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The following document is the latest proposal for the Enhanced Parallel Interface technical report.

Proposed Working Draft

T10/1143D

Revision 13
March 26, 1998

Information Technology -
SCSI Enhanced Parallel Interface - EPI

This is an internal working document of NCITS T10 of the Accredited Standards Committee NCITS. As such, this is not a completed report and has not been approved by Task Group T10. The contents may be modified by the T10 Task Group. This document is made available for review and comment only.

[Technical Editor's Note: This Rev contains a proposed outline and content based on technical information and editing time available to the editor as of March 26, 1998. The major changes in this revision is the addition of switching expanders in the sections on bridging expanders. Work is still needed on sections dealing with power and dynamic reconfigurations and the LVD options for mixed width pinouts is needed A complete draft containing content in all sections is presently envisioned for the meeting in May 1998.]

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ABSTRACT

This document describes SCSI configurations that may be achieved within the context of the specifications in the SCSI-2, SCSI-3 SPI, SPI-2, and SCSI-3 FAST 20 standards. These configurations have one or more configuration parameters expanded beyond that formally specified 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 document does supersede any requirements in the referenced standards for formal compliance with standards.

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1. Scope

This document is an ANSI technical report that provides guidance to experienced implementers and users of parallel SCSI beyond that contained in the formal standards.

2. References

SCSI-2
SCSI-3 SPI
SCSI-3 Fast 20

3. Definitions, symbols, and abbreviations

3.1. Bus related

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 must have 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 section6, Table 1, Table 2, and Table 3.

Device:

Devices include targets, initiators, bus expanders (see definition in section 3.2).

Terminator:

Interconnect components that form the ends of the transmission lines in bus segments. A SCSI domain (section 3.2) must have at least one segment and therefore at least two terminators (except for special cases where the electrical transmission lines are very short).

Bus segment types:

There are presently three types of SCSI bus segment:

- Single ended (SE)
- 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 is a bus path.

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 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 connectors 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

Other physical placement descriptions may be used.

Special note for location of 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*. Such connectors are termed housing-only connectors.

*[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 IDC part of the connector pin. The stub contained within the connector is very short and the true point of stub connection is not easily physically accessible so there is very little margin lost by considering the mating interface as the true stub connection.]

