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When the draft technical report is completed, the technical committee approval process is the same as for a draft standard. Processing by NCITS is also similar to that for a draft standard.

ABSTRACT

This technical report describes SCSI configurations that may be achieved within the context of the specifications in the SCSI-2, SCSI-3 SPI, SCSI-3 Fast-20, and SPI-2 standards. These configurations have one or more configuration parameters expanded beyond that documented in the standard documents and may require special components, special restrictions, or an interpretation of the underlying technical reasons for parameters specified in the standards. This technical report describes the considerations that can lead to effective implementations of special components but does not describe the detailed design of any component. The information in this technical report does not supersede any requirements in the referenced standards.

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1. Scope

This technical report provides guidance to experienced implementors and users of parallel SCSI beyond that contained in the formal standards.

SCSI technology offers many different options and is used in a broad set of applications ranging from notebooks to data centers. It is often desirable to build on the established installed base but certain extensions may occasionally be needed to expand the capabilities for specific applications. Examples of such extensions include longer lengths, more devices, mixing different kinds of SCSI device interfaces within the same system, and dynamic physical reconfiguration of SCSI components.

For the most part the present SCSI standards describe homogeneous implementations with conservative requirements on the components. This technical report describes how some of these extensions can be accomplished by placing specific constraints on

application parameters for the sake of extending specific capabilities. Parameters include maximum data phase speed, path width, wire gauge of cables, propagation velocity of signals in cables, transmission line effects, supply voltages used, configurations, and transmission modes.

Major clauses describe the uses of and requirements for circuitry that can physically partition the SCSI bus into segments without any effect on the software or firmware required.

Material is also included on design and implementation issues that may not be obvious from the standards.

2. References

The following documents contain provisions which, through reference in the text, constitute provisions of this technical report. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this technical report are encouraged to investigate the possibility of applying the most recent editions of the documents listed below.

Copies of the following documents may be obtained from ANSI: Approved ANSI standards, approved and draft international and regional standards (ISO, IEC, CEN/CENELEC, ITUT), and approved and draft foreign standards (including BSI, JIS, and DIN). For further information, contact ANSI Customer Service Department at 212-642-4900 (phone), 212-302-1286 (fax) or via the World Wide Web at http://www.ansi.org.

Additional availability contact information is provided below as needed.

2.1 Approved references

Small Computer Interface – 2 (SCSI-2) X3.131:1994
SCSI-3 Parallel Interface (SPI) X3.253:1995
SCSI-3 Fast–20 Parallel Interface (Fast-20) X3.277:1996
SCSI-3 Interlocked Protocol (SIP) X3.292: 1997
Detail Specification for Trapezoidal Connectors with Non-removable Ribbon Contacts on 1.27 mm Pitch Double Row used with Single Connector Attachments (SCA-2), EIA-700A0AE (SP-3651)
Detail Specification for Trapezoidal Connector 0.8mm Pitch used with Very High Density Cable Interconnect (VHDCI),EIA-700A0AF (SP-3652)

2.2 References under development

At the time of publication, the following referenced documents were still under development. For information on the current status of the document, or regarding availability, contact the relevant standards body or other organization as indicated.

SCSI Parallel Interface – 2 (SPI-2) X3.302:199x

SCSI Architecture Model – 2 (SAM-2) T10/1157-D

NOTE: For more information on the current status of the document, contact the NTCIS Secretariat at 202-737-8888 (phone), 202-638-4922 (fax) or via Email at nctis@itic.nw.dc.us. To obtain copies of this document, contact Global Engineering at 15 Inverness Way East Englewood, CO 80112-5704 at 303-792-2181 (phone), 800-854-7179 (phone), or 303-792-2192 (fax).

2.3 Other references

For information on the current status of the listed document(s), or regarding availability, contact the indicated organization.

SCSI Wiring Rules for Mixed Cable Plants, SFF-8017
VHDCI Shielded Configurations, SFF-8441
SCA-2 Unshielded Connections, SFF-8451

NOTE: For more information on the current status of the document, contact the SFF committee at 408-867-6630 (phone), or 408-867-2115 (fax). To obtain copies of this document, contact the SFF committee at 14426 Black Walnut Court, Saratoga, Ca 95070 at 408-867-6630 (phone) or from FaxAccess at 408-741-1600.

3. Definitions, symbols, and abbreviations

3.1 Definitions:

bus-path: The electrical path directly between the bus terminators.

byte: Indicates an 8-bit construct.

contact: The electrically-conductive portion of a connector associated with a single conductor in a
cable.

differential: A signaling alternative that employs differential drivers and receivers.

fast-5: Negotiated to receive synchronous data at a transfer rate less than or equal to 5 megatransfers per second. Note: Existing SCSI standards referred to this transfer range as slow.

fast-10: Negotiated to receive synchronous data at a transfer rate greater than 5 megatransfers per second and less than or equal to a transfer rate of 10 megatransfers per second. Note: Existing SCSI standards referred to this transfer range as fast SCSI.

fast-20: Negotiated to receive synchronous data at a transfer rate greater than 10 megatransfers per second and less than or equal to a transfer rate of 20 megatransfers per second.

fast-40: Negotiated to receive synchronous data at a transfer rate greater than 20 megatransfers per second and less than or equal to a transfer rate of 40 megatransfers per second.

initiator: An SCSI device containing application clients that originate device service and task management requests to be processed by a target SCSI device. See the SCSI-3 Architecture Model standard for a detailed definition of an initiator.

logical unit: An externally addressable entity within a target that implements an SCSI device model. See the SCSI-3 Architecture Model standard for a detailed definition of a logical unit.

logical unit number: An identifier for a logical unit.

megatransfers per second: The repetitive rate at which data are transferred across the bus. This is equivalent to megabytes per second on an 8-bit wide bus.

multimode single-ended (MSE): A signaling alternative for multimode SCSI devices that employs MSE (see SPI-2) drivers and receivers to allow multimode SCSI devices to operate when SE SCSI devices are present on the bus.

path: The cable, printed circuit board or other means for providing the conductors and insulators that connect two or more points.

SCSI bus: The consists of all the conductors and connectors required to attain signal line continuity between every driver, receiver, and terminator for each signal.

signal assertion: The act of driving a signal to the true state.

signal negation: The act of performing a signal release or of driving a signal to the false state.

stub: Any electrical path connected to the bus that is not part of the bus-path.

target: A SCSI device that receives SCSI commands and directs such commands to one or more logical units.

3.2 Abbreviations and symbols

AWG: American wire gauge
Diff: Differential
FEP: Fluorinated ethylene propylene
E: End of stub
EMC: Electromagnetic compatibility
ES1: End state where the device is in full operation
ES2: End state where the device is in its storage container
ESD: Electrostatic discharge
HVD: High voltage differential

GFI: Ground fault interrupt
Lmax: Maximum physical length of a domain
LUN: Logical unit number
LVD: Low voltage differential
MSE: Multimode single ended
NA: Not applicable
ND: No data
NR: Not recommended
PTFE: Polytetrafluoroethylene
SCA: Single connector attachment
SCSI: Small computer system interface
SE: Single ended
SFF: An industry group focused on storage interfaces and hardware
T: Terminator
Tdi: Time delay through the "i" th device
Tdp: Delay through a pair of expanders
Tds: Delay though a single expander
Tdd: The sum of the delays from all devices on the domain (including any segment connecting elements)
TPE: Thermo plastic elastomer
v_p: Velocity of propagation

4. General

This technical report describes configurations and extensions that are possible within the context of the existing SCSI standards but that may not be obvious or presently documented by the standards. It is the intent of this technical report to provide technical information and guidance to enable these expanded capabilities in an effective way.

The common theme on all of these enhancements is expansion of applications that can be addressed without changing the features of existing SCSI device implementations that comply with the existing standards. Of special interest are interconnecting devices capable of different widths, extending the physical length of the SCSI domain, increasing the dynamic physical reconfigurability of domains, and extending the number of addressable devices in a single domain.

5. Bus model

The concepts are presented in logical order, rather than alphabetical order, to avoid using terms in the concept that have not been previously discussed when the concept is presented.

5.1 Bus related terminology and concepts

Bus Segment:

A SCSI bus segment consists of all the conductors and connectors required to attain signal line continuity between every driver, receiver, and two terminators for each signal. It is not necessary that a SCSI bus segment contain any initiators or targets but it has at least two devices attached. Drivers and receivers may be part of expanders as well as part of initiators and targets.

The allowed length of a bus segment depends on the electrical loading, type of transmission media, and data transfer rate. In many cases heavier loading, smaller wires, and higher speeds demand shorter lengths. Loading is produced by increasing the number of devices in a given length of bus or by using longer stubs or higher capacitance devices. The details of the segment length limits are given in clause 6, Table 1, Table 2, and Table 3.

Device:

Devices include targets, initiators and bus expanders. The term "SCSI device" is limited to targets and initiators; see SAM-2.

Terminator:

Interconnect components that form the ends of the transmission lines in bus segments. A SCSI domain (5.2) has at least one segment and at least two terminators (except for special cases where the electrical transmission lines are very short). Terminators bias the signals on a bus segment to the false state. This ensures a false state when no devices are driving. Terminators also minimize signal reflections.

Bus segment types:

There are presently three types of SCSI bus segment:

- Single ended (i.e., monomode single ended (SE) or multimode single ended (MSE))
- High voltage differential (HVD)
- Low voltage differential (LVD)

The bus segment type is determined by the properties of the terminators used. Devices that do not have the same transceiver type as the terminators cannot operate in the segment defined by the terminators.

Bus-path:

The electrical connection directly between the two terminators in a bus segment

Stub:

Any electrical path in a bus segment that is not part of the bus-path

Stub connection:

The point where a stub meets the bus-path

Transmission medium (media):

An electrical conductor having bus termination on each end and possibly stubs

Common examples of media are cables, printed wiring boards, backplanes, flex circuits, and connectors that create the electrical connections between SCSI devices and/or bus expanders (see below) and terminators.

SCSI bus (segment) connector:

Any connector used to create a SCSI bus segment

SCSI bus connectors are defined both by their function AND by their physical placement. There are only two allowed functions: bus-path and stub. There are numerous physical placement descriptions. Examples of SCSI bus connectors are “device stub connector” and “terminator bus-path connector”.

Bus-path connector (functional description):

Any connector used to provide part of the bus-path

Stub connector (functional description):

Any connector used to provide part of a stub

Device connector (physical placement description):

Any connector physically part of a SCSI device

Cable connector (physical placement description):

Any connector that is physically part of a cable assembly, attached to backplanes, or other non-device conductors

Terminator connector (physical placement description):

Any connector physically part of a terminator

It is not uncommon for terminators to have both stub and bus-path connectors (see Figure 1).

Enclosure connector (physical placement description):

Any connector that is physically part of an enclosure

Note: The above list of physical placement descriptions contains examples and is not intended to be complete. Other physical placement descriptions may be used.

Note concerning the location of the stub connection point:

The mating interface of stub connectors is considered to be the stub connection if the path between the true stub connection and the mating interface is contained wholly within the connector housing[1]*. Such connectors are termed housing-only connectors.

Figure 1 shows examples of connectors, bus-paths, stubs, and stub connections in a single bus segment.

[1] *This condition is common for connectors that are directly attached to flat ribbon cable. The true stub connection is the point where the wire of the ribbon cable meets the insulation displacement part of the connector contact and is not easily physically accessible. The stub contained within the connector housing is very short and very little error is introduced by considering the mating interface as the true stub connection.

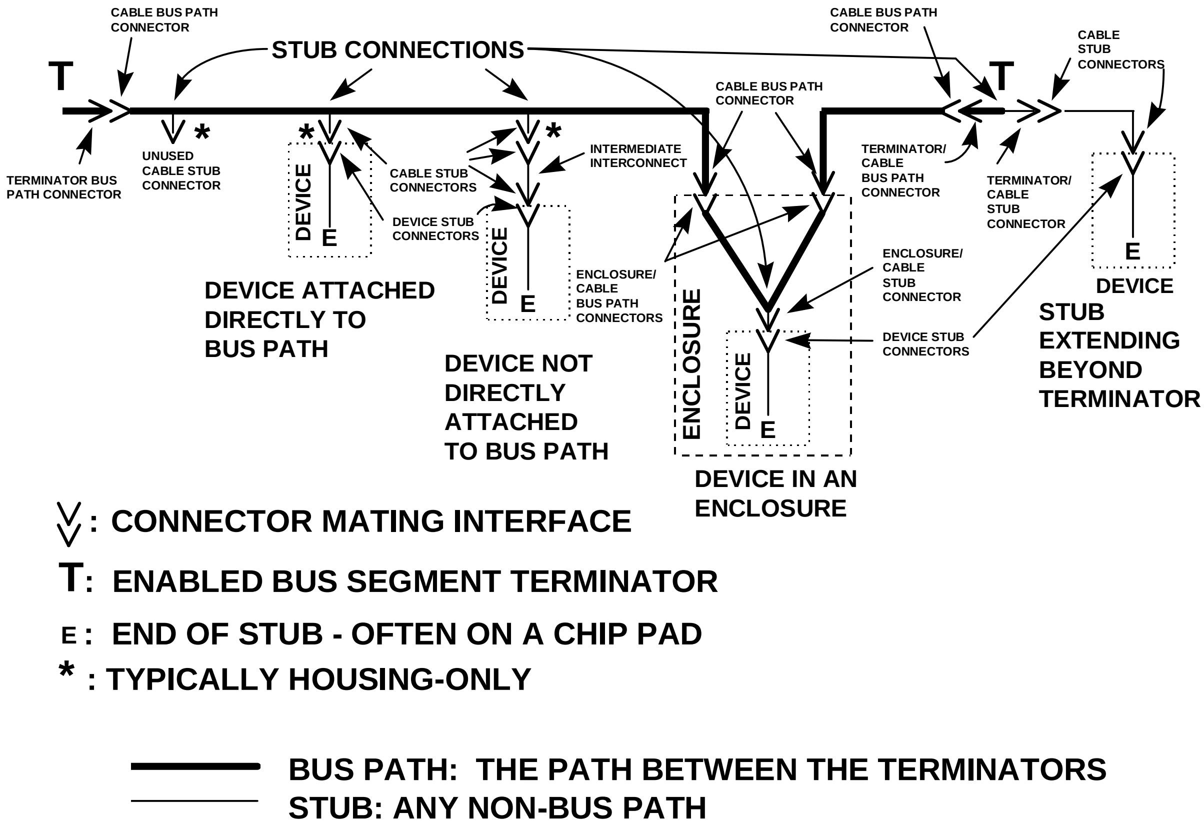

Figure 1 - Single segment physical architecture and terminology examples

5.2 SCSI domain related terminology and concepts

SCSI domain:

A SCSI domain is a logical bus with at least one bus segment, at least one initiator, and at least one target. Domains with multiple bus segments are enabled through the use of bus expanders. Domains consist of the set of SCSI devices that are addressable from an initiator or target. Wide domains are limited to a maximum of 16 initiators and/or targets without the use of bridging expanders. Narrow domains are limited to a maximum of 8 initiators and/or targets without the use of bridging expanders.

Simple expander:

Devices that couple bus segments together without any impact on the SCSI protocol or software/firmware are called simple bus expanders. See 5.1.

Bridging expander:

> Devices that couple a bus segment to another SCSI segment or another kind of port by using addressable SCSI ports.

6. Bus segments in a SCSI domain

Existing SCSI standards define parameters for SCSI busses based on the assumption that there is a single electrically conducting path between bus terminators for each signal and that a SCSI domain contains all the devices between these two terminators. This electrical path is assumed to pass signals in both directions without delay other than that caused by the propagation delay of the transmission line associated with the path. It is assumed that there are no intervening active components in the path between the bus terminators.

A more general concept recognizes that it is possible to build SCSI domains that use more complex physical implementations where there may be active electrical components between SCSI devices. A building block for these more complex implementations is the bus segment which is defined as two bus terminators and the associated single electrically conducting path between these terminators (for each signal) that satisfies the assumptions in the first paragraph of this clause. Multiple bus segments may be functionally connected together by special coupling circuits described in clause 10.

7. SCSI bus segments

Each bus segment has TERMPWR sources and TERMPWR distribution parameters.

Bus segments always use the same transmission type (HVD, LVD, or SE) within the segment. A domain may contain segments that use different transmission types.

Bus segments follow the same rules individually that are described in the existing standards (with important exceptions). Using multiple bus segments with coupling circuits in the same domain allows much more of the full properties supported by the SCSI bus protocol to be realized than when using single segment domains.

Some of the salient properties impacted are device count limits, physical length limits, ground voltage shifts, dynamic removal and replacement of portions of domains, and mixing of device types (SE, HVD, LVD).

7.1 Segment length parameters

The existing SCSI-2 and SCSI-3 SPI standards mention physical lengths as recommended or required maximums for certain conditions. The SCSI-3 Fast-20 and SPI-2 standards incorporate information that allows implementers significant leeway in the maximum

physical lengths through the use of informative material provided in annexes. The reasons behind the length numbers contained in the existing standards are not always stated in the standards and some of the technology that existed some years ago has improved since these standards were stabilized. Both of these points invite re-examination of length related parameters based on the latest knowledge and technology.

The concept of a bus segment is introduced for the first time in this technical report. Using multiple bus segments in the same SCSI domain challenges the notion of using physical length alone as a domain configuration limit. In order to understand and give guidance concerning appropriate physical length of bus segments and domains the properties that affect this length need to be examined.

Bus segments and SCSI domains have physical length limits that are determined by (1) the time required for signal propagation or (2) by loss of signal quality due to resistance, dispersion, delay skew, transmission line reflections, jitter or other factors. As long as the physical plant delivers the signals to SCSI device connectors and bus terminators with the proper timing and signal quality there is no technical reason to further restrict the physical length. These criteria are applied to the lines that first fall outside of acceptable bounds as the length is increased. In some cases the TERMPWR lines limit the length. See clause 13.

For the domain length limits the propagation time consumed by the elements that connect the bus segments as well as that consumed in the individual segments are considered. The length limits for individual segments may be independently considered as long as the domain length (protocol timing) limits are not exceeded. A single domain may contain many segments since some of the most attractive versions of SCSI have very short segment length limits (caused by signal quality) that consume only a small part of the domain timing budget.

Clause 10 considers the propagation delay issues for the elements that connect bus segments. The remainder of this clause considers the factors that affect the physical length of single segment domains and segments within multi-segment domains.

7.1.1 Protocol timing limits

The SCSI arbitration and service boundary protocols define a time of 400 ns for the bus to settle after certain conditions described in the SCSI-3 SIP and SPI-2 documents are possible. The intent of this bus settle delay is to allow a full round trip time for electrical disturbances to decay before proceeding to the next steps in the protocol. This means that the overall time required for a signal to travel from one end of the bus to the other and to reflect back to the starting point is a maximum of 400 ns. A one way transit time of 200 ns is used for each segment. It may be possible to extend the one way time to 400 ns for a multi-segment domain. See 10.1.4.4.1. Even in this case each segment shall individually meet the 200 ns one way requirement.

If one has a uniform bus media and a known signal propagation velocity, v_P, this establishes the maximum physical length as (v_P)(200 ns). With the presently allowed slowest v_P of approximately 0.2 m/ns this gives a maximum length of 40 m. One cannot use this number as a general limit because the transmission media is not uniform and the

signals are delayed by the non-uniformities. The next clause considers the most important additional effects caused by device loading.

7.1.1.1 Device loading parameters

When real devices are present on a segment their stubs and capacitive loads add to the delay for the signals. The amount of this delay depends on the details of the loading. In the normal worst case with a 0.1 meter stub and a 25 pF capacitive load this delay has been reported to be approximately 0.5 ns per device.

In general the allowed transit time is reduced by the delay caused by the loads. The device delay is denoted Tdi for the "i"th device and the total delay is the sum of the delays from all devices on the domain (including any segment connecting elements) and is denoted Tdd.

This gives a general formula for the maximum domain length Lmax, as:

$$Lmax = (200ns - Tdd) \times (v_P)$$

With 14 devices each having a delay of 0.5 ns per device there is a total of 7 ns reduction in the time available. One should also allow some delay for connectors and other disturbances. A reasonable number for this may be 2 ns for a domain having several connectors. Tdd becomes approximately 9 ns for a fully loaded wide SCSI segment and the maximum length is based on 191 ns transit time.

7.1.1.2 Caution when using HVD interfaces (separate transceivers)

The times relating to the signal propagation are defined as measured from the device connectors. This is important when using interfaces with separate transceivers, such as those used with HVD, since the propagation time through the transceivers can be several tens of nanoseconds. The SCSI standards do not allow any special budget for these extra transceiver delays. HVD interfaces shall be implemented suchthat the timings of protocol chips and other device and domain design parameters accommodate separate transceivers.

7.1.2 Propagation - time - limited domain length

Using the numbers in 7.1.1.1 for a 14 device bus with connectors (191 ns transit time) and assuming $(v_P)^{-1}$ is 5 ns/m the maximum single segment length is 191/5 = 38.2 meters. The number in the present standards use a more conservative $(v_P)^{-1}$ of 5.4 ns/m which yields Lmax = 35.4m. for the same transit time. The maximum allowed length in the standards is 25 meters showing considerable extra margin even for the minimum allowed propagation velocity. Assuming $(v_P)^{-1}$ is 5 ns/m in a real cable the maximum length of the bus could be 38.2 – 25 = 13.2 meters longer than the standard specifies. For media built for high propagation velocity one can achieve $(v_P)^{-1}$ of at least 3.76 ns/m

for a loaded length of 191/3.76 = 50.8m or more than double that in the present standards.

Another way of looking at this issue is to consider the extra time made available by using 25 meter maximum length. Assuming a practical $(v_p)^{-1}$ of 5 ns/m, the 25 meters (with 14 devices and connectors) only consumed 125 + 9 = 134 ns of the 200 ns budget. The extra 66 ns is used in many practical systems to allow for the propagation time through the differential interfaces. Limiting the length to 25 meters allows the same protocol chip to be used for both HVD and SE devices.

From a transit time point of view, SE segments are better positioned (than HVD segments) to take advantage of this extra time by extending the maximum length.

Lengths above 6 meters are reserved by the standards for differential transmissions. For certain special cases, however, one may extend the length of a SE segment beyond 6 meters. This is examined in more detail in 7.1.3.

7.1.3 Signal quality limits

This clause explores the effects of segment lengths on signal quality.

There are two factors related to length that affect signal quality: attenuation and the duration of reflections. When a reflection is needed to achieve a usable signal size it is vital that this reflection reach the receiver before the next pulse edge. The pulse will never reach a detectable level If this does not happen. A second consequence of the reflection being too long is disturbance of subsequent pulses and very complex interactions between pulses.

Attenuation becomes a limiting factor for long, lightly loaded and point to point segments. It is the a.c. attenuation that contributes most when attenuation is the limit. The lengths necessary to reach attenuation limited conditions far exceed that for reflection limited lengths. This statement may not apply if using very small gauge wire (less than 32 gauge). In the normal situation where 32 gauge or larger wire is being used one can establish some conditions that relate segment length to keeping the first reflection within the same pulse. This condition is that the round trip propagation time be less than the minimum assertion or negation period for the signals.

The minimum assertion/negation period varies with the synchronous data transfer rate. Fast-5 SCSI has a period of 90 ns, Fast-10 is 30 ns, Fast-20 is 15 ns, Fast-40 is 8 ns. Assuming an inverse propagation velocity of 5 ns/meter a signal edge can propagate 18 meters in 90 ns, 6 meters in 30 ns, 3 meters in 15 ns, and 1.6 meters in 8 ns. Since these are round trip times 9, 3, 1.5, and 0.8 meters respectively are the maximum lengths possible before the reflection could exceed the assertion/negation period. These lengths match the recommendations in the standards for Fast-10 and Fast-20 and show that Fast-5 SCSI has more margin in this respect.

It is appropriate to consider that a significant decrease in noise margin exists when these reflection length limits are exceeded. For example, if the 3 meter limit is exceeded for Fast-10 SCSI, transmission line parameters need to be under very good control to ensure incident wave switching.

The condition where there is no need for a reflection to achieve a good detectable signal is called incident wave switching. This means that the first pulse edge gets detected. The published length limits of 6, 3, and 1.5 meters for Fast-5, Fast-10 and Fast-20 are rendered unnecessary if one can guarantee that incident wave switching will occur. If one is in an incident wave switching mode there is a possibility of complex interactions between pulses since the reflections (although not needed for initial switching) may appear in pulses other than those where they originated. With incident wave switching even the SE Fast-20 segments may reach well beyond the 1.5 meter limit toward the 25+ meter controlled by the bus settle delay.

When an incident wave switching mode is not applicable there are parameters within the segment that can provide additional margin. The most important of these is the loaded characteristic impedance of the segment. The better this matches the unloaded case the higher the noise margin. Another parameter is the propagation velocity of the loaded media for the segment. The faster this velocity the quicker the reflections arrive and the more high level pulse is available for detection. Note the relationship between these two parameters. In order to increase the propagation velocity it is usually necessary to decrease the capacitance per unit length of the media. This decrease makes the loaded characteristic impedance more affected by loads. However, when assuming non incident wave switching it is quite likely that the higher propagation velocity will result in a net increase in noise margin. Cables made with FEP, TPE and PTFE may offer somewhat higher noise margin because of their increased propagation velocity.

The factor that most likely forces the signal out of the incident wave switching mode is clustered loads on the segment media. All else being equal, the capacitance per unit length of the media is the single most important property that affects its ability to withstand clustered loads. Media with higher capacitance are disturbed less by loads. Where higher capacitance is needed the most - in backplane applications - it may exist due to the construction of the backplane.

7.1.4 Printed circuit board parameters

Printed circuit boards (or backplanes) with the right characteristic impedance usually have higher capacitance per unit length than cables and are better suited to handle clustered loads. The cable to PCB capacitance ratio is frequently around 0.5 or lower. While this helps when it is desired to have devices close together it also produces a greater sensitivity to stub length. Stubs in a backplane should be reduced by at least twice over a cable implementation.

Printed circuit boards may have much higher attenuation per unit length than a cable. This is usually not a concern since PCBs have short bus lengths.

7.2 Other segment properties

Segments offer not only confinement for reflections they also offer the possibility of separating grounds within a domain by using multiple segments for the domain. Within any segment strict observance of the ground shift requirement is necessary.

8. Bus segment guidelines

As discussed in clause 6 there are three main features that determine the maximum bus segment length: bus settle delay, electrical loading by devices, and maximum speed of operation. These relate to propagation delay, intensity of reflections and a.c. attenuation respectively. In addition, there are number of other requirements that apply independently of these features.

In this clause guidelines based on some bus loading conditions are presented that indicate the maximum length that may be achievable. These loading conditions are specified in greater detail than available in the existing standards and include important conditions that are not addressed in the existing standards.

