for all channels. If FSCO is clear, the coefficients for each filter are stored sequentially in memory for each channel.

#### 12.5.1.2.2 Complex Mode

Complex mode performs FIR type filtering with complex data based on the following equations where  $H(n)$  is the coefficients,  $D(n)$  is the input data, and  $F(n)$  is the output data at time  $n$ .

$$\begin{aligned} \text{Re}(F(n)) &= \sum_{i=0}^{N-1} \text{Re}(H(i)) \cdot \text{Re}(D(n-i)) - \text{Im}(H(i)) \cdot \text{Im}(D(n-i)) \\ \text{Im}(F(n)) &= \sum_{i=0}^{N-1} \text{Re}(H(i)) \cdot \text{Im}(D(n-i)) + \text{Im}(H(i)) \cdot \text{Re}(D(n-i)) \end{aligned}$$

Two samples, the real part then the imaginary part of the input, are written to the FDIR. The EFCOP processes the data, and then two samples—the real and then the imaginary part of the output—are read from the FDOR.

Complex mode is selected by setting the FCSR[FOM] bits to 01. In Complex mode, the number written to the FCNT register should be twice the number of filter coefficients. Also, the coefficients are stored in the

FCM with the real part of the coefficient in the memory location preceding the memory location holding the imaginary part of the coefficient.

### 12.5.1.2.3 Alternating Complex Mode

Alternating Complex mode performs FIR type filtering with complex data, providing alternating real and complex results based on the following equations where  $H(n)$  is the coefficients,  $D(n)$  is the input data, and  $F(n)$  is the output data at time  $n$ .

$$\begin{aligned} \text{Re}(F(n|_{\text{even}})) &= \sum_{i=0}^{N-1} \text{Re}(H(i)) \cdot \text{Re}(D(n-i)) - \text{Im}(H(i)) \cdot \text{Im}(D(n-i)) \\ \text{Im}(F(n|_{\text{odd}})) &= \sum_{i=0}^{N-1} \text{Re}(H(i)) \cdot \text{Im}(D(n-i)) + \text{Im}(H(i)) \cdot \text{Re}(D(n-i)) \end{aligned}$$

Two samples, the real part then the imaginary part of the input, are written to the FDIR. The EFCOP processes the data. Then one sample, alternating between the real part and the imaginary part of the output, is read from the FDOR.

Alternating Complex mode is selected by setting the FCSR[FOM] bits to 10. In Alternating Complex mode, the number written to the FCNT register should be twice the number of filter coefficients. Also, the coefficients should be stored in the FCM with the real part of the coefficient in the memory location preceding the memory location holding the imaginary part of the coefficient.

### 12.5.1.2.4 Magnitude Mode

Magnitude mode calculates the magnitude of an input signal based on the following equation where  $D(n)$  is the input data and  $F(n)$  is the output data at time  $n$ .

$$F(n) = \sum_{i=0}^{N-1} D(n-i)^2$$

One sample, the real input, is written to the FDIR. The EFCOP processes the data. Then one sample, the real magnitude of the input signal, is read from the FDOR. Magnitude mode is selected by setting both the FCSR[FOM] bits.

### 12.5.1.2.5 Initialization

Before the first sample is processed, the EFCOP filter must be initialized; that is, the input samples for times before  $n = 0$  (assuming that time starts at 0) must be loaded into the FDM. The number of samples needed to initialize the filter is the number of filter coefficients minus one. To select Initialization mode, clear the FCSR[FPRC] bit. If FCSR[FPRC] is set, initialization is disabled and the EFCOP assumes that the core wrote the initial input values to the FDM before the EFCOP was enabled. Thus, the first value written to FDIR is the first sample to be filtered.

If FCSR[FPRC] is clear, initialization mode is enabled and the EFCOP initializes the FDM by receiving the number of coefficients minus one samples through the FDIR. After samples are loaded, the next value written to the FDIR is the first sample to be filtered.

#### 12.5.1.2.6 Decimation

Decimation is another option that can be used with any four of the modes available with the FIR filter type. Decimation cannot be used in conjunction with Adaptive and Multichannel modes. Decimation decreases (downsamples) the sampling rate. The decimation ratio defines the number of input samples per output sample. The decimation ratio is one plus the number in the FDCH[FDCM] bits. The decimation ratio can be programmed from 1 to 16.

For Real and Magnitude modes the decimation ratio number of samples must be written to the FDIR before an output sample is read from the FDOR. For Complex mode, two times the decimation ratio number of samples (one for the real part and one for the imaginary part of the input) must be written to the FDIR before two output samples (one for the real part and one for the imaginary part of the output) can be read from the FDOR. For Alternating Complex mode, two times the decimation ratio number of samples must be written to the FDIR (one for the real part and one for the imaginary part of the input) before one output sample (alternating between the real part and the imaginary part of the output) can be read from the FDOR.

### 12.5.2 IIR Filter Type

To select the IIR filter type, set the FCSR[FLT] bit and perform the processing shown in [Figure 12-8](#) based on the equation shown here.

$$y(n) = S \left( w(n) + \sum_{j=1}^M A_j y(n-j) \right)$$

The EFCOP multiplies each previous output value in the FDM by the corresponding coefficient,  $A$ , stored in the FCM; accumulates the multiplication results; adds the input,  $w(n)$ , from the FDIR (which is optionally not scaled by  $S$ , depending on the FACR[FISL] bit setting); places the accumulation result,  $y(n)$ , in the FDOR; and saves the output while shifting the previous outputs down in the FDM. This is done for each sample input to the FDIR. To process a complete IIR filter, a FIR filter type session followed by an IIR filter type session is needed.

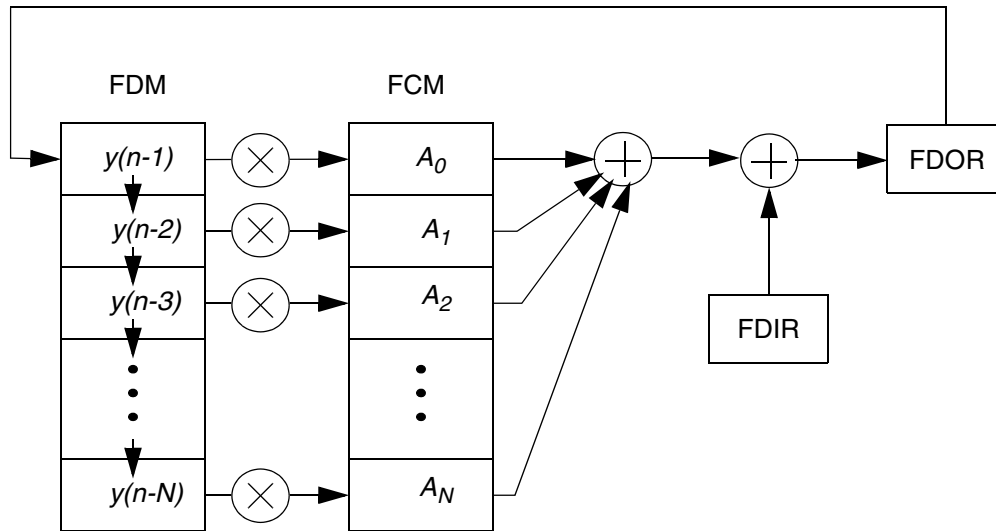


Figure 12-8 IIR Filter Type Processing

Real mode is one of two operating modes available with the IIR filter type. Thus, the FCSR[FOM] bits are ignored when the IIR filter type is in use. Real mode performs IIR type filtering with real data. One sample, the real input, is written to the FDIR, and the EFCOP processes the data. Then one sample, the real output, is read from the FDOR. Another option available for the IIR filter type is Multichannel mode.

Multichannel mode for IIR filter type works exactly the same as it does for FIR filter type, as explained in [Section 12.5.1.2.1, "Multichannel Mode"](#). Decimation and Adaptive modes are not available with the IIR filter type. Initialization is always disabled with the IIR filter type, and the FCSR[FPRC] bit is ignored. Thus, the DSP56300 core must write the initial input values before the EFCOP is enabled. The first value written to FDIR is always the first sample to be filtered.

## 12.6 Data Transfer

This section describes how to transfer data to and from the EFCOP using an FIR filter configuration. Here, we provide background information to help you understand the examples in [Section 12.7, "Examples of Use in Different Modes"](#). The examples employ the following notations:

- $D(n)$ : Data sample at time  $n$
- $H(n)$ : Filter coefficient at time  $n$
- $F(n)$ : Output result at time  $n$
- #filter\_count: Number of coefficient values in the coefficient memory bank FCM; it is equal to the initial value written to the FCNT register plus 1.
- Compute: Perform all calculations to determine one filter output  $F(n)$  for a specific set of input data samples

To transfer data to/from the EFCOP input/output registers, the Filter Data Input Register (FDIR) and the Filter Data Output Register (FDOR) are triggered by three different methods:

- Direct Memory Access (DMA)
- Interrupts
- Polling



Two FCSR bits (FDIBE and FDOBF) indicate the status of the FDIR and the FDOR, respectively. All three data transfer methods use these two FCSR bits as their control mechanism. If FDIBE is set, the input buffer is empty; if FDOBF is set, the output buffer is full. Because these bits come into full operation only when the EFCOP is enabled (FCSR:FEN is set), the polling, DMA, or interrupt methods can be initialized either before or after the EFCOP is enabled. No service request is issued until the EFCOP is enabled, since FDIBE and FDOBF are cleared while the EFCOP is in the Individual Reset state.

The most straightforward EFCOP data transfer method uses the core processor to poll the status flags, monitoring for input/output service requests. The disadvantage of this approach is that it demands large amounts of (if not all of) the core's processing time. The interrupt and DMA methods are more efficient in their use of the core processor. Interrupts intervene on the core processor infrequently to service input/output data.

DMA can operate concurrently with the processor core and demands only minimal core resource for setup. DMA transfers are recommended when the EFCOP is in FIR/IIR filtering mode since the core can operate independently of the EFCOP while DMA transfers data to the FDIR and from the FDOR. Since the EFCOP input buffer (FDIR) is four words deep, the DMA can input in blocks of up to four words. A combination of DMA transfer for input and an interrupt request for processing the output is recommended for adaptive FIR mode. This combination gives the following benefits:

- Input data transfers to the FDIR can occur independently of the core.
- There is minimal intervention of the core while the weight update multiplier is updated.

If the initialization mode is enabled (that is, if the FCSR[FPRC] bit is cleared), the core can initialize the coefficient bank while the DMA controller concurrently transfers initial data values to the data bank. The EFCOP state machine starts computation as soon as #filter\_count data samples are input. If no initialization mode is used (the FCSR[FPRC] bit is set), the EFCOP starts computation as soon as the first data sample is available in the input buffer. The filter coefficient bank must therefore be initialized before an input data transfer starts. The DMA input channel can continue transferring data whenever the input FIFO becomes empty, while the EFCOP state machine takes data words from the FIFO whenever required.

## 12.7 Examples of Use in Different Modes

The following sections provide examples of how to use the EFCOP in Real FIR Filter (Mode 0) and Adaptive FIR filter mode.

### 12.7.1 Real FIR Filter: Mode 0

In this example, an N tap FIR filter is represented as follows:

$$F(n) = \sum_{i=0}^{N-1} H(i) \cdot D(n-i)$$

The filter is implemented with three different data transfers using the EFCOP in data initialization mode:

1. DMA input/DMA output
2. DMA input/Polling output
3. DMA input/Interrupt output

This transfer combination is only one of many possible combinations.<sup>1</sup>

### 12.7.1.1 DMA Input/DMA Output

A 20-tap FIR filter using a 28-input sample signal is implemented in the following stages:

*Setup:*

1. Set the filter count register (FCNT) to the length of the filter coefficients –1 (i.e N-1).
2. Set the Data and Coefficient Base Address pointers (FDBA, FCBA).
3. Set the operation mode (FCSR[5:4] = FOM[00]).
4. Set Initialization mode (FCSR[7] = FPRC = 0).
5. Set DMA registers:

DMA input: A two-dimensional (2D) DMA transfer fills up the FDM bank via channel 0. The DMA input control registers are initialized as shown in [Table 12-10](#).

**Table 12-10 DMA Channel 0 Register Initialization**

Register Setting	Description
DCR0 bit values are as follows:	DMA Control Register 0
DIE = 0	Disables end-of-transfer interrupt.
DTM = 2	Chooses line transfer triggered by request; DE auto clear on end of transfer.
DPR = 2	Priority 2
DCON = 0	Disables continuous mode.
DRS = \$15	Chooses DMA to trigger on EFCOP input buffer empty.
D3D = 0	Chooses non-3D mode.
DAM = \$20	Sets the following DMA Address Mode: <ul style="list-style-type: none"> <li>• source address - 2D</li> <li>• counter mode B</li> <li>• offset DOR0</li> <li>• destination address - no update, no offset</li> </ul>
DDS = 1	Destination in Y memory space (because the EFCOP is in Y memory).
DSS = 0	Source in X memory space.

1. For information on DMA transfers, refer to the Freescale application note entitled *Using the DSP56300 Direct Memory Access Controller* (APR23/D).

Table 12-10 DMA Channel 0 Register Initialization (continued)

Register Setting	Description
DOR0=1	DMA Offset Register 0
DCO0= \$006003	DMA Counter Register 0 Gives transfer of $7 * 4 = 28$ items (input sequence length).
DSR0 = Address of source data	DMA Source Address Register 0
DDR0 = \$FFFFB0	DMA Destination Address Register for Channel 0

DMA output: Channel 1 is used, with a configuration similar to that of the DMA input channel, except for a 1D transfer. The DMA output control registers are initialized as shown in Table 12-11.

Table 12-11 DMA Channel 1 Register Initialization

Register Setting	Description
DCR1 bit values are as follows:	DMA Control Register 1
DIE = 0	Disables end-of-transfer interrupt.
DTM = 1	Chooses word transfer triggered by request, DE auto clear on end of transfer.
DPR = 3	Priority 3.
DCON = 0	Disables continuous mode.
DRS = \$16	Chooses DMA to trigger on EFCOP output buffer full.
D3D = 0	Chooses non-3D mode.
DAM = \$2C	Sets the following DMA address mode <ul style="list-style-type: none"> <li>source address - no update, no offset</li> <li>destination address - 1D, post-increment by 1, no offset.</li> </ul>
DDS = 0	Destination in X memory space.
DSS = 1	Source in Y memory space (because EFCOP is in Y memory).
DCO1 = \$12	DMA Counter Register 1 Gives transfer of 9 items.
DSR1 = address of FDOR = \$FFFFFFB1	DMA Source Address Register 1
DDR1 = address of destination memory space	DMA Destination Address Register 1

### NOTE

Setting the DCO0 and DCO1 must be considered carefully. These registers must be loaded with one less than the number of items to be transferred. Also, the following equality must hold:  $DCO1 = \text{input length} - \text{filter length}$ .

Examples of Use in Different Modes

- 6. Initialization:
  - a) Enable DMA channel 1 (output) DCR1[23] DE=1
  - b) Enable EFCOP FCSR[0] FEN=1
  - c) Enable DMA channel 0. (input) DCR0[23] DE=1
- 7. Processing:
  - a) Whenever the Input Data Buffer (FDIR) is empty (that is, FDIBE = 1), the EFCOP triggers DMA input to transfer up to four new data words to FDIR.
  - b) Compute F(n); The result is stored in FDOR, and this triggers the DMA for an output data transfer.

NOTE

The filter coefficients are stored in “reverse order,” as [Figure 12-9](#) shows.

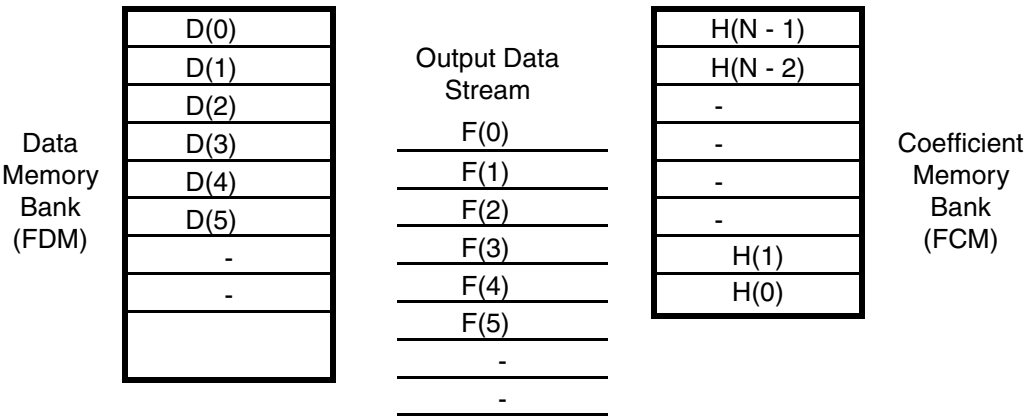


Figure 12-9 Real FIR Filter Data Stream

**Example 12.1 Real FIR Filter Using DMA Input/DMA Output**

```

                INCLUDE 'ioequ.asm'
;;*****
                                ; equates
;;*****
Start          equ    $00100      ; main program starting address
FCON           equ    $001        ; EFCOP FSCR register contents:
                                ; enable the EFCOP
FIR_LEN        equ     20         ; EFCOP FIR length
SRC_ADDRS      equ    $3040       ; ; DMA source address point to
                                ; DATA bank
DST_ADDRS      equ    $3000       ; address at which to begin output
SRC_COUNT      equ    $006003     ; DMA0 count (7*4 word transfers)
DST_COUNT      equ     8          ; number of outputs generated.
FDBA_ADDRS     equ    $C000       ; Input samples Start Address x:$C000
FCBA_ADDRS     equ    $C000       ; Coeff. Start Address y:$C000
;;*****
                                ; main program
;;*****

                ORG p:Start
move           #FDBA_ADDRS,r0      ; FDM memory area
move           #0,x0
rep            #DST_COUNT
move           x0,x:(r0)+          ; clear FDM memory area
                                ; ** DMA channel 1 initialisation - output
                                ; from EFCOP **
movep          #M_FDOR,x:M_DSR1    ; DMA source address points to the EFCOP F R
                                ; FDIR
movep          #DST_ADDRS,x:M_DDR1 ; Init DMA destination address.
movep          #DST_COUNT,x:M_DCO1 ; Init DMA count.
movep          #$8EB2C1,x:M_DCR1   ; Start DMA 1 with FDOBF request.
                                ; ** EFCOP initialisation **
movep          #FIR_LEN-1,y:M_FCNT ; FIR length
movep          #FDBA_ADDRS,y:M_FDBA ; FIR input samples Start Address
movep          #FCBA_ADDRS,y:M_FCBA ; FIR Coeff. Start Address
movep          #FCON,y:M_FCSR      ; Enable EFCOP
                                ; ** DMA channel 0 initialisation - input to
                                ; EFCOP **
movep          #SRC_ADDRS,x:M_DSR0 ; DMA source address points to the DATA
                                ; bank.
movep          #M_FDIR,x:M_DDR0    ; Init DMA destination address.
movep          #SRC_COUNT,x:M_DCO0 ; Init DMA count to line mode.
movep          #$1,x:M_DOR0        ; DMA offset reg. is 1.
movep          #$94AA04,x:M_DCR0   ; Init DMA control reg to line mode FDI BE
                                ; request.
nop

```

## Examples of Use in Different Modes

```
nop
;;*****
jcl      #0,x:M_DSTR,*
jclr     #1,x:M_DSTR,*
nop
nop

stop_label
nop
jmp stop_label

        org x:SRC_ADDRS
        INCLUDE 'input.asm'

        org y:FCBA_ADDRS
        INCLUDE 'coefs.asm'
```

### 12.7.1.2 DMA Input/Polling Output

The different stages of input/polling are as follows:

1. Setup:
  - a) Set the filter count register (FCNT) to the length of the filter coefficients –1 (i.e N-1).
  - b) Set the data and coefficient base address pointers (FDBA, FCBA).
  - c) Set the operation mode (FCSR[5:4] = FOM[00], = 1).
  - d) Set the initialization mode (FCSR[7] = FPRC = 0).
  - e) Set DMA registers: DMA input: as per channel 0 in [Section 12.7.1.1, "DMA Input/DMA Output"](#)
2. Initialization:
  - a) Enable EFCOP FCSR[0] FEN=1.
  - b) Enable DMA input channel, DCR0[23] DE=1.
3. Processing:
  - a) Whenever the Input Data Buffer (FDIR) is empty (that is, FDI BE = 1), the EFCOP triggers DMA input to transfer up to four new data words to FDM via FDIR.
  - b) Compute F(n); the result is stored in FDOR.
  - c) The core keeps polling the FCSR[FDOBF] bit and stores the data in memory.

**Example 12.2 Real FIR Filtering using DMA input/Polling output**

```

INCLUDE 'ioequ.asm'
;;*****
; equates
;;*****
Start      equ    $00100      ; main program starting address
FCON       equ    $001        ; EFCOP FSCR register contents:
                                ; enable the EFCOP
FIR_LEN     equ    20         ; EFCOP FIR length
SRC_ADDRS  equ    $3040       ; DMA source address point to DATA bank
DST_ADDRS  equ    $3000       ; address at which to begin output
SRC_COUNT  equ    $006003     ; DMA0 count (7*4 word transfers)
DST_COUNT  equ    8           ; number of outputs generated.
FDBA_ADDRS equ    $C000       ; Input samples Start Address x:$C000
FCBA_ADDRS equ    $C000       ; Coeff. Start Address y:$C000
;;*****
; main program
;;*****

ORG p:Start
move       #0,b
move       #0,a
move       #DST_COUNT,b0      ; counter for output interrupt
move       #FDBA_ADDRS,r0     ; FDM memory area
move       #0,x0
rep        #DST_COUNT
move       x0,x:(r0)+          ; clear FDM memory area
move       #DST_ADDRS,r0      ; Destination address
                                ; ** EFCOP initialisation **
movep      #FIR_LEN-1,y:M_FCNT ; FIR length
movep      #FDBA_ADDRS,y:M_FDBA ; FIR input samples Start Address
movep      #FCBA_ADDRS,y:M_FCBA ; FIR Coeff. Start Address
movep      #FCON,y:M_FCSR      ; Enable EFCOP

                                ; ** DMA channel 0 initialisation - input to
                                ; : EFCOP **
movep      #SRC_ADDRS,x:M_DSR0 ; DMA source address points to the DATA
                                ; bank.
movep      #M_FDIR,x:M_DDR0    ; Init DMA destination address.
movep      #SRC_COUNT,x:M_DCO0 ; Init DMA count to line mode.
movep      #$1,x:M_DOR0        ; DMA offset reg. is 1.
movep      #$94AA04,x:M_DCR0   ; Init DMA control reg to line mode FDIBE
                                ; request.

nop
nop
;;*****
do         #DST_COUNT, endd

```

## Examples of Use in Different Modes

```
nop
jclr      #15,y:M_FCSR,*
movep     y:M_FDOR,x:(r0)+
endd
nop
nop

stop_label
nop

jmp stop_label
        org x:SRC_ADDRS
        INCLUDE 'input.asm'

        org y:FCBA_ADDRS
        INCLUDE 'coefs.asm'
```

### 12.7.1.3 DMA Input/Interrupt Output

The different stages of DMA input and interrupt output are as follows:

1. Setup:
  - a) Set the filter count register (FCNT) to the length of the filter coefficients –1 (i.e N-1).
  - b) Set the Data and Coefficient Base Address pointers (FDBA, FCBA).
  - c) Set the operation mode (FCSR[5:4] = FOM[00],).
  - d) Set Initialization mode (FCSR[7] = FPRC = 0).
  - e) Set Filter Data Output Interrupt Enable FSCR[11]=FDOIE=1.
  - f) Set DMA register with DMA input as per channel 0 in [Section 12.7.1.1, "DMA Input/DMA Output"](#).
2. Initialization:
  - a) Enable interrupts in the Interrupt Priority Register IPRP[10:11]=E0L=11.
  - b) Enable interrupts in the Status Register SR[8:9]=00.
  - c) Enable EFCOP FCSR[0]=FEN=1.
  - d) Enable the DMA input channel, DCR0[23]=DE=1.
3. Processing:
  - a) Whenever the Input Data Buffer (FDIR) is empty (that is, FDIBE = 1), the EFCOP triggers DMA, which loads the next input into the FDIR.
  - b) Compute F(n); the result is stored in FDOR; The core is interrupted when FDOBF is set and stores the data in memory.



## Example 12.3 Real FIR Filter DMA Input/Interrupt Output

```

INCLUDE 'ioequ.asm'
;;*****
; equates
;;*****
Start      equ    $00100      ; main program starting address
FCON       equ    $801        ; EFCOP FSCR register contents:
                                ; enable output interrupt
                                ; enable the EFCOP
FIR_LEN     equ    20         ; EFCOP FIR length
SRC_ADDRS  equ    $3040       ; DMA source address point to DATA bank
DST_ADDRS  equ    $3000       ; address at which to begin output
SRC_COUNT  equ    $006003     ; DMA0 count (7*4 word transfers)
DST_COUNT  equ    8          ; number of outputs generated.
FDBA_ADDRS equ    $C000       ; Input samples Start Address x:$C000
FCBA_ADDRS equ    $C000       ; Coeff. Start Address y:$C000
;;*****
        org P:$0
jmp      Start
        ORG p:$6a
jsr      >kdo
nop
nop
;;*****
; main program
;;*****
        org p:Start
                                ; ** interrupt initialisation **
bset     #10,x:M_IPRP          ;
bset     #11,x:M_IPRP          ; enable EFCOP interrupts in IPRP
bclr     #8,SR                 ;
bclr     #9,SR                 ; enable interrupts in SR
move     #0,b
move     #0,a
move     #DST_COUNT,b0         ; counter for output interrupt
move     #FDBA_ADDRS,r0        ; FDM memory area
move     #0,x0
rep      #DST_COUNT
move     x0,x:(r0)+            ; clear FDM memory area
move     #DST_ADDRS,r0         ; Destination address
                                ; ** EFCOP initialisation **
movep    #FIR_LEN-1,y:M_FCNT   ; FIR length
movep    #FDBA_ADDRS,y:M_FDBA ; FIR input samples Start Address
movep    #FCBA_ADDRS,y:M_FCBA ; FIR Coeff. Start Address
movep    #FCON,y:M_FCSR        ; Enable EFCOP

```

## Examples of Use in Different Modes

```

; ** DMA channel 0 initialisation - input to
; EFCOP **
movep      #SRC_ADDRS,x:M_DSR0 ; DMA source address points to the DATA
; bank.
movep      #M_FDIR,x:M_DDR0    ; Init DMA destination address.
movep      #SRC_COUNT,x:M_DCO0 ; Init DMA count to line mode.
movep      #$1,x:M_DOR0        ; DMA offset reg. is 1.
movep      #$94AA04,x:M_DCR0   ; Init DMA control reg to line mode FDIIE request.
nop
nop
;;*****
waitl
jset       #11,y:M_FCSR,*      ; Wait until FDOIE is cleared.
do         #40,endd
nop
endd
nop
nop

stop_label
nop

jmp stop_label
;;*****
kdo
movep      y:M_FDOR,x:(r0)+    ; Interrupt handler for EFCOP output
; Get y(k) from FDOR
; Store in destination memory space.

nop
dec        b
jne        cont
nop
bclr       #11,y:M_FCSR        ; Disable output interrupt
cont
rti
nop
nop
nop

org x:SRC_ADDRS
INCLUDE 'input.asm'

org y:FCBA_ADDRS
INCLUDE 'coefs.asm'

```

## 12.7.2 Real FIR Filter With Decimation by M

An N tap real FIR filter with decimation by M of a sequence of real numbers is represented by

$$F(n|_M) = \sum_{i=0}^{N-1} H(i) \cdot D(n-i)$$

A DMA data transfer occurs in the following stages for both input and output. The stages are similar to the ones described in [Section 12.7.1.1, "DMA Input/DMA Output"](#). The difference is: set FDCH[11:8] = FDCM = M.

Processing:

1. Whenever the Input Data Buffer (FDIR) is empty (that is, FDIBE = 1), the EFCOP triggers DMA input to transfer up to four new data words to FDM via FDIR.
2. Compute F(n); the result is stored in FDOR; the EFCOP triggers DMA output for an output data transfer.
3. Repeat M times:

```
{
    Get new data word; EFCOP increments data memory pointer.
}
```

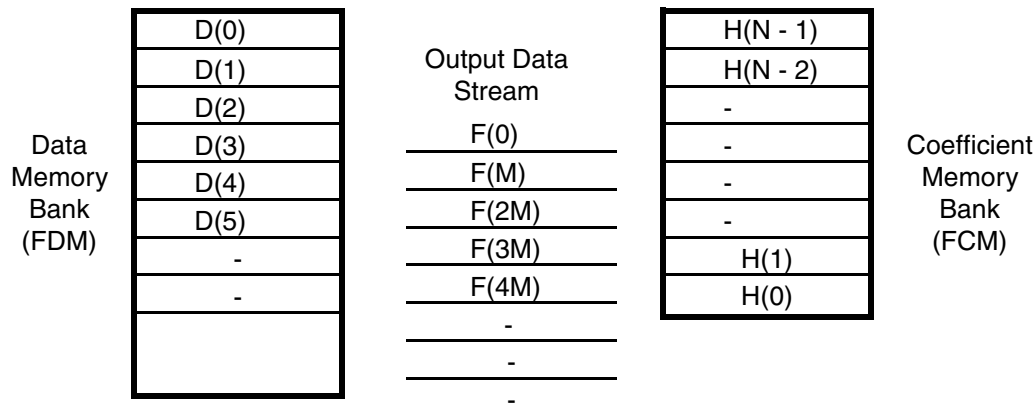


Figure 12-10 Real FIR Filter Data Stream With Decimation by M

## 12.7.3 Adaptive FIR Filter

An adaptive FIR filter is represented in [Figure 12-11](#). The goal of the FIR filter is to adjust the filter coefficients so that the output, F(n), becomes as close as possible to the desired signal,

R(n)—that is, E(n) → 0.

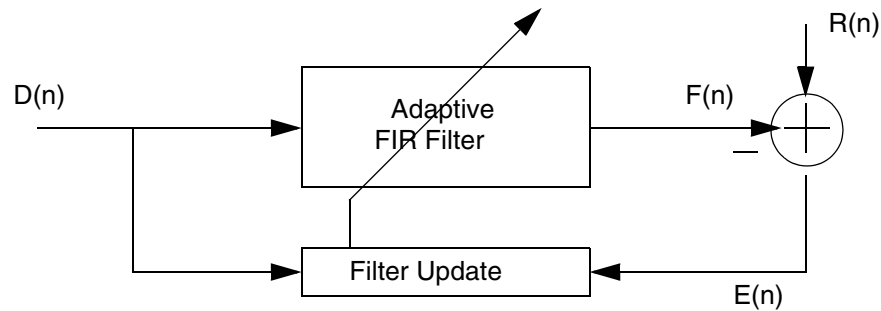


Figure 12-11 Adaptive FIR Filter

The adaptive FIR filter typically comprises four stages, which are performed for each input sample at time  $n$ :

- **Stage 1.** The FIR filter output value is calculated for the EFCOP FIR session according to this equation where  $H_n(i)$  are the filter coefficients at time  $n$ ,  $D(n)$  is the input signal and  $F(n)$  is the filter output at time  $n$ .

$$F(n) = \sum_{i=0}^{N-1} H_n(i)D(n-i)$$

This stage requires  $N$  MAC operations, calculated by the EFCOP FMAC unit.