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

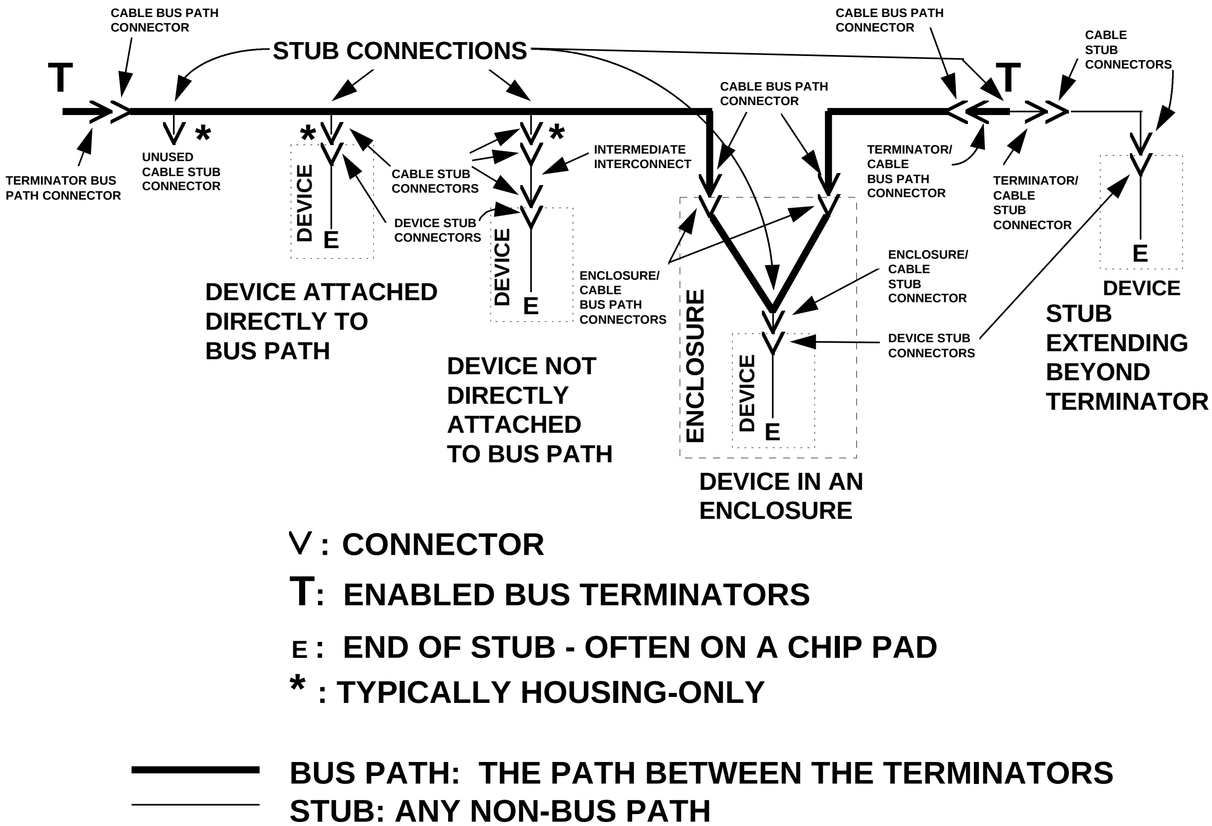

Figure 1 - Single segment physical architecture and terminology examples

3.2. SCSI domain related

SCSI domain:

A SCSI domain is a logical bus with at least one bus segment, at least one initiator, and at least one targets. Domains with multiple bus segments are enabled through the use of bus expanders. Domains are limited by the device addressability. Domains are limited to a maximum of 16 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 8.

Bridging expander

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

4. General

This document describes configurations and extensions that are possible within the context of the existing SCSI standards but that may not be obvious or formally allowed by the standards. It is the intent of this document 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 reconfigurability of domains, and extending the number of addressable devices in a single domain.

5. Bus segment concept

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 section. Multiple bus segments may be functionally connected together by special coupling circuits described in section 8.

Each bus segment has TERMPOWER sources and TERMPOWER distribution parameters.

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

Bus segments largely 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 (single ended, high voltage differential, and low voltage differential).

5.1. 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 standard incorporates 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 significantly 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 document. Using multiple bus segments in the same SCSI domain directly 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 one must look at the properties that affect this length.

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 must be 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 section 11.

For the domain length limits one must consider the propagation time consumed by the elements that connect the bus segments as well as that consumed in the individual segments. 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.

Section 8 considers the propagation delay issues for the elements that connect bus segments. The remainder of this section considers the factors that affect the physical length of single segment domains and segments within multi-segment domains.

5.1.1. 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 document 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 beginning" is a maximum of 400 ns. A one way transit time of 200 ns must be used for each segment. It may be possible to extend the one way time to 400ns for a multi-segment domain. See 8.1.3. Even in this case each segment must individually meet the 200 ns one way requirement.

If one has a uniform bus media and a known signal propagation velocity, Vp, this establishes the maximum physical length as Lmax = 200ns/Vp. With the presently allowed slowest Vp of approximately 5ns/m this gives a maximum length of 40 meters. 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 section considers the most important additional effects caused by device loading.

5.1.1.1. Device loading parameters

When real devices are present on a segment their stubs and capacitive loads add to the bus 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 must be 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 as:

$$Lmax = (200ns - Tdd) / Vp$$

With 14 devices having a total of 0.5 ns per device there is a 7 ns reduction. 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 therefore becomes approximately 9 ns for a fully loaded wide SCSI segment

5.1.1.2. Caution when using differential interfaces

It is important to note that the times relating to the signal propagation are defined as measured from the device connectors. This is especially important when using differential interfaces with separate transceivers since the propagation time through the transceivers can be several tens of nanoseconds. The SCSI standard does not allow any special budget for these extra transceiver delays so designers of differential interfaces must ensure that the timings of protocol chips and other device design parameters accommodate separate transceivers.