A three level risk class system is used for these guidelines where risk is varied by class. The lowest risk class, class 1, largely reflects parameters and loading conditions listed in the standards documents. Class 2 guidelines consider loading conditions not directly considered or not adequately considered in existing standards. The lengths listed under class 2 reflect experience with testing results to support the parameters. Class 3 guidelines consider conditions that go beyond that considered in classes 1 and 2. The lengths listed under class 3 should be possible under careful implementation conditions but have not had any significant verification or testing. Using class 3 guidelines is the highest risk and requires more attention to details and experience with SCSI implementations. There are some conditions where no guidance is presented due to lack of available data. Table 1, Table 2, and Table 3 use these risk classes to define different capabilities.

8.1 Bus segment loading

Five categories of loading are defined:

1) Point to point using uniform bus media

This case is the least demanding on the transmission interconnect. Only two electrical loads may be present near the terminators in the segment. This case is commonly found between host adapters and disk controllers, for single remote tapes and other devices, and for length extension segments between expanders. See clause 10.

Uniform bus media means same style of cabling used throughout (e. g. round shielded only). In-line connectors are allowed.

2) Devices spaced at least 1 meter apart using uniform bus media

This case normally does not stress the transmission line properties since the loads are very far apart. This case is commonly found when daisy chaining multiple external enclosures with external shielded Y cables. Enclosures that use internal ribbon cabling may not work well in this application due to the wide spacing required between devices.

3) Devices spaced at least 0.2 meter apart (cables)

This case is found within enclosures such as PCs, workstations, and for some closely spaced external enclosures. It is more electrically demanding than case 2 because the devices are placed closer together and because cables are sometimes not as good as backplanes at accommodating devices loads.

For certain heavily loaded cases the lengths are reduced below those used for the more lightly loaded cases.

4) Devices spaced at least 0.1 meter apart (backplanes)

This case is a common backplane condition when using 3.5" form factor devices. It is able to accommodate closer spacing because the backplane interconnect is better able to absorb the device loads. When cables are attached directly to the backplane significant extra signal degradation is usually experienced so the simple length rules are modified.

Significant benefit is expected from using expander circuits directly off the enclosures that have backplane interconnect.

5) Devices spaced at least 0.1 meter apart with 0.2 meter stubs (backplanes)

This case is found in some backplane configurations that use large form factor devices. It is perhaps the most demanding condition for the interconnect.

There is some correlation between large form factor devices and higher device capacitance which makes it unclear whether the stub length or the higher capacitance is the main cause of the signal degradations for this class of configuration. Part of the increased capacitance comes from the stub itself but in some cases it is the device that is mainly responsible.

It is expected that the use of expanders on the backplane enclosures will allow the large form factor configurations to operate at all speeds.

Special note for bus expanders (See 10): All SCSI bus expanders are treated as a device when counting electrical loads. Even though expanders do not occupy SCSI IDs they still produce electrical loading. Expander loads can be important if the segment length depends on the number of devices.

8.2 Maximum speed of operation

There are five bus transfer rates defined in SPI-2: Asynchronous, Fast-5, Fast-10, Fast-20, and Fast-40.

Each of these transfer rates is applied to the synchronous data phase only except the asynchronous which applies to all phases except the synchronous data phase. It is frequently possible to operate a bus segment in the asynchronous speed mode when it will not work in a high speed synchronous mode. In other cases a very slow synchronous mode may work the best. For configurations that will not operate under one speed mode the speed may be changed.

Operation in a slower speed mode may keep the system alive and will allow in-band communication for diagnostic purposes as long as the basic electrical connections are in place.

The successful operation of bus segments and SCSI domains at the maximum rate requires that the bus segments operate within prescribed length and loading parameters.

8.3 Other segment guidelines

All SE segments are assumed to be terminated with active, linear terminators properly placed in the bus segment. This does not mean that other termination schemes cannot work well in many applications but the specific data in this technical report only addresses the referenced kind of terminator.

All HVD segments are assumed to be terminated with linear, totem pole terminators as specified in the SCSI standards, properly placed in the bus segment.

SE segments have ground distribution systems that control ground offset to less than 50 mV. Normal good installations have ground offsets much less than 50 mV. This ground offset requirement applies at the logic ground of the SCSI devices which may not always be at the same ground as the chassis. SCSI devices should normally have the logic ground connected directly to the chassis ground to ensure that this requirement is met.

Differential segments have the ground offset controlled to less than 350 mV for LVD and 500 mV for HVD. The same comments concerning logic/chassis ground apply as for SE above.

The maximum stub length is assumed to be 0.1 meter for SE and LVD and 0.2 meter for HVD unless otherwise noted. Stubs are any electrical path within the segment that is not part of the bus-path. (The electrical path between the terminators is the bus-path). Stub length is measured from the point of attachment to the bus-path to the farthest point along the stub path. Frequently the end of the stub will be at a chip bonding pad within a chip package.

The maximum device connector contact capacitance to ground for SE devices is 25 pF measured at 0.5V d. c.

Differential capacitance is measured as C1/C2/C3 following the SPI-2 standard where C1 is the capacitance from + signal to ground, C2 is the capacitance from - signal to ground and C3 is between + signal and - signal. For HVD the maximum capacitance is 30/30/15 pF and for LVD the maximum capacitance is 20/20/10 pF.

For devices located very near (within 0.1 m) one of the SCSI bus terminators being used for segment termination the allowed device capacitance may be increased to the point where the combination of the terminator capacitance and the device capacitance does not exceed 50 pF for SE or 40/40/20 for HVD. Note that this applies at positions near terminators is being used for bus termination. Devices that use switchable terminators only qualify under this condition if the terminator is switched on and the device is providing one of the two bus segment terminations. At most 2 higher capacitance devices per segment are allowed.

Cable media complies with the appropriate SCSI standard.

8.4 Comments on the segment length rules

There is presently adequate experience with using SE to SE expanders to create several risk class 1 applications. This experience and similar earlier experience with the SE to HVD expanders provides significant confidence that the extrapolations to the higher risk classes in this technical report are likely to be reasonable.

The extended SE lengths (beyond 6 meters) are based on testing of SE systems and experience with differential systems that operate at the longer lengths. The timing properties of the differential implementations are more demanding than the SE versions and both the signal integrity and actual full protocol operation have been verified at these extended SE lengths. The risk is diminishing here as broad experience grows with SE devices at these extended lengths.

Some asynchronous conditions have not been tested and have risk class 3 designation. If the silicon in the SCSI protocol chips has been properly designed these asynchronous conditions should work even if the signal integrity is very poor on the pulse edges.

For LVD, the lengths indicated may appear to eliminate the need for expanders. This is not a valid interpretation since isolation may be required to achieve hot plugging and are required in some configurations for flexibility. Data from LVD/MSE backplanes indicates that expanders are required between the backplane and the external cable for cables longer than approximately 3 meters.

8.5 Segment length tables

Table 1 - Length limits for SE bus segments

TRANSFER RATE	RISK CLASS	POINT TO POINT WITH UNIFORM BUS MEDIA	LOADS SPACED AT LEAST 1 METER APART WITH UNIFORM BUS MEDIA	LOADS SPACED AT LEAST 0.2 METER APART (CABLES)	LOADS SPACED AT LEAST 01. METER APART (BACKPLANES)	LOADS SPACED AT LEAST 0.1 METER APART WITH 8" STUBS (BACKPLANES)
ASYNC	1	6	6	6	6	1; 5 LOADS
	2	20**	20	20	20	ND
	3	35	25	25	25	20
Fast-5	1	6	6	6	6	1; 5 LOADS*
	2	20**	6	ND	ND	NR
	3	35	15	ND	ND	NR
Fast-10	1	3	3	3; 8 LOADS 2.2; 16 LOADS	3; 8 LOADS 2.2; 16 LOADS	1; 5 LOADS*
	2	20**	6	ND	ND	NR
	3	35	15	ND	ND	NR
Fast-20	1	3	3	1.5; 8 LOADS 3; 4 LOADS	1; 8 LOADS*	1; 5 LOADS*
	2	20**	4	ND	ND	NR
	3	35	15	ND	ND	NR

Risk classes:
1. derived from field and lab testing
2. derived from the known behavior of the SCSI bus and has been tested but have not been extensively tested or used
3. projected to be possible with custom control of all components in the segment and special analysis performed by SCSI experts

Loading: 1 load is a maximum capacitance / maximum stub length device (including expanders) (25 pF / 0.1 meter)

ND = no data, maximum length and number of loads is unknown
NR = not recommended to exceed risk class 1 lengths

Fast-40 SE is not defined.

* Requires expander within 0.2 meter of backplane
** Two loads within 0.5 meter of the terminator are allowed on each end

All length data is in meters.

Table 2 - Length limits for HVD bus segments

TRANSFER RATE	RISK CLASS	POINT TO POINT	LOADS SPACED AT LEAST 1 METER APART	LOADS SPACED AT LEAST 0.2 METER APART (CABLES)	LOADS SPACED AT LEAST 0.1 METER APART (BACKPLANES)	LOADS SPACED AT LEAST 0.1 METER APART WITH 0.2 METER STUBS (BACKPLANES)
ASYNC	1	25	25	25	ND	ND
	2	35	35	35	ND	ND
	3	ND	ND	ND	25	25
Fast-5	1	25	25	25	ND	ND
	2	35	35	35	ND	ND
	3	ND	ND	ND	25	25
Fast-10	1	25	25	25	ND	ND
	2	35	35	35	ND	ND
	3	ND	ND	ND	25	25
Fast-20	1	25	25	25	ND	ND
	2	35	35	35	ND	ND
	3	ND	ND	ND	25	25
Fast-40	1	ND	ND	ND	ND	ND
	2	ND	ND	ND	ND	ND
	3	ND	ND	ND	ND	ND

Risk classes:
1. derived from field and lab testing
2. derived from the known behavior of the SCSI bus and has been tested but have not been extensively tested or used
3. projected to be possible with custom control of all components in the segment and special analysis performed by SCSI experts

ND = no data, maximum length and number of loads is unknown

Loading: 1 load is a maximum capacitance / maximum stub length device (including expanders) (25/25/12.5 pF / 0.2 meter)

All length data is in meters.

Table 3 - Length limits for LVD bus segments

TRANSFER RATE	RISK CLASS	POINT TO POINT	LOADS SPACED AT LEAST 1 METER APART	LOADS SPACED AT LEAST 0.2 METER APART (CABLES)	LOADS SPACED AT LEAST 0.1 METER APART (BACKPLANES)	LOADS SPACED AT LEAST 0.1 METER APART WITH 0.2 METER STUBS
ASYNC	1	25	12	12	4	NR
	2	25	20	15	6	NR
	3	35	35	25	12	NR
Fast-5	1	25	12	12	4	NR
	2	25	20	15	6	NR
	3	35	35	25	12	NR
Fast-10	1	25	12	12	4	NR
	2	25	20	15	6	NR
	3	35	35	25	12	NR
Fast-20	1	25	12	12	4	NR
	2	25	20	15	6	NR
	3	35	35	25	12	NR
Fast-40	1	25	12	12	4	NR
	2	25	20	15	6	NR
	3	35	35	25	12	NR

Risk classes:

1. derived from field and lab testing
2. derived from the known behavior of the SCSI bus and has been tested but have not been extensively tested or used
3. projected to be possible with custom control of all components in the segment and special analysis performed by SCSI experts

ND = no data, maximum length and number of loads is unknown
NR = not recommended

Loading: 1 load is a maximum capacitance / maximum stub length device (including expanders) (20/20/10 pF / 0.1 meter)

All length data is in meters.

9. Mixed width operation

SCSI is specified to operate with any of three data path widths: 8-bit, 16-bit, and 32 bit. This technical report does not consider the 32 bit operation. Conditions exist where it is desirable to implement both 8 and 16-bit SCSI devices within the same bus segment. When this happens the bus segment is said to be using mixed width operation.

Since the timing requirements become more strict at higher data rates the risk of using mixed width operation increases at higher data rates. The details of these risks are explored in this clause. This clause describes four different ways to configure mixed width bus segments. Each requires separate consideration and each shall adhere to the wiring tables shown in clause 15.

9.1 16-bit main path

9.1.1 Async, Fast-5, Fast-10, and Fast-20 cases

The simplest form of mixed width segment has a 16-bit main path to which either 8-bit devices, 16-bit devices, or both are attached. Only the 16-bit main path has bus termination. No 8-bit devices may provide any bus termination.

Figure 2 shows the architecture of this implementation. Every 8-bit connection only contacts the SCSI lines that are used for 8-bit devices. The upper 9 bits (data and parity) are not contacted by the 8-bit device. This condition produces more electrical load on the lower 9 bits (data and parity) than on the upper 9 bits.

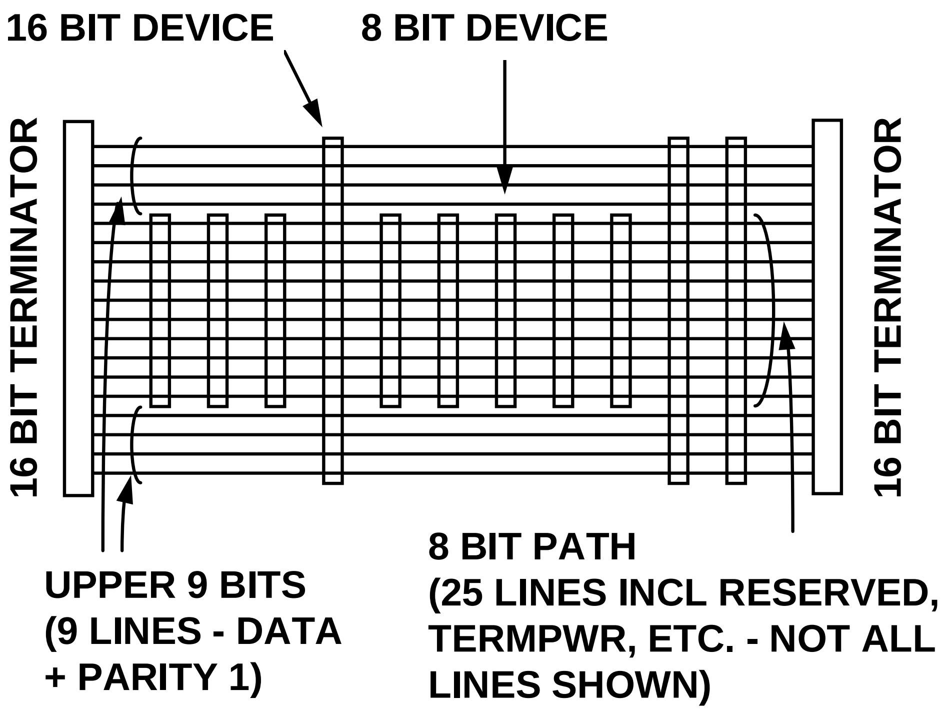

Figure 2 - Mixed width connections using 16-bit main path

This non-uniform loading produces timing skew in direct proportion to the number of 8-bit devices used and the electrical load they present. The worst case is when two 16-bit devices are near the opposite ends of the bus and there are 6 8-bit devices in between. Up to 14 8-bit devices could be placed between the 16-bit devices without exceeding the total device count of 16, but 14 8-bit devices could not work since there are only 8 address bits available on 8-bit devices and only 8 devices can be addressed. Since two of the devices are the 16-bit devices the maximum number of 8-bit devices is 6. With 6 8-bit devices between the two 16-bit devices there is 6 times the individual device loading skew on the data lines. Measurements have shown that a typical delay induced by a single SE device with 25 pF connector contact capacitance is approximately 0.5 ns. The one way timing skew in this worst case situation is approximately (6) x (0.5ns) = 3 ns. This is larger than the typical propagation delay timing skew produced by the cable media itself over long lengths and could be responsible for data errors in the upper 9 bits.

One way to lessen the impact of the non-uniform loading is to add electrical load to the upper 9 bits by the connection scheme used between the 8-bit devices and the 16-bit path.

If the 16-bit path uses the common 0.025" centerline flat ribbon cable there will be a connector conversion necessary to attach the 8-bit device. The connection to the flat ribbon cable will require a high density 68 position connector while the 8-bit device will require a 50 position low density connector. It is convenient to add discrete capacitors within the connector converter device between each of the upper 9 bits and a ground line. The value of the capacitors should be approximately the same as the connector

contact capacitance of the 8-bit device. Not all 8-bit devices have the same connector contact capacitance but a reasonable approximation is from 10 to 20 pF.

This compensation scheme can significantly reduce the skew to levels that are negligible.

If using round cable (either shielded or unshielded) for the 16-bit path it is possible to use the 50 position low density connector directly to the 16-bit path. In this case one should be careful not to break the conductors while attaching this connector in order to maintain equal path lengths for the lines. There is no convenient access to the upper 9 bits in this case so the non-uniform loading will still be present.

A better way is to use the 68 high density connectors for the round cable and use the scheme described above within the connector converter device.

The TERMPWR distribution also needs to be considered for this case. The 16-bit path has 4 conductors available for the TERMPWR. These 4 lines should be connected together by the 8/16-bit connector converter and passed to the TERMPWR lines on the 8-bit side. There is an issue however on the 8-bit side because the SE and HVD / LVD TERMPWR requirements are different. The SE uses only one TERMPWR line while both HVD AND LVD use two lines.

The risk is that some older SE devices may ground one of the contacts used for HVD and LVD TERMPWR. If one of these devices is attached it will connect the TERMPWR line to ground and disable the entire bus. The simple solution is to connect only the SE TERMPWR line from the 8-bit side to the 4 lines on the 16-bit side. This connector converter will work for both SE and HVD / LVD applications.

For the differential case any TERMPWR sources on the 8-bit devices will only use one TERMPWR line through the connector converter. Since the 8-bit devices are not allowed to have bus termination in this case one does not need to consider this condition.

9.1.2 Fast-40 case

When using Fast-40 LVD or HVD the structure described in 9.1.1 may be used. In this case the requirements for adding the appropriate capacitive loads to the upper nine bits may become even more critical because there is a stringent requirement for matching the capacitance on the data, parity, and REQ/ACK lines. In general it will require knowledge of the device capacitive loading to know how much capacitance is required so it is expected that the connector conversion device will need to be designed for the LVD device being used.

In practice, however, unless there are many 8-bit LVD devices to be added to the main 16-bit path this caution may be ignored because it is the combined effects of several devices that create the skew problems. One or two 8-bit LVD devices may be added to a 16-bit main path without the need for special, tweaked, connector adapters.

9.2 8-bit main path

The basic 8-bit main path option is shown in Figure 3. In this case there is no possibility of any 16-bit operation. The 16-bit devices are attached only to their control lines and lower data and parity lines. Since all the lower data and parity lines are connected in every device there is no possibility of the skew problems discussed in 9.1. The risks in this configuration are mainly (1) that the upper data and parity bits in the 16-bit devices will not be pulled to the false (negated) state at all times and will fail to complete the ARBITRATION phase and (2) that the ARBITRATION phase completes normally and the wide devices negotiate and attempt to execute a wide transfer.

If the upper bits are not set to a false (negated) state the 16-bit devices may detect that other 16-bit devices are arbitrating for the bus (since the upper data bits are true (asserted)) and will fail. Some electrical means for biasing these bits to the false (negated) state should be provided. One simple way for SE devices is to add a high value resistor (say 100K) to the 5V or 3V supply. This will keep the signals in a false (negated) state and will not significantly increase the device loading if the device is used in a wide application. For differential devices the +signal line may be grounded through a high value resistor and the - signal line may be connected to the 5V or 3V supply through a high value resistor.

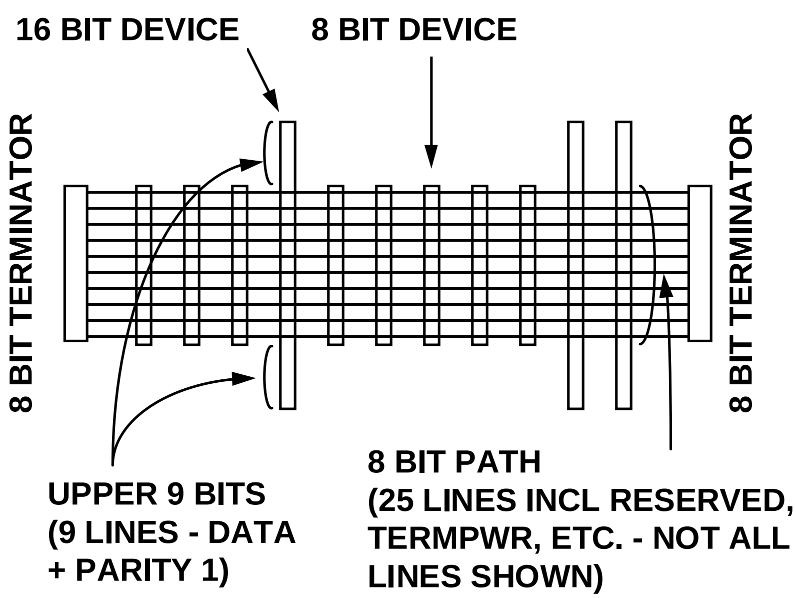

Figure 3 - Mixed width connections using 8-bit main path

If means are provided for setting the upper data and parity bits to the false state then additional constraints are needed to prevent negotiation of wide transfers between the wide devices.

9.3 Single 16-bit path and single 8-bit path

Figure 4 shows the configuration for a single 16-bit path and a single 8-bit path.

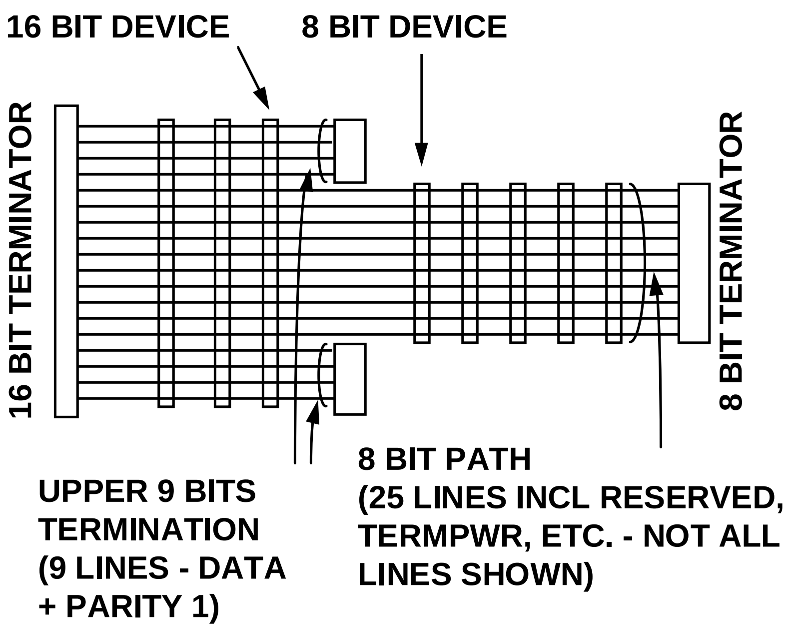

Figure 4 - Mixed width using a single 8-bit and a single 16-bit path

9.4 Multiple 8 or 16-bit paths

Figure 5 shows the configuration for two 8-bit paths and a single 16-bit path.

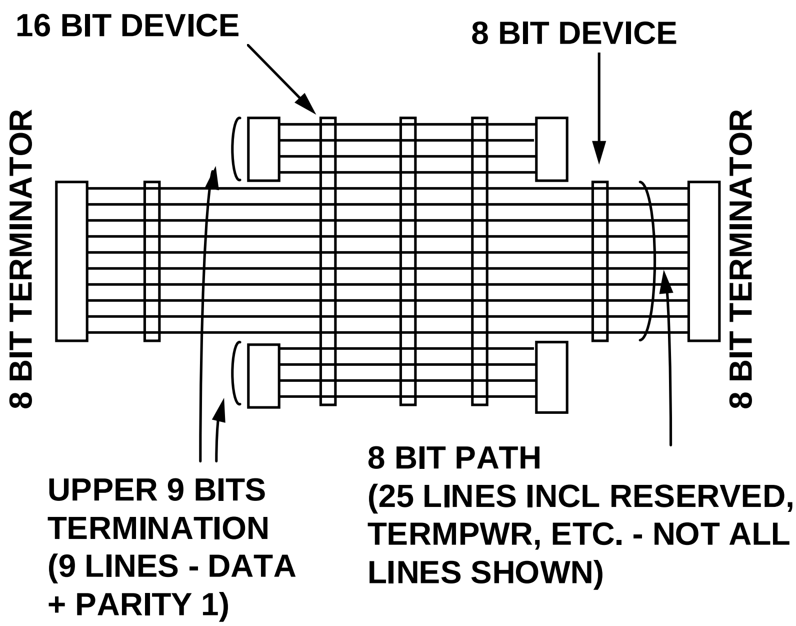

Figure 5 - Mixed width configuration with two 8-bit paths and one 16-bit path

Figure 6 shows two 16-bit paths and a single 8-bit path. This configuration is illegal unless independent means are provided to prevent negotiating a wide transfer between the wide devices. The wide transfer will fail since there is no wide path between the wide devices shown.

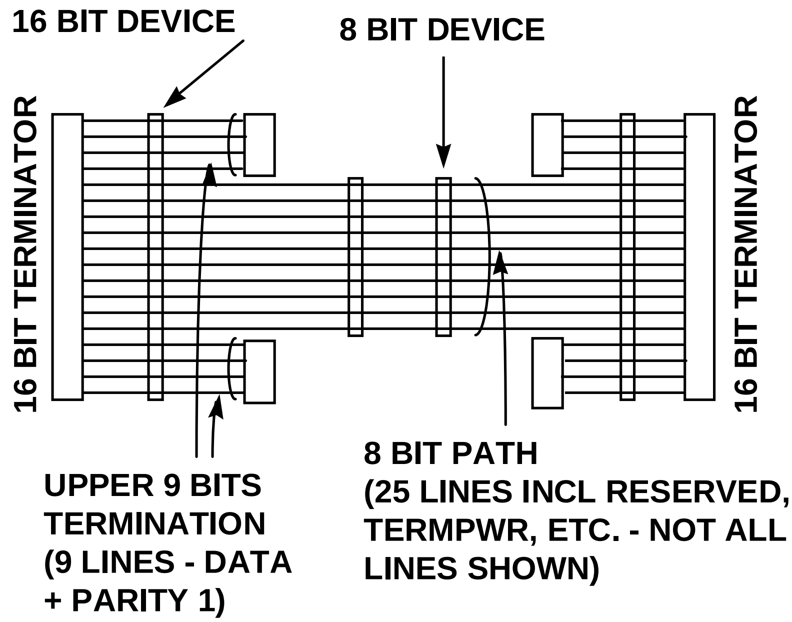

Figure 6 - Mixed width configuration with two 16-bit paths

10. Bus expanders

Bus expanders are elements used for connecting segments together. There are two basic types: simple and bridging. Simple expanders do not occupy a SCSI ID and are intended to be "invisible" to the protocols. Bridging expanders have SCSI IDs on all ports, participate in SCSI arbitration and messaging, and are “ devices” in the SCSI sense. The following clauses describe both types of expander.