- **Stage 2.** The core calculates the error signal,  $E(n)$ , in software according to the following equation where  $R(n)$  is the desired signal at time  $n$ .

$$E(n) = R(n) - F(n)$$

This stage requires a single arithmetic operation.

- **Stage 3.** The core calculates the weight multiplier,  $K_e(n)$ , in software according to the following equation where  $K$  is the convergence factor of the algorithm.

$$K_e(n) = K * E(n)$$

After calculating the weight multiplier,  $K_e$ , the core must write it into the FKIR.

- **Stage 4.** The coefficients are updated by the EFCOP update session where  $H_{n+1}(i)$  are the adaptive filter coefficients at time  $n+1$ ,  $K_e(n)$  is the weight multiplier at time  $n$ , and  $D(n)$  is the input signal.

$$H_{n+1}(i) = H_n(i) + K_e D(n-i)$$

This stage starts immediately after  $K_e(n)$  is written in the FKIR (if Adaptive mode is enabled).

### 12.7.3.1 Implementation Using Polling

Figure 12-12 shows a flowchart for an adaptive FIR filter that uses polling to transfer data.

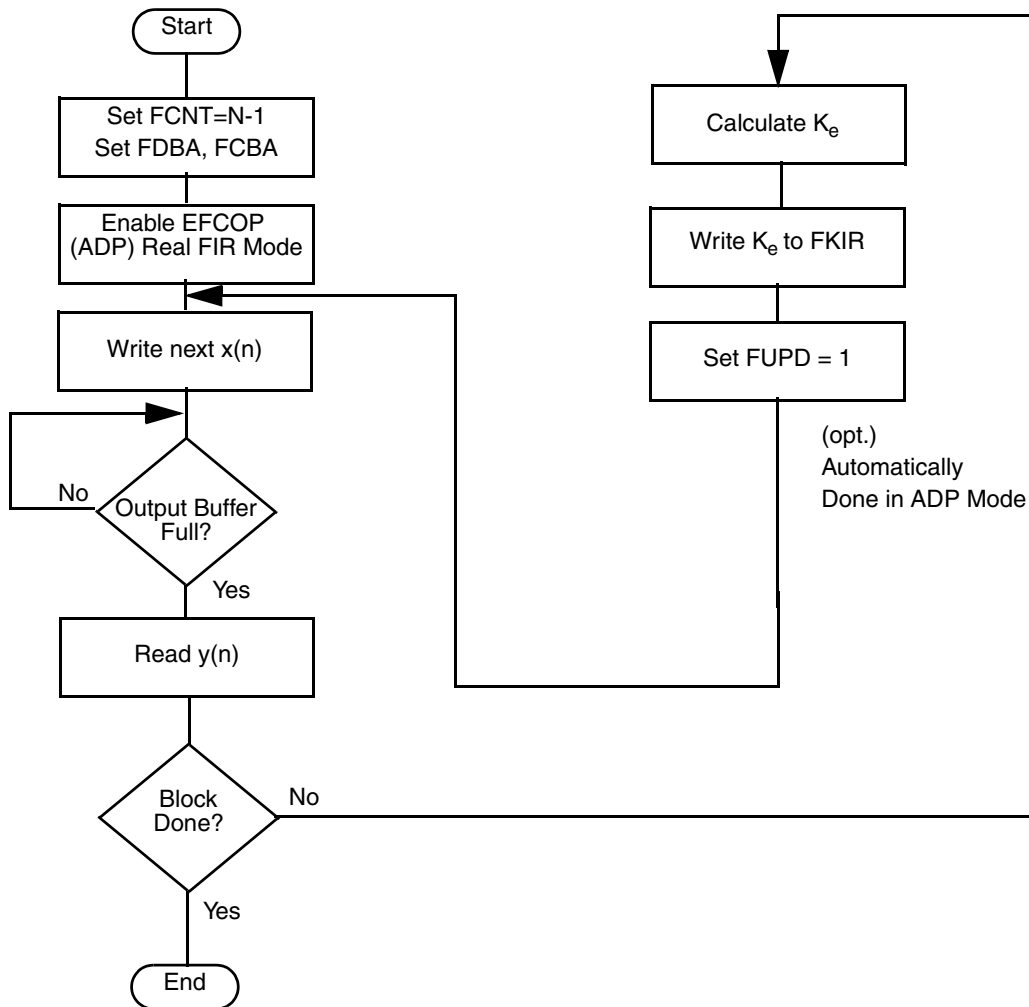


Figure 12-12 Adaptive FIR Filter Using Polling

### 12.7.3.2 Implementation Using DMA Input and Interrupt Output

Figure 12-13 shows a flowchart for an adaptive FIR filter that uses DMA and an interrupt to transfer data.

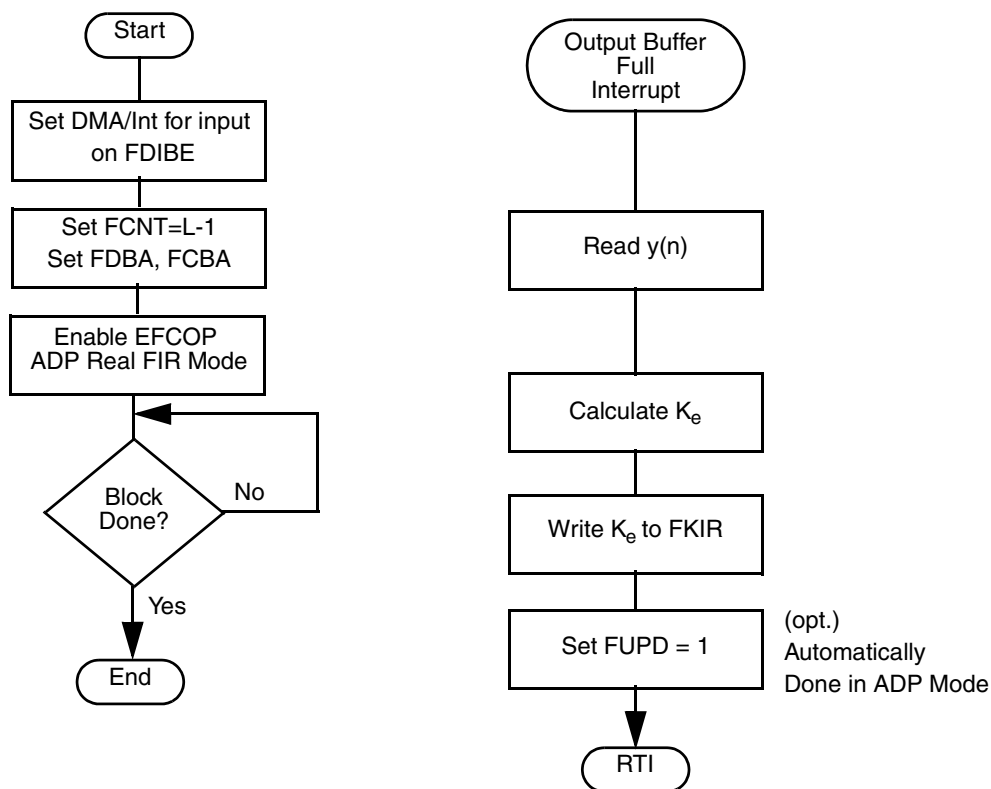


Figure 12-13 Adaptive FIR Filter Using DMA Input and Interrupt Output

### 12.7.3.3 Updating an FIR Filter

The following example shows an FIR adaptive filter that is updated using the LMS algorithm.

**Example 12.4 FIR Adaptive Filter Update Using the LMS Algorithm**

```

        TITLE 'ADAPTIVE'
        INCLUDE 'ioequ.asm'

;*****
; equates
;*****
Start      equ    $00100      ; main program starting address
FCON       equ    $805        ; EFCOP FSCR register contents:
                                ; enable output interrupt
                                ; Choose adaptive real FIR mode
                                ; enable the EFCOP

FIR_LEN     equ    20          ; EFCOP FIR length
DES_ADDRS   equ    $3200      ; Desired signal R(n)
SRC_ADDRS   equ    $3100      ; Reference signal D(n)
DST_ADDRS   equ    $3000      ; address at which to begin output (signal F(n))
SRC_COUNT   equ    $06003     ; DMA0 count (7*4 word transfers)
DST_COUNT   equ    8          ; number of outputs generated.
MU2         equ    $100000     ; stepsize mu = 0.0625 (that is 2mu =
                                ; 0.125)

FDDBA_ADDRS equ    $C000      ; Input samples Start Address x:$C000
FCBA_ADDRS  equ    $C000      ; Coeff. Start Address y:$C000

;*****
org p:$0
jmp          Start

ORG p:$6a

jsr          >kdo
nop
nop

;*****
; main program
;*****
ORG p:Start

; ** interrupt initialisation **

bset         #10,x:M_IPRP
bset         #11,x:M_IPRP      ; enable EFCOP interrupts in IPRP

```

## Examples of Use in Different Modes

```

bclr          #8,SR          ;
bclr          #9,SR          ; enable interrupts in SR

move          #0,b
move          #0,a
move          #DST_COUNT,b0   ; counter for output interrupt

; ** FDM memory initialisation **

move          #FDBA_ADDRS,r0   ; FDM memory area
move          #0,x0
rep           #FIR_LEN
move x0,x:(r0)+                ; clear FDM memory area

; ** address register initialisation **

move          #DST_ADDRS,r0    ; Destination address
move          #DES_ADDRS,r1    ; Desired signal address

rep           #FIR_LEN-1
move          (r1)+            ; Set reference pointer correctly

; ** EFCOP initialisation **

movep         #FIR_LEN-1,y:M_FCNT ; FIR length
movep         #FDBA_ADDRS,y:M_FDBA ; FIR input samples Start Address
movep         #FCBA_ADDRS,y:M_FCBA ; FIR Coeff. Start Address
movep         #FCON,y:M_FCSR      ; Enable EFCOP

; ** DMA channel 0 initialisation - input to EFCOP **

movep         #SRC_ADDRS,x:M_DSR0 ; DMA source address points to the DATA
                                ; bank.
movep         #M_FDIR,x:M_DDR0    ; Init DMA destination address.
movep         #SRC_COUNT,x:M_DCO0 ; Init DMA count to line mode.
movep         #$1,x:M_DOR0        ; DMA offset reg. is 1.
movep         #$94AA04,x:M_DCR0   ; Init DMA control reg to line mode FDIBE request.

nop
nop

;;*****
waitl
jset          #11,y:M_FCSR,*      ; Wait until FDOIE is cleared.
do            #40,endd
nop
endd
nop

```



```

nop

stop_label
nop

jmp stop_label

;;*****
kdo                                ; Interrupt handler for EFCOP output
movep          y:M_FDOR,x:(r0)    ; Get F(n) from FDOR
                                ; Store in destination memory space.
;***** Calculate Ke *****
move           x:(r1)+,a          ; Retrieve desired value R(n)
move           x:(r0)+,y0         ;
sub            y0,a               ; calculate E(n) = R(n) - F(n)
move           #MU2,y0           ;
move           a,y1              ;
mpy            y0,y1,a           ; calculate Ke = mu * 2 * E(n)

;*****
movep          a1,y:M_FKIR        ; store Ke in FKIR

dec            b
jne            cont
nop
bclr           #11,y:M_FCSR       ; Disable output interrupt
cont
rti
nop
nop
nop

;;*****
;;*****
ORG y:FCBA_ADDRS

        dc      $000000
        dc      $000000
        dc      $000000
        dc      $000000
        dc      $000000
        dc      $000000
        dc      $000000
        dc      $000000
        dc      $000000
        dc      $000000
        dc      $000000
        dc      $000000
        dc      $000000

```

## Verification For All Exercises

```
dc    $000000
dc    $000000
dc    $000000
dc    $000000
dc    $000000
dc    $000000
dc    $000000
dc    $000000
dc    $000000
```

```
ORG x:SRC_ADDRS
```

```
INCLUDE 'input.asm'                ; Reference signal D(n)
```

```
ORG x:DES_ADDRS
```

```
INCLUDE 'desired.asm'             ; Desired signal R(n)
```

## 12.8 Verification For All Exercises

### 12.8.1 Input Sequence (input.asm)

```
dc    $000000
dc    $37cc8a
dc    $343fae
dc    $0b63b1
dc    $0595b4
dc    $38f46e
dc    $6a4ea2
dc    $5e8562
dc    $2beda5
dc    $1b3cd0
dc    $42f452
dc    $684ca0
dc    $5093b0
dc    $128ab8
dc    $f74ee1
dc    $15c13a
dc    $336e48
dc    $15e98e
dc    $d428d2
dc    $b76af5
dc    $d69eb3
dc    $f749b6
dc    $dee460
dc    $a43601
dc    $903d59
dc    $b9999a
dc    $e5744e
```

## 12.8.2 Filter Coefficients (coefs.asm)

```
dc    $F8125C
dc    $F77839
dc    $F4E9EE
dc    $F29373
dc    $F2DC9A
dc    $F51D6E
dc    $F688CE
dc    $F6087E
dc    $F5B5D3
dc    $F7E65E
dc    $FBE0F8
dc    $FEC8B7
dc    $FF79F5
dc    $000342
dc    $02B24F
dc    $06C977
dc    $096ADD
dc    $097556
dc    $08FD54
dc    $0A59A5
```

## 12.8.3 Output Sequence for Examples D-1, D-2 and D-3

```
$d69ea9
$ccae36
$c48f2a
$be8b28
$bad8c5
$b9998c
$bad8cb
$be8b2d
$c7b906
```

## 12.8.4 Desired Signal for Example D-4

```
dc    $000000
dc    $0D310F
dc    $19EA7C
dc    $25B8E2
dc    $30312E
dc    $38F46D
dc    $3FB327
dc    $443031
dc    $4642D6
dc    $45D849
dc    $42F452
dc    $3DB126
```

## Verification For All Exercises

```
dc    $363E7F
dc    $2CDFE8
dc    $21EA5B
dc    $15C13A
dc    $08D2CE
dc    $FB945D
dc    $EE7E02
dc    $E2066F
dc    $D69EB2
dc    $CCAE3C
dc    $C48F2F
dc    $BE8B32
dc    $BAD8D3
dc    $B99999
dc    $BAD8D3
dc    $BE8B32
```

### 12.8.5 Output Sequence for Example D-4

```
$000000
$f44c4c
$ee54b3
$e7cd6b
$daed26
$cc1071
$c7db1c
$cdfc45
```

## Appendix A Bootstrap ROM Contents

### A.1 DSP56371 Bootstrap Program

```
; BOOTSTRAP CODE FOR DSP56371 Rev. 0 silicon - (C) Copyright 1999 Freescale Semiconductor, Inc.
;
;
; Revision 0.0 1999/JAN/26 - Modified from 56362_RevA_regular_boot_rev01.asm:
; - Change the length of xram and the length of yram
; in burn-in code
; - Change the address of the reserved area in the
; Program ROM to $FFAF80 - $FFAFFF
;
; Revision 0.1 1999/MAR/29 - Enabled 100ns I2C filter in bootstrap
; mode 0110.
; - Added 5 NOP instructions after OnCE enable.
;
; Revision 0.2 2002/JUN/26 - Remove Host boot and external memory boot.
; - Remove burn in test modes.
;
; This is the Bootstrap program contained in the DSP56371 192-word Boot
; ROM. This program can load any program RAM segment the SHI serial interface.
;
;
;
; Operation mode MD:MC:MB:MA=x000 is reserved.
; Operation mode MD:MC:MB:MA=0001 is reserved.
;
;
; If MD:MC:MB:MA=0010, the bootstrap code jumps to the internal
; Program ROM, without loading the Program RAM.
;
;
;
; Operation mode MD:MC:MB:MA=0011 is reserved.
;
;
; If MD:MC:MB:MA=01xx, the Program RAM is loaded from the SHI.
; MD:MC:MB:MA=0100 - reserved for SHI
; MD:MC:MB:MA=0101 - Bootstrap from SHI (SPI slave)
; MD:MC:MB:MA=0110 - reserved
; MD:MC:MB:MA=0111 - Bootstrap from SHI (I2C slave, HCKFR=0)
;
;
;
; If MD:MC:MB:MA=1000, the program RAM is loaded from Serial EEPROM.
;
```

```

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
; Operation mode MD:MC:MB:MA=1001 is reserved.
; Operation mode MD:MC:MB:MA=1010 is reserved
; Operation mode MD:MC:MB:MA=1011 is reserved
; Operation mode MD:MC:MB:MA=1100 is reserved.
; Operation mode MD:MC:MB:MA=1101 is reserved
; Operation mode MD:MC:MB:MA=1110 is reserved
; Operation mode MD:MC:MB:MA=1111 is reserved
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;

        page      132,55,0,0,0

        opt       cex,mex,mu

        section BOOTSTRAP

;;
;;;;;;;;;;;;;;;;;;;;;;;;;; GENERAL EQUATES ;;;;;;;;;;;;;;;;;;;;;;;;;;
;;
PROMADDR equ     $FF00C0          ; Starting PROM address

MA      EQU      0
MB      EQU      1
MC      EQU      2
MD      EQU      3

;;
;;;;;;;;;;;;;;;;;;;;;;;;;; DSP I/O REGISTERS ;;;;;;;;;;;;;;;;;;;;;;;;;;
;;

M_OGDB  EQU      $FFFFFFC        ; OnCE GDB Register

M_HRX   EQU      $FFFF94         ; SHI Receive FIFO
M_HCSR  EQU      $FFFF91         ; SHI Control/Status Register
M_HCKR  EQU      $FFFF90         ; SHI Clock Control Register
HRNE    EQU      17              ; SHI FIFO Not Empty flag
HI2C    EQU      1               ; SHI I2C Enable Control Bit
HCKFR   EQU      4               ; SHI I2C Clock Freeze Control Bit
HFM0    EQU      12              ; SHI I2C Filter Mode Bit 0
HFM1    EQU      13              ; SHI I2C Filter Mode Bit 1

        ORG P:$ff0000           ; bootstrap code starts at $ff0000

START
        movep    #$0,X:M_OGDB    ; enable OnCE
        nop                          ; 5 NOP instructions, needed for test procedure

```

```

nop
nop
nop
nop
clr a #$0,r5          ; clear a and init R5 with 0
jset #MD,omr,OMR1XXX   ; If MD:MC:MB:MA=1xxx go to OMR1XXX
jset #MC,omr,SHILD      ; If MD:MC:MB:MA=01xx, go load from SHI
jclr #MB,omr,RESERVED   ; If MD:MC:MB:MA=0001, go to RESERVED
jset #MA,omr,RESERVED   ; If MD:MC:MB:MA=0011, go to RESERVED

;=====
; This is the routine that jumps to the internal Program ROM.
; MD:MC:MB:MA=0010

        move #PROMADDR,r1      ; store starting PROM address in r1

        bra    <FINISH

;=====
; This is the routine that loads from SHI.
; MD:MC:MB:MA=0100 - reserved for SHI
; MD:MC:MB:MA=0101 - Bootstrap from SHI (SPI slave)
; MD:MC:MB:MA=0110 - reserved
; MD:MC:MB:MA=0111 - Bootstrap from SHI (I2C slave, HCKFR=0)

SHILD

; This is the routine which loads a program through the SHI port.
; The SHI operates in the slave
; mode, with the 10-word FIFO enabled, and with the HREQ pin enabled for
; receive operation. The word size for transfer is 24 bits. The SHI
; operates in the SPI or in the I2C mode, according to the bootstrap mode.
;
; The program is downloaded according to the following rules:
; 1) 3 bytes - Define the program length.
; 2) 3 bytes - Define the address to which to start loading the program to.
; 3) 3n bytes (while n is the program length defined by the first 3 bytes)
; The program words will be stored in contiguous PRAM memory locations starting
; at the specified starting address.
; After storing the program words, program execution starts from the same
; address where loading started.

        move    #$A9,r1        ; prepare SHI control value in r1

; HEN=1, HI2C=0, HM1-HM0=10, HCKFR=0, HFIFO=1, HMST=0,
; HRQE1-HRQE0=01, HIDLE=0, HBIE=0, HTIE=0, HRIE1-HRIE0=00

```

```

        jclr    #MA,omr,RESERVED    ; If MD:MC:MB:MA=01x0, go to SHI clock freeze

        jclr    #MB,omr,shi_loop    ; If MD:MC:MB:MA=0101, select SPI mode

        bset    #HI2C,r1            ; otherwise select I2C mode.

shi_loop    movep    r1,x:M_HCSR        ; enable SHI

        jclr    #HRNE,x:M_HCSR,*    ; wait for no. of words
        movep    x:M_HRX,a0

        jclr    #HRNE,x:M_HCSR,*    ; wait for starting address
        movep    x:M_HRX,r0
        move     r0,r1

        do      a0,_LOOP2
        jclr    #HRNE,x:M_HCSR,*    ; wait for HRX not empty
        movep    x:M_HRX,p:(r0)+    ; store in Program RAM
        nop      ; req. because of restriction

_LOOP2

        bra     <FINISH

```

```

;=====

```

OMR1XXX

```

        jset    #MC,omr,RESERVED    ; IF MD:MC:MB:MA=11xx, go to RESERVED
        jset    #MB,omr,OMR101X    ; IF MD:MC:MB:MA=101x, go to OMR101X
        jclr    #MA,omr,RESERVED    ; If MD:MC:MB:MA=1000, go to RESERVED
        jmp     SerialEEPROM        ; If MD:MC:MB:MA=1001, go to Serial EEPROM

```

OMR101X

```

        jclr    #MA,omr,BURN        ; If MD:MC:MB:MA=1010, go to BURN
        jmp     RESERVED            ; If MD:MC:MB:MA=1011, go to RESERVED

```

```

;=====

```

```

; This is the exit handler that returns execution to normal
; expanded mode and jumps to the RESET vector.

```

FINISH

```

        andi    #$0,ccr            ; Clear CCR as if RESET to 0.
        jmp     (r1)                ; Then go to starting Prog addr.

```

```

;=====

```

```

; The following modes are reserved, some of which are used for internal testing

```



```
; Operation mode MD:MC:MB:MA=0000 is reserved
; Operation mode MD:MC:MB:MA=0001 is reserved
; Operation mode MD:MC:MB:MA=0011 is reserved
; Operation mode MD:MC:MB:MA=1000 is reserved
; Operation mode MD:MC:MB:MA=1010 is reserved
; Operation mode MD:MC:MB:MA=1011 is reserved
; Operation mode MD:MC:MB:MA=1100 is reserved
; Operation mode MD:MC:MB:MA=1101 is reserved
; Operation mode MD:MC:MB:MA=1110 is reserved
; Operation mode MD:MC:MB:MA=1111 is reserved
```

RESERVED

```
bra    <*
```

```
;=====
; Code for burn-in
;=====
; MD:MC:MB:MA=1001
```

```
M_PCRC EQU    $FFFFBF    ;; Port C GPIO Control Register
M_PDRC EQU    $FFFFBD    ;; Port C GPIO Data Register
M_PSRC EQU    $FFFFBE    ;; Port C Direction Register
SCKT EQU    $3            ;; SCKT is GPIO bit #3 in ESAI (Port C)
```

```
EQUALDATA equ    0        ;; 1 if xram and yram are of equal
                        ;; size and addresses, 0 otherwise.
```

```
    if    (EQUALDATA)
start_dram equ    0        ;;
length_dram equ    $1600   ;; same addresses
    else
start_xram1 equ    0        ;; 12k XRAM
length_xram1 equ    $3000
start_yram1 equ    0        ;; 8k YRAM
length_yram1 equ    $2000
start_xram2 equ    $c000   ;; 24k XRAM
length_xram2 equ    $6000
start_yram2 equ    $c000   ;; 40k YRAM
length_yram2 equ    $a000
    endif

start_pram equ    0        ;; 4k PRAM
length_pram equ    $1000
```

BURN

```

;; get PATTERN pointer
clr b    #PATTERNS,r6          ;; b is the error accumulator
move     #<(NUM_PATTERNS-1),m6 ;; program runs forever in
                                   ;; cyclic form

;; configure SCKT as gpio output.
movep    b,x:M_PDRC            ;; clear GPIO data register
bclr     #SCKT,x:M_PCRC        ;; Define SCKT as output GPIO pin
bset     #SCKT,x:M_PPRC        ;; SCKT toggles means test pass

                                   ;; r5 = test fail flag = $000000
                                   ;; r7 = test pass flag = $FFFFFF
burnin_loop    lua      (r5)-,r7

                do #9,burn1
;;-----
;; test RAM
;; each pass checks 1 pattern
;;-----
move     p:(r6)+,x1            ;; pattern for x memory
move     p:(r6)+,x0            ;; pattern for y memory
move     p:(r6)+,y0            ;; pattern for p memory

;; write pattern to all memory locations

if      (EQUALDATA)            ;; x/y ram symmetrical
;; write x and y memory
clr a    #start_dram,r0        ;; start of x/y ram
move     #>length_dram,n0      ;; length of x/y ram
rep      n0
mac x0,x1,a x1,l:(r0)+         ;; exercise mac, write x/y ram

else                                         ;; x/y ram not symmetrical

;; write x memory
clr a    #start_xram1,r0        ;; start of xram
move     #>length_xram1,n0      ;; length of xram
rep      n0
mac x0,y0,a x1,x:(r0)+         ;; exercise mac, write xram

clr a    #start_xram2,r0        ;; start of xram
move     #>length_xram2,n0      ;; length of xram
rep      n0
mac x0,y0,a x1,x:(r0)+         ;; exercise mac, write xram

```

```

        ;; write y memory
        clr a    #start_yram1,r1        ;; start of yram
        move    #>length_yram1,n1      ;; length of yram
        rep     n1
        mac x1,y0,a x0,y:(r1)+          ;; exercise mac, write yram

        clr a    #start_yram2,r1        ;; start of yram
        move    #>length_yram2,n1      ;; length of yram
        rep     n1
        mac x1,y0,a x0,y:(r1)+          ;; exercise mac, write yram

endif

        ;; write p memory
        clr a    #start_pram,r2         ;; start of pram
        move    #>length_pram,n2        ;; length of pram
        rep     n2
        move    y0,p:(r2)+              ;; write pram

        ;; check memory contents

if      (EQUALDATA)                     ;; x/y ram symmetrical

        ;; check dram
        clr a    #start_dram,r0         ;; restore pointer, clear a
        do      n0,_loopd
        move    x:(r0),a1               ;; a0=a2=0
        eor     x1,a
        add     a,b                     ;; accumulate error in b
        move    y:(r0)+,a1              ;; a0=a2=0
        eor     x0,a
        add     a,b                     ;; accumulate error in b
_loopd

else                                       ;; x/y ram not symmetrical

        ;; check xram
        clr a    #start_xram1,r0        ;; restore pointer, clear a
        move    #>length_xram1,n0
        do      n0,_loopx1
        move    x:(r0)+,a1              ;; a0=a2=0
        eor     x1,a
        add     a,b                     ;; accumulate error in b
_loopx1

        clr a    #start_xram2,r0        ;; restore pointer, clear a
        move    #>length_xram2,n0

```

```

do      n0,_loopx2
move    x:(r0)+,a1          ;; a0=a2=0
eor     x1,a
add     a,b                 ;; accumulate error in b

_loopx2

;; check yram
clr a   #start_yram1,r1    ;; restore pointer, clear a
move    #>length_yram1,n1
do      n1,_loopy1
move    y:(r1)+,a1         ;; a0=a2=0
eor     x0,a
add     a,b                 ;; accumulate error in b

_loopy1

clr a   #start_yram2,r1    ;; restore pointer, clear a
move    #>length_yram2,n1
do      n1,_loopy2
move    y:(r1)+,a1         ;; a0=a2=0
eor     x0,a
add     a,b                 ;; accumulate error in b

_loopy2

endif

;; check pram
clr a   #start_pram,r2     ;; restore pointer, clear a
do      n2,_loopp
move    p:(r2)+,a1         ;; a0=a2=0
eor     y0,a
add     a,b                 ;; accumulate error in b

_loopp

;;-----
;; toggle pin if no errors, stop execution otherwise.
;;-----
;; if error
tne     r5,r7               ;; r7=$FFFFFFF as long as test pass
                           ;; condition codes preserved
                           ;; this instr can be removed in case of shortage
movep   r7,x:M_OGDB         ;; write pass/fail flag to OnCE
                           ;; condition codes preserved
                           ;; this instr can be removed in case of shortage

beq     labell
bclr    #SCKT,x:M_PDRC      ;; clear SCKT if error,
enddo    ;; terminate the loop normally
                           ;; this instr can be removed in case of shortage

bra     <burn1              ;; and stop execution

```

```

label1          bchg      #SCKT,x:M_PDRC          ;; if no error
                                                    ;; toggle pin and keep on looping

burn1           debug          ;; test completion
                                                    ;; enter debug mode if OnCE port enabled
                                                    ;; this instr can be removed in case of shortage
                                                    ;; enter wait otherwise (OnCE port disabled)

wait

BURN_END

                ORG P:
PATTERNS        dsm          4                    ;; align for correct modulo addressing

                ORG  P:BURN_END

                dup PATTERNS-*          ; write address in unused Boot ROM location
                dc *
                endm

                ORG      P:PATTERNS          ;; Each value is written to all memories

                dc      $555555
                dc      $AAAAAA
                dc      $333333
                dc      $F0F0F0

NUM_PATTERNS    equ      *-PATTERNS

;=====
; This code fills the unused bootstrap rom locations with their address

                dup $FF00C0-*
                dc *
                endm

;=====
; Serial EEPROM Boot Loader

                include  'SerialBootloader_Release1.asm'

;=====
; This code fills the unused bootstrap rom locations with their address

```

```
dup $FFFF60-*  
dc *  
endm
```

```
;=====
```

```
endsec
```

```
end
```

## A.2 Using the Serial EEPROM Boot Mode

There is a boot-up mode included which allows the downloading of code directly from a serial EEPROM. This can be used in applications where there are no microcontrollers available as the DSP itself is used as the master clock source.

Configuration of the MOD pins

To boot up in this mode, the MOD pins should be as follows: -

Mode	MODD	MODC	MODB	MODA	Reset Vector
9	1	0	0	1	\$FF0000

See table 4.2 for the other boot modes available.