5.1.2. Propagation - time - limited domain length

Using the numbers in section 5.1.1.1 and assuming a Vp of 5 ns/m we find a maximum single segment length (with reflections) to be 191/5 = 38.2 meters. The number in the present standards use a much more conservative Vp of 6.6 ns/m (28.93m) and adds extra margin to report a maximum length of 25 meters. Using the real numbers without the extra margin we gain an extra 13.2 meters in total segment length. For media specially built for high propagation velocity one can achieve at least 3.76ns/m for a loaded length of 50.8m or double that in the present standards without changing any protocol timings (if the signal quality remains adequate).

Lengths above 6 meters are suggested as mainly applicable to differential transmissions in the standards. We will examine this assumption in more detail in section 5.1.3.

It is not necessary to abandon the length based scheme to achieve the benefits of multisegment domains but it is necessary to adopt some relationship between length and time to allow for the coupling circuits between domains. This relationship can be provided by the equation in section 5.1.1.1. One may think of the length based scheme as a significantly conservative specification method.

5.1.3. Signal quality limits

This section 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 useable 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 one is using very small gauge wire (less than 32 gauge). In the normal situation where 32 gauge or larger wire is being used one can readily establish some conditions that relate segment length to keeping the first reflection within the same pulse. This condition is simply 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. Slow SCSI has a period of 90 ns, fast is 30 ns, fast 20 is 15 ns, fast 40 is 8 ns. Assuming a propagation velocity of 5 ns/meter one can go 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 one would get 9, 3, 1.5, and 0.8 meters respectively as the maximum length possible before the reflection could exceed the assertion/negation period. These lengths match perfectly the recommendations in the standards for fast and fast 20 and show that slow SCSI has relatively 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 one exceeds the 3 meter limit for fast SCSI he should expect that reflections would need to be under very good control or some other features would need to be better than minimally required.

The condition where there is no need for a reflection to achieve a good detectable signal is called incident wave switching. This simply means that the first pulse edge actually gets detected. The published length limits of 6, 3, and 1.5 meters for slow, fast 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 single ended fast 20 segments may reach well beyond the 1.5 meter limit toward the 25+ meter controlled by the bus settle delay.

When not assuming an incident wave switching mode 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. Watch out for an unfortunate 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 easily affected by loads. However, since we were assuming non incident wave switching anyway 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" generally offer somewhat higher noise margin because of their increased propagation velocity.

The factor that most likely forces one 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. Fortunately, where we need higher capacitance the most (in backplane applications) it actually may exist due to the construction of the backplane.

5.1.4. Printed circuit board parameters

Printed circuit boards (or backplanes) with the right characteristic impedance usually have higher capacitance per unit length than cables and therefore 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 PCB’s have short bus lengths.

5.2. 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.

6. Bus segment length guidelines

As discussed in 5 there are three main features that determine the maximum bus segment length: bus settle delay, electrical loading by devices, and maximum speed of operation. This relates to propagation delay, needing reflections and a.c. attenuation respectively. In addition, there a number of other requirements that apply independent of these features.

In this section 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 class system 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.

6.1. 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 8.

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 is a normally very electrically friendly case 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.

3) Devices spaced at least 8” apart (cables)

This case is found within enclosures such as PC’s, 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 must be reduced below that used for the more lightly loaded cases.

4) Devices spaced at least 4” 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 must be modified.

Very significant benefit is expected by using expander circuits directly off the enclosures that have backplane interconnect.

5) Devices spaced at least 4” apart with 8” 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 8): All SCSI bus expanders are treated as a device when counting electrical loads. Even though expanders do not occupy SCSI ID’s they still produce electrical loading. Expander loads can be important if the segment length depends on the number of devices.

6.2. Maximum speed of operation

There are five bus transfer rates presently identified:

Asynchronous, slow, fast (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 be the most friendly. For configurations that will not operate under one speed mode the speed may be changed.

Operation in a slower speed mode will frequently 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.

6.3. Other segment guidelines

All single ended 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 document only addresses the referenced kind of terminator.

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

Single ended 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 single ended above.

The maximum stub length is assumed to be 4” for single ended and LVD and 8” 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 pin capacitance to ground for single ended devices is 25 pF measured at 0.5V d. c.

Differential capacitance is measured as C1/C2/C3 following the LVD spec 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 SCSI the maximum capacitance is 30/30/15 pF and for LVD SCSI the maximum capacitance is 20/20/10 pF.