10.1 Simple expanders

The following features are desirable properties of simple bus expanders:

- Minimal propagation delay budget consumed during arbitration
- No SCSI IDs, no arbitrations initiated, no messages originating with the expander sent (messages sent from initiators and targets could be read if desired)
- Retransmitted signal timing skew (both delay and hi/lo) no worse than from a valid SCSI device
- Does not interfere with the REQ/ACK offset count
- Min/Max pulse widths maintained
- A RESET filter required
- Powered expanders retransmit RESET assertions from one segment to the other regardless of the state of any other SCSI signals on either side
- Arbitrary placement of the initiator and targets with respect to the simple expander
- TERMPWR not connected between the segments being coupled
- May or may not need to know the negotiated data phase speed or any other variable property of a transaction (depending on implementation design)
- DIFFSENS line not electrically or logically connected between segments being coupled
- Transmission mode (SE/LVD, etc.) changes on one segment cause the expander to issue a SCSI bus RESET on the other side
- Propagates RESET under all powered up conditions.
  This allows the domain to be reset due to catastrophic events on one side that could lock up the expander.

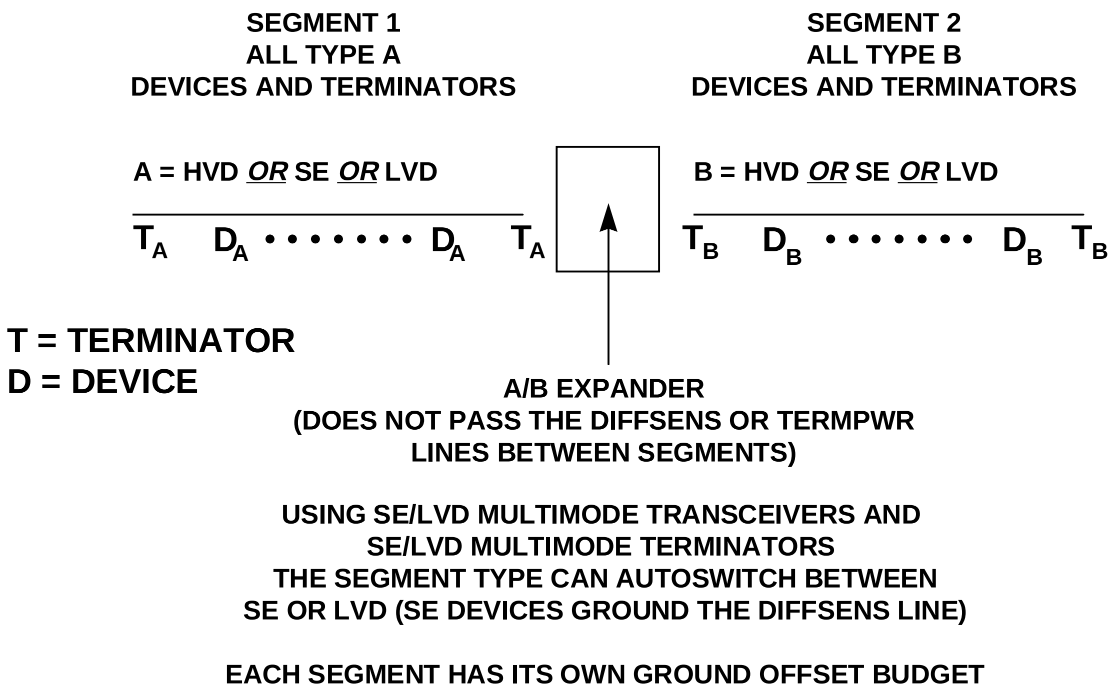

Figure 7 - A two segment domain using a single expander circuit

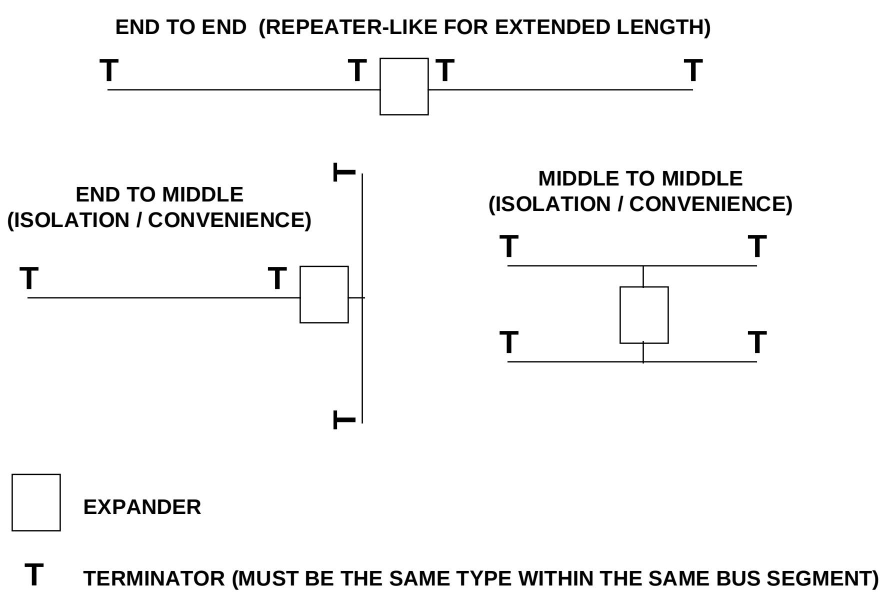

Figure 8 - Three ways to couple bus segments together with expanders

10.1.1 Homogeneous type

If an expander has the same type of segment on both sides it is termed a homogeneous expander. The homogeneous expander does not do type conversion (e.g. SE to HVD).

This kind of expander may be very useful in existing systems where dramatic domain length increases may be achieved by inserting a single homogeneous expander in the right place. Such a condition exists, for example in a domain where several SE devices are connected to a backplane and subsequently to a host adapter. By placing a homogeneous expander near the backplane one creates a short, heavily loaded backplane segment and a point to point segment to the host adapter. According to Table 1 the point to point SE segment length limit is 20 meters. Without the expander only 1.5 meters including that on the backplane is allowed.

If extended lengths are all that is needed, homogeneous expanders act somewhat similarly to simplex serial line repeaters. They must do more than repeat the signal to work with SCSI but they occupy the same position in a domain drawing as a “repeater”.

Homogeneous expanders also provide for isolation of segments from a “main” segment.

10.1.2 Heterogeneous types

Expanders that have different bus transmission types on each side are heterogeneous expanders. Using this kind of expander frequently requires planning the domain details before acquiring the devices and expanders, rather than “upgrading” afterwards as with the homogeneous expander. Of course, any expander that implements the multimode MSE/LVD transceivers can become either homogeneous or heterogeneous.

Heterogeneous expanders are sometimes termed “bus converters”.

Heterogeneous expanders may be used in “repeater” modes or in “isolation” modes in the same general way as homogeneous expanders.

10.1.3 Domain examples using simple expanders

Figure 9 shows some examples of domains that may be built using only simple expanders.

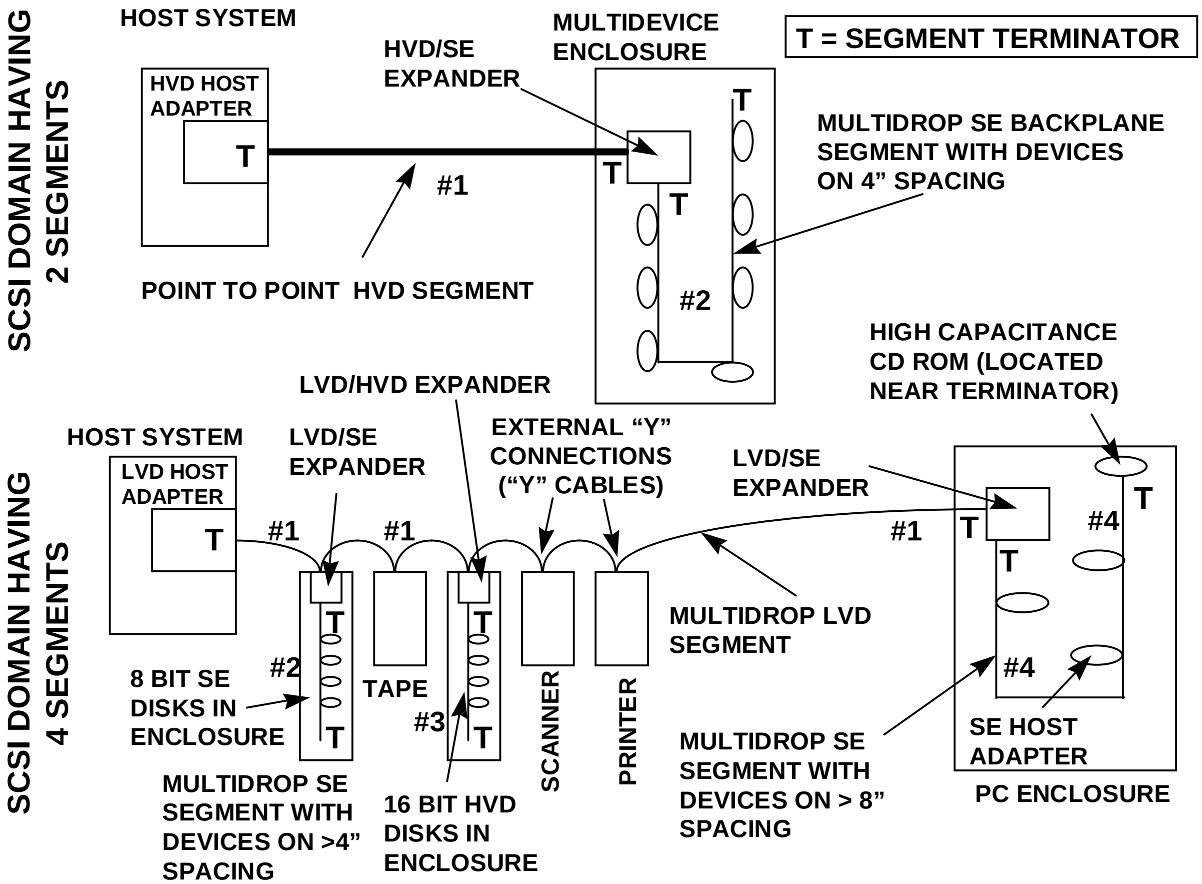

Figure 9 - Examples of domains using simple expanders

10.1.4 General rules for SCSI domains using simple expanders

The rules are summarized in 10.1.4.1 followed by detailed discussion for each in the subsequent clauses.

10.1.4.1 Rule summary

Valid SCSI domains shall follow these five rules:

1. All bus segments in the domain shall comply with their individual bus segment length limits and other segment related requirements as defined in clause 8.

2. Any segment between two other segments shall support the highest performance level that can be negotiated between the two other segments. For example two wide LVD Fast-40 segments shall not be separated by a segment that does not support both wide and Fast-40. See Table 4 for definition of increasing performance levels. See Figure 10 for examples.

3. The maximum propagation delay between any two devices in the domain shall not exceed 400 ns. For devices that use extremely long times for responding to BUS FREE (the so-called BUS SET DELAY) the one way propagation limit is 300 ns instead of 400 ns (See Figure 11). These extremely long times are caused by devices that use excessive tolerance for their internal clock frequency (like 2x) with resulting sluggish response to asserting their IDs if they wish to participate in arbitration. It is suspected that this condition may exist in older applications.

4. The number of addressable devices shall not exceed 16 unless the domain contains LUN bridges.

5. Loops are not allowed.

6. The REQ/ACK offset negotiated between any two devices shall be large enough to ensure that adequate offset and buffering is available to accommodate the round trip time between the devices. For Fast-20 data phase speeds with a maximum domain propagation time this is a minimum offset of 18. See Table 6.

10.1.4.2 Rule 1

Rule 1 is defined in detail in clause 8.

10.1.4.3 Rule 2

Rule 2 relates to intermediate segments which only exist in domains of at least three segments. The segment between the two other segments is the intermediate segment. The formal ranking of the performance properties for segments is specified in Table 4.

Table 4 - Performance ranking for intermediate segments

Performance features listed in order of increasing performance	
Bus segment width	Maximum data phase speed
8-bit	Async
	Fast-5 sync
16-bit	Fast-10 sync
	Fast-20 sync
	Fast-40 sync
	Higher speeds to be defined in future

Configurations might exist that satisfy Rule 2 but violate Rule 1. An example of such a configuration is shown in Figure 10.

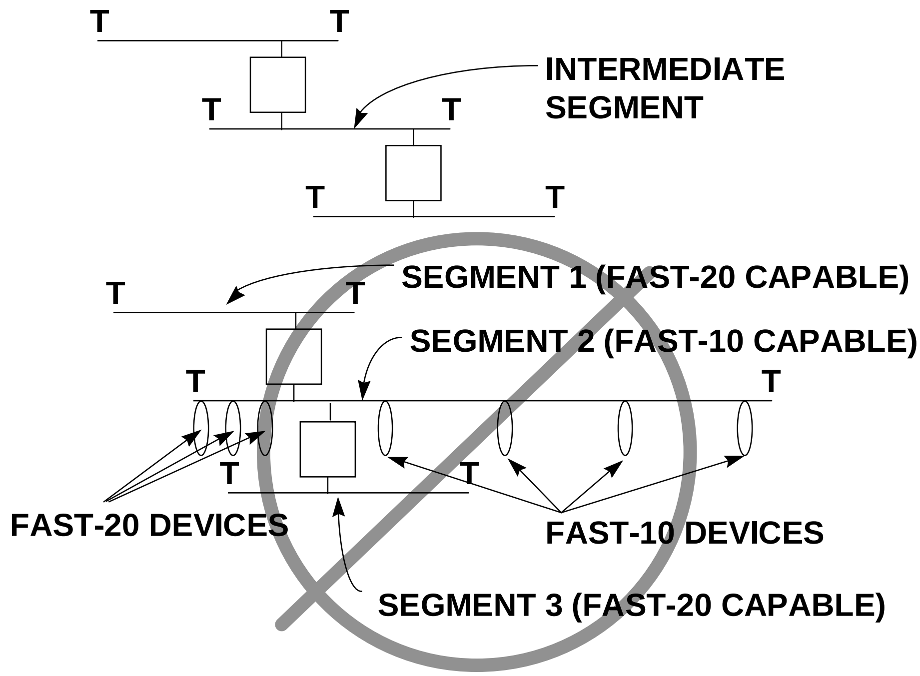

Figure 10 - Intermediate segments and performance ranking

The configuration in Figure 10 is valid only if the data phase rate is limited to Fast-10 for any data phase transactions between segment 1 and segment 2, segment 2 and segment 3 or segment 1 and segment 3. Even though the Fast-20 devices in segment 2 are located close to the expanders and the distance between the expanders is small, the segment length is defined by the distance between the terminators - not by the distance to the expander connection or to the devices. The intermediate segment is not Fast-20 capable and may not be used for Fast-20 transactions between segment 1 and segment 3. Segment 2 is also not to be used for Fast-20 transactions within segment 2. Fast-20 transactions are allowed between devices in segment 1 or between devices in segment 3.

The intermediate segment in this example will see signals at the higher data rates on the DATA and parity lines but since the devices in the intermediate segment are not participating in the higher data rate transmission and are waiting for the next BUS FREE, RESET or other general SCSI phase they are unaffected by the higher speeds.

For multimode segments, any dynamic change of transmission mode (LVD to SE etc.) is treated as a fault and the expander is obligated to assert the RESET line on the segment opposite the one that experienced the transmission mode change. The expander will detect this state change by sensing the DIFFSENS line. This scheme ensures that the initiators on the other segments are aware of the change in transmission mode and can reassess whether this mode change is consistent with the performance requirements for the segments and the overall parameters for the domain before allowing traffic to resume. There is no reliable way to communicate the transmission mode change condition other than using the RESET line. Once RESET is asserted initiators are obliged to renegotiate and should initiate a console level investigation as to the health of the entire domain. (Note that multimode SCSI interface devices such as LVD/MSE are intended to simplify the inventory and part number proliferation issues and are not intended to support dynamic transmission mode changes.)

10.1.4.4 Rule 3

10.1.4.4.1 Effects of wired-or glitches

Wired-or glitches occur when two on more drivers are asserting the same bus line and one ceases to drive the line. This happens frequently during arbitration on the BSY signal. This change in the number of asserted drivers causes a redistribution of current In the bus (with resulting voltage glitches) and may cause false detection of BUS FREE. The worst case condition is when two devices near a segment terminator are involved. In this case it requires a full segment length round trip time before the line is again stable (after the device stopped asserting the line). If this condition applies, the round trip time allowed is 400 ns. The one way time is 200 ns.

Waiting the entire domain round trip time may be avoided by ensuring that wired-or glitches do not pass through the expander. This technical report does not describe how these expanders are implemented but expanders do exist that have these glitch filters. If glitches are not propagated through the expanders and the conditions described in 10.1.4.4.2 do not apply, then the round trip domain signal propagation time is 800 ns and the one way domain propagation time is 400 ns.

10.1.4.4.2 Effects of slow response to BUS FREE

For devices that use extremely long times for responding to BUS FREE (BUS SET DELAY), the one way propagation limit is 300 ns instead of 400 ns. Figure 11 shows how this 300 ns is derived. The maximum bus set delay is set at 1800 ns in SCSI-2, SCSI-3 SPI, and SCSI-3 Fast-20. The new number in SPI-2 is 1600 ns. Domains that contain only SPI-2 compliant devices are not affected by this clause.

For other domains It is recommended to ignore this 300 ns limit and use either 200 ns or 400 ns for developing specific implementations.

The conditions where the 300 ns domain propagation limit applies are defined in Figure 11.

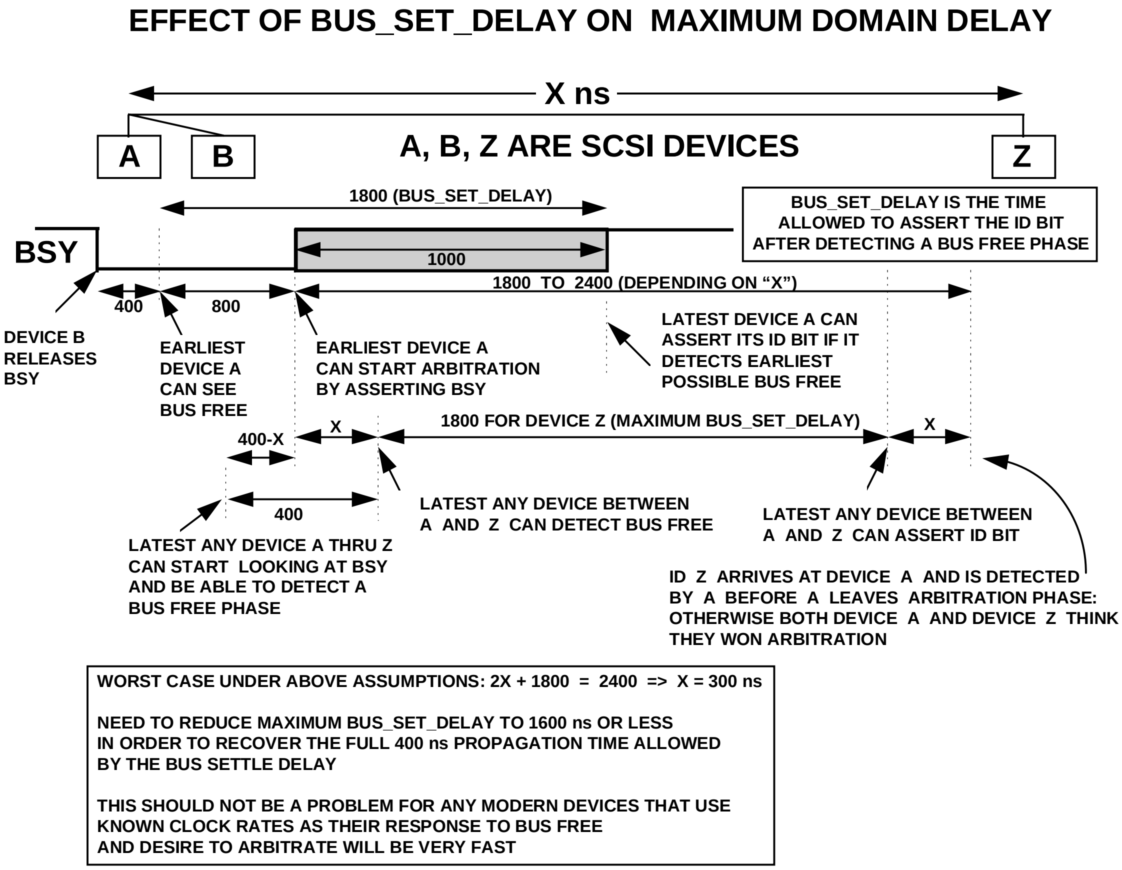

Figure 11 - Explanation of the 300 ns domain limit caused by 1800 ns BUS_SET_DELAY

10.1.4.4.3 Expander propagation delay effects

The expander is said to be in series with initiators and/or targets when the path between the initiators and/or targets goes through an expander. In this case the propagation delay through the expander shall be counted as part of the 400 ns budget between those devices.

The delay varies depending on the implementations. Care shall be exercised when considering expanders to understand the capabilities of the expanders being used. When two expanders are in series the delay across the pair may be much less than twice the individual delays. This is because the " direction" change that consumes much of the propagation delay during arbitration will only apply to one of the expanders at a time. The single expander delay, Tds and the expander series pair delay, Tdp should be specified.

Delays for SE/HVD expanders are much longer than the delays through SE/SE versions. This is caused by the additional propagation time through the HVD interface and the fact that the direction reversal is the most time consuming part of the propagation delay for the differential transceivers.

If the expander is attached to a segment (as in case of the device enclosures in the bottom part of Figure 9) it is only in series between the devices in the enclosure and other devices in the domain. The expander in the enclosure would not be in series between the two host ports for example.

The propagation delay through the differential transceivers of initiators and targets does not need to be separately accounted for if the wired-or glitches cannot propagate through the expander. The differential transceiver delay effects are confined to the differential segments. Using expanders that do not pass the wired-or glitch prevents one segment's delays from being passed on to the next. This is indeed fortunate since the propagation time through differential transceivers can be significant and would subtract from the overall domain budget.

If devices that use the high voltage differential interface are built in compliance with the SCSI standard there will be no difference due to transceiver propagation delay because all SCSI timings are measured at the device connector independent of whether it is a SE, HVD, or LVD interface. On the other hand, since many protocol chips offer direct SE or MSE/LVD transceiver options it is very likely that the propagation delay through the separate HVD transceivers will not have been counted in the single segment timing budget (as seen by the protocol chip). This will not matter in most cases if the single segment length is limited to 25 meters since there is adequate margin included in the 25 meter maximum length. HVD segments that extend the length beyond 25 meters and do not observe the timings at the device connector may produce excessively long wired-or glitches as seen by the protocol chips.

10.1.4.4.4 Sample calculations

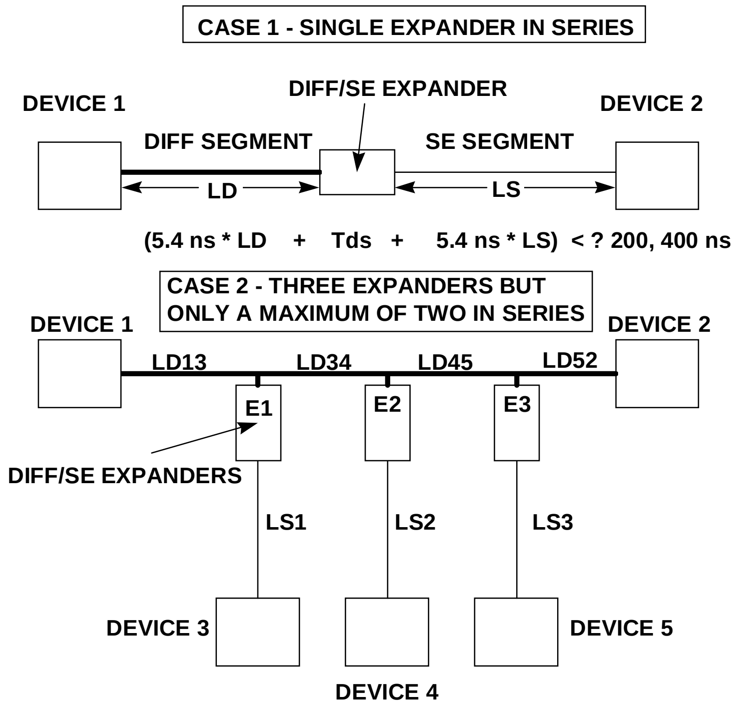

Figure 12 - Two configurations for domain delay calculations

Figure 12 shows two sample SCSI domain configurations. In Figure 12 parameters whose first letter is "L" are physical lengths, "D" refers to differential segments and "S" refers to single ended segments. In case 1 the delay calculations are shown in the figure. For the more complex case 2 one shall consider all the possible combinations between any two devices. These calculations are shown in Table 5. The device pair that has the largest combination of expander delay and interconnect delay determines if this configuration meets the 200, 300, or 400 ns requirement.

While this may appear complex, the limiting cases may be obvious without the rigorous analysis.

Table 5 - Domain delay calculations

DEVICE PAIR	PATH BETWEEN DEVICES	EXPANDERS DELAY (ns)	INTERCONNECT DELAY (ns)
1-2	LD13,LD34,LD45,LD52	0	5.4*(LD13+LD34+LD45+LD52)
1-3	LD13,E1,LS1	Tds	5.4*(LD13+LS1)
1-4	LD13,LD34,E2,LS2	Tds	5.4*(LD13+LD34+LS2)
1-5	LD13,LD34,LD45,E3,LS3	Tds	5.4*(LD13+LD34+LD45+LS3)
2-3	LD52,LD45,LD34,E1,LS1	Tds	5.4*(LD52+LD45+LD34+LS1)
2-4	LD52,LD45,E2,LS2	Tds	5.4*(LD52+LD45+LS2)
2-5	LD52,E3,LS3	Tds	5.4*(LD52+LS3)
3-4	LS1,E1,LD34,E2,LS2	Tdp	5.4*(LS1+LD34+LS2)
3-5	LS1,E1,LD34,LD45,E3,LS3	Tdp	5.4*(LS1+LD34+LD45+LS3)
4-5	LS2,E2,LD45,E3,LS3	Tdp	5.4*(LS2+LD45+LS3)

10.1.4.5 Rule 4

Without special expanders that remap the SCSI IDs to LUNS (LUN bridges 10.2.2) there are only 16 data bit lines everywhere in a wide domain and this sets the upper limit of the number of initiators plus the number of targets to 16 for the entire domain. For narrow domains the maximum number is 8.

10.1.4.6 Rule 5

Since each line is required to remain responsive to the drivers it is necessary that no lock up conditions exist. Using expanders connected in a loop it is very easy to create conditions where both an expander and a target or initiator are asserting a line. Under these conditions the line will not return to the negated state when the initiator or target releases the line since it will continue to be driven by the expander. The logic state of the line will not change and a lock up condition exists.