Constraints of EEPROM Used

To use this mode, the following constraints must be followed: -

- \* Only I2C capable devices can be used
- \* The EEPROM must have the device ID 1010

Below are listed some suggestions for suitable devices: -

ST Microelectronics M24128 (128Kbit Serial I2C Bus EEPROM)  
ST Microelectronics M24256 (256Kbit Serial I2C Bus EEPROM)  
ST Microelectronics M24512 (512Kbit Serial I2C Bus EEPROM)  
ST Microelectronics M24M01(1Mbit Serial I2C Bus EEPROM)

Format used for external EEPROM

The DSP expects to receive the data in the following format: -

Assuming the EEPROM address starts at 0: -

EEPROM Address	Byte expected at DSP	Example
0	PstartAddress2	00
1	PstartAddress1	04
2	PstartAddress0	00
3	XstartAddress2	00
4	XstartAddress1	05
5	XstartAddress0	00
6	YstartAddress2	00
7	YstartAddress1	06
8	YstartAddress0	00
9	PdataLength2	67
10	PdataLength1	45

```

11          PdataLength0          00
12          XdataLength2          21
13          XdataLength1          35
14          XdataLength0          43
15          YdataLength2          56
16          YdataLength1          64
17          YdataLength0          24
18          data in P, X and Y order -
19          must make up whole 24 bit words
-
-
-
-          PstartAddress2          00
-          PstartAddress1          04
-          PstartAddress0          00
          (final word is start address of rogram to run)

```

The above example would store: \$004567 words from P:\$400  
                                   \$433521 words from X:\$500  
                                   \$246456 words from Y:\$600  
 And will start running from P:\$400 once all of the data has been downloaded.

Format used in EEPROM

The format that should be used to store the data on the DSP is Intel HEX format, an example and explanation of this is given below: -

```

:10008000AF5F67F0602703E0322CFA92007780C361
:1000900089001C6B7EA7CA9200FE10D2AA00477D81
:0B00A00080FA92006F3600C3A00076CB
:00000001FF

```

Now look at the top line...

- \* The first character (:) indicates the start of a record.
- \* The next two characters indicate the record length (10h in this case).
- \* The next four characters give the load address (0080h in this case).
- \* The next two characters indicate the record type (see below).
- \* Then we have the actual data.
- \* The last two characters are a checksum (sum of all bytes + checksum = 00).

The last line of the file is special, and will always look like that above.

Record types:

- \* 00 - Data record
- \* 01 - End of file record



- \* 02 - Extended segment address record
- \* 03 - Start segment address record
- \* 04 - Extended linear address record
- \* 05 - Start linear address record

Listing of the boot code

Below is the boot code used in this mode: -

```

        TITLE 'SerialBootloader';Name of Program

BootROM      equ          $FFFF00    ;ROM boot area.
HCKR         equ          $FFFF90    ;SHI Clock Control Register.
HCSR         equ          $FFFF91    ;SHI Control/Status Register.
HRX          equ          $FFFF94    ;SHI Receive Data FIFO
HTX          equ          $FFFF93    ;SHI Transmit Data Register


        SECTION    p_memory          ;P memory start
        org        p:BootROM

Start:                                ;Start of program

;Need to initialise SHI to operate in I2C master mode first...

;Need to generate the slave address 1010 for ST
;M24256/M24128 serial EEPROM
;This is sent as 1010 0001 (0001 to signify reading from EEPROM)

;1 - set up SHI for I2C master mode + program appropriate clock rate
;2 - Check HTX is empty i.e. HTDE = 1
;3 - set HIDLE bit
;4 - write slave address (1010 0001 0000 0000 0000 0000) to HTX register
;5 - this causes a stop event, start event and the 8 MSBs of data to be TXed
;6 - slave device should transmit an ack bit on reception of it's device ID

;7 - slave device should continue to transmit data bytes which the master DSP will acknowledge

;*** Reset SHI ***
movep        #$0,X:HCSR

;*** Set clock Rate ***
movep        #$000040,X:HCKR

```

```

;Set to /64 for max crystal value (i.e. 25MHz/(8*8) = ;390625
;*** Check HTX is empty i.e. HTDE=1 ***

HTXfull:
    brclr      #15,X:HCSR,HTXfull

;*** Set HIDLE bit/Master Mode/8 bit data/I2C ***

    movep     #$008243,X:HCSR

;*** Write slave address to HTX register ***
;(will cause HIDLE bit to clear)
;Address $A1 applicable to ST M24256/M24128 serial ; ;EEPROMs

    movep     #$A10000,X:HTX

;FORMAT AS FOLLOWS

;      Example, 8 bit EEPROM starting at 0
;
;      0      - PstartAddress2e.g. 00
;      1      - PstartAddress1      04
;      2      - PstartAddress0      00
;      3      - XstartAddress2      00
;      4      - XstartAddress1      05
;      5      - XstartAddress0      00
;      6      - YstartAddress2      00
;      7      - YstartAddress1      06
;      8      - YstartAddress0      00
;      9      - PdataLength2          67
;     10      - PdataLength1          45
;     11      - PdataLength0          00
;     12      - XdataLength2          21
;     13      - XdataLength1          35
;     14      - XdataLength0          43
;     15      - YdataLength2          56
;     16      - YdataLength1          64
;     17      - YdataLength0          24
;     18      - data in P, X and Y order - must make up whole 24 bit words
;      .
;      .
;      .
;      .
;      .
;      .      - PstartAddress2      00
;      .      - PstartAddress1      04

```

```

;          .          - PstartAddress0      00          -final word is start address of
;
; Example would store $004567 words from P:$400
;
;                                     $433521 words from X:$500
;                                     $246456 words from Y:$600
; Will start running from P:$400

```

```

; 'GetWord' will return word in x0

```

```

; *** Get Header Data from EEPROM ***

```

```

        jsr      GetWord          ;Get P address
        move     x0,r0            ;Pointer to P memory
        jsr      GetWord          ;Get X address
        move     x0,r1            ;Pointer to X memory
        jsr      GetWord          ;Get Y address
        move     x0,r2            ;Pointer to Y memory
        jsr      GetWord          ;Get P length
        move     x0,r4            ;Store P length
        jsr      GetWord          ;Get X length
        move     x0,r5            ;Store X length
        jsr      GetWord          ;Get Y length
        move     x0,r6            ;Store Y length

```

```

; *****

```

```

; *** Get data from EPROM ***

```

```

        move     r4,a0            ;Get length of P data
        do       a0,EndofP
        jsr      GetWord
        move     x0,p:(r0)+

```

```

EndofP:

```

```

        move     r5,a0            ;Get length of X data
        do       a0,EndofX
        jsr      GetWord
        move     x0,x:(r1)+

```

```

EndofX:

```

```

        move     r6,a0            ;Get length of Y data
        do       a0,EndofY
        jsr      GetWord
        move     x0,y:(r2)+

```

```

EndofY:

```

```
;*** Get P Start Address ***
```

```
    jsr      GetWord          ;Get final word (start address)
    movep    #$008243,X:HCSR  ;Set HIDE bit high
                                ;again to terminate data receive
    move     x0,r7            ;P start address
    jmp      r7              ;Start running program
```

```
;*****END OF BOOTLOADER*****
```

```
; *** Get data bytes from HRX and process ***
```

```
GetWord:
```

```
    brset    #19,X:HCSR,ReadByte2 ;Read byte received or
                                ;wait until FIFO full
    bra      GetWord
```

```
ReadByte2:
```

```
    move     x:HRX,a1          ;Move byte 2 into y1
    asr      #16,a,a
    move     a1,y1            ;Shift 2 MSBs to 2 LSBs
```

```
getByte1:
```

```
    brset    #19,X:HCSR,ReadByte1 ;Read byte received or
                                ;wait until FIFO full
    bra      getByte1
```

```
ReadByte1:
```

```
    move     x:HRX,a1          ;Move byte 1 into y0
    asr      #16,a,a
    move     a1,y0            ;Shift 2 MSBs to 2 LSBs
```

```
getByte0:
```

```
    brset    #19,X:HCSR,ReadByte0 ;Read byte received or
                                ;wait until FIFO full
    bra      getByte0
```

```
ReadByte0:
```

```
    move     x:HRX,a1          ;Move byte 0 into x1
    asr      #16,a,a
    move     a1,x1            ;Shift 2 MSBs to 2 LSBs
```

```
; Routine which takes 3 8-bit values
; from y1,y0,x1 and makes
; up a 24-bit value in b1
; Format is LSB-MSB-USB
```

```

MakeWord:
    move    y1,b2                ;Move byte into b2 first
    asr     #8,b,b              ;Then shift right 8 and repeat
    move    y0,b2                ;Move byte into b2 first
    asr     #8,b,b              ;Then shift right 8 and repeat
    move    x1,b2                ;Move byte into b2 first
    asr     #8,b,b              ;Then shift right 8 and repeat
EndofWord:
    move    b1,x0                ;Result stored in b1
    rts                                ;Store in x0
                                ;Return from subroutine

```

```

;*****

```

```

ENDSEC                                ;End of P memory

```

## NOTES

## Appendix B Equates

```
*****
;
;
;   EQUATES for DSP56371 interrupts
;
;   Initial update: July 2, 2003
;
;
*****

    page    132,55,0,0,0
    opt     mex

integu ident 1,0

    if      @DEF(I_VEC)      ;leave user definition as is.
    else
I_VEC     equ    $0
    endif

;-----
;
; Non-Maskable interrupts
;
;-----

I_RESET EQU I_VEC+$00 ; Hardware RESET
I_STACK EQU I_VEC+$02 ; Stack Error
I_ILL EQU I_VEC+$04 ; Illegal Instruction
I_IINST EQU I_VEC+$04 ; Illegal Instruction
I_DBG EQU I_VEC+$06 ; Debug Request
I_TRAP EQU I_VEC+$08 ; Trap
I_NMI EQU I_VEC+$0A ; Non Maskable Interrupt

;-----

; Interrupt Request Pins

;-----

I_IRQA EQU I_VEC+$10 ; IRQA
I_IRQB EQU I_VEC+$12 ; IRQB
I_IRQC EQU I_VEC+$14 ; IRQC
I_IRQD EQU I_VEC+$16 ; IRQD

;-----

; DMA Interrupts
```

```

;-----
I_DMA0    EQU    I_VEC+$18    ; DMA Channel 0
I_DMA1    EQU    I_VEC+$1A    ; DMA Channel 1
I_DMA2    EQU    I_VEC+$1C    ; DMA Channel 2
I_DMA3    EQU    I_VEC+$1E    ; DMA Channel 3
I_DMA4    EQU    I_VEC+$20    ; DMA Channel 4
I_DMA5    EQU    I_VEC+$22    ; DMA Channel 5

;-----

; DAX Interrupts

;-----

I_DAXTUE   EQU    I_VEC+$28    ; DAX Underrun Error
I_DAXBLK   EQU    I_VEC+$2A    ; DAX Block Transferred
I_DAXTD    EQU    I_VEC+$2E    ; DAX Audio Data Empty

;-----

; ESAI Interrupts

;-----

I_ESAIRD   EQU    I_VEC+$30    ; ESAI Receive Data
I_ESAIRE   EQU    I_VEC+$32    ; ESAI Receive Even Data
I_ESAIRDE  EQU    I_VEC+$34    ; ESAI Receive Data With Exception Status
I_ESAIRLS  EQU    I_VEC+$36    ; ESAI Receive Last Slot
I_ESAITD   EQU    I_VEC+$38    ; ESAI Transmit Data
I_ESAITE   EQU    I_VEC+$3A    ; ESAI Transmit Even Data
I_ESAITDE  EQU    I_VEC+$3C    ; ESAI Transmit Data With Exception Status
I_ESAITLS  EQU    I_VEC+$3E    ; ESAI Transmit Last Slot

;-----

; SHI Interrupts

;-----

I_SHITD    EQU    I_VEC+$40    ; SHI Transmit Data
I_SHITUE   EQU    I_VEC+$42    ; SHI Transmit Underrun Error
I_SHIRNE   EQU    I_VEC+$44    ; SHI Receive FIFO Not Empty
I_SHIRFF   EQU    I_VEC+$48    ; SHI Receive FIFO Full
I_SHIROE   EQU    I_VEC+$4A    ; SHI Receive Overrun Error
I_SHIBER   EQU    I_VEC+$4C    ; SHI Bus Error

;-----

; Timer Interrupts

;-----

```



```

I_TIM0C EQU I_VEC+$54 ; TIMER 0 compare
I_TIM0OF EQU I_VEC+$56 ; TIMER 0 overflow
I_TIM1C EQU I_VEC+$58 ; TIMER 1 compare
I_TIM1OF EQU I_VEC+$5A ; TIMER 1 overflow
I_TIM2C EQU I_VEC+$5C ; TIMER 2 compare
I_TIM2OF EQU I_VEC+$5E ; TIMER 2 overflow

;-----

; EFCOP Interrupts

;-----

I_EFCOPIBE EQU I_VEC+$68 ; EFCOP Input Buffer Empty
I_EFCOPOBF EQU I_VEC+$6A ; EFCOP Output Buffer Full

;-----

; ESAI_1 Interrupts

;-----

I_ESAI1RD EQU I_VEC+$70 ; ESAI_1 Receive Data
I_ESAI1RED EQU I_VEC+$72 ; ESAI_1 Receive Even Data
I_ESAI1RDE EQU I_VEC+$74 ; ESAI_1 Receive Data With Exception Status
I_ESAI1RLS EQU I_VEC+$76 ; ESAI_1 Receive Last Slot
I_ESAI1TD EQU I_VEC+$78 ; ESAI_1 Transmit Data
I_ESAI1TED EQU I_VEC+$7A ; ESAI_1 Transmit Even Data
I_ESAI1TDE EQU I_VEC+$7C ; ESAI_1 Transmit Data With Exception Status
I_ESAI1TLS EQU I_VEC+$7E ; ESAI_1 Transmit Last Slot

;-----

; INTERRUPT ENDING ADDRESS

;-----

I_INTEND EQU I_VEC+$FF ; last address of interrupt vector space

;----- end of intequ.asm -----

;*****
;
; EQUATES for DSP56371 I/O registers and ports
; Last update: July 2, 2003
;
;*****

```

```

page    132,55,0,0,0
opt     mex

```

```
ioequ   ident   1,0
```

```

;-----
;
;      EQUATES for I/O Port Programming
;
;-----

```

```
;      Register Addresses
```

```

M_PCRF EQU $FFFFBF      ; X space: Port C Control Register
M_PRRF EQU $FFFFBE      ; X space: Port C Direction Register
M_PDRF EQU $FFFFBD      ; X space: Port C GPIO Data Register
M_PCRD EQU $FFFFD7      ; X space: Port D Control register
M_PRRD EQU $FFFFD6      ; X space: Port D Direction Data Register
M_PDRD EQU $FFFFD5      ; X space: Port D GPIO Data Register
M_PCRE EQU $FFFF9F      ; Y space: Port E Control register
M_PPRE EQU $FFFF9E      ; Y space: Port E Direction Data Register
M_PDRE EQU $FFFF9D      ; Y space: Port E GPIO Data Register
M_PDRF EQU $FFFFF5      ; Y space: Port F Data Register
M_PRRF EQU $FFFFF6      ; Y space: Port F Data Direction Register
M_PCRF EQU $FFFFF7      ; Y space: Port F Control Register

M_OGDB EQU $FFFFFC      ; X space: OnCE GDB Register

```

```

;-----
;
;      EQUATES for Exception Processing
;
;-----
;      Register Addresses

```

```

M_IPRC EQU $FFFFFF      ; X space: Interrupt Priority Register Core
M_IPRP EQU $FFFFFFE     ; X space: Interrupt Priority Register Peripheral

```

```
;      Interrupt Priority Register Core (IPRC)
```

```

M_IAL EQU $7            ; IRQA Mode Mask
M_IAL0 EQU 0            ; IRQA Mode Interrupt Priority Level (low)
M_IAL1 EQU 1            ; IRQA Mode Interrupt Priority Level (high)
M_IAL2 EQU 2            ; IRQA Mode Trigger Mode
M_IBL EQU $38           ; IRQB Mode Mask
M_IBL0 EQU 3            ; IRQB Mode Interrupt Priority Level (low)
M_IBL1 EQU 4            ; IRQB Mode Interrupt Priority Level (high)
M_IBL2 EQU 5            ; IRQB Mode Trigger Mode
M_ICL EQU $1C0          ; IRQC Mode Mask
M_ICL0 EQU 6            ; IRQC Mode Interrupt Priority Level (low)
M_ICL1 EQU 7            ; IRQC Mode Interrupt Priority Level (high)
M_ICL2 EQU 8            ; IRQC Mode Trigger Mode
M_IDL EQU $E00          ; IRQD Mode Mask
M_IDL0 EQU 9            ; IRQD Mode Interrupt Priority Level (low)
M_IDL1 EQU 10           ; IRQD Mode Interrupt Priority Level (high)

```

```

M_IDL2 EQU 11 ; IRQD Mode Trigger Mode
M_D0L EQU $3000 ; DMA0 Interrupt priority Level Mask
M_D0L0 EQU 12 ; DMA0 Interrupt Priority Level (low)
M_D0L1 EQU 13 ; DMA0 Interrupt Priority Level (high)
M_D1L EQU $C000 ; DMA1 Interrupt Priority Level Mask
M_D1L0 EQU 14 ; DMA1 Interrupt Priority Level (low)
M_D1L1 EQU 15 ; DMA1 Interrupt Priority Level (high)
M_D2L EQU $30000 ; DMA2 Interrupt priority Level Mask
M_D2L0 EQU 16 ; DMA2 Interrupt Priority Level (low)
M_D2L1 EQU 17 ; DMA2 Interrupt Priority Level (high)
M_D3L EQU $C0000 ; DMA3 Interrupt Priority Level Mask
M_D3L0 EQU 18 ; DMA3 Interrupt Priority Level (low)
M_D3L1 EQU 19 ; DMA3 Interrupt Priority Level (high)
M_D4L EQU $300000 ; DMA4 Interrupt priority Level Mask
M_D4L0 EQU 20 ; DMA4 Interrupt Priority Level (low)
M_D4L1 EQU 21 ; DMA4 Interrupt Priority Level (high)
M_D5L EQU $C00000 ; DMA5 Interrupt priority Level Mask
M_D5L0 EQU 22 ; DMA5 Interrupt Priority Level (low)
M_D5L1 EQU 23 ; DMA5 Interrupt Priority Level (high)

; Interrupt Priority Register Peripheral (IPRP)

M_ESL EQU $3 ; ESAI Interrupt Priority Level Mask
M_ESL0 EQU 0 ; ESAI Interrupt Priority Level (low)
M_ESL1 EQU 1 ; ESAI Interrupt Priority Level (high)
M_SHL EQU $C ; SHI Interrupt Priority Level Mask
M_SHL0 EQU 2 ; SHI Interrupt Priority Level (low)
M_SHL1 EQU 3 ; SHI Interrupt Priority Level (high)
M_DAL EQU $C0 ; DAX Interrupt Priority Level Mask
M_DAL0 EQU 6 ; DAX Interrupt Priority Level (low)
M_DAL1 EQU 7 ; DAX Interrupt Priority Level (high)
M_TAL EQU $300 ; Timer Interrupt Priority Level Mask
M_TAL0 EQU 8 ; Timer Interrupt Priority Level (low)
M_TAL1 EQU 9 ; Timer Interrupt Priority Level (high)
M_ES1L EQU $C00 ; ESAI_1 Interrupt Priority Level Mask
M_ES1L0 EQU 10 ; ESAI_1 Interrupt Priority Level (low)
M_ES1L1 EQU 11 ; ESAI_1 Interrupt Priority Level (high)
M_EFC EQU $30000 ; EFCOP Interrupt Priority Level Mask
M_EFC0 EQU 16 ; EFCOP Interrupt Priority Level (low)
M_EFC1 EQU 17 ; EFCOP Interrupt Priority Level (high)

;-----
;
; EQUATES for Direct Memory Access (DMA)
;
;-----

; Register Addresses Of DMA

M_DSTR EQU $FFFFFF4 ; X space: DMA Status Register
M_DOR0 EQU $FFFFFF3 ; X space: DMA Offset Register 0
M_DOR1 EQU $FFFFFF2 ; X space: DMA Offset Register 1

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M_DOR2 EQU $FFFFF1 ; X space: DMA Offset Register 2
M_DOR3 EQU $FFFFF0 ; X space: DMA Offset Register 3

; Register Addresses Of DMA0

M_DSR0 EQU $FFFFEF ; X space: DMA0 Source Address Register
M_DDR0 EQU $FFFFEE ; X space: DMA0 Destination Address Register
M_DCO0 EQU $FFFFED ; X space: DMA0 Counter
M_DCR0 EQU $FFFFEC ; X space: DMA0 Control Register

; Register Addresses Of DMA1

M_DSR1 EQU $FFFFEB ; X space: DMA1 Source Address Register
M_DDR1 EQU $FFFFEA ; X space: DMA1 Destination Address Register
M_DCO1 EQU $FFFFE9 ; X space: DMA1 Counter
M_DCR1 EQU $FFFFE8 ; X space: DMA1 Control Register

; Register Addresses Of DMA2

M_DSR2 EQU $FFFFE7 ; X space: DMA2 Source Address Register
M_DDR2 EQU $FFFFE6 ; X space: DMA2 Destination Address Register
M_DCO2 EQU $FFFFE5 ; X space: DMA2 Counter
M_DCR2 EQU $FFFFE4 ; X space: DMA2 Control Register

; Register Addresses Of DMA3

M_DSR3 EQU $FFFFE3 ; X space: DMA3 Source Address Register
M_DDR3 EQU $FFFFE2 ; X space: DMA3 Destination Address Register
M_DCO3 EQU $FFFFE1 ; X space: DMA3 Counter
M_DCR3 EQU $FFFFE0 ; X space: DMA3 Control Register

; Register Addresses Of DMA4

M_DSR4 EQU $FFFFDF ; X space: DMA4 Source Address Register
M_DDR4 EQU $FFFFDE ; X space: DMA4 Destination Address Register
M_DCO4 EQU $FFFFDD ; X space: DMA4 Counter
M_DCR4 EQU $FFFFDC ; X space: DMA4 Control Register

; Register Addresses Of DMA5

M_DSR5 EQU $FFFFDB ; X space: DMA5 Source Address Register
M_DDR5 EQU $FFFFDA ; X space: DMA5 Destination Address Register
M_DCO5 EQU $FFFFD9 ; X space: DMA5 Counter
M_DCR5 EQU $FFFFD8 ; X space: DMA5 Control Register

; DMA Control Register

M_DSS EQU $3 ; DMA Source Space Mask (DSS0-Dss1)
M_DSS0 EQU 0 ; DMA Source Memory space 0
M_DSS1 EQU 1 ; DMA Source Memory space 1
M_DDS EQU $C ; DMA Destination Space Mask (DDS-DDS1)
M_DDS0 EQU 2 ; DMA Destination Memory Space 0
M_DDS1 EQU 3 ; DMA Destination Memory Space 1
M_DAM EQU $3f0 ; DMA Address Mode Mask (DAM5-DAM0)
M_DAM0 EQU 4 ; DMA Address Mode 0

```

```

M_DAM1 EQU 5 ; DMA Address Mode 1
M_DAM2 EQU 6 ; DMA Address Mode 2
M_DAM3 EQU 7 ; DMA Address Mode 3
M_DAM4 EQU 8 ; DMA Address Mode 4
M_DAM5 EQU 9 ; DMA Address Mode 5
M_D3D EQU 10 ; DMA Three Dimensional Mode
M_DRS EQU $F800 ; DMA Request Source Mask (DRS0-DRS4)
M_DRS0 EQU 11 ;DMA Request Source bit 0
M_DRS1 EQU 12 ;DMA Request Source bit 1
M_DRS2 EQU 13 ;DMA Request Source bit 2
M_DRS3 EQU 14 ;DMA Request Source bit 3
M_DRS4 EQU 15 ;DMA Request Source bit 4
M_DCON EQU 16 ; DMA Continuous Mode
M_DPR EQU $60000 ; DMA Channel Priority
M_DPR0 EQU 17 ; DMA Channel Priority Level (low)
M_DPR1 EQU 18 ; DMA Channel Priority Level (high)
M_DTM EQU $380000 ; DMA Transfer Mode Mask (DTM2-DTM0)
M_DTM0 EQU 19 ; DMA Transfer Mode 0
M_DTM1 EQU 20 ; DMA Transfer Mode 1
M_DTM2 EQU 21 ; DMA Transfer Mode 2
M_DIE EQU 22 ; DMA Interrupt Enable bit
M_DE EQU 23 ; DMA Channel Enable bit

; DMA Status Register

M_DTD EQU $3F ; Channel Transfer Done Status MASK (DTD0-DTD5)
M_DTD0 EQU 0 ; DMA Channel Transfer Done Status 0
M_DTD1 EQU 1 ; DMA Channel Transfer Done Status 1
M_DTD2 EQU 2 ; DMA Channel Transfer Done Status 2
M_DTD3 EQU 3 ; DMA Channel Transfer Done Status 3
M_DTD4 EQU 4 ; DMA Channel Transfer Done Status 4
M_DTD5 EQU 5 ; DMA Channel Transfer Done Status 5
M_DACT EQU 8 ; DMA Active State
M_DCH EQU $E00 ; DMA Active Channel Mask (DCH0-DCH2)
M_DCH0 EQU 9 ; DMA Active Channel 0
M_DCH1 EQU 10 ; DMA Active Channel 1
M_DCH2 EQU 11 ; DMA Active Channel 2

;-----
;
; EQUATES for Phase Locked Loop (PLL)
;
;-----

; Register Addresses Of PLL

M_PCTL EQU $FFFFFD ; X space: PLL Control Register
M_PREDIV EQU 16 ; predivide factor (base)
M_DIVFACT EQU 8 ; division factor (base)
M_MULTFACT EQU 0 ; multiplication factor (base)

; PLL Control register bits

```

```

M_MF      EQU    $FF                ; Multiplication Factor Bits Mask (MF0-MF11)
M_MF0     EQU    0                  ; Multiplication Factor bit 0
M_MF1     EQU    1                  ; Multiplication Factor bit 1
M_MF2     EQU    2                  ; Multiplication Factor bit 2
M_MF3     EQU    3                  ; Multiplication Factor bit 3
M_MF4     EQU    4                  ; Multiplication Factor bit 4
M_MF5     EQU    5                  ; Multiplication Factor bit 5
M_MF6     EQU    6                  ; Multiplication Factor bit 6
M_MF7     EQU    7                  ; Multiplication Factor bit 7
M_DF      EQU    $700               ; Division Factor Bits Mask (DF0-DF2)
M_DF0     EQU    8                  ; Division Factor bit 0
M_DF1     EQU    9                  ; Division Factor bit 1
M_DF2     EQU    10                 ; Division Factor bit 2
M_PSTP    EQU    12                 ; p stop
M_PEN     EQU    13                 ; PLL enable
M_OD0     EQU    14                 ; output divide factor [0]
M_OD1     EQU    15                 ; output divide factor [1]
M_PD      EQU    $1F0000            ; PreDivider Factor Bits Mask (PD0-PD3)
M_PD0     EQU    16                 ; PreDivider Factor bit 0
M_PD1     EQU    17                 ; PreDivider Factor bit 1
M_PD2     EQU    18                 ; PreDivider Factor bit 2
M_PD3     EQU    19                 ; PreDivider Factor bit 3
M_PD4     EQU    20                 ; PreDivider Factor bit 4

```

```

;-----
;
;      EQUATES for Status Register (SR)
;
;-----

```

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;      control and status bits in SR

```

```

M_C       EQU    0                  ; Carry
M_V       EQU    1                  ; Overflow
M_Z       EQU    2                  ; Zero
M_N       EQU    3                  ; Negative
M_U       EQU    4                  ; Unnormalized
M_E       EQU    5                  ; Extension
M_L       EQU    6                  ; Limit
M_S       EQU    7                  ; Scaling Bit
M_IO      EQU    8                  ; Interrupt Mask Bit 0

```

```

M_I1      EQU      9           ; Interrupt Mask Bit 1
M_S0      EQU      10          ; Scaling Mode Bit 0
M_S1      EQU      11          ; Scaling Mode Bit 1
M_SC      EQU      13          ; Sixteen_Bit Compatibility
M_DM      EQU      14          ; Double Precision Multiply
M_LF      EQU      15          ; DO-Loop Flag
M_FV      EQU      16          ; DO-Forever Flag
M_SA      EQU      17          ; Sixteen-Bit Arithmetic
M_CE      EQU      19          ; Instruction Cache Enable
M_SM      EQU      20          ; Arithmetic Saturation
M_RM      EQU      21          ; Rounding Mode
M_CP      EQU      $c00000     ; mask for CORE-DMA priority bits in SR
M_CP0     EQU      22          ; bit 0 of priority bits in SR
M_CP1     EQU      23          ; bit 1 of priority bits in SR

;-----
;
;      EQUATES for Operating Mode Register (OMR)
;
;-----

;      control and status bits in OMR

M_MA      EQU      0           ; Operating Mode A
M_MB      EQU      1           ; Operating Mode B
M_MC      EQU      2           ; Operating Mode C
M_MD      EQU      3           ; Operating Mode D
M_SD      EQU      6           ; Stop Delay
M_MS      EQU      7           ; Memory Switch Mode
M_CDP     EQU      $300        ; mask for CORE-DMA priority bits in OMR
M_CDP0    EQU      8           ; bit 0 of priority bits in OMR Core DMA
M_CDP1    EQU      9           ; bit 1 of priority bits in OMR Core DMA
M_XYS     EQU      16          ; Stack Extension space select bit in OMR.
M_EUN     EQU      17          ; Extended stack UNDERflow flag in OMR.
M_EOV     EQU      18          ; Extended stack OVERflow flag in OMR.
M_WRP     EQU      19          ; Extended WRaP flag in OMR.
M_SEN     EQU      20          ; Stack Extension Enable bit in OMR.
M_MSW0    EQU      21          ; Memory Switch Mode 0
M_MSW1    EQU      22          ; Memory Switch Mode 1

;-----
;
;      EQUATES for DAX (SPDIF Tx)
;
;-----

;      Register Addresses

M_XSTR     EQU      $FFFFD4     ; X space: DAX Status Register (XSTR)
M_XADRB    EQU      $FFFFD3     ; X space: DAX Audio Data Register B (XADRB)
M_XADR     EQU      $FFFFD2     ; X space: DAX Audio Data Register (XADR)
M_XADRA    EQU      $FFFFD2     ; X space: DAX Audio Data Register A (XADRA)
M_XNADR    EQU      $FFFFD1     ; X space: DAX Non-Audio Data Register (XNADR)
M_XCTR     EQU      $FFFFD0     ; X space: DAX Control Register (XCTR)

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;          status bits in XSTR

M_XADE    EQU    0          ; DAX Audio Data Register Empty (XADE)
M_XAUR    EQU    1          ; DAX Transmit Underrun Error Flag (XAUR)
M_XBLK    EQU    2          ; DAX Block Transferred (XBLK)

;          non-audio bits in XNADR

M_XVA     EQU    10         ; DAX Channel A Validity (XVA)
M_XUA     EQU    11         ; DAX Channel A User Data (XUA)
M_XCA     EQU    12         ; DAX Channel A Channel Status (XCA)
M_XVB     EQU    13         ; DAX Channel B Validity (XVB)
M_XUB     EQU    14         ; DAX Channel B User Data (XUB)
M_XCB     EQU    15         ; DAX Channel B Channel Status (XCB)

;          control bits in XCTR

M_XDIE    EQU    0          ; DAX Audio Data Register Empty Interrupt Enable (XDIE)
M_XUIE    EQU    1          ; DAX Underrun Error Interrupt Enable (XUIE)
M_XBIE    EQU    2          ; DAX Block Transferred Interrupt Enable (XBIE)
M_XCS0    EQU    3          ; DAX Clock Input Select 0 (XCS0)
M_XCS1    EQU    4          ; DAX Clock Input Select 1 (XCS1)
M_XSB     EQU    5          ; DAX Start Block (XSB)

;-----
;
;          EQUATES for SHI
;-----

;          Register Addresses

M_HRX     EQU    $FFFF94    ; X space: SHI Receive FIFO (HRX)
M_HTX     EQU    $FFFF93    ; X space: SHI Transmit Register (HTX)
M_HSAR    EQU    $FFFF92    ; X space: SHI I2C Slave Address Register (HSAR)
M_HCSR    EQU    $FFFF91    ; X space: SHI Control/Status Register (HCSR)
M_HCKR    EQU    $FFFF90    ; X space: SHI Clock Control Register (HCKR)

;          HSAR bits

M_HA6     EQU    23         ; SHI I2C Slave Address (HA6)
M_HA5     EQU    22         ; SHI I2C Slave Address (HA5)
M_HA4     EQU    21         ; SHI I2C Slave Address (HA4)
M_HA3     EQU    20         ; SHI I2C Slave Address (HA3)
M_HA1     EQU    18         ; SHI I2C Slave Address (HA1)

```



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;          control and status bits in HCSR

M_HBUSY EQU    22          ; SHI Host Busy (HBUSY)
M_HBER EQU    21          ; SHI Bus Error (HBER)
M_HROE EQU    20          ; SHI Receive Overrun Error (HROE)
M_HRFF EQU    19          ; SHI Receivr FIFO Full (HRFF)
M_HRNE EQU    17          ; SHI Receive FIFO Not Empty (HRNE)
M_HTDE EQU    15          ; SHI Host Transmit data Empty (HTDE)
M_HTUE EQU    14          ; SHI Host Transmit Underrun Error (HTUE)
M_HRIE1 EQU    13          ; SHI Receive Interrupt Enable (HRIE1)
M_HRIE0 EQU    12          ; SHI Receive Interrupt Enable (HRIE0)
M_HTIE EQU    11          ; SHI Transmit Interrupt Enable (HTIE)
M_HBIE EQU    10          ; SHI Bus-Error Interrupt Enable (HBIE)
M_HIDLE EQU    9          ; SHI Idle (HIDLE)
M_HRQE1 EQU    8          ; SHI Host Request Enable (HRQE1)
M_HRQE0 EQU    7          ; SHI Host Request Enable (HRQE0)
M_HMST EQU    6          ; SHI Master Mode (HMST)
M_HFIFO EQU    5          ; SHI FIFO Enable Control (HFIFO)
M_HCKFR EQU    4          ; SHI Clock Freeze (HCKFR)
M_HM1 EQU    3          ; SHI Serial Host Interface Mode (HM1)
M_HM0 EQU    2          ; SHI Serial Host Interface Mode (HM0)
M_HI2C EQU    1          ; SHI I2c/SPI Selection (HI2C)
M_HEN EQU    0          ; SHI Host Enable (HEN)

;          control bits in HCKR

M_HFM1 EQU    13          ; SHI Filter Model (HFM1)
M_HFM0 EQU    12          ; SHI Filter Model (HFM0)
M_HDM7 EQU    10          ; SHI Divider Modulus Select (HDM7)
M_HDM6 EQU    9          ; SHI Divider Modulus Select (HDM6)
M_HDM5 EQU    8          ; SHI Divider Modulus Select (HDM5)
M_HDM4 EQU    7          ; SHI Divider Modulus Select (HDM4)
M_HDM3 EQU    6          ; SHI Divider Modulus Select (HDM3)
M_HDM2 EQU    5          ; SHI Divider Modulus Select (HDM2)
M_HDM1 EQU    4          ; SHI Divider Modulus Select (HDM1)
M_HDM0 EQU    3          ; SHI Divider Modulus Select (HDM0)
M_HRS EQU    2          ; SHI Prescalar Rate Select (HRS)
M_CPOL EQU    1          ; SHI Clock Polarity (CPOL)
M_CPHA EQU    0          ; SHI Clock Phase (CPHA)

;-----
;
;          EQUATES for ESAI_1 Registers
; register bit equates can be the same as for the ESAI register bit equates.
;
;-----

;          Register Addresses

M_RSMB_1 EQU    $FFFF9C    ; Y space: ESAI_1 Receive Slot Mask Register B (RSMB_1)
M_RSMA_1 EQU    $FFFF9B    ; Y space: ESAI_1 Receive Slot Mask Register A (RSMA_1)
M_TSMB_1 EQU    $FFFF9A    ; Y space: ESAI_1 Transmit Slot Mask Register B (TSMB_1)
M_TSMA_1 EQU    $FFFF99    ; Y space: ESAI_1 Transmit Slot Mask Register A (TSMA_1)
M_RCCR_1 EQU    $FFFF98    ; Y space: ESAI_1 Receive Clock Control Register (RCCR_1)

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M_RCR_1 EQU    $FFFF97      ; Y space: ESAI_1 Receive Control Register (RCR_1)
M_TCCR_1 EQU    $FFFF96      ; Y space: ESAI_1 Transmit Clock Control Register (TCCR_1)
M_TCR_1 EQU     $FFFF95      ; Y space: ESAI_1 Transmit Control Register (TCR_1)
M_SAICR_1 EQU    $FFFF94      ; Y space: ESAI_1 Control Register (SAICR_1)
M_SAISR_1 EQU    $FFFF93      ; Y space: ESAI_1 Status Register (SAISR_1)
M_RX3_1 EQU     $FFFF8B      ; Y space: ESAI_1 Receive Data Register 3 (RX3_1)
M_RX2_1 EQU     $FFFF8A      ; Y space: ESAI_1 Receive Data Register 2 (RX2_1)
M_RX1_1 EQU     $FFFF89      ; Y space: ESAI_1 Receive Data Register 1 (RX1_1)
M_RX0_1 EQU     $FFFF88      ; Y space: ESAI_1 Receive Data Register 0 (RX0_1)
M_TSR_1 EQU     $FFFF86      ; Y space: ESAI_1 Time Slot Register (TSR_1)
M_TX5_1 EQU     $FFFF85      ; Y space: ESAI_1 Transmit Data Register 5 (TX5_1)
M_TX4_1 EQU     $FFFF84      ; Y space: ESAI_1 Transmit Data Register 4 (TX4_1)
M_TX3_1 EQU     $FFFF83      ; Y space: ESAI_1 Transmit Data Register 3 (TX3_1)
M_TX2_1 EQU     $FFFF82      ; Y space: ESAI_1 Transmit Data Register 2 (TX2_1)
M_TX1_1 EQU     $FFFF81      ; Y space: ESAI_1 Transmit Data Register 1 (TX1_1)
M_TX0_1 EQU     $FFFF80      ; Y space: ESAI_1 Transmit Data Register 0 (TX0_1)

```

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;-----
;
;      EQUATES for ESAI
;
;-----

```

```

;      Register Addresses

```

```

M_RSMB EQU     $FFFFBC      ; X space: ESAI Receive Slot Mask Register B (RSMB)
M_RSMA EQU     $FFFFBB      ; X space: ESAI Receive Slot Mask Register A (RSMA)
M_TSMB EQU     $FFFFBA      ; X space: ESAI Transmit Slot Mask Register B (TSMB)
M_TSMA EQU     $FFFFB9      ; X space: ESAI Transmit Slot Mask Register A (TSMA)
M_RCCR EQU     $FFFFB8      ; X space: ESAI Receive Clock Control Register (RCCR)
M_RCR EQU      $FFFFB7      ; X space: ESAI Receive Control Register (RCR)
M_TCCR EQU     $FFFFB6      ; X space: ESAI Transmit Clock Control Register (TCCR)
M_TCR EQU      $FFFFB5      ; X space: ESAI Transmit Control Register (TCR)
M_SAICR EQU     $FFFFB4      ; X space: ESAI Control Register (SAICR)
M_SAISR EQU     $FFFFB3      ; X space: ESAI Status Register (SAISR)
M_RX3 EQU      $FFFFAB      ; X space: ESAI Receive Data Register 3 (RX3)
M_RX2 EQU      $FFFFAA      ; X space: ESAI Receive Data Register 2 (RX2)
M_RX1 EQU      $FFFFA9      ; X space: ESAI Receive Data Register 1 (RX1)
M_RX0 EQU      $FFFFA8      ; X space: ESAI Receive Data Register 0 (RX0)
M_TSR EQU      $FFFFA6      ; X space: ESAI Time Slot Register (TSR)
M_TX5 EQU      $FFFFA5      ; X space: ESAI Transmit Data Register 5 (TX5)
M_TX4 EQU      $FFFFA4      ; X space: ESAI Transmit Data Register 4 (TX4)
M_TX3 EQU      $FFFFA3      ; X space: ESAI Transmit Data Register 3 (TX3)
M_TX2 EQU      $FFFFA2      ; X space: ESAI Transmit Data Register 2 (TX2)
M_TX1 EQU      $FFFFA1      ; X space: ESAI Transmit Data Register 1 (TX1)
M_TX0 EQU      $FFFFA0      ; X space: ESAI Transmit Data Register 0 (TX0)

```

```

;      RSMB Register bits

```

```

M_RS31 EQU     15           ; ESAI
M_RS30 EQU     14           ; ESAI
M_RS29 EQU     13           ; ESAI
M_RS28 EQU     12           ; ESAI
M_RS27 EQU     11           ; ESAI
M_RS26 EQU     10           ; ESAI

```

```

M_RS25 EQU 9 ; ESAI
M_RS24 EQU 8 ; ESAI
M_RS23 EQU 7 ; ESAI
M_RS22 EQU 6 ; ESAI
M_RS21 EQU 5 ; ESAI
M_RS20 EQU 4 ; ESAI
M_RS19 EQU 3 ; ESAI
M_RS18 EQU 2 ; ESAI
M_RS17 EQU 1 ; ESAI
M_RS16 EQU 0 ; ESAI

```

```

; RSMA Register bits

```

```

M_RS15 EQU 15 ; ESAI
M_RS14 EQU 14 ; ESAI
M_RS13 EQU 13 ; ESAI
M_RS12 EQU 12 ; ESAI
M_RS11 EQU 11 ; ESAI
M_RS10 EQU 10 ; ESAI
M_RS9 EQU 9 ; ESAI
M_RS8 EQU 8 ; ESAI
M_RS7 EQU 7 ; ESAI
M_RS6 EQU 6 ; ESAI
M_RS5 EQU 5 ; ESAI
M_RS4 EQU 4 ; ESAI
M_RS3 EQU 3 ; ESAI
M_RS2 EQU 2 ; ESAI
M_RS1 EQU 1 ; ESAI
M_RS0 EQU 0 ; ESAI

```

```

; TSMB Register bits

```

```

M_TS31 EQU 15 ; ESAI
M_TS30 EQU 14 ; ESAI
M_TS29 EQU 13 ; ESAI
M_TS28 EQU 12 ; ESAI
M_TS27 EQU 11 ; ESAI
M_TS26 EQU 10 ; ESAI
M_TS25 EQU 9 ; ESAI
M_TS24 EQU 8 ; ESAI
M_TS23 EQU 7 ; ESAI
M_TS22 EQU 6 ; ESAI
M_TS21 EQU 5 ; ESAI
M_TS20 EQU 4 ; ESAI
M_TS19 EQU 3 ; ESAI
M_TS18 EQU 2 ; ESAI
M_TS17 EQU 1 ; ESAI
M_TS16 EQU 0 ; ESAI

```

```

; TSMA Register bits

```

```

M_TS15 EQU 15 ; ESAI
M_TS14 EQU 14 ; ESAI
M_TS13 EQU 13 ; ESAI
M_TS12 EQU 12 ; ESAI

```

```

M_TS11 EQU 11 ; ESAI
M_TS10 EQU 10 ; ESAI
M_TS9 EQU 9 ; ESAI
M_TS8 EQU 8 ; ESAI
M_TS7 EQU 7 ; ESAI
M_TS6 EQU 6 ; ESAI
M_TS5 EQU 5 ; ESAI
M_TS4 EQU 4 ; ESAI
M_TS3 EQU 3 ; ESAI
M_TS2 EQU 2 ; ESAI
M_TS1 EQU 1 ; ESAI
M_TS0 EQU 0 ; ESAI

; RCCR Register bits

M_RHCKD EQU 23 ; ESAI
M_RFSD EQU 22 ; ESAI
M_RCKD EQU 21 ; ESAI
M_RHCKP EQU 20 ; ESAI
M_RFSP EQU 19 ; ESAI
M_RCKP EQU 18 ; ESAI
M_RFP EQU $3C000 ; ESAI MASK
M_RFP3 EQU 17 ; ESAI
M_RFP2 EQU 16 ; ESAI
M_RFP1 EQU 15 ; ESAI
M_RFP0 EQU 14 ; ESAI
M_RDC EQU $3E00 ; ESAI MASK
M_RDC4 EQU 13 ; ESAI
M_RDC3 EQU 12 ; ESAI
M_RDC2 EQU 11 ; ESAI
M_RDC1 EQU 10 ; ESAI
M_RDC0 EQU 9 ; ESAI
M_RPSR EQU 8 ; ESAI
M_RPM EQU $FF
M_RPM7 EQU 7 ; ESAI
M_RPM6 EQU 6 ; ESAI
M_RPM5 EQU 5 ; ESAI
M_RPM4 EQU 4 ; ESAI
M_RPM3 EQU 3 ; ESAI
M_RPM2 EQU 2 ; ESAI
M_RPM1 EQU 1 ; ESAI
M_RPM0 EQU 0 ; ESAI

; RCR Register bits

M_RLIE EQU 23 ; ESAI
M_RIE EQU 22 ; ESAI
M_REDIE EQU 21 ; ESAI
M_REIE EQU 20 ; ESAI
M_RPR EQU 19 ; ESAI
M_RFSR EQU 16 ; ESAI
M_RFSL EQU 15 ; ESAI
M_RSWS EQU $7C00 ; ESAI MASK
M_RSWS4 EQU 14 ; ESAI
M_RSWS3 EQU 13 ; ESAI

```

```

M_RSWS2 EQU 12 ; ESAI
M_RSWS1 EQU 11 ; ESAI
M_RSWS0 EQU 10 ; ESAI
M_RMOD EQU $300
M_RMOD1 EQU 9 ; ESAI
M_RMOD0 EQU 8 ; ESAI
M_RWA EQU 7 ; ESAI
M_RSHFD EQU 6 ; ESAI
M_RE EQU $F
M_RE3 EQU 3 ; ESAI
M_RE2 EQU 2 ; ESAI
M_RE1 EQU 1 ; ESAI
M_RE0 EQU 0 ; ESAI

```

; TCCR Register bits

```

M_THCKD EQU 23 ; ESAI
M_TFSD EQU 22 ; ESAI
M_TCKD EQU 21 ; ESAI
M_THCKP EQU 20 ; ESAI
M_TFSP EQU 19 ; ESAI
M_TCKP EQU 18 ; ESAI
M_TFP EQU $3C000
M_TFP3 EQU 17 ; ESAI
M_TFP2 EQU 16 ; ESAI
M_TFP1 EQU 15 ; ESAI
M_TFP0 EQU 14 ; ESAI
M_TDC EQU $3E00 ;
M_TDC4 EQU 13 ; ESAI
M_TDC3 EQU 12 ; ESAI
M_TDC2 EQU 11 ; ESAI
M_TDC1 EQU 10 ; ESAI
M_TDC0 EQU 9 ; ESAI
M_TPSR EQU 8 ; ESAI
M_TPM EQU $FF ;
M_TPM7 EQU 7 ; ESAI
M_TPM6 EQU 6 ; ESAI
M_TPM5 EQU 5 ; ESAI
M_TPM4 EQU 4 ; ESAI
M_TPM3 EQU 3 ; ESAI
M_TPM2 EQU 2 ; ESAI
M_TPM1 EQU 1 ; ESAI
M_TPM0 EQU 0 ; ESAI

```

; TCR Register bits

```

M_TLIE EQU 23 ; ESAI
M_TIE EQU 22 ; ESAI
M_TEDIE EQU 21 ; ESAI
M_TEIE EQU 20 ; ESAI
M_TPR EQU 19 ; ESAI
M_PADC EQU 17 ; ESAI
M_TFSR EQU 16 ; ESAI
M_TFSL EQU 15 ; ESAI
M_TSWS EQU $7C00

```

```

M_TWS4 EQU 14 ; ESAI
M_TWS3 EQU 13 ; ESAI
M_TWS2 EQU 12 ; ESAI
M_TWS1 EQU 11 ; ESAI
M_TWS0 EQU 10 ; ESAI
M_TMOD EQU $300
M_TMOD1 EQU 9 ; ESAI
M_TMOD0 EQU 8 ; ESAI
M_TWA EQU 7 ; ESAI
M_TSHFD EQU 6 ; ESAI
M_TEM EQU $3F
M_TE5 EQU 5 ; ESAI
M_TE4 EQU 4 ; ESAI
M_TE3 EQU 3 ; ESAI
M_TE2 EQU 2 ; ESAI
M_TE1 EQU 1 ; ESAI
M_TE0 EQU 0 ; ESAI

; control bits of SAICR

M_ALC EQU 8 ; ESAI
M_TEBE EQU 7 ; ESAI
M_SYN EQU 6 ; ESAI
M_OF2 EQU 2 ; ESAI
M_OF1 EQU 1 ; ESAI
M_OF0 EQU 0 ; ESAI

; status bits of SAISR

M_TODE EQU 17 ; ESAI
M_TEDE EQU 16 ; ESAI
M_TDE EQU 15 ; ESAI
M_TUE EQU 14 ; ESAI
M_TFS EQU 13 ; ESAI
M_RODF EQU 10 ; ESAI
M_REDF EQU 9 ; ESAI
M_RDF EQU 8 ; ESAI
M_ROE EQU 7 ; ESAI
M_RFS EQU 6 ; ESAI
M_IF2 EQU 2 ; ESAI
M_IF1 EQU 1 ; ESAI
M_IF0 EQU 0 ; ESAI

;-----
;
; EQUATES for TIMER
;
;-----

; Register Addresses Of TIMER0

M_TCSR0 EQU $FFFF8F ; X space: TIMER0 Control/Status Register
M_TLRO EQU $FFFF8E ; X space: TIMER0 Load Reg

```

```

M_TCPRO EQU $FFFF8D ; X space: TIMER0 Compare Register
M_TCR0 EQU $FFFF8C ; X space: TIMER0 Count Register

; Register Addresses Of TIMER1

M_TCSR1 EQU $FFFF8B ; X space: TIMER1 Control/Status Register
M_TLR1 EQU $FFFF8A ; X space: TIMER1 Load Reg
M_TCPR1 EQU $FFFF89 ; X space: TIMER1 Compare Register
M_TCR1 EQU $FFFF88 ; X space: TIMER1 Count Register

; Register Addresses Of TIMER2

M_TCSR2 EQU $FFFF87 ; X space: TIMER2 Control/Status Register
M_TLR2 EQU $FFFF86 ; X space: TIMER2 Load Reg
M_TCPR2 EQU $FFFF85 ; X space: TIMER2 Compare Register
M_TCR2 EQU $FFFF84 ; X space: TIMER2 Count Register

M_TPLR EQU $FFFF83 ; X space: TIMER Prescaler Load Register
M_TPCR EQU $FFFF82 ; X space: TIMER Prescaler Count Register

; Timer Control/Status Register Bit Flags

M_TE EQU 0 ; Timer Enable
M_TOIE EQU 1 ; Timer Overflow Interrupt Enable
M_TCIE EQU 2 ; Timer Compare Interrupt Enable
M_TC EQU $F0 ; Timer Control Mask (TC0-TC3)
M_TC0 EQU 4 ; Timer Control 0 - Timer Control Bits
M_TC1 EQU 5 ; Timer Control 1
M_TC2 EQU 6 ; Timer Control 2
M_TC3 EQU 7 ; Timer Control 3
M_INV EQU 8 ; Inverter Bit
M_TRM EQU 9 ; Timer Restart Mode
M_DIR EQU 11 ; Direction Bit
M_DI EQU 12 ; Data Input
M_DO EQU 13 ; Data Output
M_PCE EQU 15 ; Prescaled Clock Enable
M_TOF EQU 20 ; Timer Overflow Flag
M_TCF EQU 21 ; Timer Compare Flag

; Timer Prescaler Register Bit Flags

M_PS EQU $600000 ; Prescaler Source Mask
M_PS0 EQU 21
M_PS1 EQU 22

;-----
;
; EQUATES for EFCOP

```

```

;
;-----
M_EFCOP EQU    $FFFFB0
M_FDIR  EQU    M_EFCOP+$0      ; Y space: EFCOP Data Input Register
M_FDOR  EQU    M_EFCOP+$1      ; Y space: EFCOP Data Output Register
M_FKIR  EQU    M_EFCOP+$2      ; Y space: EFCOP K-Constant Input Register
M_FCNT  EQU    M_EFCOP+$3      ; Y space: EFCOP Filter Count Register
M_FCSR  EQU    M_EFCOP+$4      ; Y space: EFCOP Control Status Register
M_FACR  EQU    M_EFCOP+$5      ; Y space: EFCOP ALU Control Register
M_FDBA  EQU    M_EFCOP+$6      ; Y space: EFCOP Data Base Address
M_FCBA  EQU    M_EFCOP+$7      ; Y space: EFCOP Coefficient Base Address
M_FDCH  EQU    M_EFCOP+$8      ; Y space: EFCOP Decimation/Channel Count Register
M_FL    EQU    $30000          ; EFCOP interrupt mask

```

```

;-----
;
;      EQUATES for Patch Module
;
;-----

```

```

M_PATCH EQU    $FFFFA0
M_PATCHA0 EQU    M_PATCH+$0    ; Y space: Patch Address 0 Register
M_PATCHA1 EQU    M_PATCH+$1    ; Y space: Patch Address 1 Register
M_PATCHA2 EQU    M_PATCH+$2    ; Y space: Patch Address 2 Register
M_PATCHA3 EQU    M_PATCH+$3    ; Y space: Patch Address 3 Register
M_PATCHA4 EQU    M_PATCH+$4    ; Y space: Patch Address 4 Register
M_PATCHA5 EQU    M_PATCH+$5    ; Y space: Patch Address 5 Register
M_PATCHA6 EQU    M_PATCH+$6    ; Y space: Patch Address 6 Register
M_PATCHA7 EQU    M_PATCH+$7    ; Y space: Patch Address 7 Register
M_PATCHI0 EQU    M_PATCH+$8    ; Y space: Patch Instruction 0 Register
M_PATCHI1 EQU    M_PATCH+$9    ; Y space: Patch Instruction 0 Register
M_PATCHI2 EQU    M_PATCH+$A    ; Y space: Patch Instruction 0 Register
M_PATCHI3 EQU    M_PATCH+$B    ; Y space: Patch Instruction 0 Register
M_PATCHI4 EQU    M_PATCH+$C    ; Y space: Patch Instruction 0 Register
M_PATCHI5 EQU    M_PATCH+$D    ; Y space: Patch Instruction 0 Register
M_PATCHI6 EQU    M_PATCH+$E    ; Y space: Patch Instruction 0 Register
M_PATCHI7 EQU    M_PATCH+$F    ; Y space: Patch Instruction 0 Register

```