Loops are not allowed in any form within a domain. Figure 13 shows some examples of loops. Even if it appears that no deadlock condition is possible (in some symmetrical configurations for example) loops are still not allowed because the propagation time variability between components guarantees asymmetry and non-zero deadlock risk.

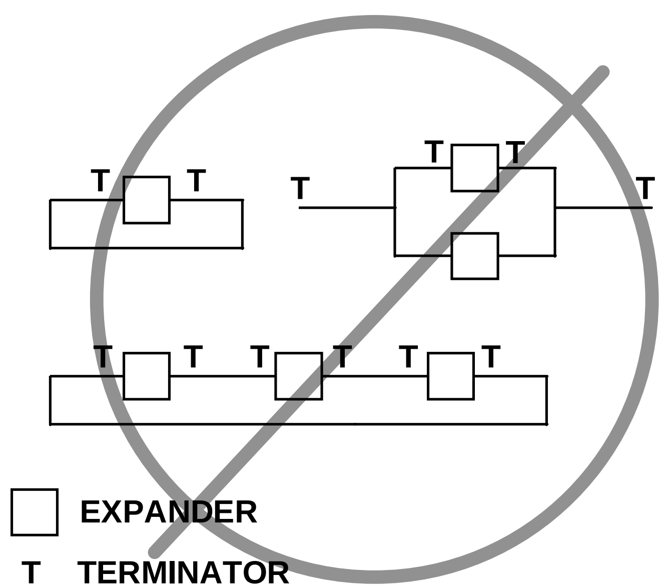

Figure 13 - Examples of illegal loops

10.1.4.7 Rule 6 (REQ/ACK offset)

The REQ/ACK offset is the difference between the number of REQ pulses sent (received) and the number of ACK pulses received (sent) in a synchronous data phase transmission. This offset allows a number of transmissions to be on the domain media at the same time.

The device offset counter is set to zero before the data phase begins. When a REQ is sent or received the offset counter is incremented. When an ACK is sent or received the counter is decremented. After the data phase is completed the offset counter should again be at zero since the number of REQs and ACKs should be the same. If this return to zero is not detected it is an indication of very serious problems and should be corrected before using the domain for any critical work.

When the target sends the first REQ pulse there is a minimum of one round trip time before the first ACK pulse can be received from the initiator. This round trip time includes the data processing time at the initiator. Meanwhile, the target may continue to issue REQ pulses until the offset counter reaches the maximum REQ/ACK offset level that was negotiated.

If the maximum offset level is reached, the target waits until it receives a decrementing ACK pulse before issuing another REQ pulse. When the maximum REQ/ACK offset is reached it means that the initiator has stalled the transfer because it is not ready to send or receive another transfer. Initiators designed for maximum performance avoid this condition.

The receiving device is required to accept up to at least the maximum REQ/ACK offset level of data phase transfers in its buffers.

REQ/ACK offsets do not apply to simple expanders.

The minimum desirable offset value is given by:

[{2x one way domain delay} / {ACK (REQ) period}] + processing overhead

Table 6 gives some representative values from the above expression assuming the processing overhead to be 2 ACK(REQ) periods in all cases.

Table 6 - Minimum REQ/ACK offset levels for maximum performance

Domain round trip delay (ns)	Data phase speed	ACK(REQ) period (min)	Minimum REQ/ACK offset to avoid performance degradation (assuming 2 overhead periods in all cases)
100	Fast-10	100	3
200	Fast-10	100	4
300	Fast-10	100	5
400	Fast-10	100	6
500	Fast-10	100	7
600	Fast-10	100	8
700	Fast-10	100	9
800	Fast-10	100	10
100	Fast-20	50	4
200	Fast-20	50	6

300	Fast-20	50	8
400	Fast-20	50	10
500	Fast-20	50	12
600	Fast-20	50	14
700	Fast-20	50	16
800	Fast-20	50	18
100	Fast-40	25	6
200	Fast-40	25	10
300	Fast-40	25	14
400	Fast-40	25	18
500	Fast-40	25	22
600	Fast-40	25	26
700	Fast-40	25	30
800	Fast-40	25	34
Higher speeds defined in the future continue to use the algorithm represented in this table unless the REQ/ACK mechanism changes			

10.2 Bridging expanders

Bridging expanders perform the electrical isolation functions of simple expanders but may not be bound by all the same configuration rules. In their most general form, bridging expanders appear as multiple internally interconnected SCSI devices (each with its own independent ID and external [to the expander] connector) that are capable of passing payload data within the expander between the SCSI ports. This architecture is shown in Figure 14.

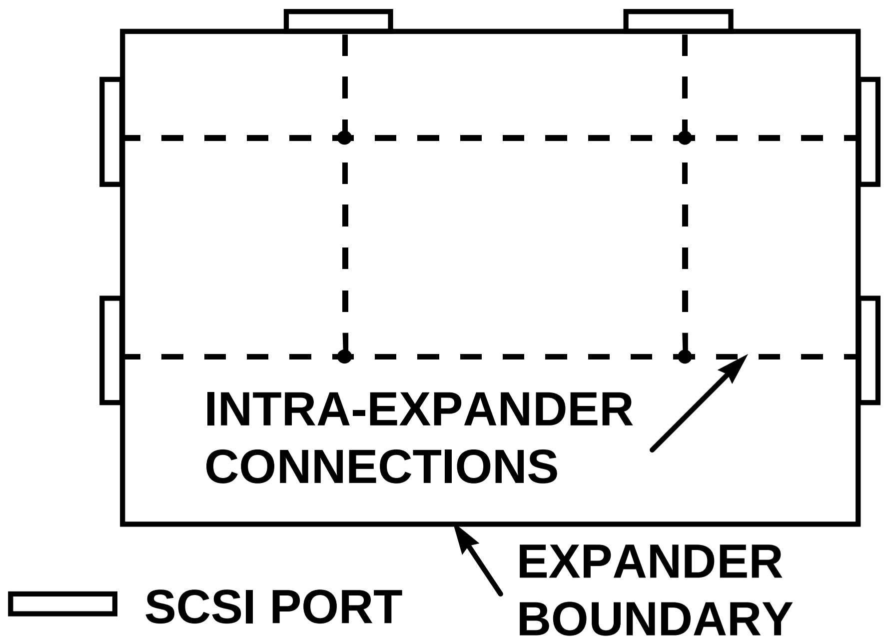

Figure 14 - General bridging expander

It is not the intent of this technical report to describe general bridging expanders since the number of possibilities are quite diverse. For example, the boundary in Figure 14 could be a server system with three dual port SCSI-to-PCI adapters.

There are three special cases of bridging expanders that will be discussed, however: (1) two-port caching expanders that allow some provision for data buffering, (2) address-enhancing expanders that use the LUN field presently defined in SCSI as the mechanism for the address expansion and (3) multiport SCSI switches that route information to specific switch ports depending on the final destination.

10.2.1 Two-port caching expanders

The least complex caching expander has two ports and some means for buffering data between the ports. This structure could be considered for use in cases where one desires to allow different data phase speed operation in the same domain thereby necessitating

buffering of data in the expander. Another use could be to accept or deliver data from/to out of band (i.e. non-SCSI) sources. Caching expanders are prone to deadlock problems if the buffer or cache ever becomes full and it requires management beyond SCSI to use this type of expander effectively. We will not consider two-port caching expanders further in this technical report. They could be integrated into a single chip but tend to be only useful for very specialized applications.

Multiport (more than two ports) expanders with caching are considered in 10.2.4 (Switching expanders).

10.2.2 Logical unit bridges

The bridging expander of primary focus in this technical report is the address-enhancing expander termed the logical unit bridge or the "LUN Bridge". The requirements for LUN bridges form the balance of this clause.

LUN bridges described in this technical report may be used in the general configuration shown in Figure 15. This is one of at least three configuration cases and the only case that will work with the LUN bridges having the properties described here. Two other cases are shown in Figure 16 and Figure 17 for reference. Case 2 and Case 3 require functionality of the LUN bridges that are beyond the scope of this technical report.

Up to 945 devices may be addressed from a single host port by using the maximum number of secondary bridge busses and maximum number of LUN bridges with the configuration shown in Figure 15. This number is derived by assuming a single initiator on the primary bridge bus, 15 LUN bridges each with 63 targets on their respective secondary busses (15 x 63 = 945). Each LUN bridge can support 64 LUNS but one is reserved for the LUN bridge itself thus leaving only 63 for ordinary target devices.

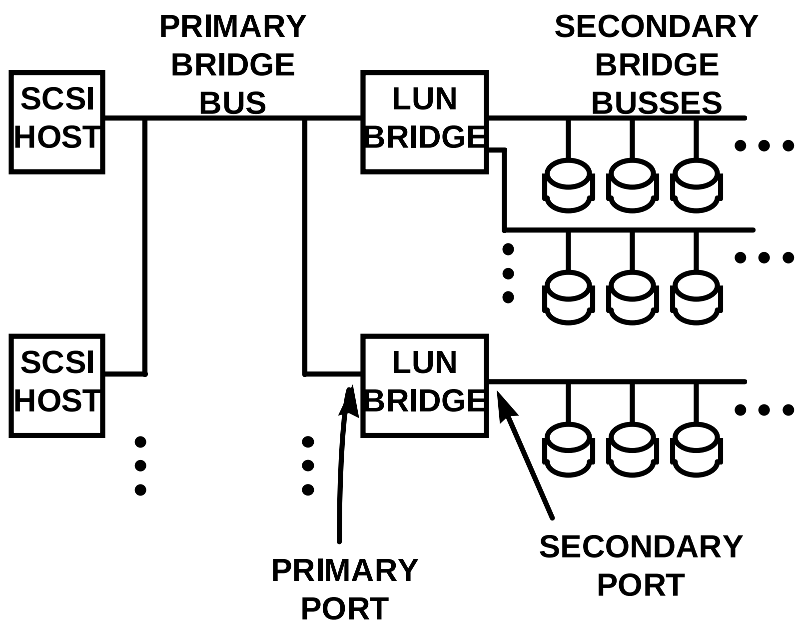

Figure 15 - Case 1 LUN bridge architecture

Each SCSI device on a primary bridge bus (which may contain simple expanders) has a unique SCSI ID (0 to 15). Each SCSI device on a secondary bridge bus has a unique ID (0 to 15). The SCSI IDs on a secondary bridge bus may be the same or different from those used by the devices on the primary bridge bus or other secondary bridge busses. The primary port of the Case 1 LUN bridge has a unique ID on the primary bridge bus. The secondary port of the Case 1 LUN bridge has a unique ID on the secondary bridge bus.

The real targets will be mapped by the Case 1 LUN bridge as LUNS under the primary port ID of the LUN bridge. For example a target with ID 3 on a secondary bridge bus on a LUN bridge with ID5 on its primary port will appear as ID 5 LUN(x) to the host. “x” is mapped by the LUN bridge.

It is the intent for Case 1 LUN bridges to be able to work with existing targets. However, LUN bridges may vary in their ability to support different features. The usual SCSI variables of transmission mode, bus width, and SCAM support may differ. Other important features may include support for multiple LUN secondary bridge bus devices and need for homogeneous speed capabilities for all devices on the secondary bridge bus.

Case 1 LUN bridges have specific requirements and constraints as detailed below. They have many of the same properties as simple expanders.

Case 1 LUN bridges may use the same implementation techniques used by simple expanders during ARBITRATION and SELECTION. The implementation techniques implied by the requirements on simple expanders (described in 10.1) are not defined in this technical report. Using these techniques avoids a separate solution for these phases for LUN bridges and includes solutions for possible difficulties with RESELECTION timing.

Primary and secondary busses may contain simple expanders with multiple segments. The overall domain configuration rules are the same as for simple expanders (10.1.4) except that the device count limit is changed to that specified in this clause.

The following features characterize Case 1 LUN bridges and the Case 1 configuration rules:

- Special case of a bridging expander (Figure 15) that has one primary port and one or more secondary ports
- Only one LUN bridge port on each secondary bridge bus
- One or more initiators on primary bridge busses
- No initiators on the secondary bus other than the LUN bridge
  This includes devices that use the AEN or COPY commands.
- LUN (0) assigned to the LUN bridge under its primary bridge bus ID to enable direct communication to the LUN bridge
- Supports the REPORT LUNS command on LUN (0)
- Retransmits data phase transfers at the same speed through the primary and secondary ports (no buffering in the LUN bridge beyond that required to achieve the retiming)
- Speed negotiations executed on a target basis only

  In the LUN bridge case the target is the LUN bridge. This means that the host does not need to know the actual speed capabilities of the real devices and that the LUN bridge shall translate the SDTR message content between the host and the target devices.
- Uses the device type code of 10h as reserved in SPC-2 for use with bridging expanders (including LUN bridges)
- A REPORT LUNS command causes the LUN bridge to report the current configuration of the secondary busses.
- LUN bridges shall either handle error messages directly with the target or pass the messages to the host
- Dynamic changes of target populations available to the host through the REPORT LUNS command

  No specific mechanism is presently defined to detect that the population has changed. If a LUN bridge detects a configuration change, it should report UNIT ATTENTION CONDITION and Additional Sense Data of REPORTED LUNS DATA HAS CHANGED (ASC=3Fh, ASCQ= 0Eh in SPC-2).
- Minimal propagation delay budget consumed during arbitration by the LUN bridge
- Retransmitted signals comply with the requirements for a valid SCSI device
- Does not interfere with the REQ/ACK offset count

- A SPI RESET filter (low pass) required
- TERMPWR not directly connected between the segments being coupled
- DIFFSENS line not electrically or logically connected between segments being coupled
- Transmission mode (SE/LVD, etc.) changes on a primary bridge bus cause the LUN bridge to issue a SCSI bus RESET on all secondary busses
- Transmission mode changes on a secondary bridge bus cause the LUN bridge to issue a RESET only for the secondary bridge bus that caused the transmission mode change

10.2.3 Unsupported configurations

10.2.3.1 Case 2

Case 2 is described as two LUN bridges attached to a secondary bus with dual and separate primary busses with each primary bus is limited to a single host.

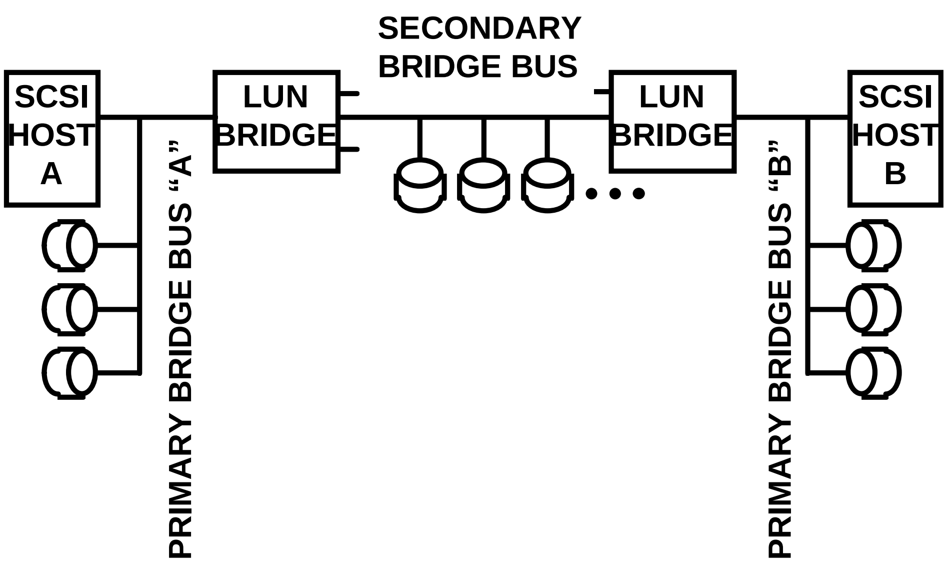

Figure 16 - Unsupported Case 2 configuration

10.2.3.2 Case 3

Case 3 is described as two LUN bridges attached to a secondary bus and multiple initiators allowed on the primary bus (each initiator attached to the same primary bus)

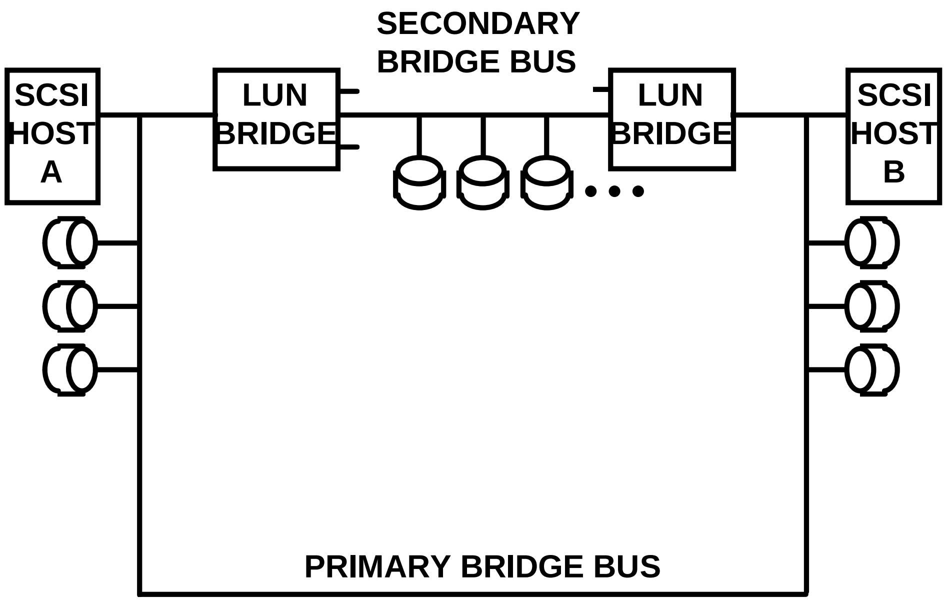

Figure 17 - Unsupported Case 3 configuration

10.2.4 Switching expanders

A form of caching bridging expander that acts as a multiple data path switch (as opposed to a mechanical switch) is considered in this clause. This architecture requires considerable non-SCSI logic to control the data paths and also requires caching functionality.

The switch is different from a case 1 LUN bridge because a more general set of ports is allowed and the requirements for device placement are relaxed. Case 1 LUN bridges require a single primary port and may not have any initiators on the secondary busses (except for the LUN bridge itself). With a switch, all ports are initiators and there are no restrictions on the number of initiators on any ports. There is no distinction between primary and secondary busses. A full range of ID/LUNS is available to use for every switch port. Every switch port has a SCSI ID for the port and that ID is part of the ID set for the domain attached to that port. LUN(0) on the port ID is reserved for the switch port.

A data path can be constructed within the switch between any two switch ports by using source and destination information contained within the SCSI information phases of the received data. By reading this information the SCSI switch can determine the final destination for the information in terms of the SCSI ports on the switch and the ID/LUN of devices on the switch port.

A SCSI switch enables an expansion of a SCSI domain to include switch ports in addition to the ID/LUNS on the switch ports.

SCSI switches use the device type code 10h as reserved for bridging expanders in SPC-2.

SCSI switches can sustain simultaneous data paths between any two ports. This capability allows much better utilization of system resources when compared to other types of expander because the busses attached to switch ports can be used simultaneously for different tasks.

Figure 18 shows one set of data paths established by the switch for specific tasks.

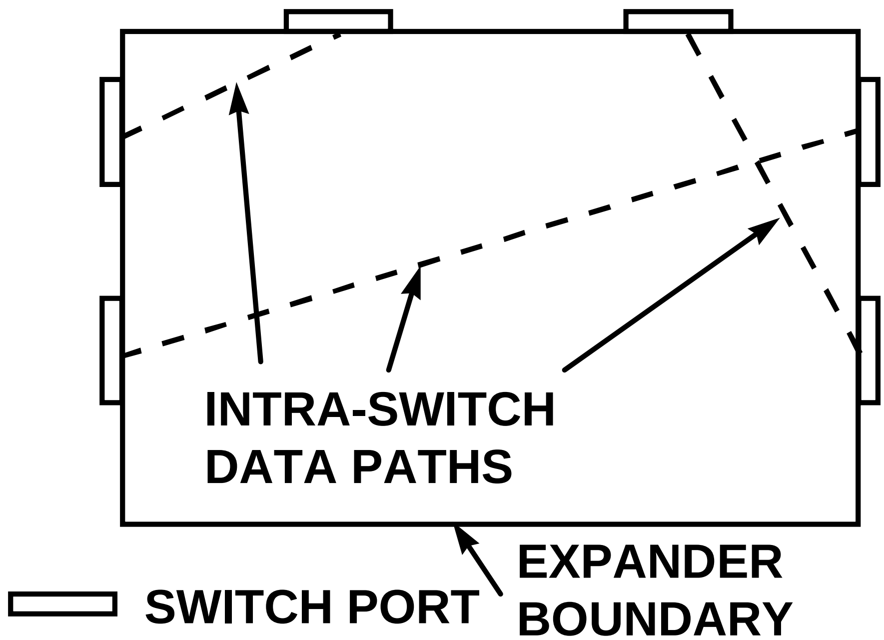

Figure 18 - One set of data paths in a SCSI switch

The data paths can be different for each information transfer requested.

Figure 19 shows the same switch servicing a different set of tasks that need a different set of data paths.

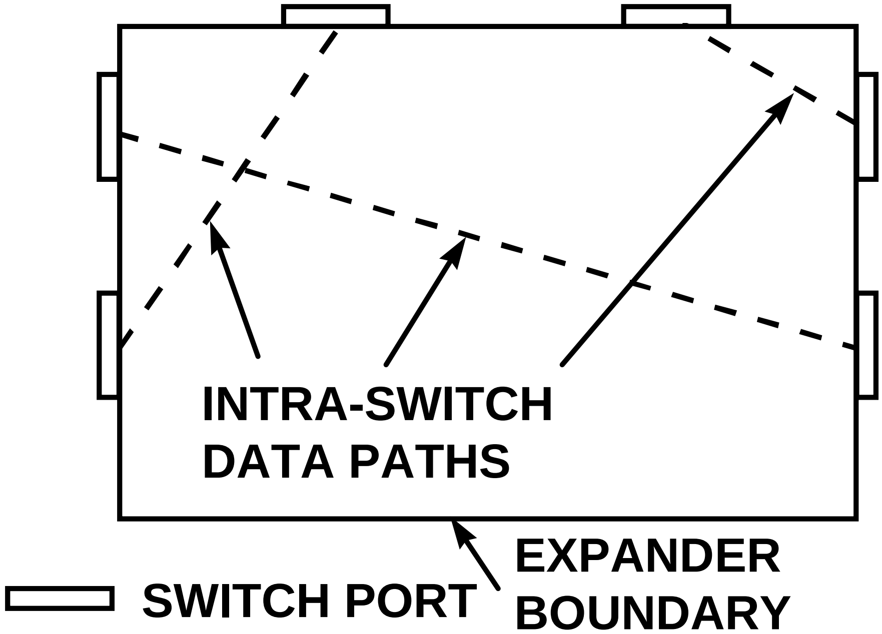

Figure 19 - Another set of data paths in the same SCSI switch

SCSI devices connected to the same switch port communicate with each other as they would if there were no switch present. Transferring information to SCSI devices connected to other switch ports or to the switch itself requires addressing the information to the switch port for the source device under the switch port's ID and LUN with information containing the destination port and the ID/LUN of the destination device. The switch has the responsibility to read this information and direct the data to the destination switch port where the switch will execute the subsequent transfer to the destination device.

All switch ports shall be initiators that support target mode.

The structure of the information directed to the switch and to devices on other switch ports is not defined in this technical report.

Requirements on switches include:

- TERMPWR not directly connected between switch ports
- DIFFSENS not connected electrically or logically between switch ports
- RESETS not passed from one switch port to another switch port (except if deemed by the switch to be needed and then shall not be implemented by a direct electrical connection)
- May supply TERMPWR to attached busses
- The REPORT LUNS command supported by every switch port under LUN(0) for reporting the configuration and status of attached devices, switch status, and port status.

- Responsible for avoiding deadlock between ports.

11. Dynamic reconfigurations of domains

This clause describes the processes operating during reconfiguration of the domain while the domain is still partially operational. Reconfigurations may take the form of changing the population, location or operational state of devices in the domain or changing the population, location or operational state of bus segments in the domain.

11.1 Addition and removal of devices

This clause describes the processes and procedures to be used when adding or removing devices from an active domain.

11.1.1 Framework for device addition and removal process

This clause describes the stages that shall be considered during the addition, removal or operational state change of SCSI devices. For convenience, this entire process is termed hot plugging in this technical report.

11.1.1.1 End states and other terminology

There are two end states involved with removal and insertion of SCSI devices:

1) Operational state (ES1):

The SCSI device in the operational state (ES1) is:

- fully secured in the service enclosure
- fully powered
- fully connected to all SCSI signal, TERMPWR, and ground contacts
- physically static (except for parts that normally move in service such as disk heads and media)
- fully enabled to participate in all activities allowed by the design of the device and system.

2) Stored state (ES2):

The SCSI device in the stored state (ES2) is:

- unpowered
- electrically discharged
- physically static

- logically unprogrammed
- physically separated from the bus and the system enclosures that contain the bus connections for the device
- residing within a device storage container.

The device being moved between the end states is termed the object device.
Object devices are outgoing object devices if they are going from ES1 to ES2 (operational state to stored state).
Object devices are incoming object devices if they are going from ES2 to ES1 (stored state to operational state).

As soon as any part of an end state condition is no longer valid the object device is said to be in transition.

The SCSI bus segment that directly connects to an object device when in the ES1 state is termed the main bus segment for that device.

11.1.1.2 Hot-plugging process

The hot plugging process requires moving SCSI devices from one end state to the other without inducing damage to any hardware, firmware or software component. Data in the system or in the object device also remains unaffected during an effective hot plugging operation.

Some level of disruption to the activities on the main bus segment occurs regardless of the hot plugging process used. For example, in one significantly disruptive hot plugging process, the main bus segment is shut down completely for parts of the object device transition. In a minimally disruptive hot plugging process, extra communications across the main bus segment are necessary to inform the object device or other devices on the main bus of the impending end state change. These communications affect the usable bandwidth of the domain. There is an intrinsic inverse trade off between the care required during the hot plugging process and the degree of disruption produced.

The SCSI device hot plugging processes described in this section focus on the most demanding applications where minimal disruption to the main bus segment activities is needed. One may move to more disruptive hot plugging processes if implementing certain requirements for minimally disruptive processes is impractical in specific applications. The degree of tolerable main bus segment disruption is application dependent. The device properties, the application requirements, and the hot plugging process should be consistent with each other.

11.1.1.3 Framework for incoming object devices

Incoming object devices will go through the steps listed below beginning with ES2 and ending with ES1.

Stored end state (ES2)

A. transition out of storage container
B. transition between storage container and service enclosure
C. initial transition into service enclosure physical constraint
D. transition to state immediately prior to making electrical contact with any service enclosure electrical pins
E. transition from no electrical contact to full electrical contact
F. device initialization
G. first communications
H. final start up communications

Operational end state (ES1)

11.1.1.4 Framework for outgoing object devices

Outgoing object devices will go through the steps listed below beginning with ES1 and ending with ES2.