```

;----- end of ioequ.asm -----

```



## Appendix C Programmer's Reference

### C.1 Introduction

This section has been compiled as a reference for programmers. It contains a table showing the addresses of all the DSPs memory-mapped peripherals, an interrupt address table, an interrupt exception priority table, and programming sheets for the major programmable registers on the DSP.

#### C.1.1 Peripheral Addresses

Table C-1 lists the memory addresses of all on-chip peripherals.

#### C.1.2 Interrupt Addresses

Table C-2 lists the interrupt starting addresses and sources.

#### C.1.3 Interrupt Priorities

Table C-3 lists the priorities of specific interrupts within interrupt priority levels.

#### C.1.4 Programming Sheets

The remaining figures describe major programmable registers on the DSP56371.

## C.1.5 INTERNAL I/O MEMORY MAP

Table C-1 Internal I/O Memory Map (X Memory)

Peripheral	Address	Register Name
IPR	X:\$FFFFFFF	INTERRUPT PRIORITY REGISTER CORE (IPR-C)
	X:\$FFFFFFE	INTERRUPT PRIORITY REGISTER PERIPHERAL (IPR-P)
PLL	X:\$FFFFFFD	PLL CONTROL REGISTER (PCTL)
ONCE	X:\$FFFFFFC	ONCE GDB REGISTER (OGDB)
BIU	X:\$FFFFFFB	BCR
	X:\$FFFFFFA	<i>Reserved</i>
	X:\$FFFFFF9	<i>Reserved</i>
	X:\$FFFFFF8	<i>Reserved</i>
	X:\$FFFFFF7	<i>Reserved</i>
	X:\$FFFFFF6	<i>Reserved</i>
	X:\$FFFFFF5	ID Register (IDR)
DMA	X:\$FFFFFF4	DMA STATUS REGISTER (DSTR)
	X:\$FFFFFF3	DMA OFFSET REGISTER 0 (DOR0)
	X:\$FFFFFF2	DMA OFFSET REGISTER 1 (DOR1)
	X:\$FFFFFF1	DMA OFFSET REGISTER 2 (DOR2)
	X:\$FFFFFF0	DMA OFFSET REGISTER 3 (DOR3)
DMA0	X:\$FFFFFEF	DMA SOURCE ADDRESS REGISTER (DSR0)
	X:\$FFFFFEE	DMA DESTINATION ADDRESS REGISTER (DDR0)
	X:\$FFFFFED	DMA COUNTER (DCO0)
	X:\$FFFFFEC	DMA CONTROL REGISTER (DCR0)
DMA1	X:\$FFFFFEB	DMA SOURCE ADDRESS REGISTER (DSR1)
	X:\$FFFFFEA	DMA DESTINATION ADDRESS REGISTER (DDR1)
	X:\$FFFFFE9	DMA COUNTER (DCO1)
	X:\$FFFFFE8	DMA CONTROL REGISTER (DCR1)
DMA2	X:\$FFFFFE7	DMA SOURCE ADDRESS REGISTER (DSR2)
	X:\$FFFFFE6	DMA DESTINATION ADDRESS REGISTER (DDR2)
	X:\$FFFFFE5	DMA COUNTER (DCO2)
	X:\$FFFFFE4	DMA CONTROL REGISTER (DCR2)
DMA3	X:\$FFFFFE3	DMA SOURCE ADDRESS REGISTER (DSR3)
	X:\$FFFFFE2	DMA DESTINATION ADDRESS REGISTER (DDR3)
	X:\$FFFFFE1	DMA COUNTER (DCO3)
	X:\$FFFFFE0	DMA CONTROL REGISTER (DCR3)

**Table C-1 Internal I/O Memory Map (X Memory) (continued)**

Peripheral	Address	Register Name
DMA4	X:\$FFFFDF	DMA SOURCE ADDRESS REGISTER (DSR4)
	X:\$FFFFDE	DMA DESTINATION ADDRESS REGISTER (DDR4)
	X:\$FFFFDD	DMA COUNTER (DCO4)
	X:\$FFFFDC	DMA CONTROL REGISTER (DCR4)
DMA5	X:\$FFFFDB	DMA SOURCE ADDRESS REGISTER (DSR5)
	X:\$FFFFDA	DMA DESTINATION ADDRESS REGISTER (DDR5)
	X:\$FFFFD9	DMA COUNTER (DCO5)
	X:\$FFFFD8	DMA CONTROL REGISTER (DCR5)
PORT D	X:\$FFFFD7	PORT D CONTROL REGISTER (PCRD)
	X:\$FFFFD6	PORT D DIRECTION REGISTER (PRRD)
	X:\$FFFFD5	PORT D DATA REGISTER (PDRD)
DAX	X:\$FFFFD4	DAX STATUS REGISTER (XSTR)
	X:\$FFFFD3	DAX AUDIO DATA REGISTER B (XADRB)
	X:\$FFFFD2	DAX AUDIO DATA REGISTER A (XADRA)
	X:\$FFFFD1	DAX NON-AUDIO DATA REGISTER (XNADR)
	X:\$FFFFD0	DAX CONTROL REGISTER (XCTR)
	X:\$FFFFCF	<i>Reserved</i>
	X:\$FFFFCE	<i>Reserved</i>
	X:\$FFFFCD	<i>Reserved</i>
	X:\$FFFFCC	<i>Reserved</i>
	X:\$FFFFCB	<i>Reserved</i>
	X:\$FFFFCA	<i>Reserved</i>
	X:\$FFFFC9	<i>Reserved</i>
	X:\$FFFFC8	<i>Reserved</i>
	X:\$FFFFC7	<i>Reserved</i>
	X:\$FFFFC6	<i>Reserved</i>
	X:\$FFFFC5	<i>Reserved</i>
	X:\$FFFFC4	<i>Reserved</i>
	X:\$FFFFC3	<i>Reserved</i>
	X:\$FFFFC2	<i>Reserved</i>
	X:\$FFFFC1	<i>Reserved</i>
	X:\$FFFFC0	<i>Reserved</i>

**Table C-1 Internal I/O Memory Map (X Memory) (continued)**

Peripheral	Address	Register Name
PORT C	X:\$FFFFBF	PORT C CONTROL REGISTER (PCRC)
	X:\$FFFFBE	PORT C DIRECTION REGISTER (PRRC)
	X:\$FFFFBD	PORT C GPIO DATA REGISTER (PDR)
ESAI	X:\$FFFFBC	ESAI RECEIVE SLOT MASK REGISTER B (RSMB)
	X:\$FFFFBB	ESAI RECEIVE SLOT MASK REGISTER A (RSMA)
	X:\$FFFFBA	ESAI TRANSMIT SLOT MASK REGISTER B (TSMB)
	X:\$FFFFB9	ESAI TRANSMIT SLOT MASK REGISTER A (TSMA)
	X:\$FFFFB8	ESAI RECEIVE CLOCK CONTROL REGISTER (RCCR)
	X:\$FFFFB7	ESAI RECEIVE CONTROL REGISTER (RCR)
	X:\$FFFFB6	ESAI TRANSMIT CLOCK CONTROL REGISTER (TCCR)
	X:\$FFFFB5	ESAI TRANSMIT CONTROL REGISTER (TCR)
	X:\$FFFFB4	ESAI COMMON CONTROL REGISTER (SAICR)
	X:\$FFFFB3	ESAI STATUS REGISTER (SAISR)
	X:\$FFFFB2	<i>Reserved</i>
	X:\$FFFFB1	<i>Reserved</i>
	X:\$FFFFB0	<i>Reserved</i>
	X:\$FFFFAF	<i>Reserved</i>
	X:\$FFFFAE	<i>Reserved</i>
	X:\$FFFFAD	<i>Reserved</i>
	X:\$FFFFAC	<i>Reserved</i>
	X:\$FFFFAB	ESAI RECEIVE DATA REGISTER 3 (RX3)
	X:\$FFFFAA	ESAI RECEIVE DATA REGISTER 2 (RX2)
	X:\$FFFFA9	ESAI RECEIVE DATA REGISTER 1 (RX1)
	X:\$FFFFA8	ESAI RECEIVE DATA REGISTER 0 (RX0)
	X:\$FFFFA7	<i>Reserved</i>
	X:\$FFFFA6	ESAI TIME SLOT REGISTER (TSR)
	X:\$FFFFA5	ESAI TRANSMIT DATA REGISTER 5 (TX5)
	X:\$FFFFA4	ESAI TRANSMIT DATA REGISTER 4 (TX4)
	X:\$FFFFA3	ESAI TRANSMIT DATA REGISTER 3 (TX3)
	X:\$FFFFA2	ESAI TRANSMIT DATA REGISTER 2 (TX2)
	X:\$FFFFA1	ESAI TRANSMIT DATA REGISTER 1 (TX1)
	X:\$FFFFA0	ESAI TRANSMIT DATA REGISTER 0 (TX0)
	X:\$FFFF9F	<i>Reserved</i>
	X:\$FFFF9E	<i>Reserved</i>

**Table C-1 Internal I/O Memory Map (X Memory) (continued)**

Peripheral	Address	Register Name
	X:\$FFFF9D	<i>Reserved</i>
	X:\$FFFF9C	<i>Reserved</i>
	X:\$FFFF9B	<i>Reserved</i>
	X:\$FFFF9A	<i>Reserved</i>
	X:\$FFFF99	<i>Reserved</i>
	X:\$FFFF98	<i>Reserved</i>
	X:\$FFFF97	<i>Reserved</i>
	X:\$FFFF96	<i>Reserved</i>
	X:\$FFFF95	<i>Reserved</i>
SHI	X:\$FFFF94	SHI RECEIVE FIFO (HRX)
	X:\$FFFF93	SHI TRANSMIT REGISTER (HTX)
	X:\$FFFF92	SHI I <sup>2</sup> C SLAVE ADDRESS REGISTER (HSAR)
	X:\$FFFF91	SHI CONTROL/STATUS REGISTER (HCSR)
	X:\$FFFF90	SHI CLOCK CONTROL REGISTER (HCKR)
TRIPLE TIMER	X:\$FFFF8F	TIMER 0 CONTROL/STATUS REGISTER (TCSR0)
	X:\$FFFF8E	TIMER 0 LOAD REGISTER (TLR0)
	X:\$FFFF8D	TIMER 0 COMPARE REGISTER (TCPR0)
	X:\$FFFF8C	TIMER 0 COUNT REGISTER (TCR0)
	X:\$FFFF8B	TIMER 1 CONTROL/STATUS REGISTER (TCSR1)
	X:\$FFFF8A	TIMER 1 LOAD REGISTER (TLR1)
	X:\$FFFF89	TIMER 1 COMPARE REGISTER (TCPR1)
	X:\$FFFF88	TIMER 1 COUNT REGISTER (TCR1)
	X:\$FFFF87	TIMER 2 CONTROL/STATUS REGISTER (TCSR2)
	X:\$FFFF86	TIMER 2 LOAD REGISTER (TLR2)
	X:\$FFFF85	TIMER 2 COMPARE REGISTER (TCPR2)
	X:\$FFFF84	TIMER 2 COUNT REGISTER (TCR2)
	X:\$FFFF83	TIMER PRESCALER LOAD REGISTER (TPLR)
	X:\$FFFF82	TIMER PRESCALER COUNT REGISTER (TPCR)
	X:\$FFFF81	<i>Reserved</i>
	X:\$FFFF80	<i>Reserved</i>

**Table C-2 Internal I/O Memory Map (Y Memory)**

Peripheral	Address	Register Name
	Y:\$FFFFFFF	<i>Reserved</i>
	Y:\$FFFFFFE	<i>Reserved</i>
	Y:\$FFFFFFD	<i>Reserved</i>
	Y:\$FFFFFFC	<i>Reserved</i>
	Y:\$FFFFFFB	<i>Reserved</i>
	Y:\$FFFFFFA	<i>Reserved</i>
	Y:\$FFFFFF9	<i>Reserved</i>
	Y:\$FFFFFF8	<i>Reserved</i>
PORT F	Y:\$FFFFFF7	PORT F CONTROL REGISTER (PCRF)
	Y:\$FFFFFF6	PORT F DIRECTION REGISTER (PRRF)
	Y:\$FFFFFF5	PORT F GPIO DATA REGISTER (PDRF)
	Y:\$FFFFFF4	<i>Reserved</i>
	Y:\$FFFFFF3	<i>Reserved</i>
	Y:\$FFFFFF2	<i>Reserved</i>
	Y:\$FFFFFF1	<i>Reserved</i>
	Y:\$FFFFFF0	<i>Reserved</i>
	Y:\$FFFFFEF	<i>Reserved</i>
	Y:\$FFFFFEE	<i>Reserved</i>
	Y:\$FFFFFED	<i>Reserved</i>
	Y:\$FFFFFEC	<i>Reserved</i>
	Y:\$FFFFFEB	<i>Reserved</i>
	Y:\$FFFFFEA	<i>Reserved</i>
	Y:\$FFFFFE9	<i>Reserved</i>
	Y:\$FFFFFE8	<i>Reserved</i>
	Y:\$FFFFFE7	<i>Reserved</i>
	Y:\$FFFFFE6	<i>Reserved</i>
	Y:\$FFFFFE5	<i>Reserved</i>
	Y:\$FFFFFE4	<i>Reserved</i>
	Y:\$FFFFFE3	<i>Reserved</i>
	Y:\$FFFFFE2	<i>Reserved</i>
	Y:\$FFFFFE1	<i>Reserved</i>
	Y:\$FFFFFE0	<i>Reserved</i>
	Y:\$FFFFFDF	<i>Reserved</i>
	Y:\$FFFFFDE	<i>Reserved</i>

**Table C-2 Internal I/O Memory Map (Y Memory) (continued)**

Peripheral	Address	Register Name
	Y:\$FFFFDD	<i>Reserved</i>
	Y:\$FFFFDC	<i>Reserved</i>
	Y:\$FFFFDB	<i>Reserved</i>
	Y:\$FFFFDA	<i>Reserved</i>
	Y:\$FFFFD9	<i>Reserved</i>
	Y:\$FFFFD8	<i>Reserved</i>
	Y:\$FFFFD7	<i>Reserved</i>
	Y:\$FFFFD6	<i>Reserved</i>
	Y:\$FFFFD5	<i>Reserved</i>
	Y:\$FFFFD4	<i>Reserved</i>
	Y:\$FFFFD3	<i>Reserved</i>
	Y:\$FFFFD2	<i>Reserved</i>
	Y:\$FFFFD1	<i>Reserved</i>
	Y:\$FFFFD0	<i>Reserved</i>
	Y:\$FFFFCF	<i>Reserved</i>
	Y:\$FFFFCE	<i>Reserved</i>
	Y:\$FFFFCD	<i>Reserved</i>
	Y:\$FFFFCC	<i>Reserved</i>
	Y:\$FFFFCB	<i>Reserved</i>
	Y:\$FFFFCA	<i>Reserved</i>
	Y:\$FFFFC9	<i>Reserved</i>
	Y:\$FFFFC8	<i>Reserved</i>
	Y:\$FFFFC7	<i>Reserved</i>
	Y:\$FFFFC6	<i>Reserved</i>
	Y:\$FFFFC5	<i>Reserved</i>
	Y:\$FFFFC4	<i>Reserved</i>
	Y:\$FFFFC3	<i>Reserved</i>
	Y:\$FFFFC2	<i>Reserved</i>
	Y:\$FFFFC1	<i>Reserved</i>
	Y:\$FFFFC0	<i>Reserved</i>
	Y:\$FFFFBF	<i>Reserved</i>
	Y:\$FFFFBE	<i>Reserved</i>
	Y:\$FFFFBD	<i>Reserved</i>
	Y:\$FFFFBC	<i>Reserved</i>

**Table C-2 Internal I/O Memory Map (Y Memory) (continued)**

Peripheral	Address	Register Name
	Y:\$FFFFBB	<i>Reserved</i>
	Y:\$FFFFBA	<i>Reserved</i>
	Y:\$FFFFB9	<i>Reserved</i>
EFCOP	Y:\$FFFFB8	EFCOP Filter decimation/channel register (FDCH)
	Y:\$FFFFB7	EFCOP Filter coefficient base address (FCBA)
	Y:\$FFFFB6	EFCOP Filter Data buffer base address (FDBA)
	Y:\$FFFFB5	EFCOP Filter ALU control register (FACR)
	Y:\$FFFFB4	EFCOP Filter control status register (FCSR)
	Y:\$FFFFB3	EFCOP Filter count register (FCNT)
	Y:\$FFFFB2	EFCOP Filter K-constant register (FKIR)
	Y:\$FFFFB1	EFCOP Filter data output register (FDOR)
	Y:\$FFFFB0	EFCOP Filter data input register (FDIR)
Patch Module	Y:\$FFFFAF	Patch Instruction 7
	Y:\$FFFFAE	Patch Instruction 6
	Y:\$FFFFAD	Patch Instruction 5
	Y:\$FFFFAC	Patch Instruction 4
	Y:\$FFFFAB	Patch Instruction 3
	Y:\$FFFFAA	Patch Instruction 2
	Y:\$FFFFA9	Patch Instruction 1
	Y:\$FFFFA8	Patch Instruction 0
	Y:\$FFFFA7	Patch Address 7
	Y:\$FFFFA6	Patch Address 6
	Y:\$FFFFA5	Patch Address 5
	Y:\$FFFFA4	Patch Address 4
	Y:\$FFFFA3	Patch Address 3
	Y:\$FFFFA2	Patch Address 2
	Y:\$FFFFA1	Patch Address 1
	Y:\$FFFFA0	Patch Address 0
PORT E	Y:\$FFFF9F	PORT E CONTROL REGISTER (PCRE)
	Y:\$FFFF9E	PORT E DIRECTION REGISTER (PRRE)
	Y:\$FFFF9D	PORT E GPIO DATA REGISTER (PDRE)



**Table C-2 Internal I/O Memory Map (Y Memory) (continued)**

Peripheral	Address	Register Name
ESAI_1	Y:\$FFFF9C	ESAI_1 RECEIVE SLOT MASK REGISTER B (RSMB_1)
	Y:\$FFFF9B	ESAI_1 RECEIVE SLOT MASK REGISTER A (RSMA_1)
	Y:\$FFFF9A	ESAI_1 TRANSMIT SLOT MASK REGISTER B (TSMB_1)
	Y:\$FFFF99	ESAI_1 TRANSMIT SLOT MASK REGISTER A (TSMA_1)
	Y:\$FFFF98	ESAI_1 RECEIVE CLOCK CONTROL REGISTER (RCCR_1)
	Y:\$FFFF97	ESAI_1 RECEIVE CONTROL REGISTER (RCR_1)
	Y:\$FFFF96	ESAI_1 TRANSMIT CLOCK CONTROL REGISTER (TCCR_1)
	Y:\$FFFF95	ESAI_1 TRANSMIT CONTROL REGISTER (TCR_1)
	Y:\$FFFF94	ESAI_1 COMMON CONTROL REGISTER (SAICR_1)
	Y:\$FFFF93	ESAI_1 STATUS REGISTER (SAISR_1)
	Y:\$FFFF92	<i>Reserved</i>
	Y:\$FFFF91	<i>Reserved</i>
	Y:\$FFFF90	<i>Reserved</i>
	Y:\$FFFF8F	<i>Reserved</i>
	Y:\$FFFF8E	<i>Reserved</i>
	Y:\$FFFF8D	<i>Reserved</i>
	Y:\$FFFF8C	<i>Reserved</i>
	Y:\$FFFF8B	ESAI_1 RECEIVE DATA REGISTER 3 (RX3_1)
	Y:\$FFFF8A	ESAI_1 RECEIVE DATA REGISTER 2 (RX2_1)
	Y:\$FFFF89	ESAI_1 RECEIVE DATA REGISTER 1 (RX1_1)
	Y:\$FFFF88	ESAI_1 RECEIVE DATA REGISTER 0 (RX0_1)
	Y:\$FFFF87	<i>Reserved</i>
	Y:\$FFFF86	ESAI_1 TIME SLOT REGISTER (TSR_1)
	Y:\$FFFF85	ESAI_1 TRANSMIT DATA REGISTER 5 (TX5_1)
	Y:\$FFFF84	ESAI_1 TRANSMIT DATA REGISTER 4 (TX4_1)
	Y:\$FFFF83	ESAI_1 TRANSMIT DATA REGISTER 3 (TX3_1)
	Y:\$FFFF82	ESAI_1 TRANSMIT DATA REGISTER 2 (TX2_1)
	Y:\$FFFF81	ESAI_1 TRANSMIT DATA REGISTER 1 (TX1_1)
	Y:\$FFFF80	ESAI_1 TRANSMIT DATA REGISTER 0 (TX0_1)

## C.1.6 INTERRUPT VECTOR ADDRESSES

Table C-3 DSP56371 Interrupt Vectors

Interrupt Starting Address	Interrupt Priority Level Range	Interrupt Source
VBA:\$00	3	Hardware RESET
VBA:\$02	3	Stack Error
VBA:\$04	3	Illegal Instruction
VBA:\$06	3	Debug Request Interrupt
VBA:\$08	3	Trap
VBA:\$0A	3	Non-Maskable Interrupt ( $\overline{\text{NMI}}$ )
VBA:\$0C	3	Reserved For Future Level-3 Interrupt Source
VBA:\$0E	3	Reserved For Future Level-3 Interrupt Source
VBA:\$10	0 - 2	IRQA
VBA:\$12	0 - 2	IRQB
VBA:\$14	0 - 2	IRQC
VBA:\$16	0 - 2	IRQD
VBA:\$18	0 - 2	DMA Channel 0