Operational end state (ES1)

A. communications to begin removal from the active bus segment
B. all I/O activity to outgoing object device ceased
C. device shut down
D. transition from full electrical contact to no electrical contact to bus segment
E. transition from state immediately after no electrical contact to ready for final removal from service enclosure
F. final removal from service enclosure physical constraints
G. transition between service enclosure and storage container
H. transition into storage container

Stored end state (ES2)

11.1.2 Electrical considerations for device insertion and removal

Hot plugging details:

This clause describes details of the mechanics that operate and considerations that should exist during the insertion and removal of devices when using the SCA-2 connector system. For incoming devices the process begins at step D and moves through step E in 11.1.1.3. For outgoing devices the process begins at step D and moves through step E in 11.1.1.4. These details apply to SE, LVD and HVD transmission modes.

11.1.2.1 Insertion

Figure 20 shows the relative contact positions of the advanced grounding, long and short contacts as specified for the SCA-2 connector system in stages 0 thru 3 of the insertion

process. Figure 21 shows stages 4 thru 7. Each stage may last for many milliseconds or seconds – not predictable.

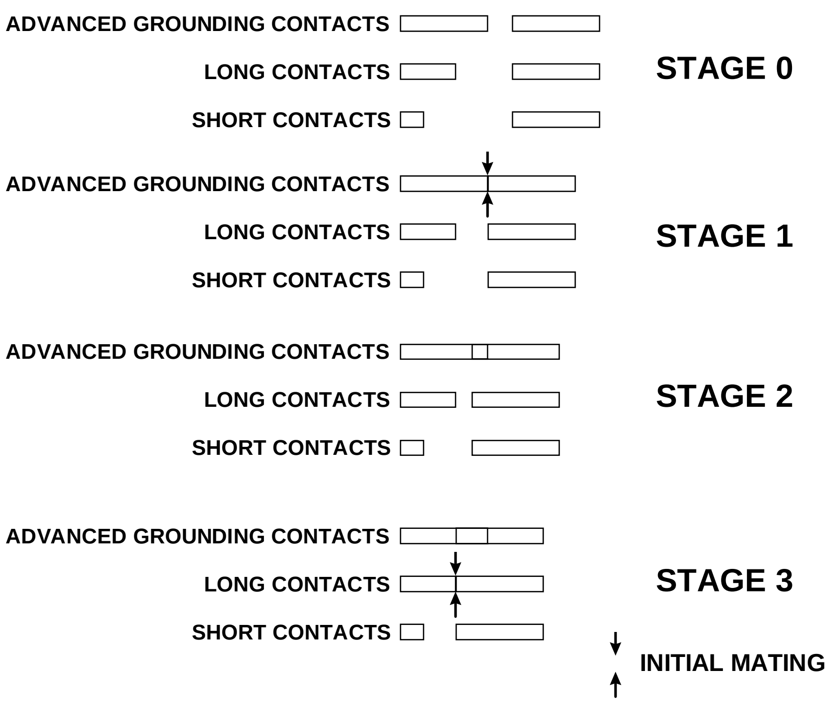

Figure 20 - Stages 0 thru 3 for the insertion process

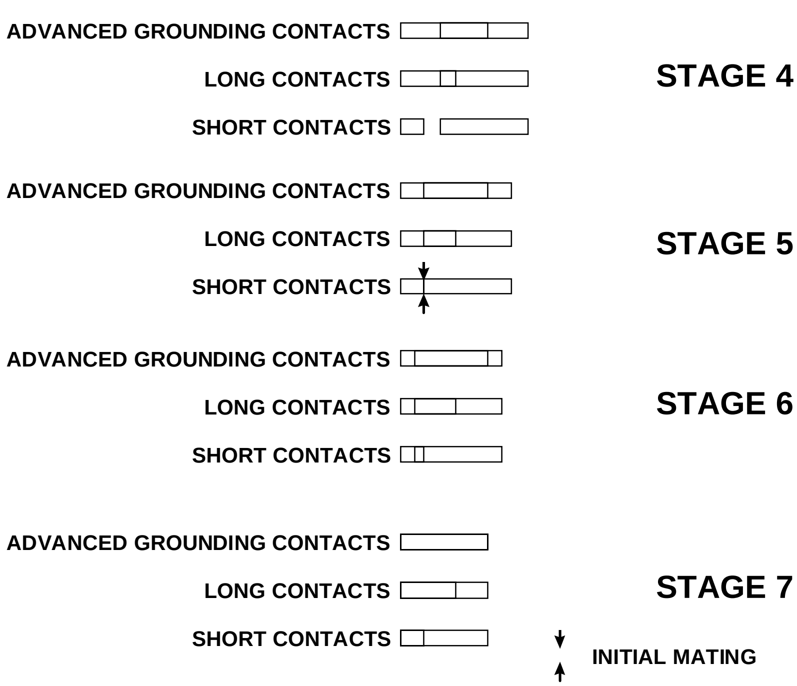

Figure 21 - Stages 4 thru 7 for the insertion process

Each stage is described in more detail below.

Stage 0 - No contacts mated (Figure 20)

Stage 0 properties:

Mechanical stresses: vibration due to handling and movement

Electrical activity: limited to possible enclosure to device "skin" ESD for devices with electrically exposed "skins".

Stage 1 - First advanced grounding contact electrical activity (Figure 20)

Stage 1 properties:

Electrical activity: ESD / ground potential equalization, white noise radiation into device cavity from metal to metal discharge, ground loop currents initiate if any power source or power ground is attached to the incoming device through a cable

Stage 2 - Wiping of advanced grounding contacts prior to first long contact electrical activity (Figure 20)

Stage 2 properties:

Electrical activity: sustained ground loop currents between incoming device and enclosure ground (if any) freely flowing / possibly interrupted by the wiping action

Stage 3 - AGC continues to wipe, first long contact electrical activity (Figure 20)

Stage 3 properties:

Three cases are considered for stage 3 depending on which contacts make the first mating.

Stage 2 issues are still in effect for all cases.

Case 1: first long contact to mate is a device ground (Figure 20)

Case 1 properties:

Electrical activity: no effect, no arcing, least disruptive case

Case 2: first long power contact to mate is a 12 V power contact (Figure 20)

Case 2 properties:

Electrical activity: arcing / white radiation at long 12V power contact during device decoupling capacitor charging; 12V power current is returned only through the ACG contacts until the first long ground contact mates after which the return current is shared between the AGC and the long ground contact; if the AGC contact is not mated prior to this event then the long 12V power contact will perform the Stage 1 ESD function and will transfer the stage 3 arcing to the next contact that mates. If the next contact to mate is the long 5V power contact (and still assuming that the AGC did not mate) then the voltage on the device ground will assume the value dictated by the capacitive division on the device between 12V and 5V – for the example where this value is 8.5V (half the difference between 12V and 5V) the 5V circuitry could see minus 3.5V until the device ground or the AGC contacts mate. This condition can also forward bias (possibly destructively) any diodes in the 5V circuitry that happen to be connected to the device ground.

Case 3: first long power contact to mate is a 5 V power contact (Figure 20)

Case 3 properties:

Electrical activity: arcing / white radiation at long 5V power contact during device decoupling capacitor charging; 5V power current is returned through the ACG contacts until the first long ground contact mates; if the AGC contact is not mated prior to this event the long 5V power contact will perform the Stage 1 ESD function and will transfer the stage 3 arcing to the next contact that mates. If the next contact to mate is the long 12V power contact (and still assuming that the AGC did not mate) then the voltage on the device ground will assume the value dictated by the capacitive division on the device between 12V and 5V – for the example where this value is 8.5V (half the difference between 12V and 5V) the 5V circuitry could see minus 3.5V until the device ground or the AGC contacts mate. This condition can also forward bias (possibly destructively) any diodes in the 5V circuitry that happen to be connected to the device ground.

Stage 4 - AGC continues to wipe, all long contacts mated and wiping (Figure 21)

Stage 4 properties:

Stage 2 issues still in effect

Electrical activity: possible power loading transients due to wiping action; power decoupling capacitors charging; logic becoming powered (non necessarily reliable in this stage); all SCSI contacts set to high impedance state (should always be in this state during all parts of stage 4)

Stage 5 - AGC continues to wipe, all long contacts mated and wiping, first short contact electrical activity (Figure 21)

Stage 5 properties:

Stages 2 and 4 issues still in effect

Electrical activity: low power transients seen on active SCSI lines of operating bus segment due to charging of device contacts - very little radiation due to low power - no detectable glitches expected if the ACG contacts operate properly and the SCSI contacts remain in the high impedance state as required; arbitrary logic patterns presented to incoming device receiver as different SCSI signal contacts begin to mate - receivers shall not operate on any inputs in this stage; additional power contacts mate providing beginnings of stable power for logic and other electronics - should be very low arcing due to precharge from long power contacts; no reliable sequencing between SCSI signals and power

Stage 6 - All contacts mated and wiping (Figure 21)

Stage 6 properties:

Stages 2 and 4 issues still in effect

No device operation should be attempted in this stage

Electrical activity: logic inputs stabilize; power stabilizes, no reliable detection that all contacts are in Stage 6 from connector behavior alone

Stage 7 - All contacts fully seated (Figure 21)

Stage 7 properties:

Stages 2, 4, and 6 issues cease

All physical transient effects completed – physical insertion process completed except for possible mechanical latching of device.

11.1.2.2 Removal

The removal process is a precise reversal of the insertion process described in 11.1.2.1.

11.1.3 Logic input states during transitions – stage 7 detection

In 11.1.2.1 and 11.1.2.2 it was noted that conditions exist in Stages 5 and 6 where the input logic state is not defined due to connector contact sequencing and " bouncing" activity but that power may be adequate for the receivers and associated logic to operate. During these periods the detected logic patterns may have nearly arbitrary values. Devices shall wait until Stage 7 is reached before using any receiver detections as valid.

Devices should use a separate signal indicating fully mated condition (not provided anywhere in the SCSI specifications or in the SCA-2 connector) as the indication that stage 7 has been achieved. One convenient place to generate this "stage 7" signal may be as part of the latch mechanism for the device. This same signal is also useful for indicating that the removal process is beginning.

11.1.4 Operational state changes for devices

Operational state changes are a required part of a SCSI device hot plugging process. Many of these changes involve the commands and messages that are needed to stop the functional operation of devices that are to be removed (prior to removal) and for re-initializing devices that have been added. Powering a device on or off is also an operational state change.

EPI does not describe the commands, messages, power controls, or other features that are not part of the physical hot plugging process.

11.2 Reconfiguration of bus segments

11.2.1 Addition and removal of bus segments

Bus segments may be added or removed from an active domain under certain conditions. This clause describes those conditions. The segment being removed / added is termed the object segment in this technical report.

Only bus segments that have a single expander attached may be considered for dynamic removal/addition. Segments between other segments shall be maintained to allow the other segments to continue to communicate.

The general topology of a portion of a domain containing a separable segment is shown in Figure 22.

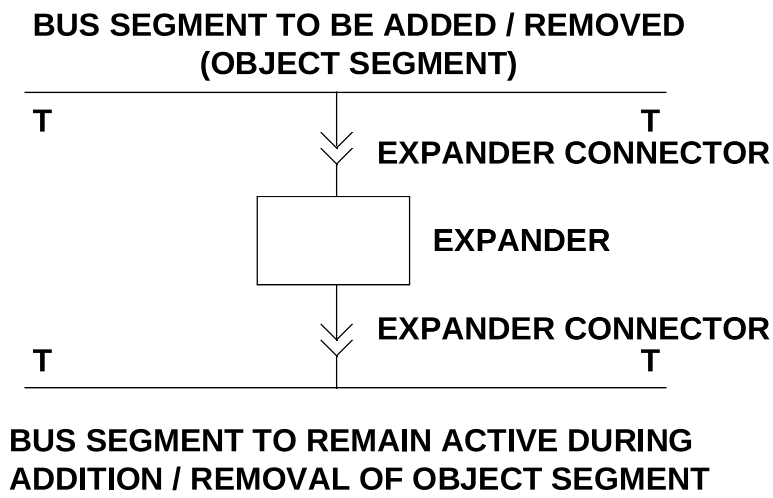

Figure 22 - Dynamic addition / removal of a bus segment

The prime requirement is that the active segment not be disturbed by the act of the removal or addition of the object segment. This requires either:

- that the inputs on the object segment side of the expander be controlled continuously while the expander is active and connected to the active segment side or
- that the expander be disabled (while powered) through a external signal

Otherwise, the signals on the object segment may be driven onto the active segment by the expander and cause a catastrophic collision with ongoing traffic.

The object segment removal process proceeds as follows:

All devices (except the expander) on the object segment cease all segment driving activity (including background polling activity). The expander may continue to drive the object segment as a result of traffic on the active segment.

At this point one of the following four options may be used:

1. disable the powered expander and then separate the active segment connector
2. remove the power from the expander and then separate the active segment connector
3. leave the expander powered and enabled and then separate the active segment connector
4. leave the expander powered and enabled and then separate the object segment connector

Option 1 requires that the expander execute the disabling process (from the start to the finish) without any transceiver on the active segment side leaving the high impedance state (even if the expander is driven by the object segment signals). The disabling process shall not begin until a BUS FREE phase is detected by the expander. If the expander supplies TERMPWR to either the active or the object segment, the act of disabling the expander shall not disrupt TERMPWR to the active segment and should not disrupt TERMPWR to the object segment. It is required that the active segment have a continuous and adequate source of TERMPWR at all times. If the expander supplies TERMPWR to the object segment then either (1) the TERMPWR

supplied to the object segment by the expander shall not be affected until the act of disabling the expander is completed or (2) the object segment has other sources of TERMPWR that maintain adequate TERMPWR to the object segment until the act of disabling the expander is completed.

Option 2 has all the requirements of option 1 with the additional requirements that the disabled state be achieved before removing the power to the expander and that no active segment transceiver leave the high impedance state at any time during the power transient.

Option 3 requires that the terminators for the object segment remain powered while the connector is being separated on the active segment side and that all SCSI activity on the object segment be suspended (stopped) prior to and during the connector separation on the active segment side.

Option 4 requires a connector on the object segment side that has all signal contacts and DIFFSENS break before the TERMPWR contact breaks if the object segment side expander connector supplies TERMPWR to the object segment. The expander shall not assert RESET on the active segment side as a result of detecting changes in transmission mode due to the measured DIFFSENS signal on the object segment side. Provision shall be made in the expander to set all input signals to the negated state on the object segment side of the expander during and after the connector separation. Examples of such schemes are described in 15.5.2. All other requirements for Case 4 (SPI) hot plugging shall be observed with this option.

The choice of which option to use is dictated by system considerations such as the existence and accessibility of the connectors, separate power controls to the expander, and the use of the expander to supply TERMPWR to the segments.

The object segment addition process proceeds as follows:

All devices (except the expander) on the object segment cease all object segment driving activity. This includes any background polling activity. The expander may drive the object segment as a result of the process of connecting the expander to the active segment.

The segment addition process uses one of the following options:

1. The unpowered object segment is assembled to the unpowered expander and the unpowered expander is then connected to the active bus segment connector. The object segment TERMPWR is then turned on. At least 300 ms later (to allow time for the termination circuitry and bus to stabilize) the expander is powered on. The object segment devices are then available for power up and initialization.
2. The unpowered expander is connected to the active bus segment without the object segment attached. The unpowered object segment is then connected to the expander, object segment TERMPWR is applied, and at least 300 ms later (to allow time for the termination circuitry and bus to stabilize) the expander is powered on. The object segment devices are then available for power up and initialization.
3. The unpowered expander, with no object segment attached, is attached to the active bus segment connector and then powered on. Provision shall be made in the expander to set all input signals to the negated state on the object segment side of the expander during the period when expander power is on but there is no object segment attached. Examples of such schemes are described in 15.5.2. The TERMPWR is then applied to the object segment (still not attached to the expander) and allowed to stabilize for at least 300 ms (to allow time for the termination circuitry and bus to stabilize). The object

segment is then attached to the object segment connector of the expander. Devices on the object segment are then available for power up and initialization.

4. The powered expander, with no object segment attached, is attached to the active bus segment connector. Provision shall be made in the expander to set all input signals to the negated state on the object segment side of the expander during the period when expander power is on but there is no object segment attached. Examples of such schemes are described in 15.5.2. The TERMPWR is then applied to the object segment (still not attached to the expander) and allowed to stabilize for at least 300 ms (to allow time for the termination circuitry and bus to stabilize). The object segment is then attached to the object segment connector of the expander. Devices on the object segment are then available for power up and initialization.
5. The expander is assembled to the object segment and both the expander power and the object segment TERMPWR are turned on. The expander is enabled. After allowing at least 300 ms for the TERMPWR to stabilize, the expander is attached to the active segment. The devices on the object segment are then available for power up and initialization.

In all cases the devices on the object segment may be powered up at any time provided their transceivers do not leave the high impedance state prior to the device initialization process. For simplicity of documentation, options 1 through 5 above assume that object segment devices are not powered up until immediately prior to initialization.

All options require the expander to power cycle without having any transceiver on the active segment side leave the high impedance state.

Options 1,2, and 5 allow the possibility of TERMPWR being supplied to the object segment by the expander. In these cases either the TERMPWR connector contact is required to mate at least 300 ms before any signal or DIFFSENS contact or the TERMPWR source shall be turned on at least 300 ms prior to the expander becoming enabled.

11.2.2 Operational state changes for segments

This technical report does not describe processes and procedures for changing the operational state of a bus segment. Examples of operational state changes are stopping (or isolating) the functional operation of the segment that is to be removed (prior to removal) and for re-initializing segments that have been added.

12. Topologies and configuration rules for dynamically reconfigurable domains

All configurations that exist during the transition between the end configurations shall comply with the configuration rules that apply to the configuration. For example, one may not have a narrow segment between two wide segments even if that condition only exists briefly while changing the domain configuration.

13. Terminator power distribution within a segment

SCSI provides the TERMPWR lines in the cables for distribution of TERMPWR from the TERMPWR sources to the terminators. Beginning with SPI-2 it is no longer required to use these lines as the only means to power terminators. The easiest way to deal with TERMPWR distribution is to provide each terminator with its own local TERMPWR source thereby obviating the need for distribution. This clause deals with the case where the TERMPWR lines are used to supply power to the terminators.

13.1 Wire effects

The options and complexity of TERMPWR distribution have grown in the last few years. This is caused by the advent of wide SCSI, low dropout regulators for active termination, demand for smaller cables with smaller wire gauge, longer busses, and devices operating from low voltage supplies. The most important of these are the low dropout regulators and the low voltage sources.

The most demanding case for TERMPWR distribution is when the TERMPWR source is at one end and the terminator at the remote end shall get its power only through the TERMPWR lines in the bus. The TERMPWR lines only need to supply the current for a single terminator. One can calculate how long the bus can be for a variety of conditions under these worst case conditions.

No allowance is made in these calculations for ground shift between the TERMPWR source and the remote terminator. See clause 14 for discussions of ground distribution. If there is more than a few millivolts of ground shift the lengths should be reduced even more (except in the rare case where the ground shift is stable and favors the current flow to the terminator).

The TERMPWR lines only need to supply power to the lines that are asserted. For 8-bit SCSI the maximum number of lines that can be asserted at any one time is 12 and for 16-bit SCSI (P cable) the maximum number is 21. This also reduces the amount of current in the TERMPWR lines.

Bus segment length limited by TERMPWR distribution is the longest length that can deliver the minimum voltage needed by the terminator when the maximum number of lines are asserted. The voltage needed by the terminator depends on the transmission mode and the kind of terminator being used.

The options considered for TERMPWR conductors are 1, 2, or 4 conductors of 28, 30 , or 32 gauge wire. Each connector will add some resistance (assumed to be 25 milliohms each mated pair). The options assumed for minimum source voltage delivered to the TERMPWR lines are 2.8 V, 2.94 V, and 4.25 V. These values are derived as shown in Table 7. The 4 conductor option is only used when assuming 21 asserted lines for the wide case.

Table 7 shows some typical cases for TERMPWR sources that are used for the analysis in 13.1.1 .

Table 7 - Typical TERMPWR source voltages

TERMPWR SOURCE	Power supply voltage (minimum) V	Forward voltage drop across isolating component V	Minimum delivered TERMPWR voltage to the TERMPWR lines V
5 V . (10%)	4.5	0.25	4.25
3.3 V. (5%)	3.135	0.2	2.935 (2.94)
3.3 V battery	3.0	0.2	2.80

13.1.1 SE

The SPI standard requires that SE terminators source current to the signal line whenever the voltage on that line falls below 2.5 V. This is a minimal condition that is used in the calculations in this clause. It is clear that this assumption does not produce as large a negated signal as normally found with the linear alternative 2 SCSI-2 active (regulated) terminator (2.85 V typical with optional nominal of 2.63 V). On the other hand, since the negated signal is not as large with the 2.5 V level, a low assertion level is not as difficult to attain. In the long cables where the TERMPWR distribution may limit the length, the assertion level is one of the more difficult features to achieve. Configurations requiring the higher negation voltages may require shorter TERMPWR distribution lengths than presented in this clause for adequate margin.

These calculations assume only regulated, linear terminators.

Regulators are used between the TERMPWR lines and the internal termination circuitry to isolate the effects of noise and source voltage level variations on the TERMPWR lines from the signal lines. Recently regulators have become available that require as little as 0.2 V difference to achieve regulation. More commonly, approximately 1.2 to 1.5 V is required and the normal expectation is that SE linear regulated terminators need 4.0 V to stay in regulation. The calculations consider the two extreme cases where (1) the best regulators and the lowest delivered voltage combine to require 2.7 V delivered to the terminator and (2) the lesser regulators and the desire for a bit higher than 2.5 V combine to require 4.0 V delivered to the terminator. The best TERMPWR distribution conditions occur when a 5V supply is used with a 2.7 V terminator.

Table 8 considers two cases for the number of connectors used between the TERMPWR source and the terminator. It is not common to have less than approximately 3 connectors and it takes a fairly complex system to have 15 connectors in the same segment so these were chosen to bound the calculations. For systems with intermediate numbers of connectors a linear interpolation is reasonable.

The range of useful length is extremely large ranging from not working at all to over 52 meters. The present SCSI standards are written assuming the case of 3 connectors, a 4.25 V source and a 4.0 V terminator with a single 28 gauge TERMPWR line. This gives the 3.29 meters in Table 8.

The two conductor case represents using both TERMPWR lines for SE TERMPWR distribution as specified for the narrow differential cases. This requires connecting both lines to the same contact normally used for supplying the terminator BEFORE getting to the terminator. The connection may be made in the cable assembly backshell, on the printed circuit board

between the cable assembly and the terminator or at the terminator contacts. SE terminators do NOT connect these lines together inside and the benefits of a double TERMPWR distribution path will not happen if the external connection is not made. Similar comments apply at the source side.

Table 8 - TERMPWR SE bus segment length limits

NARROW - 15 CONNECTORS							
SOURCE	TERM	1-28*	1-30	1-32	2-28	2-30	2-32
2.8 V	2.7 V	--	--	--	--	--	--
2.94 V	2.7 V	1.61	0.975	0.609	3.23	1.95	1.22
4.25 V	2.7 V	20.85	12.53	7.83	41.73	25.02	15.64
4.25 V	4.0 V	1.77	1.07	0.66	3.54	2.13	1.43
NARROW - 3 CONNECTORS							
2.8 V	2.7 V	1.10	0.64	0.40	2.16	1.31	0.823
2.94 V	2.7 V	3.14	1.89	1.19	6.28	3.78	2.35
4.25 V	2.7 V	22.37	13.44	8.38	44.77	26.85	16.79
4.25 V	4.0 V	3.29	1.98	1.25	6.58	3.96	2.47
WIDE - 15 CONNECTORS							
		4-28	4-30	4-32			
2.8 V	2.7 V	1.52	0.914	0.57			
2.94 V	2.7 V	6.31	3.78	2.38			
4.25 V	2.7 V	51.1	30.66	19.17			
4.25 V	4.0 V	6.64	3.99	2.50			
WIDE - 3 CONNECTORS							
2.8 V	2.7 V	3.05	1.83	1.13			
2.94 V	2.7 V	7.83	4.69	2.92			
4.25 V	2.7 V	52.63	31.58	19.75			
4.25 V	4.0 V	8.17	4.91	3.08			
* The syntax is: number of conductors - AWG for each conductor							
ALL LENGTHS IN METERS -- = DOES NOT WORK							

There are a wide variety lengths possible and a large number of traps. For example, 3.3 V battery powered devices simply cannot run narrow SCSI at the lower end of the battery voltage specification with one or two wires distributing TERMPWR.

Careful study of Table 8 is recommended for all implementations of SE SCSI.

13.1.2 LVD

SPI-2 requires LVD terminators to be delivered no lower than 3.0 V although some designs exist that operate at 2.7V. SPI-2 specifies current of at least 0.5 A per wide terminator. Designs exist that require only 100 mA. A table can be created using the procedure used in 13.1.1 with the parameters specified in 13.1 for this case.

13.1.3 LVD/MSE

For this case the terminators require voltages no lower than 3.0 V (if the SE mode uses regulators that can use 3.0 V) and current of at least 0.65 A per wide terminator. If the SE mode requires 4.0 V the voltage requirement goes to 4.0 V. A table can be created using the procedure used in 13.1.1 with the parameters specified in 13.1 for this case.

13.1.4 HVD

The HVD case requires at least 4.0 V and 1.0 A to be delivered to each wide terminator. This is by far the most demanding case for TERMPWR distribution because the current requirement is approximately twice that for the SE or LVD versions. A table can be created using the procedure used in 13.1.1 with the parameters specified in 13.1 for this case.

13.2 Mixed power configurations

This clause considers the issues involved when different kinds of TERMPWR sources are used in the same segment.

Segments with multiple sources of TERMPWR may experience certain sources providing most of the power because the sources are designed differently. Different current limiting devices, for example, will cause the TERMPWR source with the lower voltage drop across the limiting device to supply more power than sources with higher drops. This effect may be exacerbated by sources that use different basic supply sources (5V vs 3.3V).

Detailed analysis of the actual sources being used is recommended when assessing the impact of one or more sources being off line and of the actual current flowing through the TERMPWR lines..

13.3 TERMPWR source placement

TERMPWR sources are placed such that they can deliver the required power into the TERMPWR distribution system or directly to the terminators. A useful concept for many systems is to source TERMPWR from all initiators, all expander ports, and from all device enclosures (only a single source per segment per enclosure). Using SCSI targets as TERMPWR sources can result in accidental TERMPWR removal if the device that is supplying the power is removed in a hot plugging process or if the power to the device is removed.

Another risk of sourcing TERMPWR from target devices is that there may be too much current available on the TERMPWR line because too many devices are supplying TERMPWR. In the limit, up to 32 Amps could be sourced from 16 devices supplying TERMPWR. It requires an unusual defect to support this amount of current without melting or otherwise self-destructing. Conditions may exist where regulatory requirements limit the amount of current available in certain wire gauges, certain jacket types, and certain enclosure types.