VBA:\$1A	0 - 2	DMA Channel 1
VBA:\$1C	0 - 2	DMA Channel 2
VBA:\$1E	0 - 2	DMA Channel 3
VBA:\$20	0 - 2	DMA Channel 4
VBA:\$22	0 - 2	DMA Channel 5
VBA:\$24	0 - 2	Reserved
VBA:\$26	0 - 2	Reserved
VBA:\$28	0 - 2	DAX Underrun Error
VBA:\$2A	0 - 2	DAX Block Transferred
VBA:\$2C	0 - 2	Reserved
VBA:\$2E	0 - 2	DAX Audio Data Empty
VBA:\$30	0 - 2	ESAI Receive Data
VBA:\$32	0 - 2	ESAI Receive Even Data
VBA:\$34	0 - 2	ESAI Receive Data With Exception Status
VBA:\$36	0 - 2	ESAI Receive Last Slot
VBA:\$38	0 - 2	ESAI Transmit Data
VBA:\$3A	0 - 2	ESAI Transmit Even Data
VBA:\$3C	0 - 2	ESAI Transmit Data with Exception Status
VBA:\$3E	0 - 2	ESAI Transmit Last Slot

**Table C-3 DSP56371 Interrupt Vectors (continued)**

Interrupt Starting Address	Interrupt Priority Level Range	Interrupt Source
VBA:\$40	0 - 2	SHI Transmit Data
VBA:\$42	0 - 2	SHI Transmit Underrun Error
VBA:\$44	0 - 2	SHI Receive FIFO Not Empty
VBA:\$46	0 - 2	<i>Reserved</i>
VBA:\$48	0 - 2	SHI Receive FIFO Full
VBA:\$4A	0 - 2	SHI Receive Overrun Error
VBA:\$4C	0 - 2	SHI Bus Error
VBA:\$4E	0 - 2	<i>Reserved</i>
VBA:\$50	0 - 2	<i>Reserved</i>
VBA:\$52	0 - 2	<i>Reserved</i>
VBA:\$54	0 - 2	TIMER0 Compare
VBA:\$56	0 - 2	TIMER0 Overflow
VBA:\$58	0 - 2	TIMER1 Compare
VBA:\$5A	0 - 2	TIMER1 Overflow
VBA:\$5C	0 - 2	TIMER2 Compare
VBA:\$5E	0 - 2	TIMER2 Overflow
VBA:\$60	0 - 2	<i>Reserved</i>
VBA:\$62	0 - 2	<i>Reserved</i>
VBA:\$64	0 - 2	<i>Reserved</i>
VBA:\$66	0 - 2	<i>Reserved</i>
VBA:\$68	0 - 2	EFCOP Data input buffer empty
VBA:\$6A	0 - 2	EFCOP Data output buffer full
VBA:\$6C	0 - 2	<i>Reserved</i>
VBA:\$6E	0 - 2	<i>Reserved</i>
VBA:\$70	0 - 2	ESAI_1 Receive Data
VBA:\$72	0 - 2	ESAI_1 Receive Even Data
VBA:\$74	0 - 2	ESAI_1 Receive Data With Exception Status
VBA:\$76	0 - 2	ESAI_1 Receive Last Slot
VBA:\$78	0 - 2	ESAI_1 Transmit Data
VBA:\$7A	0 - 2	ESAI_1 Transmit Even Data
VBA:\$7C	0 - 2	ESAI_1 Transmit Data with Exception Status
VBA:\$7E	0 - 2	ESAI_1 Transmit Last Slot
VBA:\$80	0 - 2	<i>Reserved</i>

**Table C-3 DSP56371 Interrupt Vectors (continued)**

Interrupt Starting Address	Interrupt Priority Level Range	Interrupt Source
VBA:\$82	0 - 2	<i>Reserved</i>
VBA:\$84	0 - 2	<i>Reserved</i>
VBA:\$86	0 - 2	<i>Reserved</i>
VBA:\$88	0 - 2	<i>Reserved</i>
VBA:\$8A	0 - 2	<i>Reserved</i>
VBA:\$8C	0 - 2	<i>Reserved</i>
VBA:\$8E	0 - 2	<i>Reserved</i>
VBA:\$90	0 - 2	<i>Reserved</i>
VBA:\$92	0 - 2	<i>Reserved</i>
VBA:\$94	0 - 2	<i>Reserved</i>
VBA:\$96	0 - 2	<i>Reserved</i>
VBA:\$98	0 - 2	<i>Reserved</i>
VBA:\$9A	0 - 2	<i>Reserved</i>
VBA:\$9C	0 - 2	<i>Reserved</i>
VBA:\$9E	0 - 2	<i>Reserved</i>
VBA:\$A0	0 - 2	<i>Reserved</i>
VBA:\$A2	0 - 2	<i>Reserved</i>
VBA:\$A4	0 - 2	<i>Reserved</i>
VBA:\$A6	0 - 2	<i>Reserved</i>
VBA:\$A8	0 - 2	<i>Reserved</i>
VBA:\$AA	0 - 2	<i>Reserved</i>
VBA:\$AC	0 - 2	<i>Reserved</i>
VBA:\$AE	0 - 2	<i>Reserved</i>
VBA:\$B0	0 - 2	<i>Reserved</i>
VBA:\$B2	0 - 2	<i>Reserved</i>
VBA:\$B4	0 - 2	<i>Reserved</i>
VBA:\$B6	0 - 2	<i>Reserved</i>
VBA:\$B8	0 - 2	<i>Reserved</i>
VBA:\$BA	0 - 2	<i>Reserved</i>
:	:	:
VBA:\$FE	0 - 2	<i>Reserved</i>

## C.2 Interrupt Source Priorities (within an IPL)

Table C-4 Interrupt Sources Priorities Within an IPL

Priority	Interrupt Source
<b>Level 3 (Nonmaskable)</b>	
Highest	Hardware $\overline{\text{RESET}}$
	Stack Error
	Illegal Instruction
	Debug Request Interrupt
	Trap
Lowest	Non-Maskable Interrupt
<b>Levels 0, 1, 2 (Maskable)</b>	
Highest	$\overline{\text{IRQA}}$ (External Interrupt)
	$\overline{\text{IRQB}}$ (External Interrupt)
	$\overline{\text{IRQC}}$ (External Interrupt)
	$\overline{\text{IRQD}}$ (External Interrupt)
	DMA Channel 0 Interrupt
	DMA Channel 1 Interrupt
	DMA Channel 2 Interrupt
	DMA Channel 3 Interrupt
	DMA Channel 4 Interrupt
	DMA Channel 5 Interrupt
	ESAI Receive Data with Exception Status
	ESAI Receive Even Data
	ESAI Receive Data
	ESAI Receive Last Slot
	ESAI Transmit Data with Exception Status
	ESAI Transmit Last Slot
	ESAI Transmit Even Data
	ESAI Transmit Data

**Table C-4 Interrupt Sources Priorities Within an IPL (continued)**

Priority	Interrupt Source
	SHI Bus Error
	SHI Receive Overrun Error
	SHI Transmit Underrun Error
	SHI Receive FIFO Full
	SHI Transmit Data
	SHI Receive FIFO Not Empty
	DAX Transmit Underrun Error
	DAX Block Transferred
	DAX Transmit Register Empty
	TIMER0 Overflow Interrupt
	TIMER0 Compare Interrupt
	TIMER1 Overflow Interrupt
	TIMER1 Compare Interrupt
	TIMER2 Overflow Interrupt
	TIMER2 Compare Interrupt
	ESAI_1 Receive Data with Exception Status
	ESAI_1 Receive Even Data
	ESAI_1 Receive Data
	ESAI_1 Receive Last Slot
	ESAI_1 Transmit Data with Exception Status
	ESAI_1 Transmit Last Slot
	ESAI_1 Transmit Even Data
	ESAI_1 Transmit Data
	EFCOP Data input buffer empty
Lowest	EFCOP Data output buffer full

## C.3 Programming Sheets

The worksheets shown on the following pages contain listings of major programmable registers for the DSP56371. The programming sheets are grouped into the following order:

- Central Processor
- Serial Host Interface (SHI)
- Two Enhanced Serial Audio Interfaces (ESAI and ESAI\_1)
- Digital Audio Interface (DAX)
- Timer/Event Controller (TEC)
- GPIO (Ports B-E)

Each sheet provides room to write in the value of each bit and the hexadecimal value for each register. Programmers can photocopy these sheets and reuse them for each application development project.

For details on the instruction set of the DSP56300 family chips, see the *DSP56300 Family Manual*.

Application: \_\_\_\_\_

Date: \_\_\_\_\_  
Programmer: \_\_\_\_\_

Sheet 1 of 5

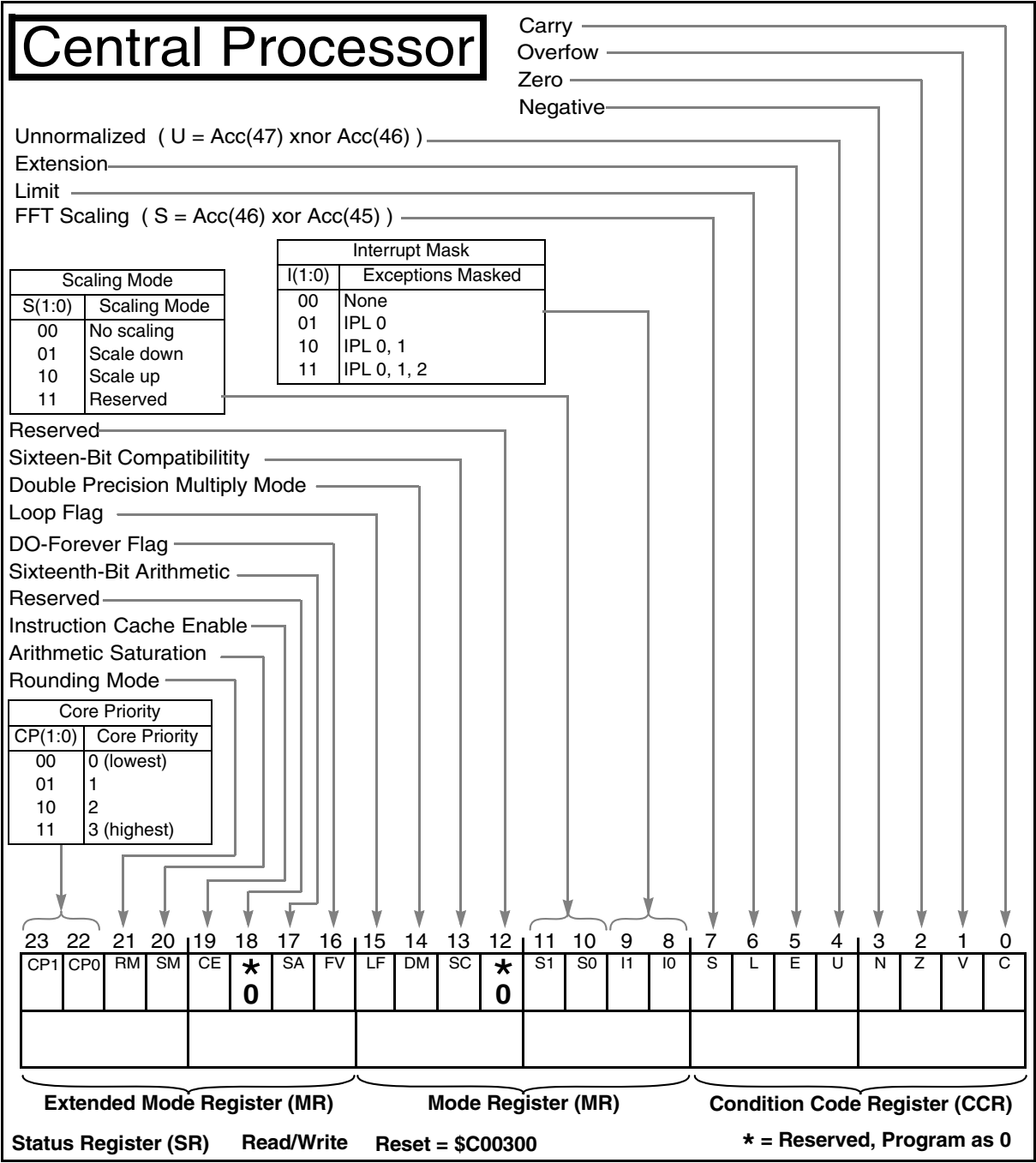


Figure C-1 Status Register (SR)



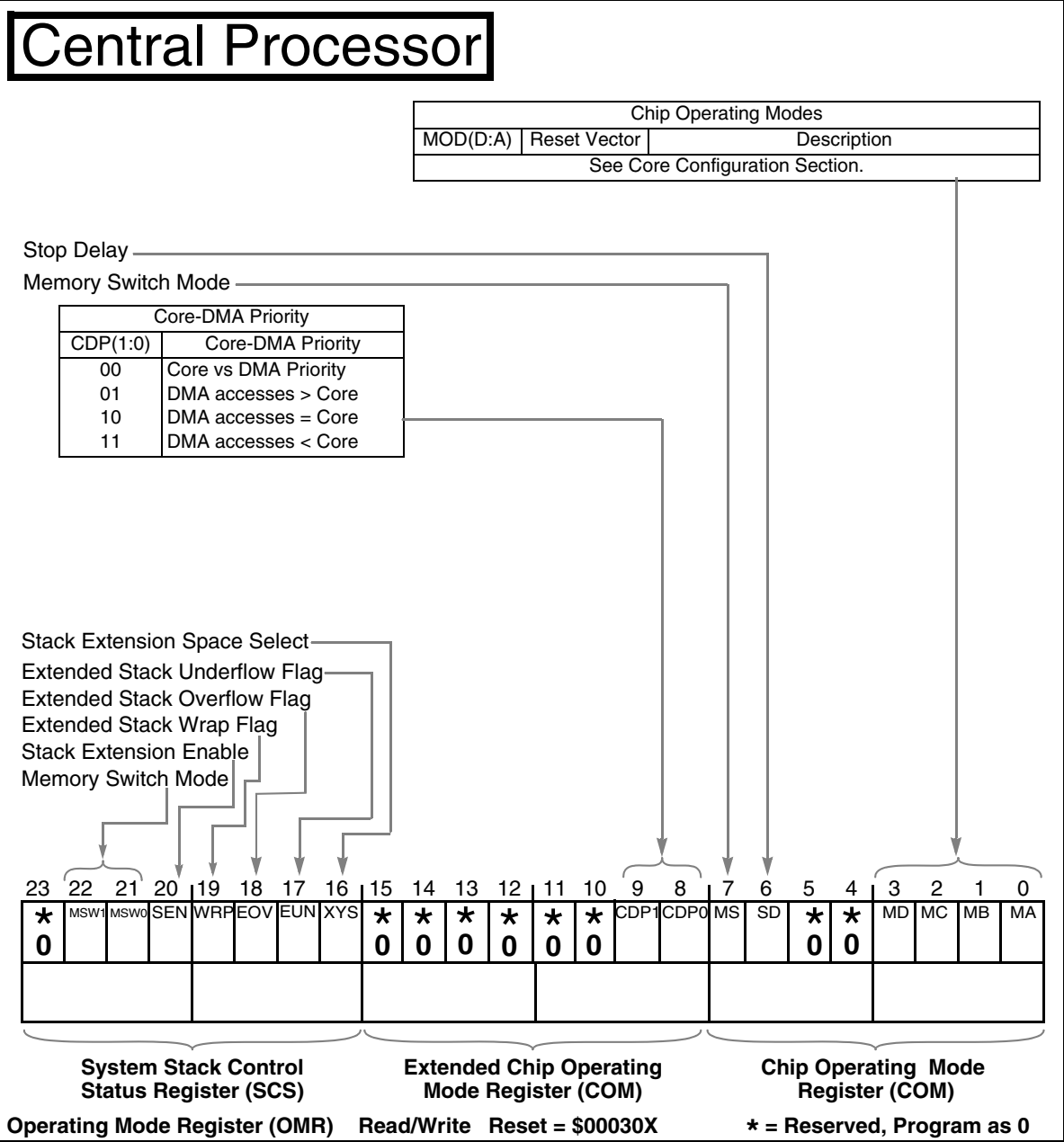


Figure C-2 Operating Mode Register (OMR)

Because of an order from the United States International Trade Commission, BGA-packaged product lines and part numbers indicated here currently are not available from Freescale for import or sale in the United States prior to September 2010: DSP56303