Every domain requires at least one initiator. More than three or four initiators in the same domain is very rare. Supplying TERMPWR from initiators may be desirable. In cases where battery sources are used to power initiators this is not recommended.

Expanders should source TERMPWR because segments can exist where there are no devices or enclosures. A trivial example is a point to point segment between two expanders. Another example is where an enclosure is expecting an initiator (that sources TERMPWR) but an expander is used instead. If the enclosure does not source TERMPWR and the expander does not source TERMPWR then there is no TERMPWR for the entire segment.

If expanders are connected in a hub configuration then the hub is architecturally positioned to minimize TERMPWR distribution losses and should source TERMPWR to all attached segments.

Enclosures should source TERMPWR because they are usually strategically placed in the domain to minimize the TERMPWR distribution losses and as a back up for expanders that do not have TERMPWR.

14. Grounding and ground distribution

This clause explores some not-so-obvious issues with achieving grounding in SCSI systems. The effects of improper grounding are more likely to be manifested when operating under extended configurations.

The objective of a good grounding system is to minimize the noise voltage generated by currents from circuits flowing through a common ground impedance and to avoid creating ground loops or to keep them as small as possible. A good ground system will improve signal quality while reducing electromagnetic emissions. This clause provides guidance on the proper usage of the lines presently identified as “ grounds” in the SCSI standards.

Figure 23 shows some of the grounding points that may be encountered in real SCSI implementations.

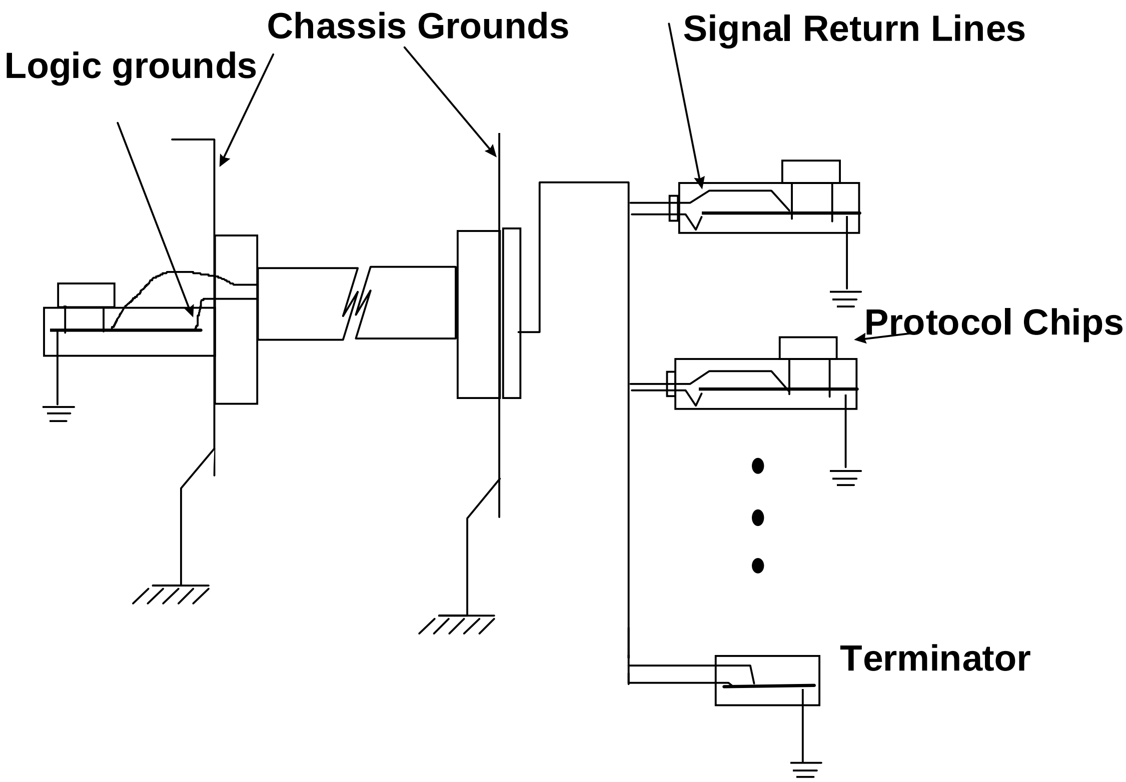

Figure 23 - Examples of various ground points

There are four types of grounds identified in the SCSI physical interface:

- logic grounds
- d. c. power grounds
- signal return lines
- shield ground

The logic ground lines are used to connect the logic grounds within all devices on the bus. They are connected to the non-signal return ground lines in the SCSI cable.

The d. c. power grounds (SCA-2 connector only) are used for connecting device power grounds to the local enclosure power ground. Unlike the logic grounds, they are confined to internal applications only and may not be exported directly onto an external SCSI cable.

The signal return lines are associated with the SE signals. Every SE signal is paired with a ground line. The signal return is the return path for the signal circuit.

The shield ground provides an important part of the EMC integrity between external enclosures.

14.1 SE systems

In SE systems the signal return lines shall be connected to the logic ground of the chip containing the SCSI transceivers in SCSI devices and to the signal ground within the terminators.

The logic ground lines should be tied to the logic ground plane in each SCSI device as close as possible to the device SCSI connector.

The d. c. power grounds (SCA-2 SE connector) shall not be directly connected to any line in the SCSI cable that leaves the enclosure containing the device with the SCA-2 connector.

14.2 Differential systems

HVD and LVD systems shall have the logic ground lines connected to the logic ground plane in each SCSI device as close to the connector as possible.

The d. c. power grounds (SCA-2 DIFF connector) shall not be directly connected to any line in the SCSI cable that leaves the enclosure containing the device with the SCA-2 connector.

14.3 Shield connections

The shield has a maximum d. c. resistance of 30 milliohms between the cable shield on the cable media and the enclosure wall. It is recommended that the cable have a 360 degree shield termination around the connector as illustrated in Figure 24. External connectors shall have a low-impedance (at all frequencies relevant to the system) bond between the cable shield and the chassis. Cable shields shall not be directly connected to logic ground within the SCSI device – such connections, if any, shall be made indirectly through grounding scheme used within the device enclosure.

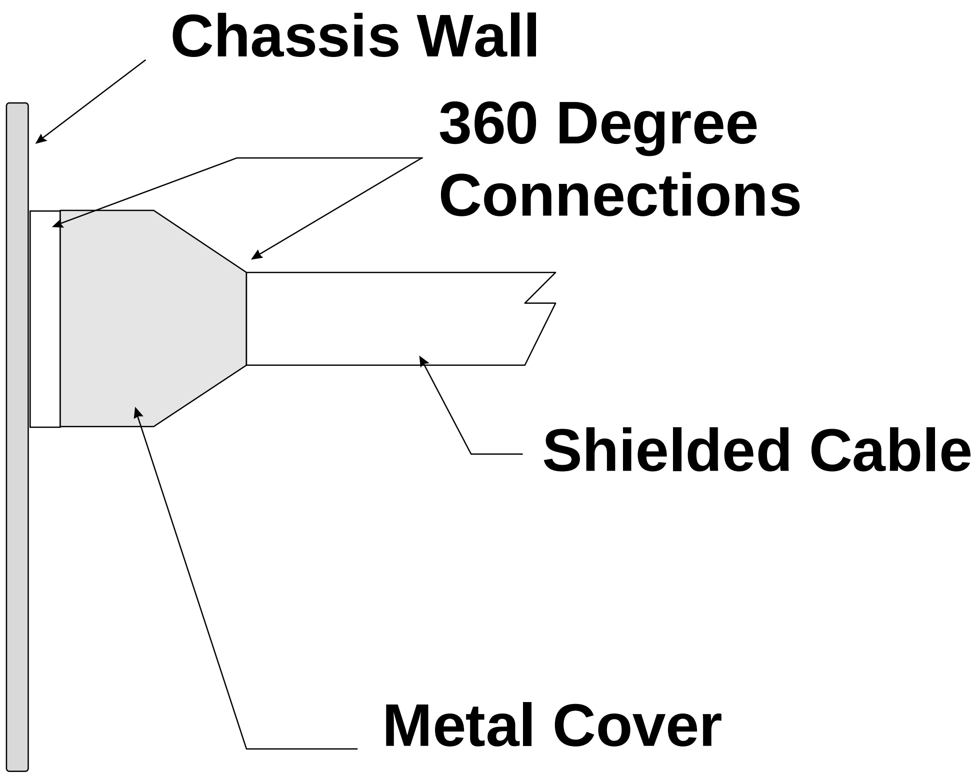

Figure 24 - Shield connection details

14.4 System considerations:

All SCSI systems are direct coupled and are affected by ground currents and voltages. All enclosures within the same SCSI bus segment should acquire their power from the same power distribution panel within the building. If possible, they should all be connected to the same power outlet. This is explained in more detail in 14.4.2.

The shield conductors and the internal cable ground lines all help to maintain the same ground voltage throughout the segment but they are frequently not enough to compensate for faulty system power distribution or for ground voltages built up between different power distribution panels in a building. Clauses 14.4.1 and 14.4.3 provide more detail.

14.4.1 Ground paths in the SCSI cable

When used with SE devices the SCSI cable provides a direct ground connection line between devices for every signal in addition to the 8 lines dedicated to ground that are not associated with signals and the cable shield itself. The total number of ground conductors in a wide SCSI cable used with SE devices is 35 plus the braided shield. In a SCSI cable used with differential transmissions there are 8 ground lines plus the shield. The shield is usually at least equivalent to an 8 AWG copper wire (typical building power cable uses 12 or 14 AWG wire i.e. much smaller than 8 AWG).

The SCSI cable itself does a very good job of establishing a solid, shielded ground connection between devices. Using SE transmissions increases the amount of copper being used for ground connection by approximately 2x compared to HVD and LVD.

14.4.2 Building power distribution

SCSI grounding depends on the integrity of the power distribution system in the building. This clause explores the basic issues involved.

There are many different ways to provide wall outlet power in buildings. One specific method, common in simple single phase installations, will be illustrated in this clause. The issues shown can be applied to other power distribution systems.

Figure 25 shows the wiring used for a simple 120/240 V system. The remote step-down transformer takes power from the high voltage primary and steps it down to a 240 V center tap secondary. Each "hot" end of the secondary provides a 120 V source to the center tap (which is connected to earth ground at the transformer) and 240 V across the ends.

The center tap ground is usually brought into the building along with each end of the secondary. The presence of this external ground wire is irrelevant to SCSI in the building (if a single step down transformer is used for the entire building).

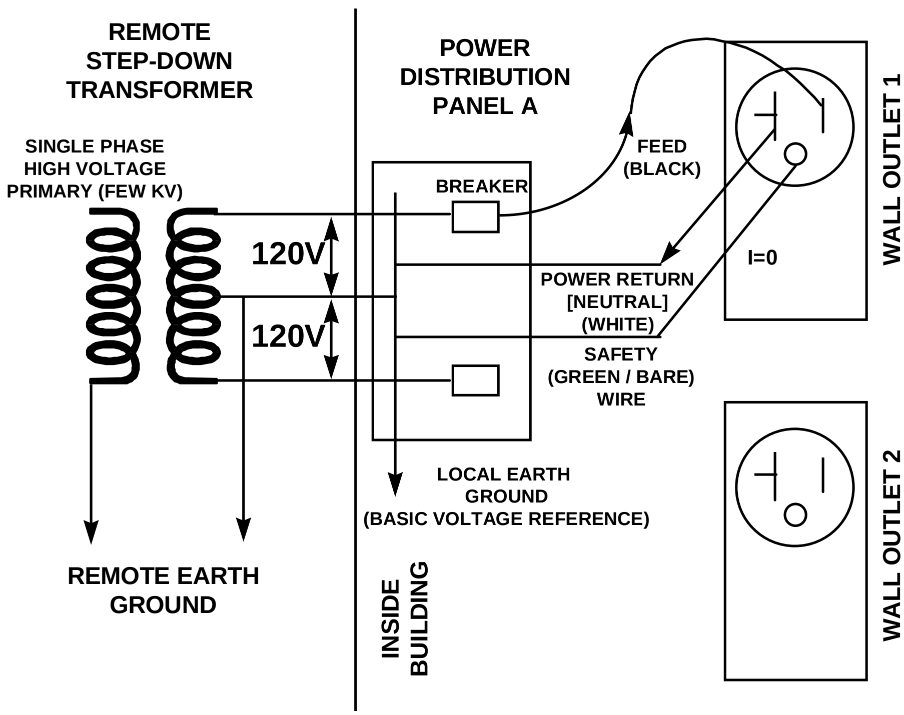

Figure 25 - Basic single phase power distribution system

Power is fed through circuit breakers in the distribution panel to the wall outlets and the current returns to the local earth ground at the distribution panel through the power return, or neutral, wire. The key to managing the SCSI part of the grounding lies in using the safety, or

green/bare wire, ground as intended. This wire also is connected to the local ground at the distribution panel but normally does not carry any current.

Since the neutral wire is carrying the full load current it will develop some voltage at the wall outlet with respect to the local ground at the distribution panel. Since the safety ground is not carrying any current it should present the local ground voltage at the distribution panel to the wall outlet. There will be a difference between the safety and neutral voltages at the wall outlet equal to the voltage drop in the neutral line. It in not uncommon for this voltage to be hundreds of millivolts or higher.

If the load plugged into the wall outlet is defective such that there is some electrical connection to the safety ground from either the feed or the neutral, or if the neutral and safety ground have been connected together in the wall outlet, then some current will be flowing through the safety ground (for this outlet only). Either of these conditions may be termed a "ground fault". A ground fault interrupt, GFI, wall outlet detects the difference between the feed and neutral currents and trips when this difference exceeds a few milliamps – the assumption being that if the feed current does not return through the neutral wire then it went into the "ground". Using GFI protection is an excellent and very inexpensive way to ensure that SCSI systems do not have any ground faults.

As long as all SCSI devices in the bus segment take their logic ground reference from this same wall outlet (normally the safety ground) these ground faults will not have a primary effect on the SCSI ground offset between SCSI devices (assuming the SCSI devices themselves do not have their own ground faults).

One potential problem arises when two or more wall outlets are used and one or more has a ground fault. This condition forces a voltage difference between the safety grounds of the different outlets and shows up as a direct noise margin reduction for SCSI. The SCSI cables reduce the ground offset between the SCSI devices since the SCSI cables provide a path between the safety grounds at each wall outlet in addition to the safety ground wires.

Even with no ground faults at the wall outlets, a very significant voltage can be developed between different power distribution panels due to local ground current differences between the panels. The local ground current will be the difference between the total currents flowing in each feed wire from the step-down transformer (less any loss to earth ground from connections to the panel within the building). Different distribution panels have different load imbalances with resulting different ground current flowing. This produces different actual ground voltages at different distribution panels. A single SCSI bus segment should always take power from the same power distribution panel (even in fault-free conditions).

14.4.3 Ground loops

Ground offsets can also be produced by a. c. induced noise into closed ground paths (loops). This technical report will not attempt to explore this mechanism except to note that keeping all devices relatively close together and using the separate shield and internal signal returns and grounds as designed into the SCSI system reduces the size of the noise at the receiver chips. The SCSI cabling helps to overcome power distribution and environmental noise.

One of the most serious conditions in SCSI systems can happen when one end of the SCSI cable shield is not solidly connected to the enclosure wall. This breaks the external ground

loop and forces it into the internal signal returns and grounds. This is a common laboratory condition where “ quick and dirty” cabling is used. For example, connecting a wide shielded cable to a wide unshielded internal cable is an excellent way to produce a partially connected shield. System failures are very likely in this case.

When SCSI cabling is connected as designed in real application conditions the shield is solidly connected at both ends.

15. Interconnects

This clause defines the wiring rules for a wide variety of interconnects that are possible using the presently available connectors described in the SCSI standards and SFF specifications.

Such connections are desirable in mixed width SCSI systems e.g. using the 68-position connector in anticipation of connecting to wide SCSI systems in the future. Other applications included in this clause describe the wiring for backplane attached devices.

The SCSI-3 Physical Interface standard specifies how to connect an A-cable to a 16-bit P-cable but does not describe how to wire a 68-position connector if it is being used only for an A-cable connection. This technical report specifies the wiring of the 68-position cable connector in this type of application. Failure to follow this specification can result in TERMPWR (Termination Power) shorts to ground, misterminated signals, and degraded signal quality due to non-uniform device loading on the bus. One likely result of wiring errors is a device failure.

The 50-position connector plug on the adapter cable is wired according to the specifications in X3.131R-199x for SCSI-2, but follows the SCSI-3 wiring requirements on pair placement in round cables (if round cables are being used).

The 68-position connector receptacle is either wired as specified in SCSI-3 SPI if it is a 16-bit P-cable device or as specified in this technical report if it is an 8-bit A-cable device.

This clause contains the wiring rules for a range of SCSI interconnects that are possible by connecting heterogeneous combinations of the cables specified in SCSI-2, SPI and SPI-2 standards and draft standards. Only connections of like transmission mode (SE, HVD, or LVD) will work.

The pin assignment tables in this clause are included for convenience, however should there be a conflict between this technical report and the pertinent standard or specification, the pin assignments in the pertinent standard or specification shall prevail.

Connections beyond the simple A-cable to A-cable, P-cable to P-cable, A-cable to P-cable bus-path connection, and SCA-2 connector to a backplane are possible and likely to be desirable in real systems. This clause contains a comprehensive collection of wiring tables for the other connections that may exist. There is no support for the SCSI-2 B-cable in this technical report.

The term A-cable in this clause means a 50-conductor cable whose lines are functioning as defined in the SCSI-2 standard.

The term P-cable in this clause means a 68-conductor cable whose lines are functioning as defined in the SCSI-3 SPI standard. The devices connected to the bus determine the function

of the lines.

The term SCA-2 connection in this clause means an 80 position connector on a SCSI device as specified in SPI-2.

The wiring tables specify how to connect either the A-cable, P-cable, or SCA-2 connection in the combinations listed below.

15.1 Connectors

The following SCSI connectors are considered.

- 50-position (low density, high density, shielded, unshielded)
- 68-position high density and VHDCI (same wiring rules and contact position numbering)
- 80-position SCA-2 (Single Connector Attachment -2)

Whether these connectors are high or low density or are shielded or not does not affect the wiring tables. Note however that the 50-position connections have different contact numbers depending on the connector contact number set being used.

The low density unshielded 50-positon connector uses connector contact number Set 1. All others use connector contact number Set 2. This translation between Set 1 and Set 2 is shown in Table 1. All other references in this specification to the A-cable connector contacts use Set 2 or the cable conductor number.

15.2 Connection types

The combination of a specific connector with a specific wiring pattern is termed a connection in this technical report.

There are two basic kinds of connection described: stub and bus-path. See Figure 1.

A stub connection occurs when breaking the connection does not cause loss of electrical continuity from terminator to terminator.

A bus-path connection occurs when breaking the connection causes loss of electrical continuity from terminator to terminator. A bus-path connection always involves bus termination. This is specified in the tables where appropriate.

In space confined situations, such as with PC option panels, one may connect two single ended A-cables through a single 68-position connector. This is done by tying grounds together and sacrificing three of the reserved lines as specified in Table 30 (Dual A-cables).

15.3 Connections covered

15.3.1 SE

Base SCSI-2 A-cable connection (device side)
Base SCSI-3 P-cable connection (device side)
Base SCA-2 A-cable connection (device side)
Base SCA-2 P-cable connection (device side)

A-cable with P-cable stub connection
A-cable with P-cable bus-path connection
P-cable with A-cable stub connection
P-cable with A-cable bus-path connection
A-cable with SCA-2 stub connection
A-cable with SCA-2 bus-path connection
P-cable with SCA-2 stub connection
P-cable with SCA-2 bus-path connection
2 A-cables with a single P-cable stub connection
2 A-cables with a single P-cable bus-path connection

15.3.2 HVD

Base SCSI-2 A-cable connection (device side)
Base SCSI-3 P-cable connection (device side)
Base SCA-2 A-cable connection (device side)
Base SCA-2 P-cable connection (device side)

A-cable with P-cable stub connection
A-cable with P-cable bus-path connection
P-cable with A-cable stub connection
P-cable with A-cable bus-path connection
A-cable with SCA-2 stub connection
A-cable with SCA-2 bus-path connection
P-cable with SCA-2 stub connection
P-cable with SCA-2 bus-path connection

15.3.3 LVD

Base SCSI-2 A-cable connection (device side)
Base SCSI-3 P-cable connection (device side)
Base SCA-2 A-cable connection (device side)
Base SCA-2 P-cable connection (device side)

A-cable with P-cable stub connection
A-cable with P-cable bus-path connection
P-cable with A-cable stub connection
P-cable with A-cable bus-path connection
A-cable with SCA-2 stub connection
A-cable with SCA-2 bus-path connection
P-cable with SCA-2 stub connection

P-cable with SCA-2 bus-path connection

15.4 Cross Reference

Table 9 identifies the combinations which are specified in clause 15.

Table 9 - Supported combinations

	Connector		
	50-position	68-position	80-position SCA-2
Basic SE cable *	Table 10	Table 13	Table 16
Basic HVD cable *	Table 11	Table 14	Table 17
Basic LVD cable *	Table 12	Table 15	Table 17
A-cable SE bus-path **	Table 10	Table 18	Table 21 ***
A-cable SE stub **	Table 10	Table 18	Table 21
A-cable HVD bus-path **	Table 11	Table 19	Table 23 ***
A-cable HVD stub **	Table 11	Table 19	Table 23
A-cable LVD bus-path	Table 12	Table 20	Table 25 ***
A-cable LVD stub	Table 12	Table 20	Table 25
P-cable SE bus-path **	NA	Table 13	Table 22 ***
P-cable SE stub **	Table 27	Table 13	Table 22
P-cable HVD bus-path **	NA	Table 14	Table 24 ***
P-cable HVD stub **	Table 28	Table 14	Table 24
P-cable LVD bus-path	NA	Table 15	Table 26 ***
P-cable LVD stub	Table 29	Table 15	Table 26
Dual A-cable SE bus-path **	NA	Table 30	NA
Dual A-cable SE stub **	NA	Table 30	NA
* Data taken from SPI-2 ** Data taken from SFF-8017, EPI is intended to supersede these parts of SFF-8017 *** Not recommended to have terminators on SCA-2 devices: bus-path connection also not recommended - see 15.6			

15.5 68 position bus segment termination

15.5.1 General applications

For 16-bit devices (devices with a 68-position connector) on-board bus termination may be accomplished:

- in the manner specified in the SPI document if the device is providing bus termination for the entire 68-position connector (end of segment device applications only).
- in the manner specified in the SPI document if the device is providing bus termination for the upper data and parity bits only (end of P-cable segment device applications only)

15.5.2 Specific precautions

The electrical state of the upper 9 signal pairs in a 16-bit P-cable wiring on the receptacle side of the 68- device connector should be determined an electrical circuit designed for that purpose. The device electrical drivers and/or segment terminators provide this function if they are connected to the upper 9 signal pairs (as happens when connected to a wide segment). If a 16-bit device is connected to an 8-bit narrow segment the upper 9 signal pairs are not normally connected to a terminator and very often are not driven by the 16-bit device. When not being driven by the device these upper 9 signal pairs may float to an asserted state for SE and to an indeterminate state for HVD or LVD. This undefined receiver input to the 16-bit device may present nonsensical logic levels and prevent the 16-bit device from working even if it is only doing 8-bit transfers. If wired according to this clause this condition will not occur.

Electronics suitable for setting the upper data and parity bit signals to the deasserted (negated) state may be connected on the device board in the case where the 16-bit device is connected only to an 8-bit path. If the unused contacts are not SCSI segment terminated or driven by the device itself, the required negations have to be provided from the cable assembly or backplane side of the connection.

The circuitry used to set the negated state on the unused lines does not have to meet the electrical requirements for SCSI bus termination and may be built of resistors connected to on-board power sources. Resistors of at least 100K ohms should be used to avoid loading the bus when the device is used in a wide application. Circuitry that may be suitable for setting the negation state is:

- high value pull up resistors for SE
- high value resistors in a totem pole for HVD and LVD

It is recommended that resistors or some alternative form of electronic biasing be implemented for the upper data and parity bits in all 16-bit devices.

15.6 Rack mount considerations

The SCA-2 connector is not designed to accept cables, but there are considerations such as cabling between two cabinets via an SCA connector and connecting a device with a SCA connector to a backplane that also has standard SCSI connectors to the outside world. Such bus-path connections are not generally allowed due to the lack of continuity in several key signals e.g. TERMPWR, RESERVED and some GROUND lines. If there is a terminator on an SCA-2 device (thereby making it a bus-path connection) AND there is a local source of TERMPWR for the terminator, the bus-path connections can be followed if the Reserved lines are not used.

15.7 Tables for specific combinations

Table 10 - SE: contact assignments - A-cable

Connector contacts and signal names: set 2	set 1	signal name	Cable conductor numbers		Connector contacts and signal names	set 1	set 2
1	1	GROUND	1	2	-DB(0)	2	26
2	3	GROUND	3	4	-DB(1)	4	27
3	5	GROUND	5	6	-DB(2)	6	28
4	7	GROUND	7	8	-DB(3)	8	29
5	9	GROUND	9	10	-DB(4)	10	30
6	11	GROUND	11	12	-DB(5)	12	31
7	13	GROUND	13	14	-DB(6)	14	32
8	15	GROUND	15	16	-DB(7)	16	33
9	17	GROUND	17	18	-DB(P)	18	34
10	19	GROUND	19	20	GROUND	20	35
11	21	GROUND	21	22	GROUND	22	36
12	23	RESERVED	23	24	RESERVED	24	37
13	25	OPEN	25	26	TERMPWR	26	38
14	27	RESERVED	27	28	RESERVED	28	39
15	29	GROUND	29	30	GROUND	30	40
16	31	GROUND	31	32	-ATN	32	41
17	33	GROUND	33	34	GROUND	34	42
18	35	GROUND	35	36	-BSY	36	43
19	37	GROUND	37	38	-ACK	38	44
20	39	GROUND	39	40	-RST	40	45
21	41	GROUND	41	42	-MSG	42	46
22	43	GROUND	43	44	-SEL	44	47
23	45	GROUND	45	46	-C/D	46	48
24	47	GROUND	47	48	-REQ	48	49
25	49	GROUND	49	50	-I/O	50	50

NOTES: 1) The conductor number refers to the conductor position when using 0.050" centerline flat ribbon cable with a low-density connector or when using 0.025" centerline flat ribbon cable with a high-density connector. Other cable types may be used to implement equivalent contact assignments.
3) Two sets of contact assignments are shown. Set 1 applies to the low density internal device connector only. Set 2 applies to all other connector styles.

Table 11 - HVD: contact assignments - A-cable

Connector contacts and signal names set 2	set 1		Cable conductor numbers		Connector contacts and signal names	set 1	set 2
1	1	GROUND	1	2	GROUND	2	26
2	3	+DB(0)	3	4	-DB(0)	4	27
3	5	+DB(1)	5	6	-DB(1)	6	28
4	7	+DB(2)	7	8	-DB(2)	8	29
5	9	+DB(3)	9	10	-DB(3)	10	30
6	11	+DB(4)	11	12	-DB(4)	12	31
7	13	+DB(5)	13	14	-DB(5)	14	32
8	15	+DB(6)	15	16	-DB(6)	16	33
9	17	+DB(7)	17	18	-DB(7)	18	34
10	19	+DB(P)	19	20	-DB(P)	20	35
11	21	DIFFSENS	21	22	GROUND	22	36
12	23	RESERVED	23	24	RESERVED	24	37
13	25	TERMPWR	25	26	TERMPWR	26	38
14	27	RESERVED	27	28	RESERVED	28	39
15	29	+ATN	29	30	-ATN	30	40
16	31	GROUND	31	32	GROUND	32	41
17	33	+BSY	33	34	-BSY	34	42
18	35	+ACK	35	36	-ACK	36	43
19	37	+RST	37	38	-RST	38	44
20	39	+MSG	39	40	-MSG	40	45
21	41	+SEL	41	42	-SEL	42	46
22	43	+C/D	43	44	-C/D	44	47
23	45	+REQ	45	46	-REQ	46	48
24	47	+I/O	47	48	-I/O	48	49
25	49	GROUND	49	50	GROUND	50	50

NOTES: 1) The conductor number refers to the conductor position when using 0.050" centerline flat ribbon cable with a low-density connector or when using 0.025" centerline flat ribbon cable with a high-density connector. Other cable types may be used to implement equivalent contact assignments.

2) Two sets of contact assignments are shown. Set 1 applies to the low density internal device connector only. Set 2 applies to all other connector styles.

Table 12 - LVD: contact assignments - A-cable

Connector contacts and signal names set 2	set 1		Cable conductor numbers		Connector contacts and signal names	set 1	set 2
1	1	+DB(0)	1	2	-DB(0)	2	26
2	3	+DB(1)	3	4	-DB(1)	4	27
3	5	+DB(2)	5	6	-DB(2)	6	28
4	7	+DB(3)	7	8	-DB(3)	8	29
5	9	+DB(4)	9	10	-DB(4)	10	30
6	11	+DB(5)	11	12	-DB(5)	12	31
7	13	+DB(6)	13	14	-DB(6)	14	32
8	15	+DB(7)	15	16	-DB(7)	16	33
9	17	+DB(P)	17	18	-DB(P)	18	34
10	19	GROUND	19	20	GROUND	20	35
11	21	DIFFSENS	21	22	GROUND	22	36
12	23	RESERVED	23	24	RESERVED	24	37
13	25	TERMPWR	25	26	TERMPWR	26	38
14	27	RESERVED	27	28	RESERVED	28	39
15	29	GROUND	29	30	GROUND	30	40
16	31	+ATN	31	32	-ATN	32	41
17	33	GROUND	33	34	GROUND	34	42
18	35	+BSY	35	36	-BSY	36	43
19	37	+ACK	37	38	-ACK	38	44
20	39	+RST	39	40	-RST	40	45
21	41	+MSG	41	42	-MSG	42	46
22	43	+SEL	43	44	-SEL	44	47
23	45	+C/D	45	46	-C/D	46	48
24	47	+REQ	47	48	-REQ	48	49
25	49	+I/O	49	50	-I/O	50	50

NOTES: 1) The conductor number refers to the conductor position when using 0.050" centerline flat ribbon cable with a low-density connector or when using 0.025" centerline flat ribbon cable with a high-density connector. Other cable types may be used to implement equivalent contact assignments.

2) Two sets of contact assignments are shown. Set 1 applies to the low density internal device connector only. Set 2 applies to all other connector styles.

Table 13 - SE: contact assignments - P-cable
(Applies to both bus-path and stub connections)

68-position connector contact and signal name	P-cable conductor position		68-position connector contact and signal name	
1 GROUND	1	2	-DB(12)	35
2 GROUND	3	4	-DB(13)	36
3 GROUND	5	6	-DB(14)	37
4 GROUND	7	8	-DB(15)	38
5 GROUND	9	10	-DB(P1)	39
6 GROUND	11	12	-DB(0)	40
7 GROUND	13	14	-DB(1)	41
8 GROUND	15	16	-DB(2)	42
9 GROUND	17	18	-DB(3)	43
10 GROUND	19	20	-DB(4)	44
11 GROUND	21	22	-DB(5)	45
12 GROUND	23	24	-DB(6)	46
13 GROUND	25	26	-DB(7)	47
14 GROUND	27	28	-DB(P)	48
15 GROUND	29	30	GROUND	49
16 GROUND	31	32	GROUND	50
17 TERMPWR	33	34	TERMPWR	51
18 TERMPWR	35	36	TERMPWR	52
19 RESERVED	37	38	RESERVED	53
20 GROUND	39	40	GROUND	54
21 GROUND	41	42	-ATN	55
22 GROUND	43	44	GROUND	56
23 GROUND	45	46	-BSY	57
24 GROUND	47	48	-ACK	58
25 GROUND	49	50	-RST	59
26 GROUND	51	52	-MSG	60
27 GROUND	53	54	-SEL	61
28 GROUND	55	56	-C/D	62
29 GROUND	57	58	-REQ	63
30 GROUND	59	60	-I/O	64
31 GROUND	61	62	-DB(8)	65
32 GROUND	63	64	-DB(9)	66
33 GROUND	65	66	-DB(10)	67
34 GROUND	67	68	-DB(11)	68

NOTE: 1) The conductor number refers to the conductor position when using 0.635mm (0.025") centerline flat-ribbon cable.

Table 14 - HVD: contact assignments - P-cable

68-position connector contact and signal name	P-cable conductor position		68-position connector contact and signal name	
1 +DB(12)	1	2	-DB(12)	35
2 +DB(13)	3	4	-DB(13)	36
3 +DB(14)	5	6	-DB(14)	37
4 +DB(15)	7	8	-DB(15)	38
5 +DB(P1)	9	10	-DB(P1)	39
6 GROUND	11	12	GROUND	40
7 +DB(0)	13	14	-DB(0)	41
8 +DB(1)	15	16	-DB(1)	42
9 +DB(2)	17	18	-DB(2)	43
10 +DB(3)	19	20	-DB(3)	44
11 +DB(4)	21	22	-DB(4)	45
12 +DB(5)	23	24	-DB(5)	46
13 +DB(6)	25	26	-DB(6)	47
14 +DB(7)	27	28	-DB(7)	48
15 +DB(P)	29	30	-DB(P)	49
16 DIFFSENS	31	32	GROUND	50
17 TERMPWR	33	34	TERMPWR	51
18 TERMPWR	35	36	TERMPWR	52
19 RESERVED	37	38	RESERVED	53
20 +ATN	39	40	-ATN	54
21 GROUND	41	42	GROUND	55
22 +BSY	43	44	-BSY	56
23 +ACK	45	46	-ACK	57
24 +RST	47	48	-RST	58
25 +MSG	49	50	-MSG	59
26 +SEL	51	52	-SEL	60
27 +C/D	53	54	-C/D	61
28 +REQ	55	56	-REQ	62
29 +I/O	57	58	-I/O	63
30 GROUND	59	60	GROUND	64
31 +DB(8)	61	62	-DB(8)	65
32 +DB(9)	63	64	-DB(9)	66
33 +DB(10)	65	66	-DB(10)	67
34 +DB(11)	67	68	-DB(11)	68

NOTE: 1) The conductor number refers to the conductor position when using 0.635mm (0.025”) centerline flat-ribbon cable.

Table 15 - LVD: contact assignments - P-cable

68 position connector contact and signal name	P cable conductor number		68 position connector contact and signal name	
1 +DB(12)	1	2	-DB(12)	35
2 +DB(13)	3	4	-DB(13)	36
3 +DB(14)	5	6	-DB(14)	37
4 +DB(15)	7	8	-DB(15)	38
5 +DB(P1)	9	10	-DB(P1)	39
6 +DB(0)	11	12	-DB(0)	40
7 +DB(1)	13	14	-DB(1)	41
8 +DB(2)	15	16	-DB(2)	42
9 +DB(3)	17	18	-DB(3)	43
10 +DB(4)	19	20	-DB(4)	44
11 +DB(5)	21	22	-DB(5)	45
12 +DB(6)	23	24	-DB(6)	46
13 +DB(7)	25	26	-DB(7)	47
14 +DB(P)	27	28	-DB(P)	48
15 GROUND	29	30	GROUND	49
16 DIFFSENS	31	32	GROUND	50
17 TERMPWR	33	34	TERMPWR	51
18 TERMPWR	35	36	TERMPWR	52
19 RESERVED	37	38	RESERVED	53
20 GROUND	39	40	GROUND	54
21 +ATN	41	42	-ATN	55
22 GROUND	43	44	GROUND	56
23 +BSY	45	46	-BSY	57
24 +ACK	47	48	-ACK	58
25 +RST	49	50	-RST	59
26 +MSG	51	52	-MSG	60
27 +SEL	53	54	-SEL	61
28 +C/D	55	56	-C/D	62
29 +REQ	57	58	-REQ	63
30 +I/O	59	60	-I/O	64
31 +DB(8)	61	62	-DB(8)	65
32 +DB(9)	63	64	-DB(9)	66
33 +DB(10)	65	66	-DB(10)	67
34 +DB(11)	67	68	-DB(11)	68

Table 16 - SE: contact assignments for 80 position SCA-2

80-position SCA-2 connector contact and signal name	Cable conductor numbers are not applicable.	80-position SCA-2 connector contact and signal name
1 12V		12V GROUND 41
2 12V		12V GROUND 42
3 12V		12V GROUND 43
4 12V		12V GROUND 44
5 RESERVED/NC		RESERVED/NC 45
6 RESERVED/NC		RESERVED/NC 46
7 -DB(11)		GROUND 47
8 -DB(10)		GROUND 48
9 -DB(9)		GROUND 49
10 -DB(8)		GROUND 50
11 -I/O		GROUND 51
12 -REQ		GROUND 52
13 -C/D		GROUND 53
14 -SEL		GROUND 54
15 -MSG		GROUND 55
16 -RST		GROUND 56
17 -ACK		GROUND 57
18 -BSY		GROUND 58
19 -ATN		GROUND 59
20 -DB(P0)		GROUND 60
21 -DB(7)		GROUND 61
22 -DB(6)		GROUND 62
23 -DB(5)		GROUND 63
24 -DB(4)		GROUND 64
25 -DB(3)		GROUND 65
26 -DB(2)		GROUND 66
27 -DB(1)		GROUND 67
28 -DB(0)		GROUND 68
29 -DB(P1)		GROUND 69
30 -DB(15)		GROUND 70
31 -DB(14)		GROUND 71
32 -DB(13)		GROUND 72
33 -DB(12)		GROUND 73
34 5V		5V GROUND 74
35 5V		5V GROUND 75
36 5V		5V GROUND 76
37 SYNC		ACTIVE LED OUT 77
38 RMT_START		DLYD_START 78
39 SCSI ID(0)		SCSI ID (1) 79
40 SCSI ID(2)		SCSI ID (3) 80

Table 17 - HVD and LVD: contact assignments for 80 position SCA-2

80-position SCA-2 connector contact and signal name	Cable conductor numbers are not applicable.	80-position SCA-2 connector contact and signal name
1 12V		12V GROUND 41
2 12V		12V GROUND 42
3 12V		12V GROUND 43
4 12V		12V GROUND 44
5 RESERVED/NC		RESERVED/NC 45
6 DIFFSENS		GROUND 46
7 -DB(11)		+DB(11) 47
8 -DB(10)		+DB(10) 48
9 -DB(9)		+DB(9) 49
10 -DB(8)		+DB(8) 50
11 -I/O		+I/O 51
12 -REQ		+REQ 52
13 -C/D		+C/D 53
14 -SEL		+SEL 54
15 -MSG		+MSG 55
16 -RST		+RST 56
17 -ACK		+ACK 57
18 -BSY		+BSY 58
19 -ATN		+ATN 59
20 -DB(P0)		+DB(P0) 60
21 -DB(7)		+DB(7) 61
22 -DB(6)		+DB(6) 62
23 -DB(5)		+DB(5) 63
24 -DB(4)		+DB(4) 64
25 -DB(3)		+DB(3) 65
26 -DB(2)		+DB(2) 66
27 -DB(1)		+DB(1) 67
28 -DB(0)		+DB(0) 68
29 -DB(P1)		+DB(P1) 69
30 -DB(15)		+DB(15) 70
31 -DB(14)		+DB(14) 71
32 -DB(13)		+DB(13) 72
33 -DB(12)		+DB(12) 73
34 5V		5V GROUND 74
35 5V		5V GROUND 75
36 5V		5V GROUND 76
37 SYNC		ACTIVE LED OUT 77
38 RMT_START		DLYD_START 78
39 SCSI ID(0)		SCSI ID (1) 79
40 SCSI ID(2)		SCSI ID (3) 80

Table 18 - SE: 68-position connector & A-cable
(Applies to both bus-path and stub connections)

68-position connector contact and signal name			A-Cable conductor position and signal name				68-position connector contact and signal name		
1	GROUND	*					*	-DB(12)	35
2	GROUND	*					*	-DB(13)	36
3	GROUND	*					*	-DB(14)	37
4	GROUND	*					*	-DB(15)	38
5	GROUND	*					*	-DB(P1)	39
6	GROUND		1	GROUND	-DB(0)	2		-DB(0)	40
7	GROUND		3	GROUND	-DB(1)	4		-DB(1)	41
8	GROUND		5	GROUND	-DB(2)	6		-DB(2)	42
9	GROUND		7	GROUND	-DB(3)	8		-DB(3)	43
10	GROUND		9	GROUND	-DB(4)	10		-DB(4)	44
11	GROUND		11	GROUND	-DB(5)	12		-DB(5)	45
12	GROUND		13	GROUND	-DB(6)	14		-DB(6)	46
13	GROUND		15	GROUND	-DB(7)	16		-DB(7)	47
14	GROUND		17	GROUND	-DB(P)	18		-DB(P)	48
15	GROUND		19	GROUND	GROUND	20		GROUND	49
16	GROUND		21	GROUND	GROUND	22		GROUND	50
17	TERMPWR	X	23	RESERVED	RESERVED	24	X	TERMPWR	51
18	TERMPWR	X	25	OPEN	TERMPWR	26		TERMPWR	52
19	RESERVED		27	RESERVED	RESERVED	28		RESERVED	53
20	GROUND		29	GROUND	GROUND	30		GROUND	54
21	GROUND		31	GROUND	-ATN	32		-ATN	55
22	GROUND		33	GROUND	GROUND	34		GROUND	56
23	GROUND		35	GROUND	-BSY	36		-BSY	57
24	GROUND		37	GROUND	-ACK	38		-ACK	58
25	GROUND		39	GROUND	-RST	40		-RST	59
26	GROUND		41	GROUND	-MSG	42		-MSG	60
27	GROUND		43	GROUND	-SEL	44		-SEL	61
28	GROUND		45	GROUND	-C/D	46		-C/D	62
29	GROUND		47	GROUND	-REQ	48		-REQ	63
30	GROUND		49	GROUND	-I/O	50		-I/O	64
31	GROUND	*					*	-DB(8)	65
32	GROUND	*					*	-DB(9)	66
33	GROUND	*					*	-DB(10)	67
34	GROUND	*					*	-DB(11)	68

X = Signal is Not Connected i.e. no connection between the connector contact and the respective cable conductor.
* = Normally no connection to the A-Cable conductor, but may be grounded or terminated for the benefit of the mating 68-signal bus. If grounded or terminated within a cable assembly, the cable assembly shall be so labeled.

Table 19 - HVD: 68-position connector & A-cable
(Applies to both bus-path and stub connections)

68-position connector contact and signal name			A-cable conductor position and signal name				68-position connector contact and signal name		
1	+DB(12)	*					*	-DB(12)	35
2	+DB(13)	*					*	-DB(13)	36
3	+DB(14)	*					*	-DB(14)	37
4	+DB(15)	*					*	-DB(15)	38
5	+DB(P1)	*					*	-DB(P1)	39
6	GROUND		1	GROUND	GROUND	2		GROUND	40
7	+DB(0)		3	+DB(0)	-DB(0)	4		-DB(0)	41
8	+DB(1)		5	+DB(1)	-DB(1)	6		-DB(1)	42
9	+DB(2)		7	+DB(2)	-DB(2)	8		-DB(2)	43
10	+DB(3)		9	+DB(3)	-DB(3)	10		-DB(3)	44
11	+DB(4)		11	+DB(4)	-DB(4)	12		-DB(4)	45
12	+DB(5)		13	+DB(5)	-DB(5)	14		-DB(5)	46
13	+DB(6)		15	+DB(6)	-DB(6)	16		-DB(6)	47
14	+DB(7)		17	+DB(7)	-DB(7)	18		-DB(7)	48
15	+DB(P)		19	+DB(P)	-DB(P)	20		-DB(P)	49
16	DIFFSENS		21	DIFFSENS	GROUND	22		GROUND	50
17	TERMPWR	X	23	RESERVED	RESERVED	24	X	TERMPWR	51
18	TERMPWR		25	TERMPWR	TERMPWR	26		TERMPWR	52
19	RESERVED		27	RESERVED	RESERVED	28		RESERVED	53
20	+ATN		29	+ATN	-ATN	30		-ATN	54
21	GROUND		31	GROUND	GROUND	32		GROUND	55
22	+BSY		33	+BSY	-BSY	34		-BSY	56
23	+ACK		35	+ACK	-ACK	36		-ACK	57
24	+RST		37	+RST	-RST	38		-RST	58
25	+MSG		39	+MSG	-MSG	40		-MSG	59
26	+SEL		41	+SEL	-SEL	42		-SEL	60
27	+C/D		43	+C/D	-C/D	44		-C/D	61
28	+REQ		45	+REQ	-REQ	46		-REQ	62
29	+I/O		47	+I/O	-I/O	48		-I/O	63
30	GROUND		49	GROUND	GROUND	50		GROUND	64
31	+DB(8)	*					*	-DB(8)	65
32	+DB(9)	*					*	-DB(9)	66
33	+DB(10)	*					*	-DB(10)	67
34	+DB(11)	*					*	-DB(11)	68

X = Signal is Not Connected i.e. no connection between the connector contact and the respective cable conductor.
* = Normally no connection to the A-Cable conductor, but may be grounded or terminated for the benefit of the mating 68-signal bus. If grounded or terminated within a cable assembly, the cable assembly shall be so labeled.

Table 20 - LVD: 68-position connector & A-cable
(Applies to both bus-path and stub connections)

68-position connector contact and signal name	A-Cable conductor position and signal name	68-position connector contact and signal name
1 +DB(12) *		* -DB(12) 35
2 +DB(13) *		* -DB(13) 36
3 +DB(14) *		* -DB(14) 37
4 +DB(15) *		* -DB(15) 38
5 +DB(P1) *		* -DB(P1) 39
6 +DB(0)	1 +DB(0) -DB(0) 2	-DB(0) 40
7 +DB(1)	3 +DB(1) -DB(1) 4	-DB(1) 41
8 +DB(2)	5 +DB(2) -DB(2) 6	-DB(2) 42
9 +DB(3)	7 +DB(3) -DB(3) 8	-DB(3) 43
10 +DB(4)	9 +DB(4) -DB(4) 10	-DB(4) 44
11 +DB(5)	11 +DB(5) -DB(5) 12	-DB(5) 45
12 +DB(6)	13 +DB(6) -DB(6) 14	-DB(6) 46
13 +DB(7)	15 +DB(7) -DB(7) 16	-DB(7) 47
14 +DB(P)	17 +DB(P) -DB(P) 18	-DB(P) 48
15 GROUND	19 GROUND GROUND 20	GROUND 49
16 DIFFSENS	21 DIFFSENS GROUND 22	GROUND 50
17 TERMPWR X	23 RESERVED RESERVED 24	X TERMPWR 51
18 TERMPWR	25 TERMPWR TERMPWR 26	TERMPWR 52
19 RESERVED	27 RESERVED RESERVED 28	RESERVED 53
20 GROUND	29 GROUND GROUND 30	GROUND 54
21 +ATN	31 +ATN -ATN 32	-ATN 55
22 GROUND	33 GROUND GROUND 34	GROUND 56
23 +BSY	35 +BSY -BSY 36	-BSY 57
24 +ACK	37 +ACK -ACK 38	-ACK 58
25 +RST	39 +RST -RST 40	-RST 59
26 +MSG	41 +MSG -MSG 42	-MSG 60
27 +SEL	43 +SEL -SEL 44	-SEL 61
28 +C/D	45 +C/D -C/D 46	-C/D 62
29 +REQ	47 +REQ -REQ 48	-REQ 63
30 +I/O	49 +I/O -I/O 50	-I/O 64
31 +DB(8) *		* -DB(8) 65
32 +DB(9) *		* -DB(9) 66
33 +DB(10) *		* -DB(10) 67
34 +DB(11) *		* -DB(11) 68

X = Signal is Not Connected i.e. no connection between the connector contact and the respective cable conductor.
* = Normally no connection to the A-Cable conductor, but may be grounded or terminated for the benefit of the mating 68-signal bus. If grounded or terminated within a cable assembly, the cable assembly shall be so labeled.

Table 21 - SE: 80-position SCA-2 connector & A-cable
(Applies to stub connection)

80-position SCA-2 connector contact and signal name			A-cable conductor position and signal name				80-position SCA-2 connector contact and signal name		
1	12V	X					X	12V GROUND	41
2	12V	X					X	12V GROUND	42
3	12V	X					X	12V GROUND	43
4	12V	X					X	12V GROUND	44
5	RESERVED/NC	X	28	RESERVED	RESERVED	27	X	RESERVED/NC	45
6	RESERVED/NC	X	24	RESERVED	RESERVED	23	X	RESERVED/NC	46
7	-DB(11)	*			GROUND	20		GROUND	47
8	-DB(10)	*			GROUND	22		GROUND	48
9	-DB(9)	*			GROUND	28		GROUND	49
10	-DB(8)	*			GROUND	34		GROUND	50
11	-I/O		50	-I/O	GROUND	49		GROUND	51
12	-REQ		48	-REQ	GROUND	47		GROUND	52
13	-C/D		46	-C/D	GROUND	45		GROUND	53
14	-SEL		44	-SEL	GROUND	43		GROUND	54
15	-MSG		42	-MSG	GROUND	41		GROUND	55
16	-RST		40	-RST	GROUND	39		GROUND	56
17	-ACK		38	-ACK	GROUND	37		GROUND	57
18	-BSY		36	-BSY	GROUND	35		GROUND	58
19	-ATN		32	-ATN	GROUND	31		GROUND	59
20	-DB(P0)		18	-DB(P)	GROUND	17		GROUND	60
21	-DB(7)		16	-DB(7)	GROUND	15		GROUND	61
22	-DB(6)		14	-DB(6)	GROUND	13		GROUND	62
23	-DB(5)		12	-DB(5)	GROUND	11		GROUND	63
24	-DB(4)		10	-DB(4)	GROUND	9		GROUND	64
25	-DB(3)		8	-DB(3)	GROUND	7		GROUND	65
26	-DB(2)		6	-DB(2)	GROUND	5		GROUND	66
27	-DB(1)		4	-DB(1)	GROUND	3		GROUND	67
28	-DB(0)		2	-DB(0)	GROUND	1		GROUND	68
29	-DB(P1)	*			GROUND	19		GROUND	69
30	-DB(15)	*			GROUND	21		GROUND	70
31	-DB(14)	*			GROUND	29		GROUND	71
32	-DB(13)	*			GROUND	33		GROUND	72
33	-DB(12)	*			GROUND	30		GROUND	73
34	5V	X	26	TERMPWR	OPEN	25	X	5V GROUND	74
35	5V	X					X	5V GROUND	75
36	5V	X					X	5V GROUND	76
37	SYNC	X					X	ACTIVE LED OUT	77
38	RMT_START	X					X	DLYD_START	78
39	SCSI ID(0)	X					X	SCSI ID (1)	79
40	SCSI ID(2)	X					X	SCSI ID (3)	80

X = Signal is Not Connected i.e. no connection between the connector contact and the respective cable conductor.
* = May be terminated/grounded in cable assembly (and should be so labeled). Signals should be negated on 8-bit devices with high value resistors to avoid false assertions - see 15.5.2.
NOTE: See also 15.6.