Application: \_\_\_\_\_

Date: \_\_\_\_\_

Programmer: \_\_\_\_\_

Sheet 3 of 5

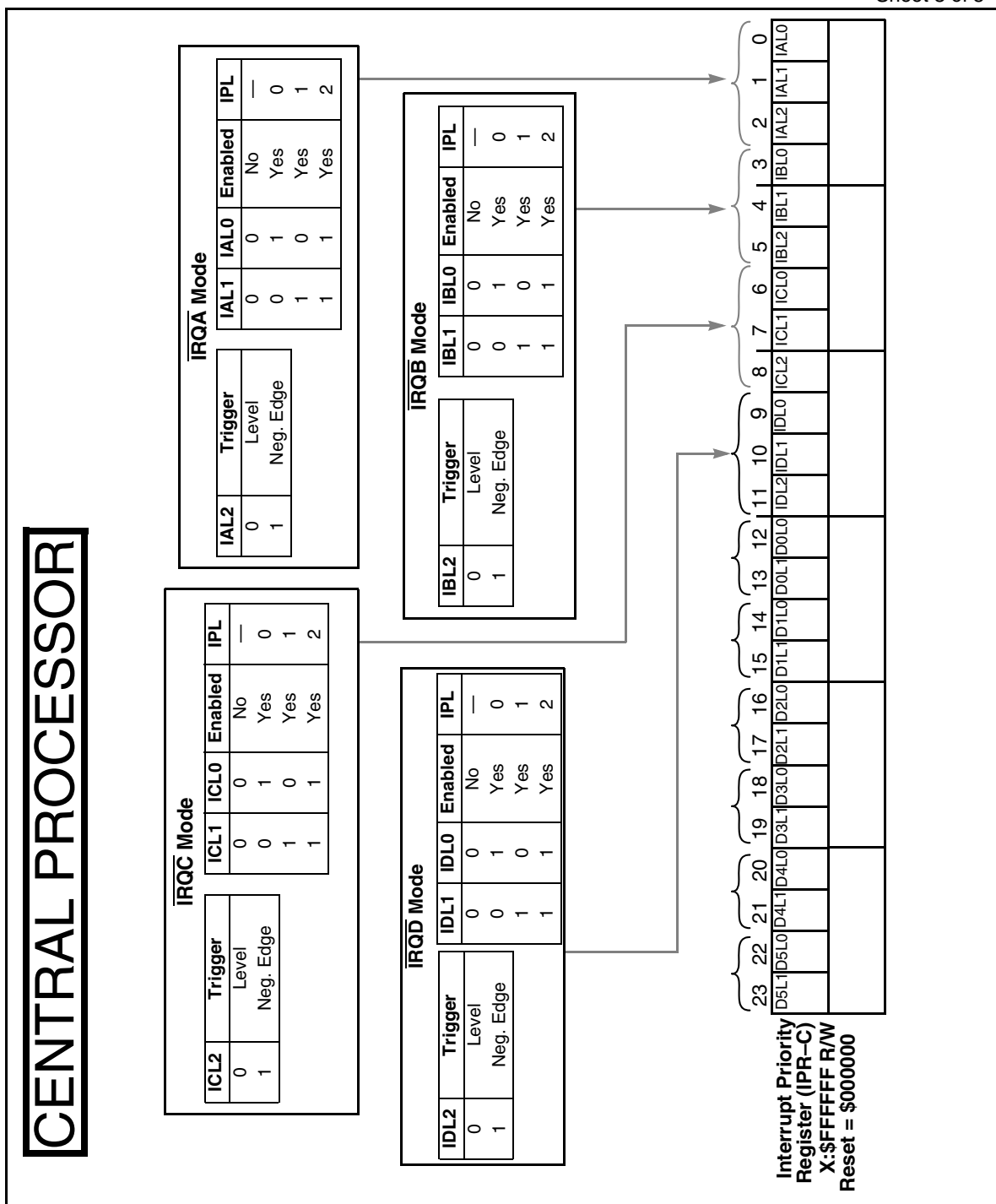
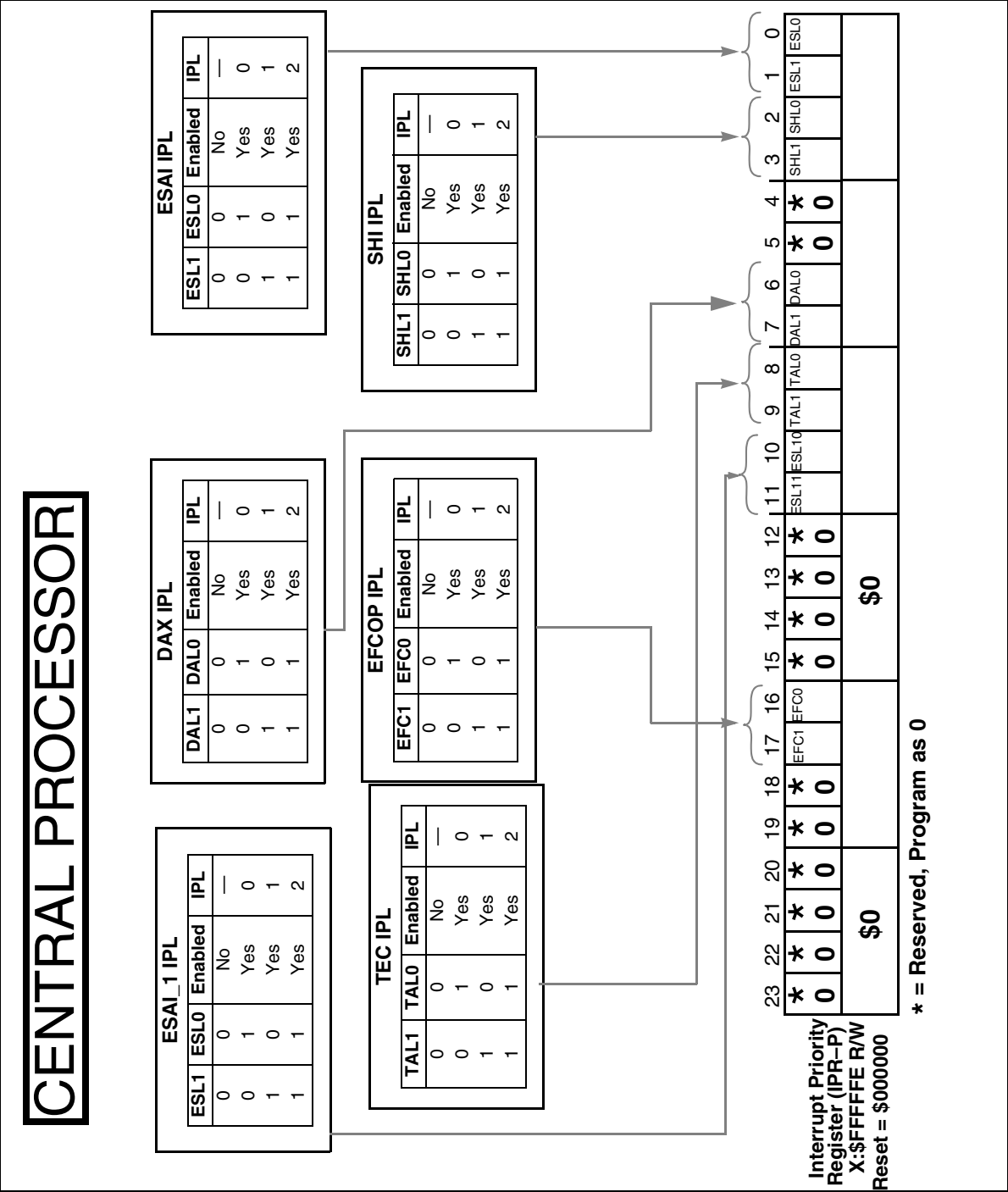


Figure C-3 Interrupt Priority Register-Core (IPR-C)



Application: \_\_\_\_\_

Date: \_\_\_\_\_

Programmer: \_\_\_\_\_

Sheet 5 of 5

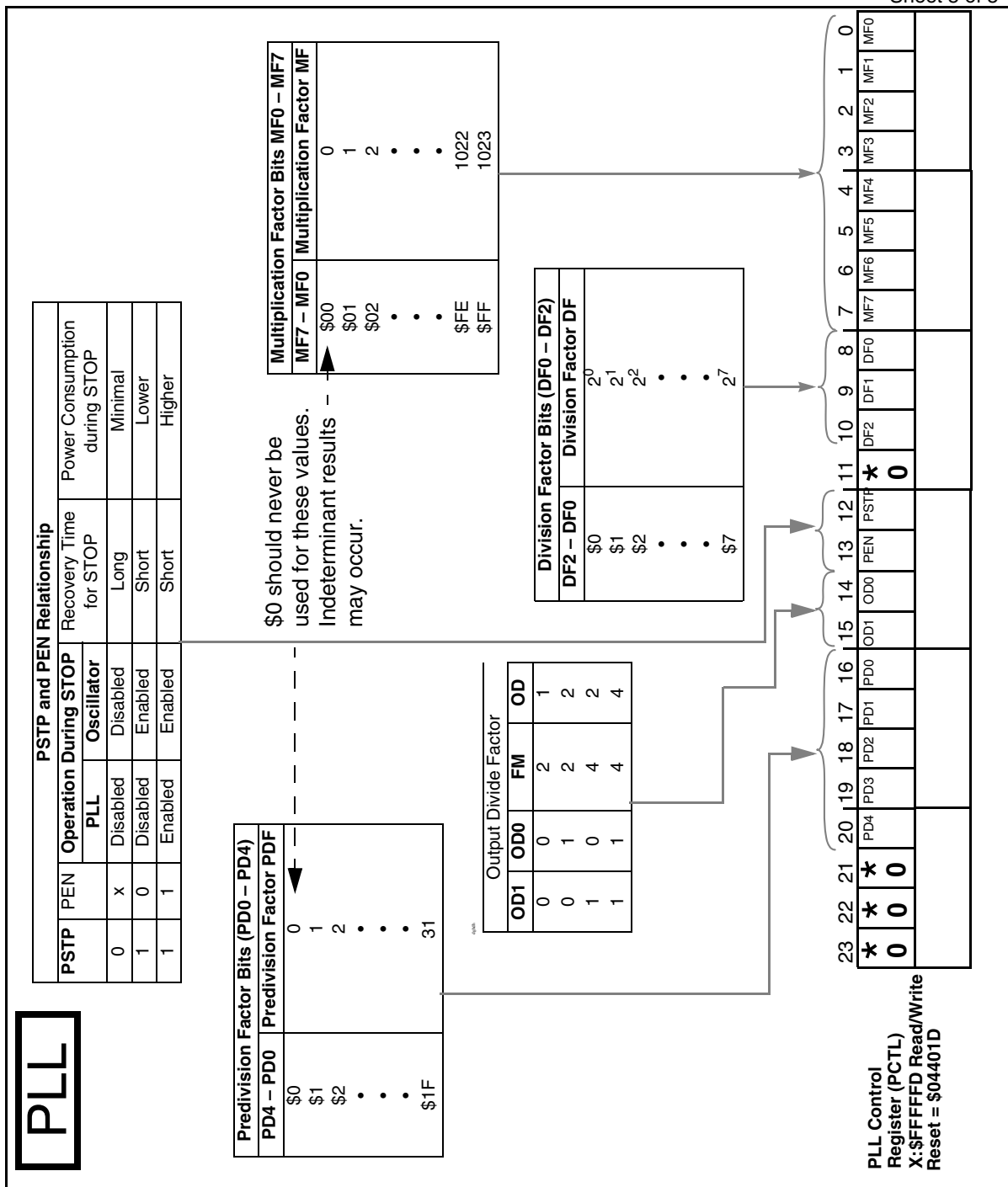


Figure C-5 Phase Lock Loop Control Register (PCTL)

Application: \_\_\_\_\_

Date: \_\_\_\_\_

Programmer: \_\_\_\_\_

Sheet 1 of 3

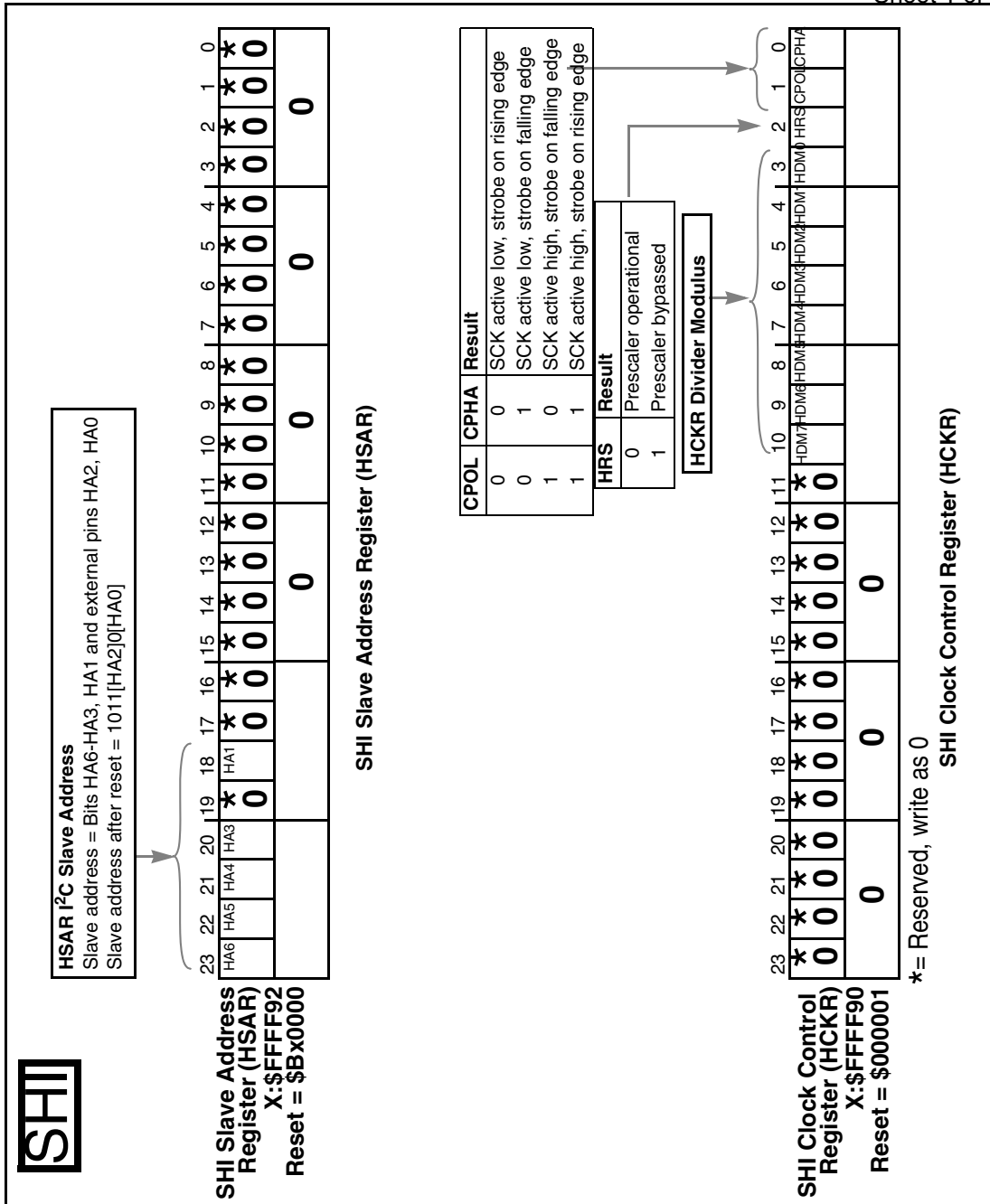


Figure C-6 SHI Slave Address and Clock Control Registers

Application: \_\_\_\_\_

Date: \_\_\_\_\_

Programmer: \_\_\_\_\_

Sheet 2 of 3

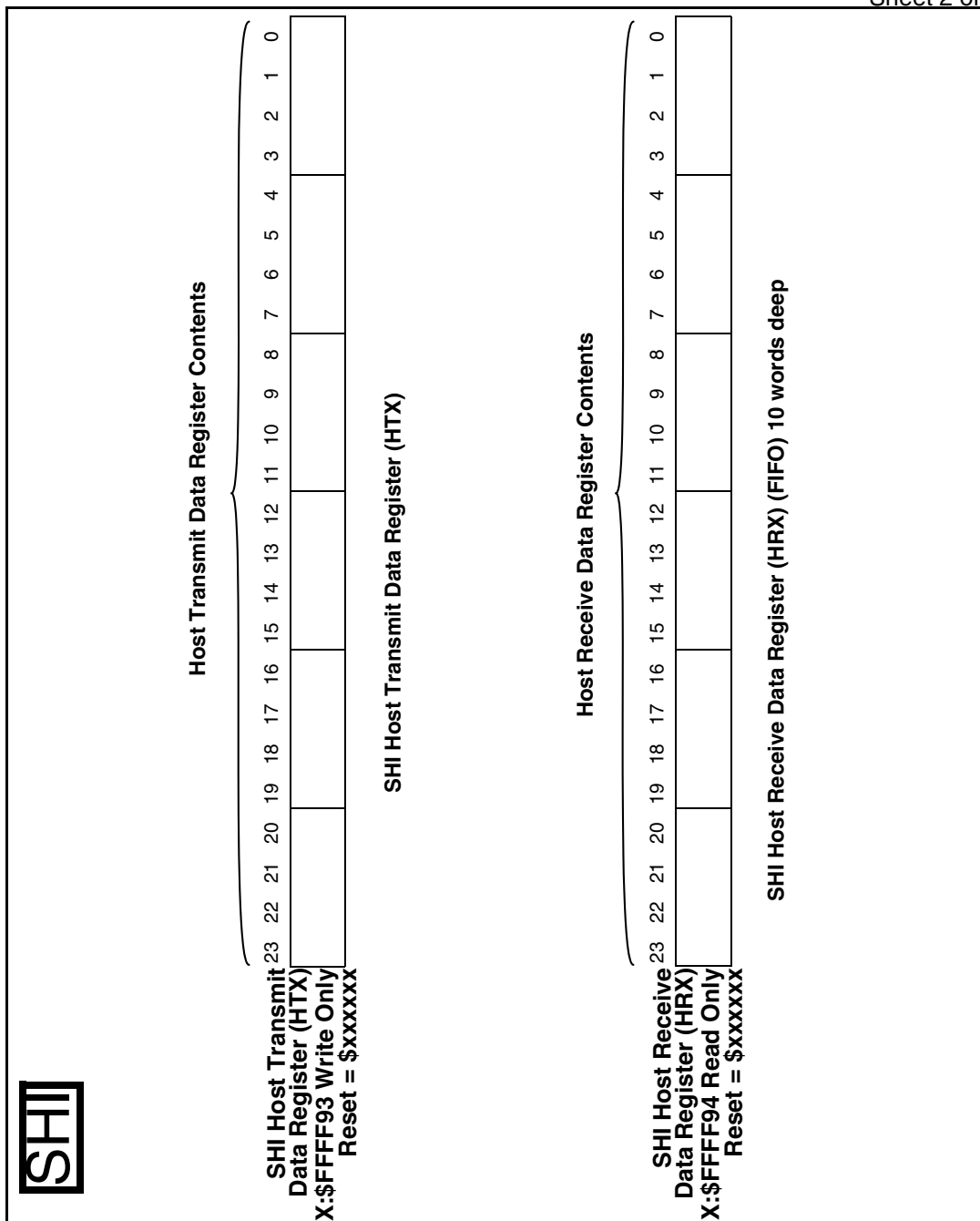


Figure C-7 SHI Transmit and Receive Data Registers

Application: \_\_\_\_\_

Date: \_\_\_\_\_

Programmer: \_\_\_\_\_

Sheet 3 of 3

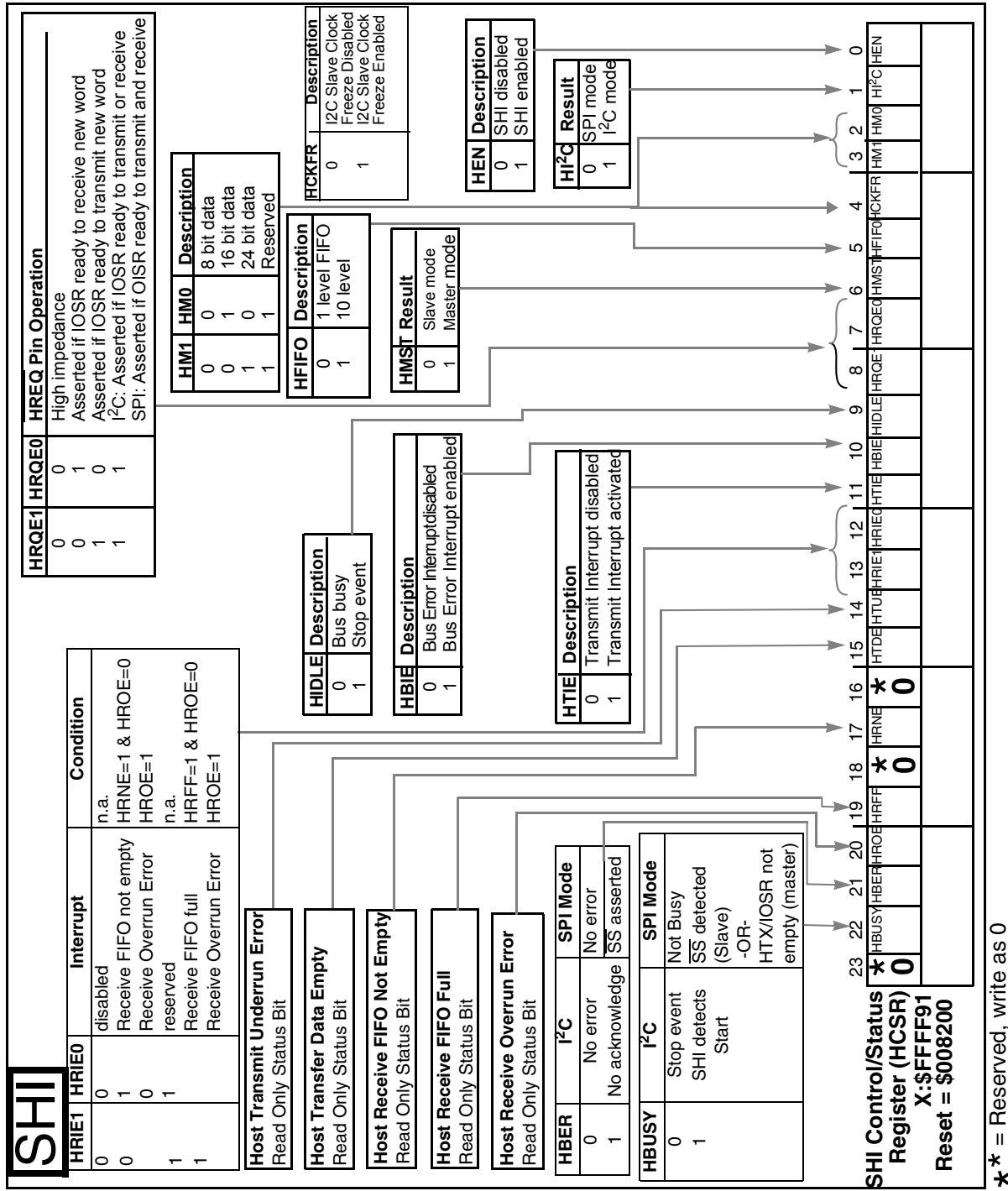
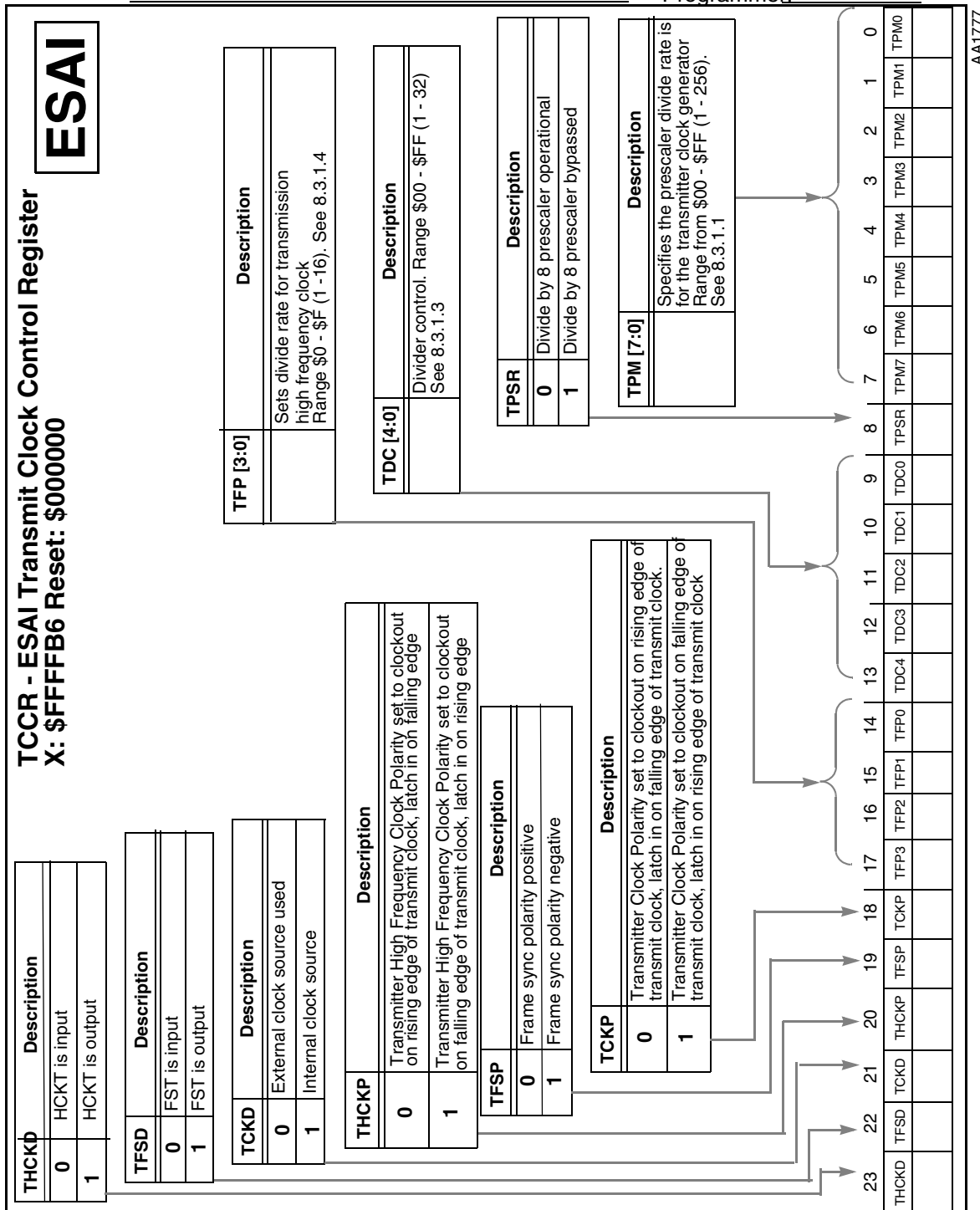


Figure C-8 SHI Host Control/Status Register



### Figure C-9 ESAI Transmit Clock Control Register



Application: \_\_\_\_\_ Date: \_\_\_\_\_

Programmer: \_\_\_\_\_

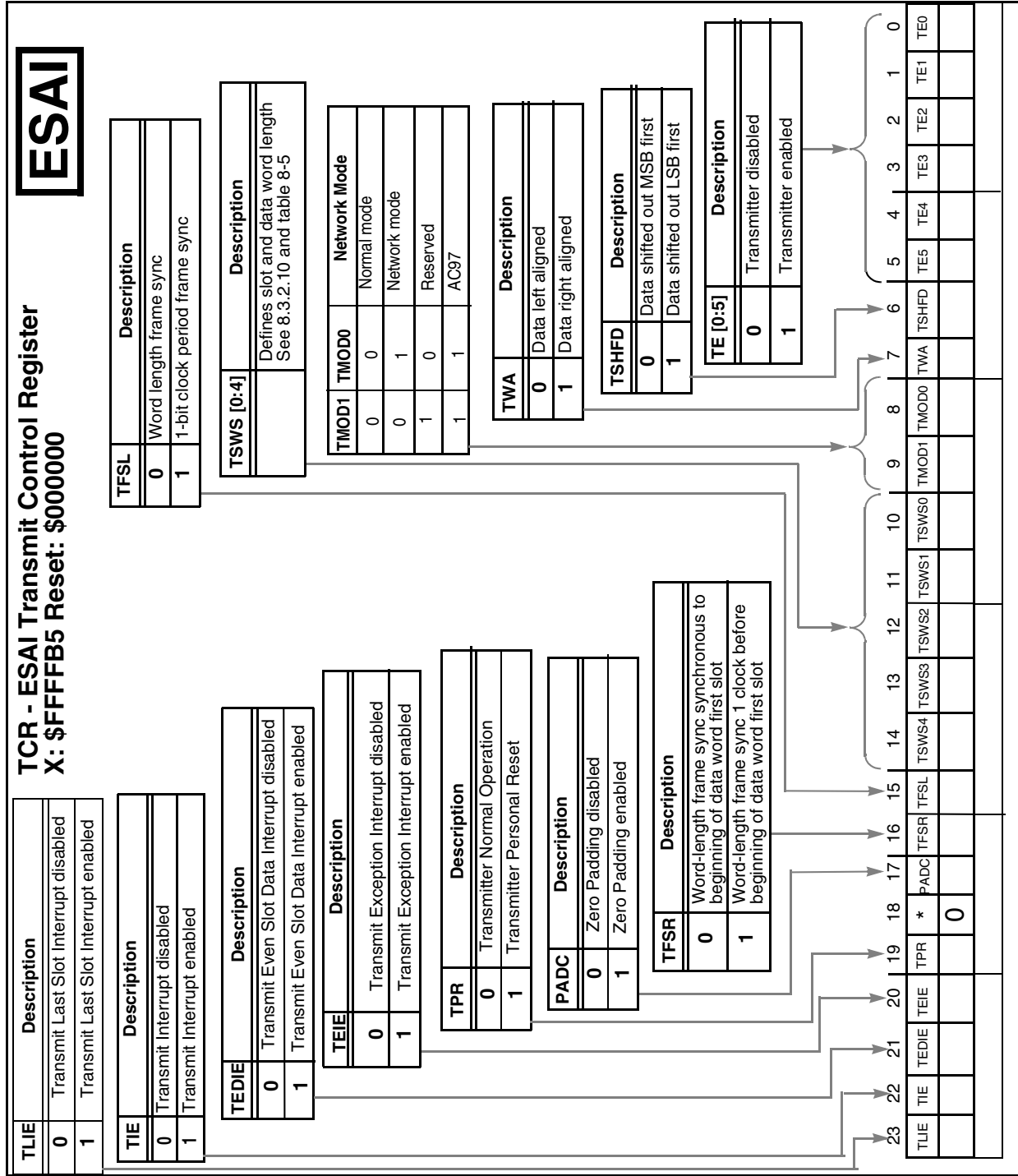


Figure C-10 ESAI Transmit Control Register

Application: \_\_\_\_\_

Date: \_\_\_\_\_

Programmer: \_\_\_\_\_

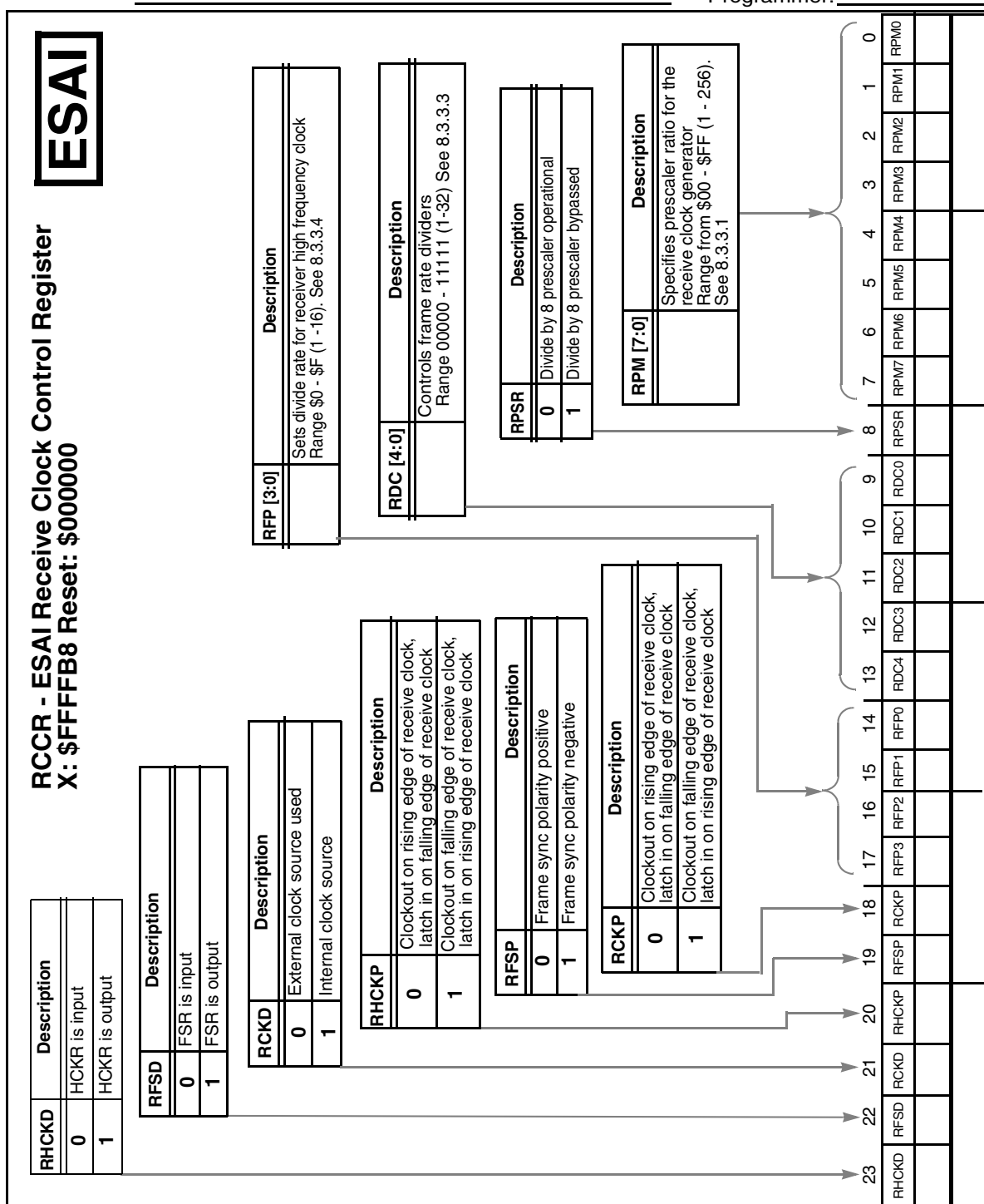


Figure C-11 ESAI Receive Clock Control Register

Application: \_\_\_\_\_

Date: \_\_\_\_\_

Programmer: \_\_\_\_\_

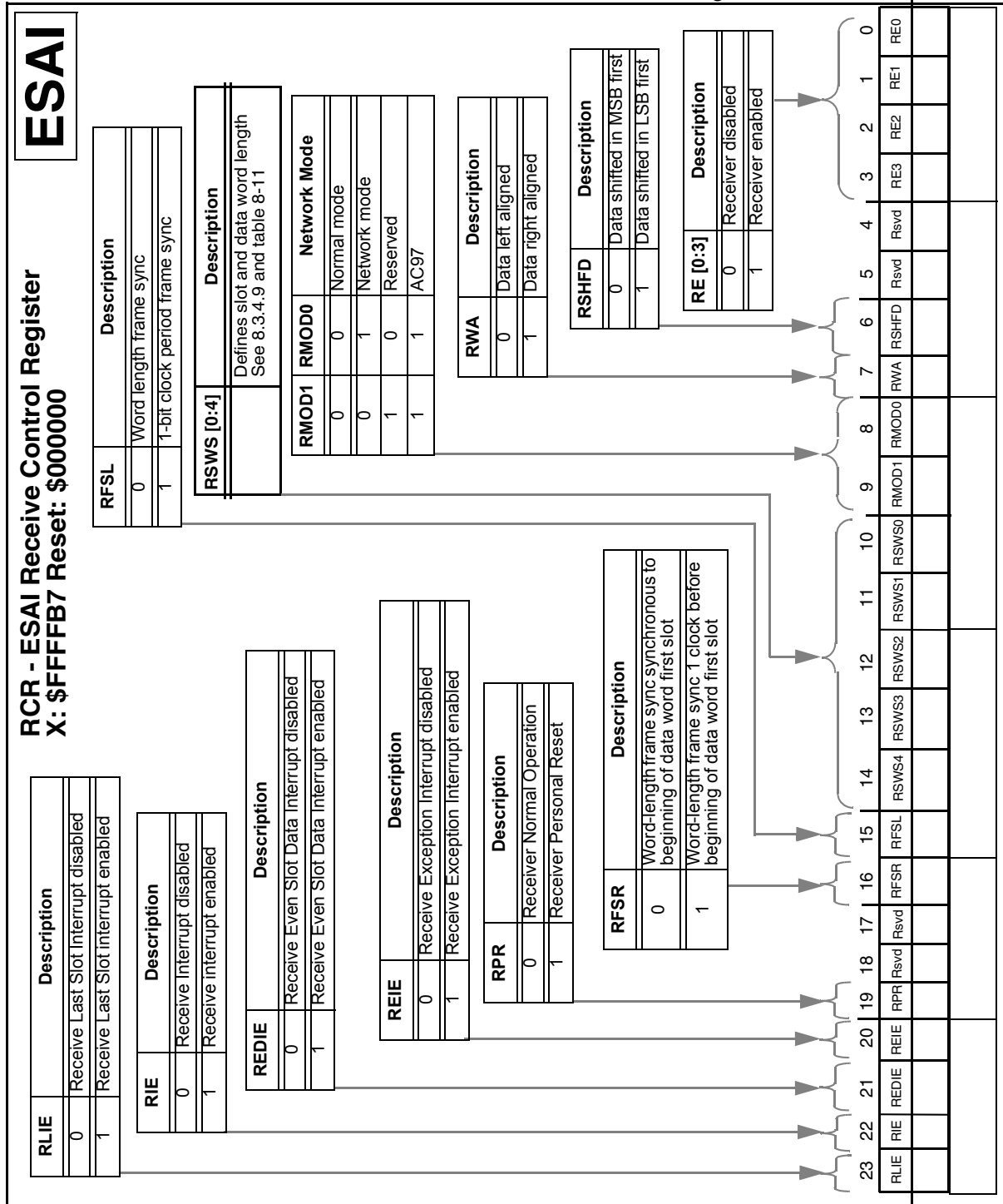


Figure C-12 ESAI Receive Control Register

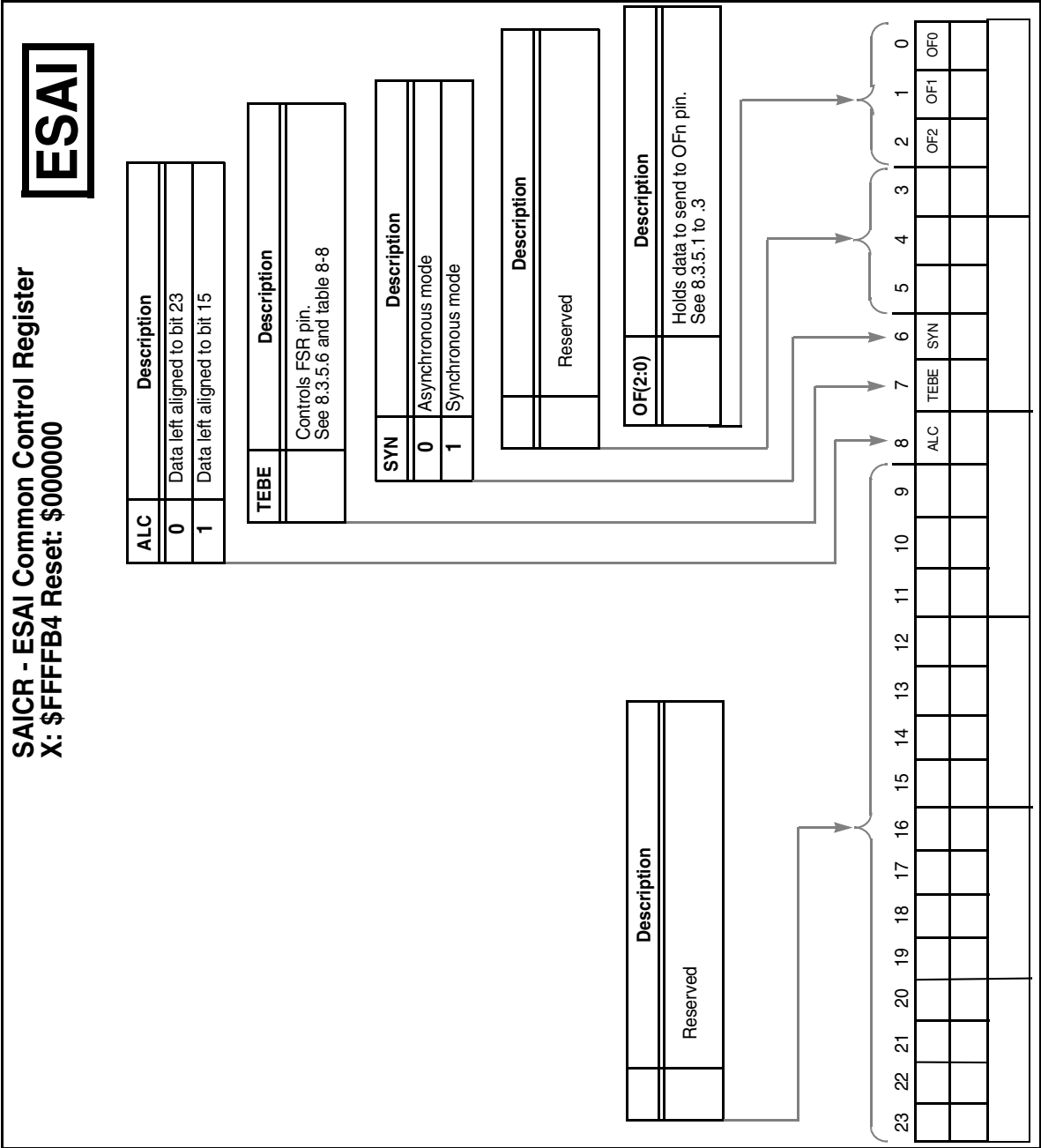


Figure C-13 ESAI Common Control Register

Application: \_\_\_\_\_ Date: \_\_\_\_\_

Programmer: \_\_\_\_\_

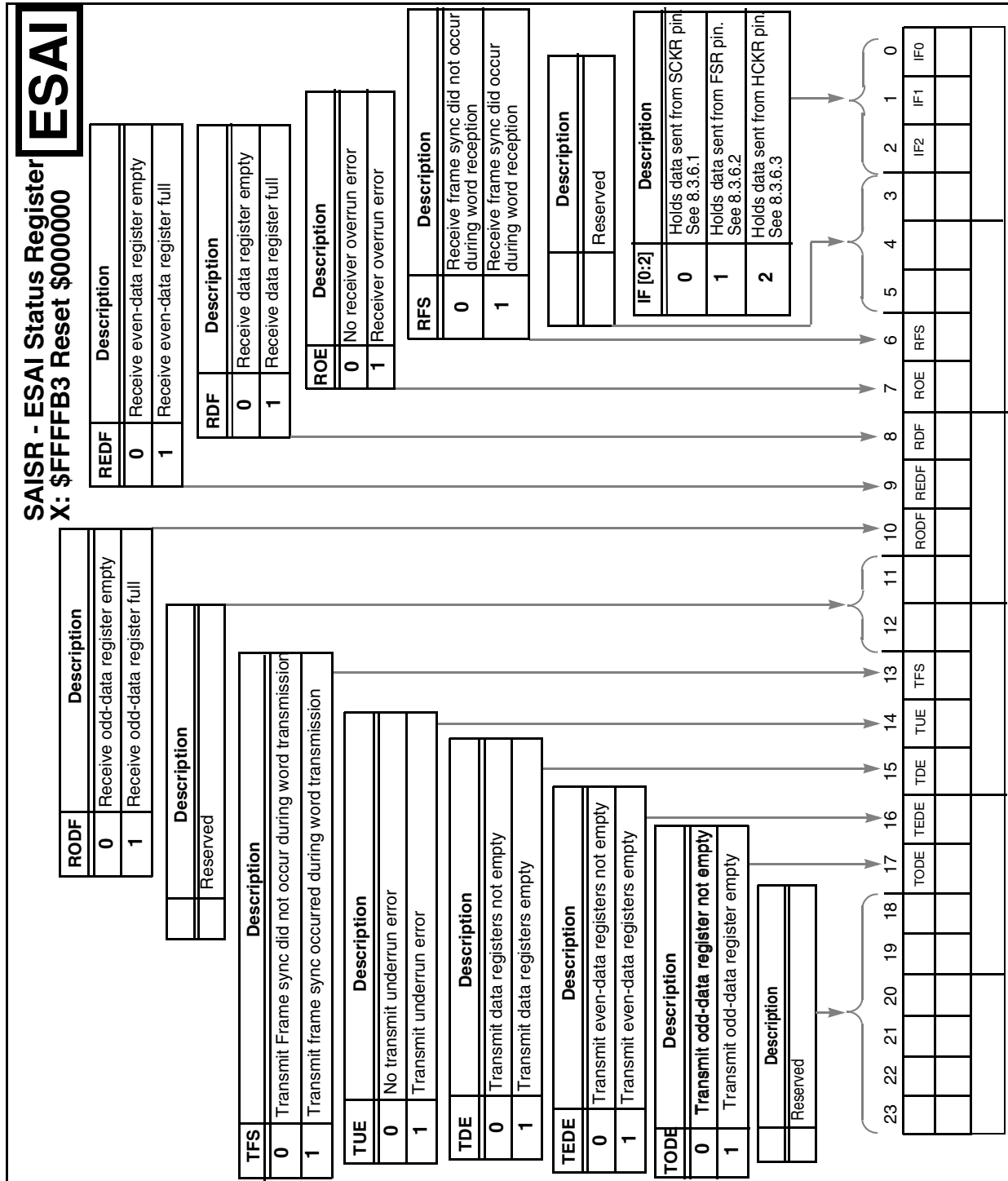


Figure C-14 ESAI Status Register

## TCCR\_1 - ESI\_1 Transmit Clock Control Register

Y: \$FFFF96 Reset: \$000000

# ESAI 1

THCKD	Description
0	HCKT_1 is input
1	HCKT_1 is output

TFSD	Description
0	FST_1 is input
1	FST_1 is output

TCKD	Description
0	External clock source used
1	Internal clock source

THCKP	Description
0	Transmitter High Frequency on rising edge of transmit clock
1	Transmitter High Frequency on falling edge of transmit clock

TFSP	Description
0	Frame sync polarity positive
1	Frame sync polarity negative

TCKP	Description
0	Transmitter Clock transmit clock, late
1	Transmitter Clock transmit clock, late

### Figure C-15 ESAI\_1 Transmit Clock Control Register

Application: \_\_\_\_\_ Date: \_\_\_\_\_

Programmer: \_\_\_\_\_

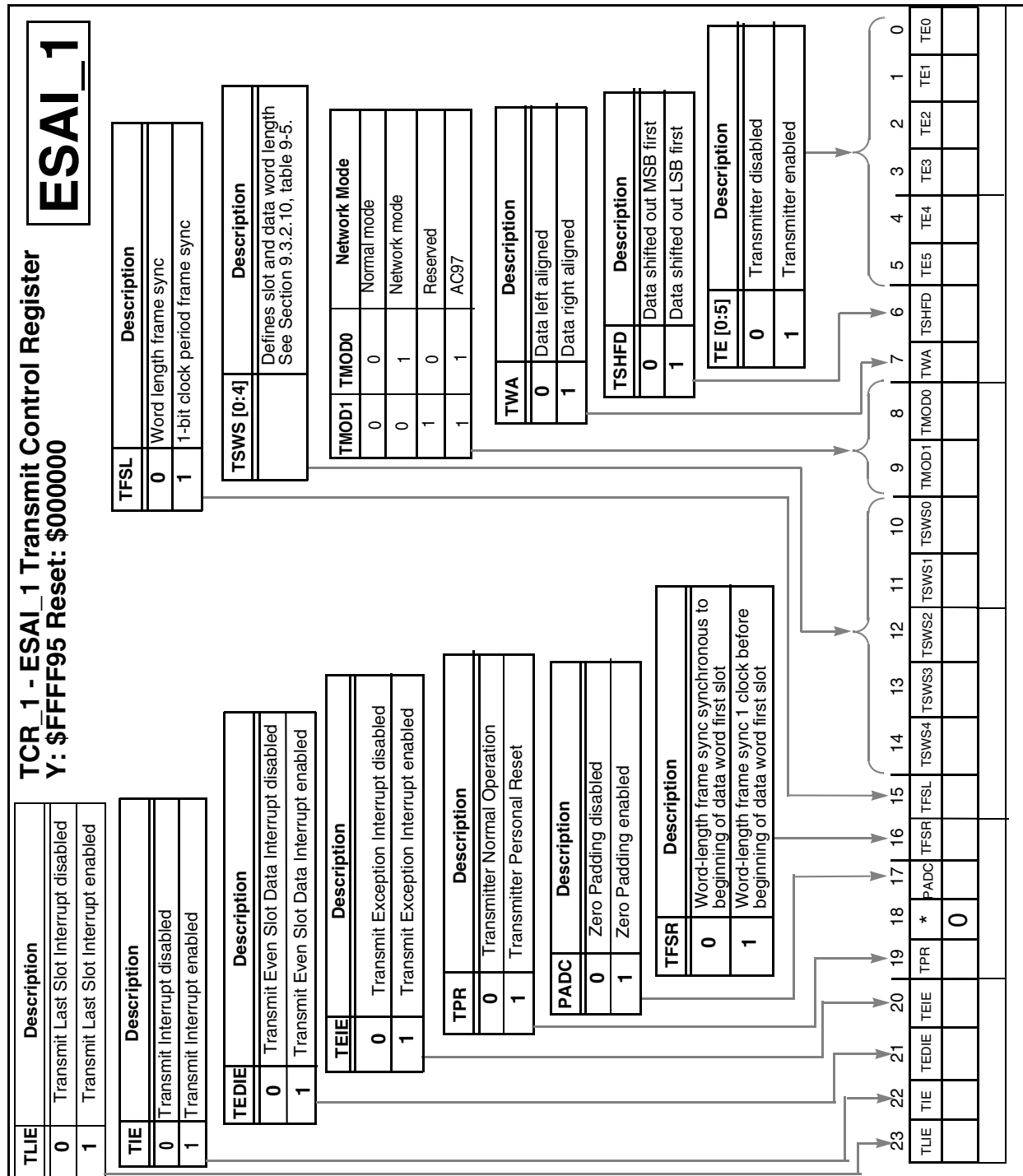


Figure C-16 ESAI\_1 Transmit Control Register

Application: \_\_\_\_\_

Date: \_\_\_\_\_

Programmer: \_\_\_\_\_

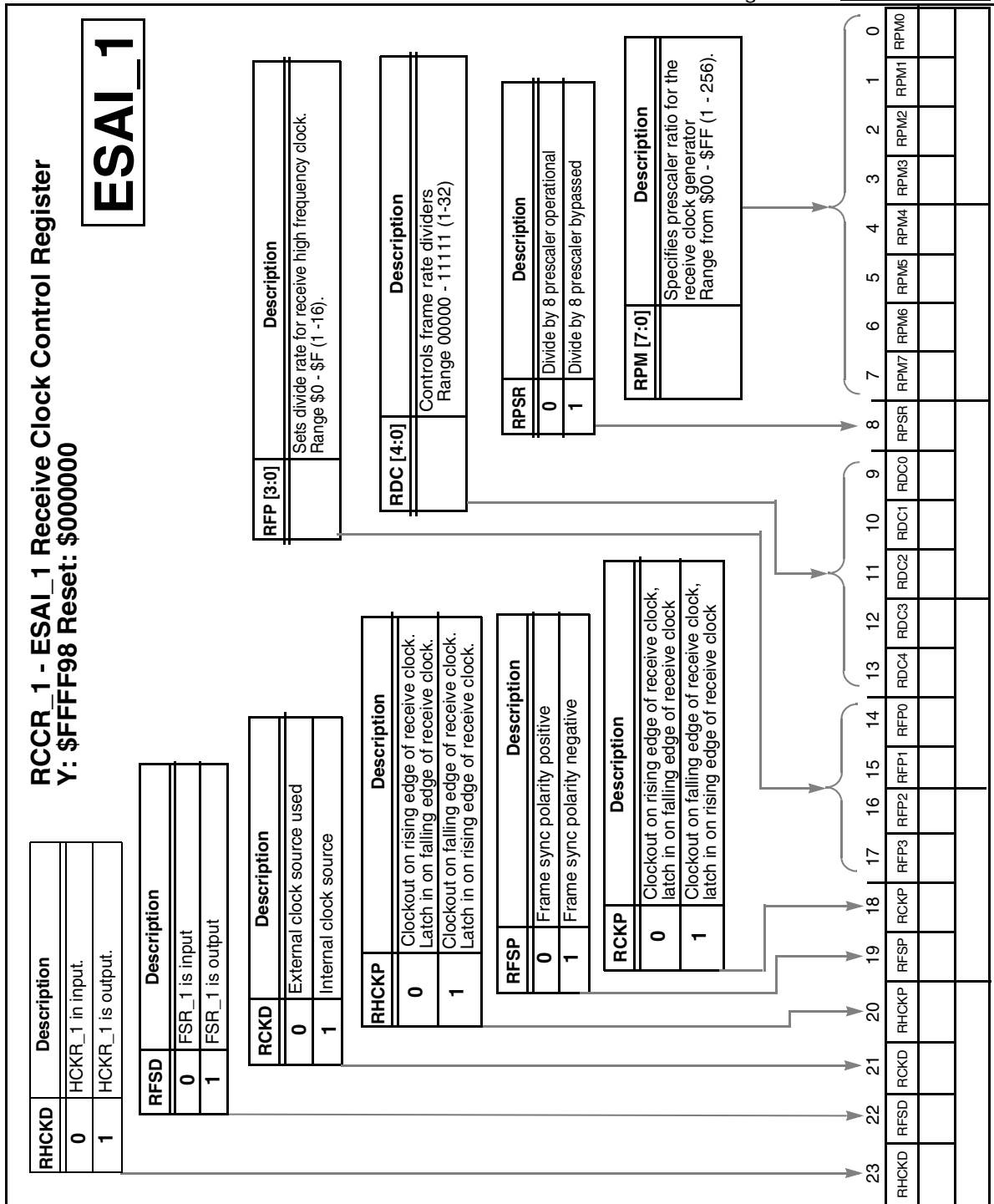


Figure C-17 ESAI\_1 Receive Clock Control Register



Application: \_\_\_\_\_

Date: \_\_\_\_\_

Programmer: \_\_\_\_\_

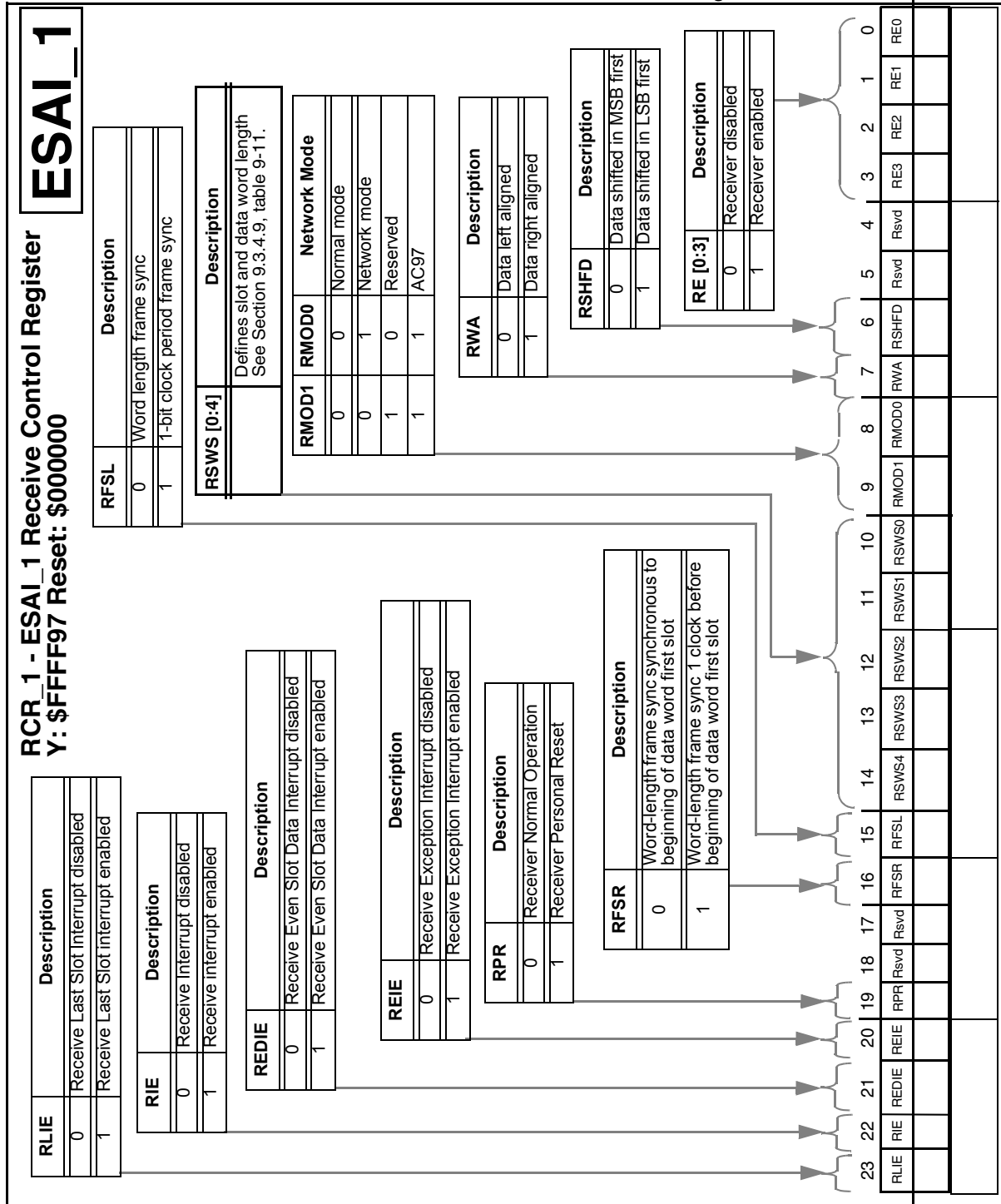


Figure C-18 ESAI\_1 Receive Control Register

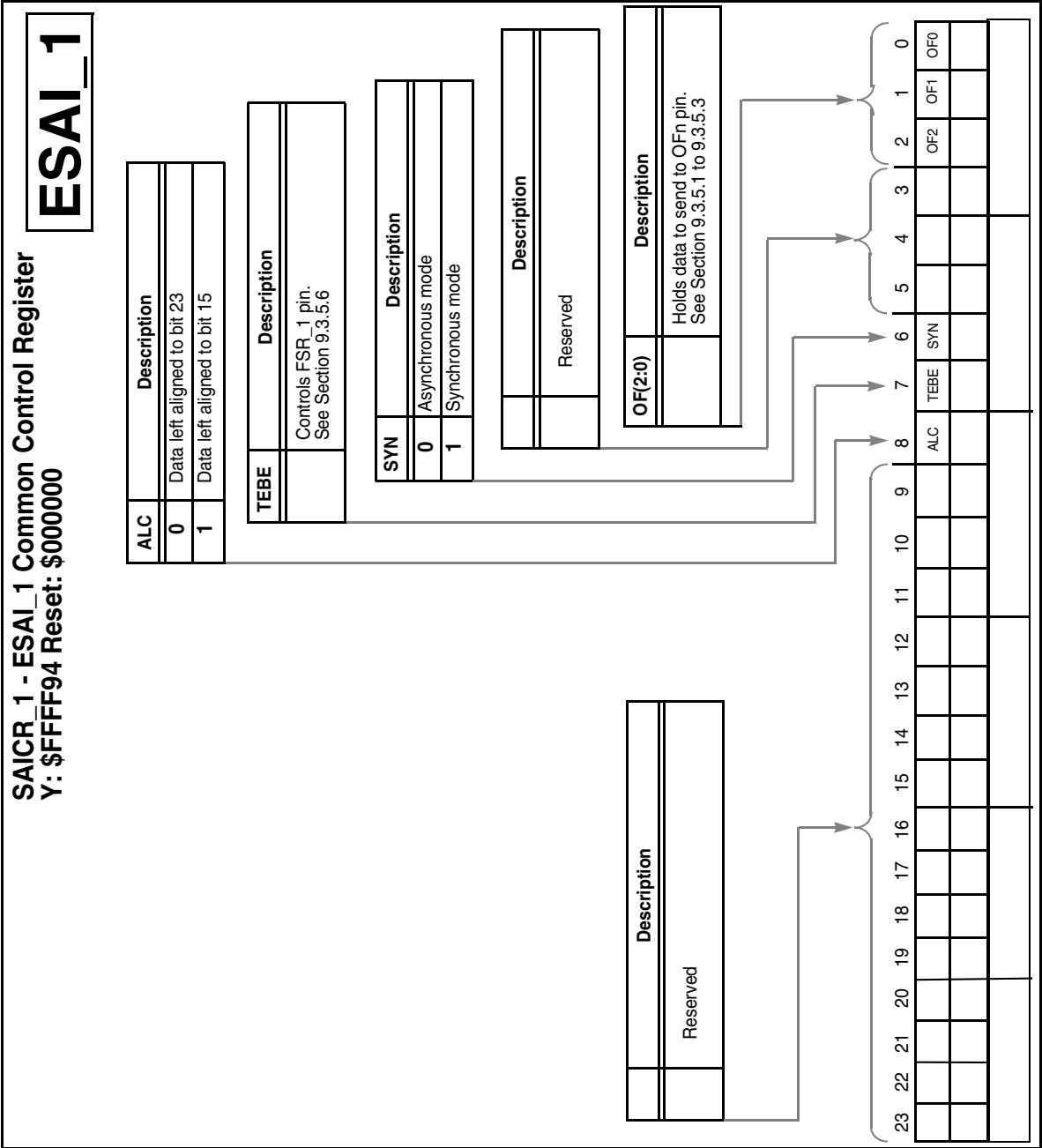
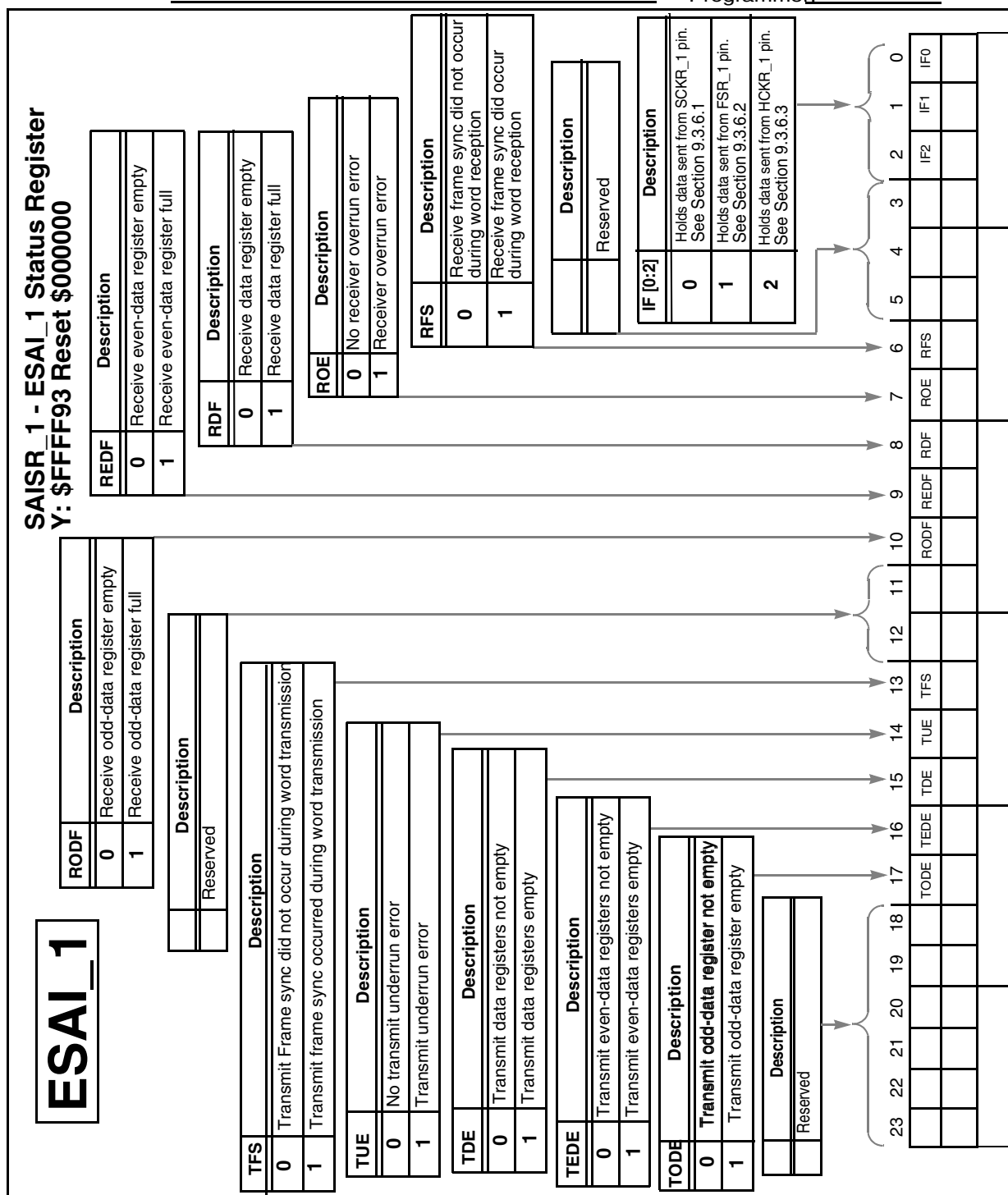


Figure C-19 ESAI\_1 Common Control Register

SAISR\_1 - ESAI\_1 Status Register  
Y: \$FFFF93 Reset \$000000

### Figure C-20 ESAI\_1 Status Register

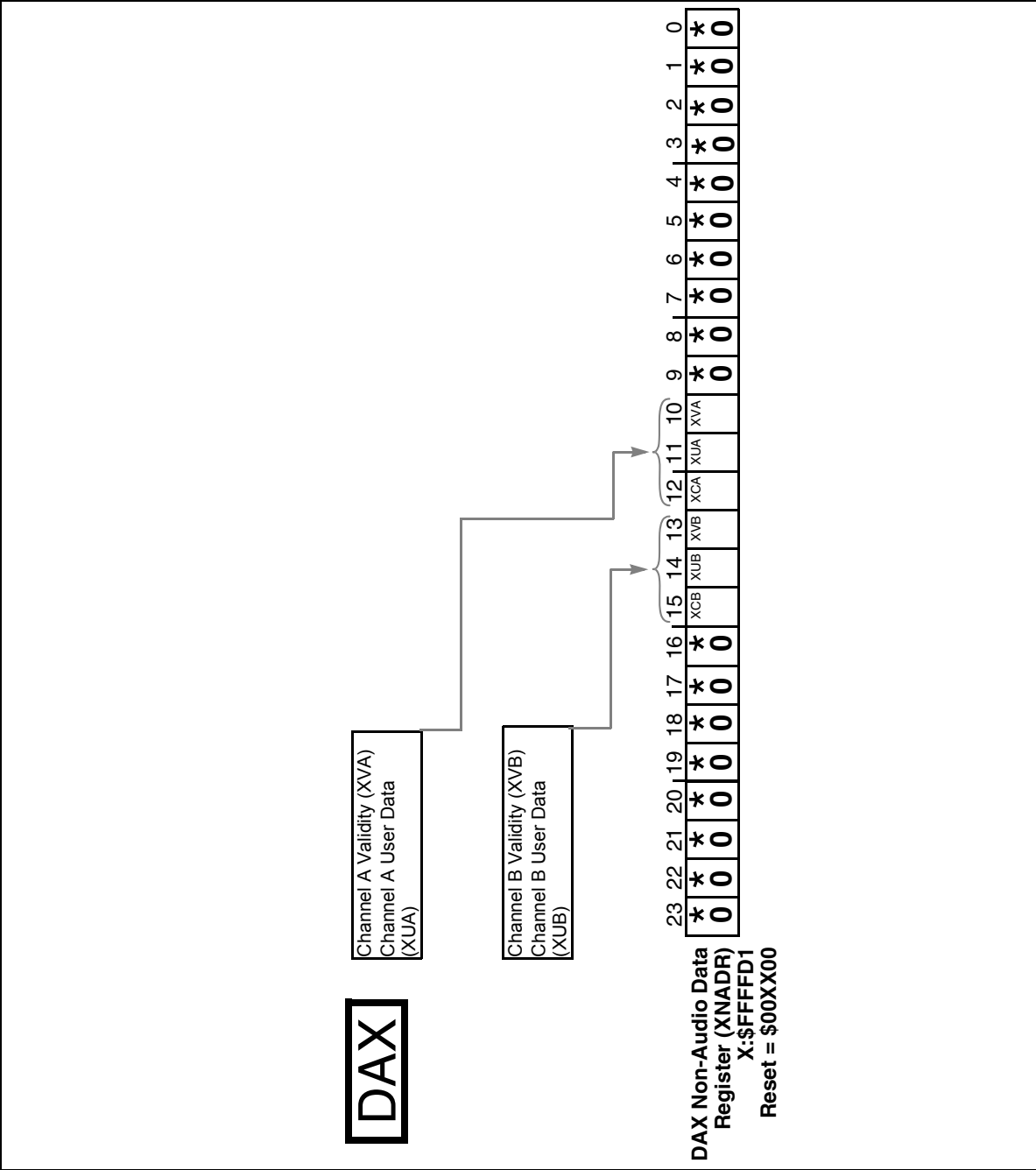


Figure C-21 DAX Non-Audio Data Register

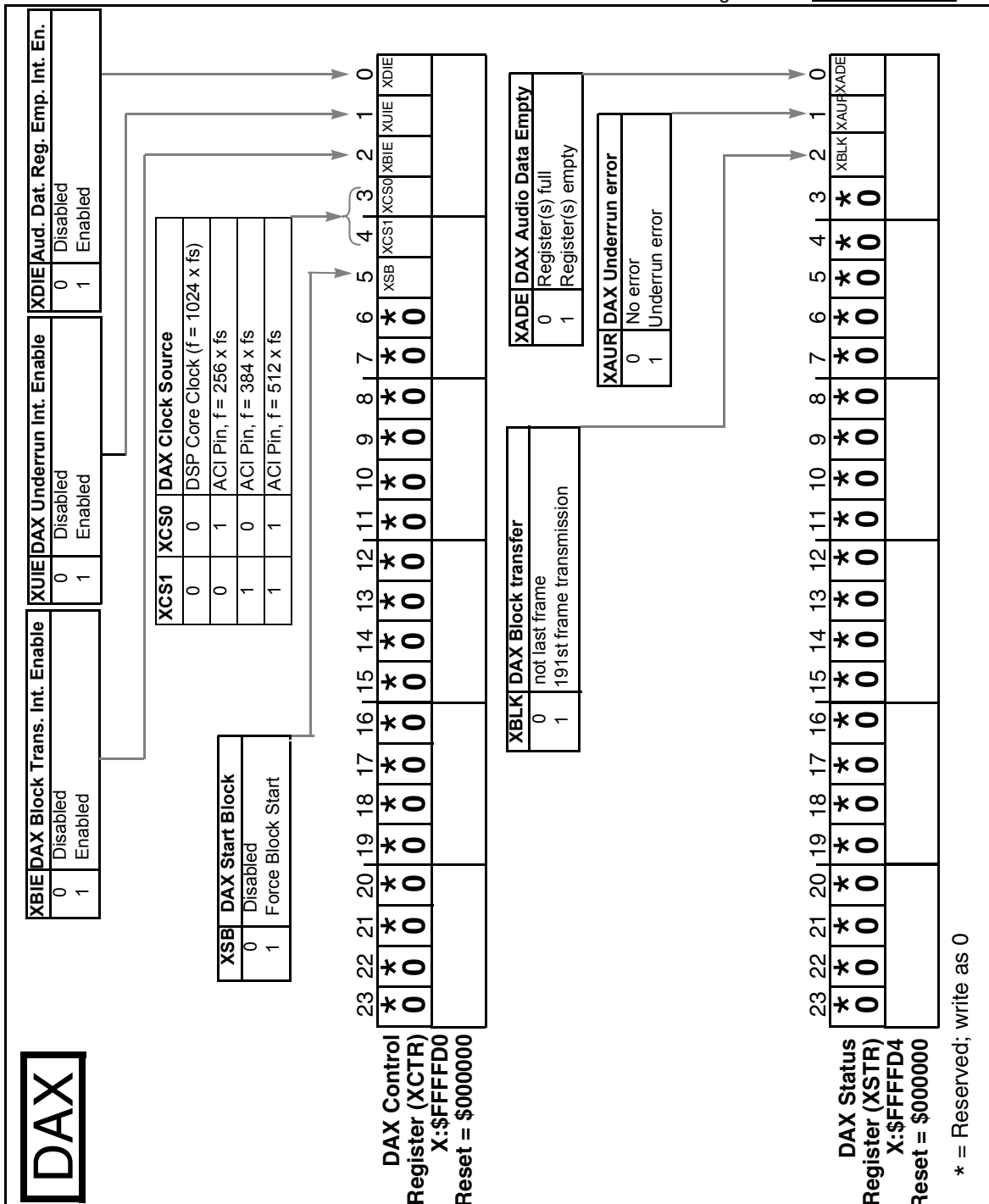


Figure C-22 DAX Control and Status Registers



Application: \_\_\_\_\_

Date: \_\_\_\_\_

Programmer: \_\_\_\_\_

Sheet 2 of 3

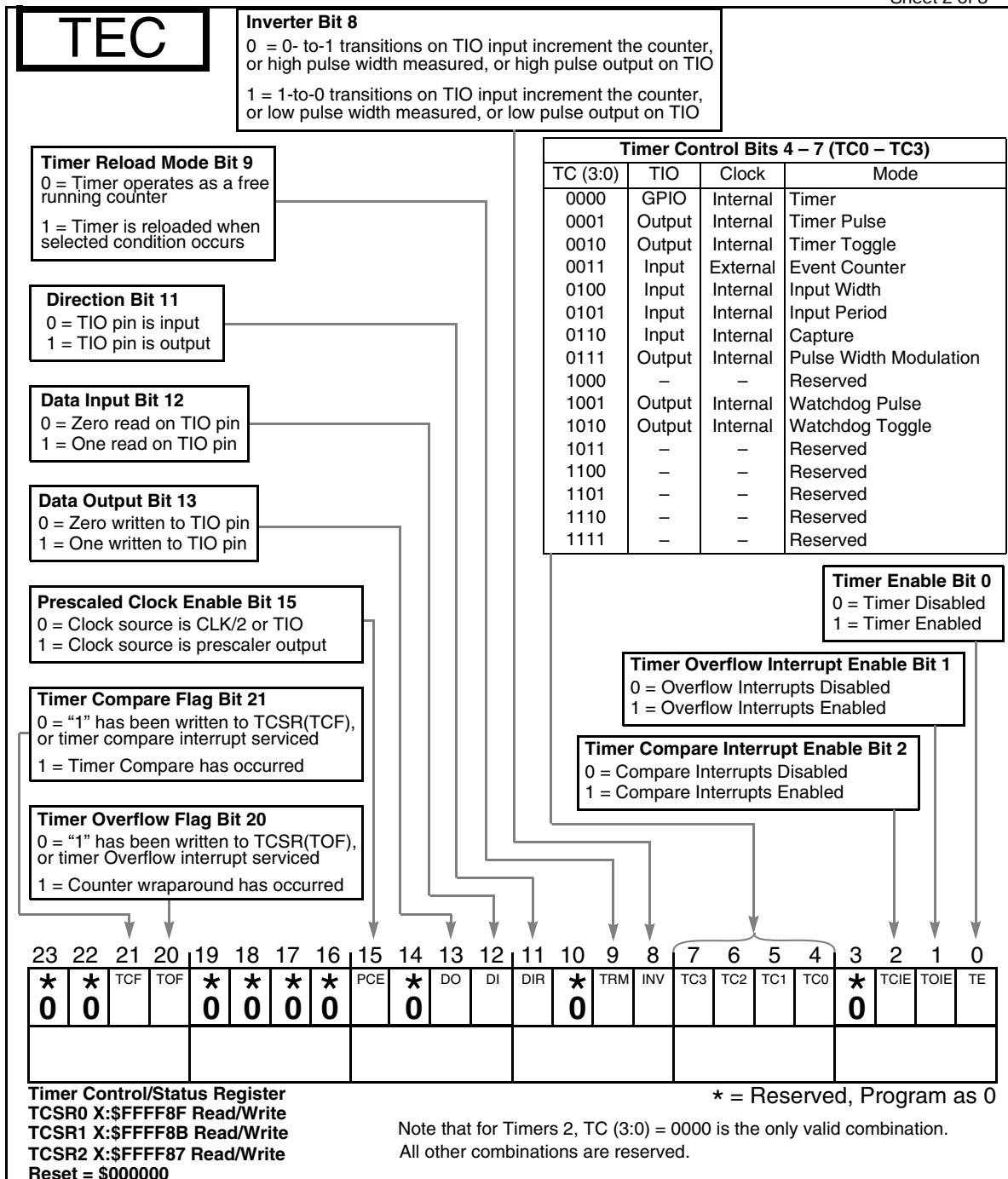


Figure C-24 Timer Control/Status Register

Application: \_\_\_\_\_

Date: \_\_\_\_\_

Programmer: \_\_\_\_\_

Sheet 3 of 3

TEC																							
23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Timer Reload Value																							
<b>Timer Load Register</b> TLR0 X:\$FFFF8E Write Only TLR1 X:\$FFFF8A Write Only TLR2 X:\$FFFF86 Write Only Reset = \$XXXXXX																							
23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Value Compared to Counter Value																							
<b>Timer Compare Register</b> TCPR0 X:\$FFFF8D Read/Write TCPR1 X:\$FFFF89 Read/Write TCPR2 X:\$FFFF85 Read/Write Reset = \$XXXXXX																							
23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Timer Count Value																							
<b>Timer Count Register</b> TCR0 X:\$FFFF8C Read Only TCR1 X:\$FFFF88 Read Only TCR2 X:\$FFFF84 Read Only Reset = \$000000																							

Figure C-25 Timer Load, Compare and Count Registers

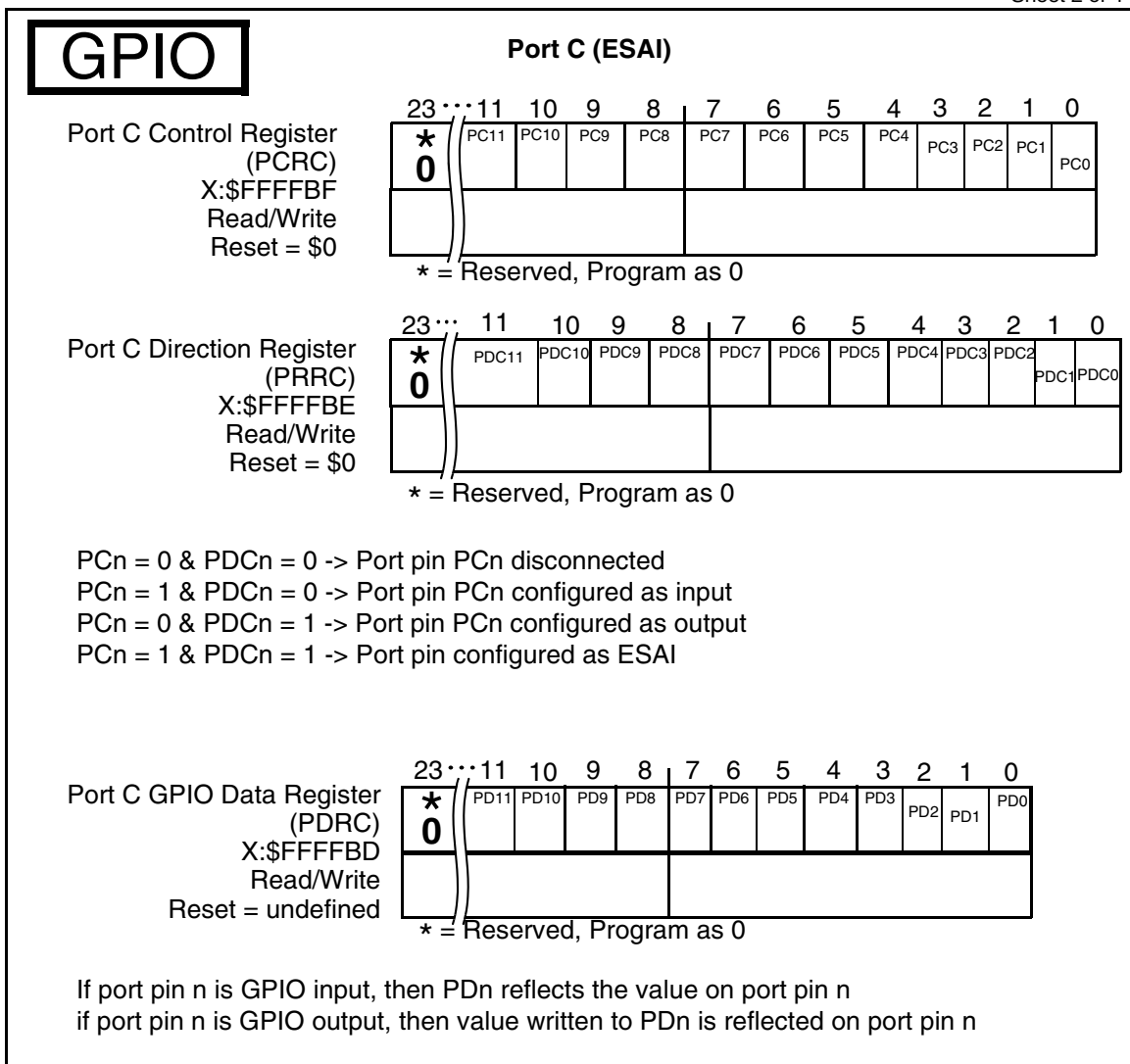


Application: \_\_\_\_\_

Date: \_\_\_\_\_

Programmer: \_\_\_\_\_

Sheet 2 of 4

**Figure C-26 GPIO Port C**

Application:\_\_\_\_\_

Date:\_\_\_\_\_

Programmer:\_\_\_\_\_

Sheet 3 of 4

**GPIO****Port D (DAX)**

	23	...	6	5	4	3	2	1	0
Port D Control Register (PCRD)	*		*	*	*	*	*	PC1	PC0
X:\$FFFFD7	0		0	0	0	0	0		
Read/Write									
Reset = \$0									

\* = Reserved, Program as 0

	23	...	6	5	4	3	2	1	0
Port D Direction Register (PRRD)	*		*	*	*	*	*	PDC1	PDC0
X:\$FFFFD6	0		0	0	0	0	0		
Read/Write									
Reset = \$0									

\* = Reserved, Program as 0

PCn = 0 &amp; PDCn = 0 -&gt; Port pin PDn disconnected

PCn = 1 &amp; PDCn = 0 -&gt; Port pin PDn configured as input

PCn = 0 &amp; PDCn = 1 -&gt; Port pin PDn configured as output

PCn = 1 &amp; PDCn = 1 -&gt; Port pin configured as DAX

	23	...	6	5	4	3	2	1	0
Port D GPIO Data Register (PDRD)	*		*	*	*	*	*	PD1	PD0
X:\$FFFFD5	0		0	0	0	0	0		
Read/Write									
Reset = \$0									

\* = Reserved, Program as 0

If port pin n is GPIO input, then PDn reflects the value on port pin n

if port pin n is GPIO output, then value written to PDn is reflected on port pin n

**Figure C-27 GPIO Port D**

Application: \_\_\_\_\_

Date: \_\_\_\_\_

Programmer: \_\_\_\_\_

Sheet 4 of 4

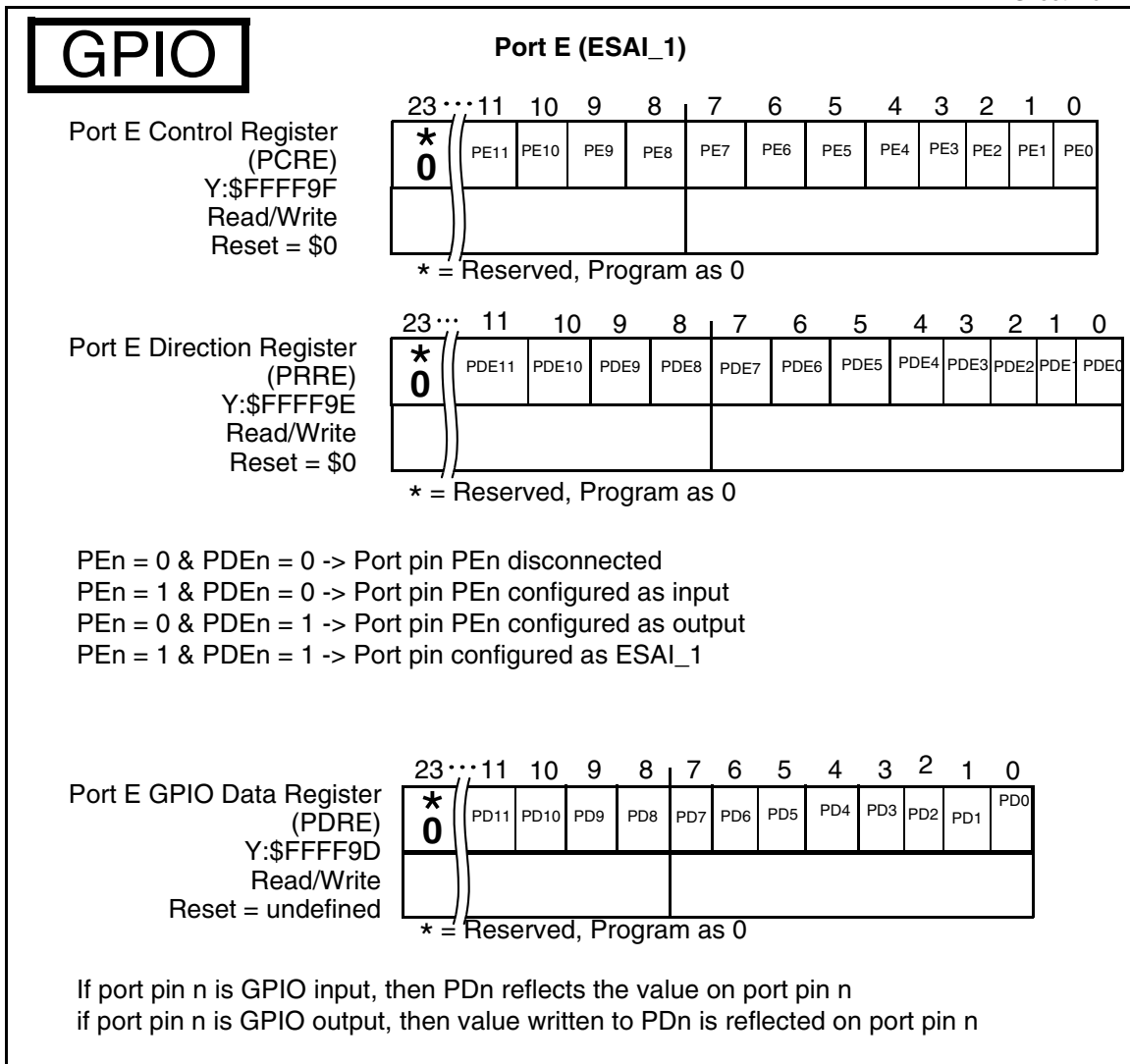


Figure C-28 GPIO Port E

Application:\_\_\_\_\_

Date:\_\_\_\_\_

Programmer:\_\_\_\_\_

Sheet 1 of 4

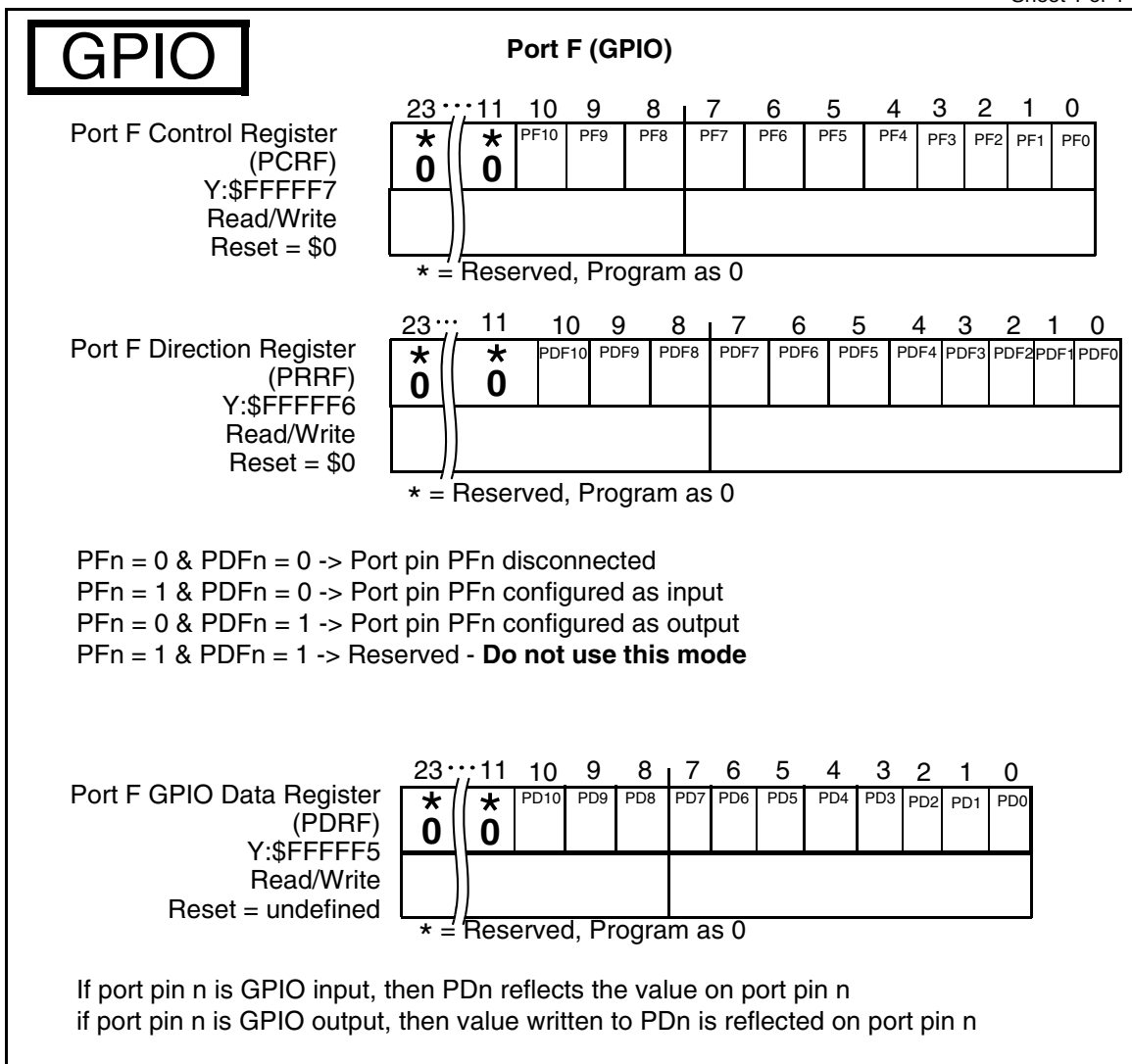


Figure C-29 GPIO Port F

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