Table 22 - SE: 80-positon SCA-2 connector & P-cable
(Applies to stub connection)

80-position SCA-2 connector contact and signal name			P-cable conductor position and signal name				80-position SCA-2 connector contact and signal name		
1	12V	X					X	12V GROUND	41
2	12V	X					X	12V GROUND	42
3	12V	X					X	12V GROUND	43
4	12V	X	32	GROUND	GROUND	31	X	12V GROUND	44
5	RESERVED/NC	X	38	RESERVED	RESERVED	37	X	RESERVED/NC	45
6	RESERVED/NC	X	30	GROUND	GROUND	29	X	RESERVED/NC	46
7	-DB(11)		68	-DB(11)	GROUND	67		GROUND	47
8	-DB(10)		66	-DB(10)	GROUND	65		GROUND	48
9	-DB(9)		64	-DB(9)	GROUND	63		GROUND	49
10	-DB(8)		62	-DB(8)	GROUND	61		GROUND	50
11	-I/O		60	-I/O	GROUND	59		GROUND	51
12	-REQ		58	-REQ	GROUND	57		GROUND	52
13	-C/D		56	-C/D	GROUND	55		GROUND	53
14	-SEL		54	-SEL	GROUND	53		GROUND	54
15	-MSG		52	-MSG	GROUND	51		GROUND	55
16	-RST		50	-RST	GROUND	49		GROUND	56
17	-ACK		48	-ACK	GROUND	47		GROUND	57
18	-BSY		46	-BSY	GROUND	45		GROUND	58
19	-ATN		42	-ATN	GROUND	41		GROUND	59
20	-DB(PO)		28	-DB(P)	GROUND	27		GROUND	60
21	-DB(7)		26	-DB(7)	GROUND	25		GROUND	61
22	-DB(6)		24	-DB(6)	GROUND	23		GROUND	62
23	-DB(5)		22	-DB(5)	GROUND	21		GROUND	63
24	-DB(4)		20	-DB(4)	GROUND	19		GROUND	64
25	-DB(3)		18	-DB(3)	GROUND	17		GROUND	65
26	-DB(2)		16	-DB(2)	GROUND	15		GROUND	66
27	-DB(1)		14	-DB(1)	GROUND	13		GROUND	67
28	-DB(0)		12	-DB(0)	GROUND	11		GROUND	68
29	-DB(P1)		10	-DB(P1)	GROUND	9		GROUND	69
30	-DB(15)		8	-DB(15)	GROUND	7		GROUND	70
31	-DB(14)		6	-DB(14)	GROUND	5		GROUND	71
32	-DB(13)		4	-DB(13)	GROUND	3		GROUND	72
33	-DB(12)		2	-DB(12)	GROUND	1		GROUND	73
34	5V	X	33	TERMPWR	GROUND	44	X	5V GROUND	74
35	5V	X	34	TERMPWR	GROUND	43	X	5V GROUND	75
36	5V	X	35	TERMPWR	GROUND	40	X	5V GROUND	76
37	SYNC	X	36	TERMPWR	GROUND	39	X	ACTIVE LED OUT	77
38	RMT_START	X					X	DLYD_START	78
39	SCSI ID(O)	X					X	SCSI ID (1)	79
40	SCSI ID(2)	X					X	SCSI ID (3)	80

X = Signal is Not Connected i.e. no connection between the connector contact and the respective cable conductor.
* = May be terminated/grounded in cable assembly (and should be so labeled). Signals should be negated on 8-bit devices with high value resistors to avoid false assertions - see

15.5.2.
NOTE: See also 15.6.

Table 23 - HVD : 80-position SCA-2 connector & A-cable
(Applies to stub connection)

80-position SCA-2 connector contact and signal name			A-cable conductor position and signal name				80-position SCA-2 connector contact and signal name		
1	12V	X			GROUND	1	X	12V GROUND	41
2	12V	X			GROUND	2	X	12V GROUND	42
3	12V	X			GROUND	22	X	12V GROUND	43
4	12V	X			GROUND	31	X	12V GROUND	44
5	RESERVED/NC	X	28	RESERVED	RESERVED	27	X	RESERVED/NC	45
6	DIFFSENS		21	DIFFSENS	RESERVED	23	X	RESERVED/NC	46
7	-DB(11)	*					*	+DB(11)	47
8	-DB(10)	*					*	+DB(10)	48
9	-DB(9)	*					*	+DB(9)	49
10	-DB(8)	*					*	+DB(8)	50
11	-I/O		48	-I/O	+I/O	47		+I/O	51
12	-REQ		46	-REQ	+REQ	45		+REQ	52
13	-C/D		44	-C/D	+C/D	43		+C/D	53
14	-SEL		42	-SEL	+SEL	41		+SEL	54
15	-MSG		40	-MSG	+MSG	39		+MSG	55
16	-RST		38	-RST	+RST	37		+RST	56
17	-ACK		36	-ACK	+ACK	35		+ACK	57
18	-BSY		34	-BSY	+BSY	33		+BSY	58
19	-ATN		30	-ATN	+ATN	29		+ATN	59
20	-DB(P0)		20	-DB(P)	+DB(P)	19		+DB(P0)	60
21	-DB(7)		18	-DB(7)	+DB(7)	17		+DB(7)	61
22	-DB(6)		16	-DB(6)	+DB(6)	15		+DB(6)	62
23	-DB(5)		14	-DB(5)	+DB(5)	13		+DB(5)	63
24	-DB(4)		12	-DB(4)	+DB(4)	11		+DB(4)	64
25	-DB(3)		10	-DB(3)	+DB(3)	9		+DB(3)	65
26	-DB(2)		8	-DB(2)	+DB(2)	7		+DB(2)	66
27	-DB(1)		6	-DB(1)	+DB(1)	5		+DB(1)	67
28	-DB(0)		4	-DB(0)	+DB(0)	3		+DB(0)	68
29	-DB(P1)	*					*	+DB(P1)	69
30	-DB(15)	*					*	+DB(15)	70
31	-DB(14)	*					*	+DB(14)	71
32	-DB(13)	*					*	+DB(13)	72
33	-DB(12)	*					*	+DB(12)	73
34	5V	X	26	TERMPWR	GROUND	32	X	5V GROUND	74
35	5V	X	25	TERMPWR	GROUND	49	X	5V GROUND	75
36	5V	X			GROUND	50	X	5V GROUND	76
37	SYNC	X			RESERVED	24	X	ACTIVE LED OUT	77
38	RMT_START	X					X	DLYD_START	78
39	SCSI ID(0)	X					X	SCSI ID (1)	79
40	SCSI ID(2)	X					X	SCSI ID (3)	80

X = Signal is Not Connected i.e. no connection between the connector contact and the respective cable conductor.
* = May be terminated/grounded in cable assembly (and should be so labeled). Signals should be negated on 8-bit devices with high value resistors to avoid false assertions - see 15.5.2.
NOTE: See also 15.6.

Table 24 - HVD : 80-position SCA-2 connector & P-cable
(Applies to stub connection)

80-position SCA-2 connector contact and signal name			P-cable conductor position and signal name				80-position SCA-2 connector contact and signal name		
1	12V	X			GROUND	11	X	12V GROUND	41
2	12V	X			GROUND	12	X	12V GROUND	42
3	12V	X			GROUND	32	X	12V GROUND	43
4	12V	X			GROUND	41	X	12V GROUND	44
5	RESERVED/NC	X	38	RESERVED	RESERVED	37	X	RESERVED/NC	45
6	DIFFSENS		31	DIFFSENS			X	RESERVED/NC	46
7	-DB(11)		68	-DB(11)	+DB(11)	67		+DB(11)	47
8	-DB(10)		66	-DB(10)	+DB(10)	65		+DB(10)	48
9	-DB(9)		64	-DB(9)	+DB(9)	63		+DB(9)	49
10	-DB(8)		62	-DB(8)	+DB(8)	61		+DB(8)	50
11	-I/O		58	-I/O	+I/O	57		+I/O	51
12	-REQ		56	-REQ	+REQ	55		+REQ	52
13	-C/D		54	-C/D	+C/D	53		+C/D	53
14	-SEL		52	-SEL	+SEL	51		+SEL	54
15	-MSG		50	-MSG	+MSG	49		+MSG	55
16	-RST		48	-RST	+RST	47		+RST	56
17	-ACK		46	-ACK	+ACK	45		+ACK	57
18	-BSY		44	-BSY	+BSY	43		+BSY	58
19	-ATN		40	-ATN	+ATN	39		+ATN	59
20	-DB(P0)		30	-DB(P)	+DB(P)	29		+DB(P0)	60
21	-DB(7)		28	-DB(7)	+DB(7)	27		+DB(7)	61
22	-DB(6)		26	-DB(6)	+DB(6)	25		+DB(6)	62
23	-DB(5)		24	-DB(5)	+DB(5)	23		+DB(5)	63
24	-DB(4)		22	-DB(4)	+DB(4)	21		+DB(4)	64
25	-DB(3)		20	-DB(3)	+DB(3)	19		+DB(3)	65
26	-DB(2)		18	-DB(2)	+DB(2)	17		+DB(2)	66
27	-DB(1)		16	-DB(1)	+DB(1)	15		+DB(1)	67
28	-DB(0)		14	-DB(0)	+DB(0)	13		+DB(0)	68
29	-DB(P1)		10	-DB(P1)	+DB(P1)	9		+DB(P1)	69
30	-DB(15)		8	-DB(15)	+DB(15)	7		+DB(15)	70
31	-DB(14)		6	-DB(14)	+DB(14)	5		+DB(14)	71
32	-DB(13)		4	-DB(13)	+DB(13)	3		+DB(13)	72
33	-DB(12)		2	-DB(13)	+DB(12)	1		+DB(12)	73
34	5V	X	33	TERMPWR	GROUND	42	X	5V GROUND	74
35	5V	X	34	TERMPWR	GROUND	59	X	5V GROUND	75
36	5V	X	35	TERMPWR	GROUND	60	X	5V GROUND	76
37	SYNC	X	36	TERMPWR			X	ACTIVE LED OUT	77
38	RMT_START	X					X	DLYD_START	78
39	SCSI ID(0)	X					X	SCSI ID (1)	79
40	SCSI ID(2)	X					X	SCSI ID (3)	80

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X = Signal is Not Connected i.e. no connection between the connector contact and the respective cable conductor.

* = May be terminated/grounded in cable assembly (and should be so labeled). Signals should be negated on 8-bit devices with high value resistors to avoid false assertions - see 15.5.2.

NOTE: See also 15.6.

Table 25 - LVD : 80-position SCA-2 connector & A-cable
(Applies to stub connection)

80-position SCA-2 connector contact and signal name			A-cable conductor position and signal name				80-position SCA-2 connector contact and signal name		
1	12V	X			GROUND	19	X	12V GROUND	41
2	12V	X			GROUND	20	X	12V GROUND	42
3	12V	X			GROUND	22	X	12V GROUND	43
4	12V	X			GROUND	29	X	12V GROUND	44
5	RESERVED/NC	X	28	RESERVED	RESERVED	27	X	RESERVED/NC	45
6	DIFFSENS		21	DIFFSENS	RESERVED	23	X	RESERVED/NC	46
7	-DB(11)	*					*	+DB(11)	47
8	-DB(10)	*					*	+DB(10)	48
9	-DB(9)	*					*	+DB(9)	49
10	-DB(8)	*					*	+DB(8)	50
11	-I/O		50	-I/O	+I/O	49		+I/O	51
12	-REQ		48	-REQ	+REQ	47		+REQ	52
13	-C/D		46	-C/D	+C/D	45		+C/D	53
14	-SEL		44	-SEL	+SEL	43		+SEL	54
15	-MSG		42	-MSG	+MSG	41		+MSG	55
16	-RST		40	-RST	+RST	39		+RST	56
17	-ACK		38	-ACK	+ACK	37		+ACK	57
18	-BSY		36	-BSY	+BSY	35		+BSY	58
19	-ATN		32	-ATN	+ATN	31		+ATN	59
20	-DB(P0)		18	-DB(P)	+DB(P)	17		+DB(P0)	60
21	-DB(7)		16	-DB(7)	+DB(7)	15		+DB(7)	61
22	-DB(6)		14	-DB(6)	+DB(6)	13		+DB(6)	62
23	-DB(5)		12	-DB(5)	+DB(5)	11		+DB(5)	63
24	-DB(4)		10	-DB(4)	+DB(4)	9		+DB(4)	64
25	-DB(3)		8	-DB(3)	+DB(3)	7		+DB(3)	65
26	-DB(2)		6	-DB(2)	+DB(2)	5		+DB(2)	66
27	-DB(1)		4	-DB(1)	+DB(1)	3		+DB(1)	67
28	-DB(0)		2	-DB(0)	+DB(0)	1		+DB(0)	68
29	-DB(P1)	*					*	+DB(P1)	69
30	-DB(15)	*					*	+DB(15)	70
31	-DB(14)	*					*	+DB(14)	71
32	-DB(13)	*					*	+DB(13)	72
33	-DB(12)	*					*	+DB(12)	73
34	5V	X	26	TERMPWR	GROUND	30	X	5V GROUND	74
35	5V	X	25	TERMPWR	GROUND	33	X	5V GROUND	75
36	5V	X			GROUND	34	X	5V GROUND	76
37	SYNC	X			RESERVED	24	X	ACTIVE LED OUT	77
38	RMT_START	X					X	DLYD_START	78
39	SCSI ID(0)	X					X	SCSI ID (1)	79
40	SCSI ID(2)	X					X	SCSI ID (3)	80

X = Signal is Not Connected i.e. no connection between the connector contact and the respective cable conductor.
* = May be terminated/grounded in cable assembly (and should be so labeled). Signals should be negated on 8-bit devices with high value resistors to avoid false assertions - see 15.5.2.
NOTE: See also 15.6.

Table 26 - LVD : 80-position SCA-2 connector & P-cable
(Applies to stub connection)

80-position SCA-2 connector contact and signal name			P-cable conductor position and signal name				80-position SCA-2 connector contact and signal name		
1	12V	X			GROUND	29	X	12V GROUND	41
2	12V	X			GROUND	30	X	12V GROUND	42
3	12V	X			GROUND	32	X	12V GROUND	43
4	12V	X			GROUND	39	X	12V GROUND	44
5	RESERVED/NC	X	38	RESERVED	RESERVED	37	X	RESERVED/NC	45
6	DIFFSENS		31	DIFFSENS			X	RESERVED/NC	46
7	-DB(11)		68	-DB(11)	+DB(11)	67		+DB(11)	47
8	-DB(10)		66	-DB(10)	+DB(10)	65		+DB(10)	48
9	-DB(9)		64	-DB(9)	+DB(9)	63		+DB(9)	49
10	-DB(8)		62	-DB(8)	+DB(8)	61		+DB(8)	50
11	-I/O		60	-I/O	+I/O	59		+I/O	51
12	-REQ		58	-REQ	+REQ	57		+REQ	52
13	-C/D		56	-C/D	+C/D	55		+C/D	53
14	-SEL		54	-SEL	+SEL	53		+SEL	54
15	-MSG		52	-MSG	+MSG	51		+MSG	55
16	-RST		50	-RST	+RST	49		+RST	56
17	-ACK		48	-ACK	+ACK	47		+ACK	57
18	-BSY		46	-BSY	+BSY	45		+BSY	58
19	-ATN		42	-ATN	+ATN	41		+ATN	59
20	-DB(P0)		28	-DB(P)	+DB(P)	27		+DB(P0)	60
21	-DB(7)		26	-DB(7)	+DB(7)	25		+DB(7)	61
22	-DB(6)		24	-DB(6)	+DB(6)	23		+DB(6)	62
23	-DB(5)		22	-DB(5)	+DB(5)	21		+DB(5)	63
24	-DB(4)		20	-DB(4)	+DB(4)	19		+DB(4)	64
25	-DB(3)		18	-DB(3)	+DB(3)	17		+DB(3)	65
26	-DB(2)		16	-DB(2)	+DB(2)	15		+DB(2)	66
27	-DB(1)		14	-DB(1)	+DB(1)	13		+DB(1)	67
28	-DB(0)		12	-DB(0)	+DB(0)	11		+DB(0)	68
29	-DB(P1)		10	-DB(P1)	+DB(P1)	9		+DB(P1)	69
30	-DB(15)		8	-DB(15)	+DB(15)	7		+DB(15)	70
31	-DB(14)		6	-DB(14)	+DB(14)	5		+DB(14)	71
32	-DB(13)		4	-DB(13)	+DB(13)	3		+DB(13)	72
33	-DB(12)		2	-DB(12)	+DB(12)	1		+DB(12)	73
34	5V	X	33	TERMPWR	GROUND	40	X	5V GROUND	74
35	5V	X	34	TERMPWR	GROUND	43	X	5V GROUND	75
36	5V	X	35	TERMPWR	GROUND	44	X	5V GROUND	76
37	SYNC	X	36	TERMPWR			X	ACTIVE LED OUT	77
38	RMT_START	X					X	DLYD_START	78
39	SCSI ID(0)	X					X	SCSI ID (1)	79
40	SCSI ID(2)	X					X	SCSI ID (3)	80

X = Signal is Not Connected i.e. no connection between the connector contact and the respective cable conductor.
* = May be terminated/grounded in cable assembly (and should be so labeled). Signals should be negated on 8-bit devices with high value resistors to avoid false assertions - see

15.5.2.
NOTE: See also 15.6.

Table 27 - SE: 50-position connector & P-cable
(Applies to stub connection)

50-position connector contact and signal name	P-cable conductor position and signal name	50-position connector contact and signal name
X	1 GROUND -DB(12) 2	X
X	3 GROUND -DB(13) 4	X
X	5 GROUND -DB(14) 6	X
X	7 GROUND -DB(15) 8	X
X	9 GROUND -DB(P1) 10	X
1 GROUND	11 GROUND -DB(0) 12	-DB(0) 26
2 GROUND	13 GROUND -DB(1) 14	-DB(1) 27
3 GROUND	15 GROUND -DB(2) 16	-DB(2) 28
4 GROUND	17 GROUND -DB(3) 18	-DB(3) 29
5 GROUND	19 GROUND -DB(4) 20	-DB(4) 30
6 GROUND	21 GROUND -DB(5) 22	-DB(5) 31
7 GROUND	23 GROUND -DB(6) 24	-DB(6) 32
8 GROUND	25 GROUND -DB(7) 26	-DB(7) 33
9 GROUND	27 GROUND -DB(P) 28	-DB(P) 34
10 GROUND	29 GROUND GROUND 30	GROUND 35
11 GROUND	31 GROUND GROUND 32	GROUND 36
12 RESERVED X	33 TERMPWR TERMPWR 34	X RESERVED 37
13 OPEN X	35 TERMPWR TERMPWR 36	TERMPWR 38
14 RESERVED	37 RESERVED RESERVED 38	RESERVED 39
15 GROUND	39 GROUND GROUND 40	GROUND 40
16 GROUND	41 GROUND -ATN 42	-ATN 41
17 GROUND	43 GROUND GROUND 44	GROUND 42
18 GROUND	45 GROUND -BSY 46	-BSY 43
19 GROUND	47 GROUND -ACK 48	-ACK 44
20 GROUND	49 GROUND -RST 50	-RST 45
21 GROUND	51 GROUND -MSG 52	-MSG 46
22 GROUND	53 GROUND -SEL 54	-SEL 47
23 GROUND	55 GROUND -C/D 56	-C/D 48
24 GROUND	57 GROUND -REQ 58	-REQ 49
25 GROUND	59 GROUND -I/O 60	-I/O 50
X	61 GROUND -DB(8) 62	X
X	63 GROUND -DB(9) 64	X
X	65 GROUND -DB(10) 66	X
X	67 GROUND -DB(11) 68	X

X = Signal is Not Connected i.e. no connection between the connector contact and the respective cable conductor.

Table 28 - HVD: 50-position connector & P-cable
(Applies to stub connection)

50-position connector contact and signal name			P-Cable conductor position and signal name				50-position connector contact and signal name		
		X	1	+DB(12)	-DB(12)	2	X		
		X	3	+DB(13)	-DB(13)	4	X		
		X	5	+DB(14)	-DB(14)	6	X		
		X	7	+DB(15)	-DB(15)	8	X		
		X	9	+DB(P1)	-DB(P1)	10	X		
1	GROUND		11	GROUND	GROUND	12		GROUND	26
2	+DB(0)		13	+DB(0)	-DB(0)	14		-DB(0)	27
3	+DB(1)		15	+DB(1)	-DB(1)	16		-DB(1)	28
4	+DB(2)		17	+DB(2)	-DB(2)	18		-DB(2)	29
5	+DB(3)		19	+DB(3)	-DB(3)	20		-DB(3)	30
6	+DB(4)		21	+DB(4)	-DB(4)	22		-DB(4)	31
7	+DB(5)		23	+DB(5)	-DB(5)	24		-DB(5)	32
8	+DB(6)		25	+DB(6)	-DB(6)	26		-DB(6)	33
9	+DB(7)		27	+DB(7)	-DB(7)	28		-DB(7)	34
10	+DB(P)		29	+DB(P)	-DB(P)	30		-DB(P)	35
11	DIFFSENS		31	DIFFSENS	GROUND	32		GROUND	36
12	RESERVED	X	33	TERMPWR	TERMPWR	34	X	RESERVED	37
13	TERMPWR		35	TERMPWR	TERMPWR	36		TERMPWR	38
14	RESERVED		37	RESERVED	RESERVED	38		RESERVED	39
15	+ATN		39	+ATN	-ATN	40		-ATN	40
16	GROUND		41	GROUND	GROUND	42		GROUND	41
17	+BSY		43	+BSY	-BSY	44		-BSY	42
18	+ACK		45	+ACK	-ACK	46		-ACK	43
19	+RST		47	+RST	-RST	48		-RST	44
20	+MSG		49	+MSG	-MSG	50		-MSG	45
21	+SEL		51	+SEL	-SEL	52		-SEL	46
22	+C/D		53	+C/D	-C/D	54		-C/D	47
23	+REQ		55	+REQ	-REQ	56		-REQ	48
24	+I/O		57	+I/O	-I/O	58		-I/O	49
25	GROUND		59	GROUND	GROUND	60		GROUND	50
		X	61	+DB(8)	-DB(8)	62	X		
		X	63	+DB(9)	-DB(9)	64	X		
		X	65	+DB(10)	-DB(10)	66	X		
		X	67	+DB(11)	-DB(11)	68	X		

X = Signal is not connected i.e. no connection between the connector contact and the respective cable conductor.

Table 29 - LVD: 50-position connector & P-cable
(Applies to stub connection)

50-position connector contact and signal name			P-cable conductor position and signal name				50-position connector contact and signal name		
		X	1	+DB(12)	-DB(12)	2	X		
		X	3	+DB(13)	-DB(13)	4	X		
		X	5	+DB(14)	-DB(14)	6	X		
		X	7	+DB(15)	-DB(15)	8	X		
		X	9	+DB(P1)	-DB(P1)	10	X		
1	+DB(0)		11	+DB(0)	-DB(0)	12		-DB(0)	26
2	+DB(1)		13	+DB(1)	-DB(1)	14		-DB(1)	27
3	+DB(2)		15	+DB(2)	-DB(2)	16		-DB(2)	28
4	+DB(3)		17	+DB(3)	-DB(3)	18		-DB(3)	29
5	+DB(4)		19	+DB(4)	-DB(4)	20		-DB(4)	30
6	+DB(5)		21	+DB(5)	-DB(5)	22		-DB(5)	31
7	+DB(6)		23	+DB(6)	-DB(6)	24		-DB(6)	32
8	+DB(7)		25	+DB(7)	-DB(7)	26		-DB(7)	33
9	+DB(P)		27	+DB(P)	-DB(P)	28		-DB(P)	34
10	GROUND		29	GROUND	GROUND	30		GROUND	35
11	DIFFSENS		31	DIFFSENS	GROUND	32		GROUND	36
12	RESERVED	X	33	TERMPWR	TERMPWR	34	X	RESERVED	37
13	TERMPWR		35	TERMPWR	TERMPWR	36		TERMPWR	38
14	RESERVED		37	RESERVED	RESERVED	38		RESERVED	39
15	GROUND		39	GROUND	GROUND	40		GROUND	40
16	+ATN		41	+ATN	-ATN	42		-ATN	41
17	GROUND		43	GROUND	GROUND	44		GROUND	42
18	+BSY		45	+BSY	-BSY	46		-BSY	43
19	+ACK		47	+ACK	-ACK	48		-ACK	44
20	+RST		49	+RST	-RST	50		-RST	45
21	+MSG		51	+MSG	-MSG	52		-MSG	46
22	+SEL		53	+SEL	-SEL	54		-SEL	47
23	+C/D		55	+C/D	-C/D	56		-C/D	48
24	+REQ		57	+REQ	-REQ	58		-REQ	49
25	+I/O		59	+I/O	-I/O	60		-I/O	50
		X	61	+DB(8)	-DB(8)	62	X		
		X	63	+DB(9)	-DB(9)	64	X		
		X	65	+DB(10)	-DB(10)	66	X		
		X	67	+DB(11)	-DB(11)	68	X		

X = Signal is Not Connected i.e. no connection between the connector contact and the respective cable conductor.

Table 30 - SE: 68 position connector & dual A-cable
(applies to stub and bus-path connections)

BUS 1 50-position connector contact and signal name (set 2)			68 position connector contact and signal name BUS 1		BUS 2		BUS 2 50 position connector contact and signal name (set 2)		
1	GROUND		1	GROUND	GROUND	1		GROUND	1
26	-DB0		2	-DB(0)	-DB(0)	35		-DB(0)	26
2	GROUND		36	GROUND	GROUND	36		GROUND	2
27	-DB(1)		3	-DB(1)	-DB(1)	37		-DB(1)	27
3	GROUND		4	GROUND	GROUND	4		GROUND	3
28	-DB(2)		5	-DB(2)	-DB(2)	38		-DB(2)	28
4	GROUND		39	GROUND	GROUND	39		GROUND	4
29	-DB(3)		6	-DB(3)	-DB(3)	40		-DB(3)	29
5	GROUND		7	GROUND	GROUND	7		GROUND	5
30	-DB(4)		8	-DB(4)	-DB(4)	41		-DB(4)	30
6	GROUND		42	GROUND	GROUND	42		GROUND	6
31	-DB(5)		9	-DB(5)	-DB(5)	43		-DB(5)	31
7	GROUND		10	GROUND	GROUND	10		GROUND	7
32	-DB(6)		11	-DB(6)	-DB(6)	44		-DB(6)	32
8	GROUND		45	GROUND	GROUND	45		GROUND	8
33	-DB(7)		12	-DB(7)	-DB(7)	46		-DB(7)	33
9	GROUND		16	GROUND	GROUND	16		GROUND	9
34	-DB(P)		13	-DB(P)	-DB(P)	47		-DB(P)	34
10	GROUND	X					X	GROUND	10
35	GROUND/SWAP L		14	GND/SWP	GND/SWP	48		GROUND/SWAP L	35
11	GROUND	X					X	GROUND	11
36	GROUND/SHLF OK H		15	GND/SHL	GND/SHL	49		GROUND/SHLF OK H	36
12	RESERVED	X					X	RESERVED	12
37	RESERVED	X					X	RESERVED	37
13	OPEN	X	17			51	X	OPEN	13
38	TERMPWR		18	TERMPWR	TERMPWR	52		TERMPWR	38
14	RESERVED	X					X	RESERVED	14
39	RESERVED		19	RESERVED	RESERVED	50		RESERVED	39
15	GROUND	X					X	GROUND	15
40	GROUND/FLT CLK H		20	GND/FLTC	GND/FLTC	53		GROUND/FLT CLK H	40
16	GROUND		56	GROUND	GROUND	56		GROUND	16
41	-ATN		21	-ATN	-ATN	54		-ATN	41
17	GROUND	X					X	GROUND	17
42	GROUND/FLT DAT A		22	GND/FLTD	GND/FLTD	55		GROUND/FLT DAT A	42
18	GROUND		24	GROUND	GROUND	24		GROUND	18
43	-BSY		23	-BSY	-BSY	57		-BSY	43
19	GROUND		59	GROUND	GROUND	59		GROUND	19
44	-ACK		25	-ACK	-ACK	58		-ACK	44
20	GROUND		27	GROUND	GROUND	27		GROUND	20
45	-RST		26	-RST	-RST	60		-RST	45
21	GROUND		62	GROUND	GROUND	62		GROUND	21
46	-MSG		28	-MSG	-MSG	61		-MSG	46
22	GROUND		30	GROUND	GROUND	30		GROUND	22
47	-SEL		29	-SEL	-SEL	63		-SEL	47
23	GROUND		65	GROUND	GROUND	65		GROUND	23
48	-C/D		31	-C/D	-C/D	64		-C/D	48
24	GROUND		33	GROUND	GROUND	33		GROUND	24
49	-REQ		32	-REQ	-REQ	66		-REQ	49
25	GROUND		68	GROUND	GROUND	68		GROUND	25
50	-I/O		34	-I/O	-I/O	67		-I/O	50

X = Signal is not connected i.e. no connection between the A cable conductor and any 68 position connector contact.

Note: positions 17 and 51 on the 68 position connector are not connected to prevent TERMPWR shorts if an ordinary P cable were accidentally mated to a dual A cable.

Note: SWAP, SHLF, FLT CLK, FLT DAT are optional non-SCSI signals used in some proprietary RAID applications.

Note: A 34 pair "P" cable cannot provide a dual "A" cable function because it cannot take advantage of
the commoning of the signal grounds without destroying the characteristic impedance of the signal line.