For devices located very near (within 4 inches) one of the SCSI bus terminators 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 single ended or 40/40/20 for differential. Note that this MUST be at a position where the terminator is actually 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 the end of the bus segment providing one of the two bus segment terminations. Therefore at most 2 higher capacitance devices per segment are allowed.

Cable media complies with the appropriate SCSI standard.

6.4. Comments on the segment length rules

There is presently little data available to determine for sure exactly what the effects of using single ended to single ended expanders will be.

The experience with the present single ended to HVD expanders provides significant confidence that the extrapolations in this rev of the document are likely to be accurate.

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

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

For LVD SCSI 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 will be required for configuration flexibility. Data from multimode backplanes indicates that expanders will be needed between the backplane and external cable for cables longer than approximately 3 meters. Further, most of the presently available LVD data is class 2 based on signal quality and timing analyses only. Only the point to point data has presently been tested with full protocol devices.

6.5. Segment length tables

Table 1 - Length limits for single ended SCSI bus segments

TRANSFER RATE	RULE CLASS	POINT TO POINT WITH UNIFORM BUS MEDIA	LOADS SPACED AT LEAST 1 METER APART WITH UNIFORM BUS MEDIA	LOADS SPACED AT LEAST 8" APART (CABLES)	LOADS SPACED AT LEAST 4" APART (BACKPLANES)	LOADS SPACED AT LEAST 4" APART WITH 8" STUBS (BACKPLANES)
ASYNC	1	6	6	6	6	
	2	20***	20	20	20	6 ??
	3	35	25	25	25	20
SLOW	1	6	6	6	6	1; 5 LOADS*
	2	20***	6			
	3	35	15			
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			
	3	35	15			
FAST 20	1	3	3	1.5; 8 LOADS 3; 4 LOADS	1; 8 LOADS*	1; 5 LOADS*
	2	20***	4			
	3	35				
FAST 40**						

* REQUIRES EXPANDER WITHIN 8" OF BACKPLANE
** FAST 40 SINGLE ENDED IS NOT PRESENTLY DEFINED
*** TWO LOADS WITHIN 0.5 METER OF THE TERMINATOR ARE ALLOWED ON EACH END

Rule 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)

All length data in meters

Table 2 - Length limits for high voltage differential SCSI bus segments

TRANSFER RATE	RULE CLASS	POINT TO POINT	LOADS SPACED AT LEAST 1 METER APART	LOADS SPACED AT LEAST 8” APART (CABLES)	LOADS SPACED AT LEAST 4” APART (BACKPLANES)	LOADS SPACED AT LEAST 4” APART WITH 8” STUBS (BACKPLANES)
ASYNC	1	25	25	25	?	?
	2	35	35	35	?	?
	3				25	25
SLOW	1	25	25	25	?	?
	2	35	35	35	?	?
	3				25	25
FAST 10	1	25	25	25	?	?
	2	35	35	35	?	?
	3				25	25
FAST 20	1	25	25	25	?	?
	2	35	35	35	?	?
	3				25	25
FAST 40	1	?	?	?	?	?
	2	25	12	12	?	?
	3	35	25	20	20	?

Rule 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) (25/25/12.5 pF / 0.2 meter)

All length data in meters.

Table 3 - Length limits for low voltage differential SCSI bus segments

TRANSFER RATE	RULE CLASS	POINT TO POINT	LOADS SPACED AT LEAST 1 METER APART	LOADS SPACED AT LEAST 8” APART (CABLES)	LOADS SPACED AT LEAST 4” APART (BACKPLANES)	LOADS SPACED AT LEAST 4” APART WITH 8” STUBS
ASYNC	1					****
	2	25	25	12		
	3	35	35	20	15	
SLOW	1					****
	2	25	20	15	12	
	3	35	35	20	15	
FAST 10	1					****
	2	25	20	15	12	
	3	35	35	20	15	
FAST 20	1					****
	2	25	15	15		
	3	35	35		15	
FAST 40						****
		25	12	12		
		35	35		12	
**** NOT PRESENTLY KNOWN -- THIS CONDITION IS MORE AFFECTED BY CAPACITIVE LOADING THAN BY STUB LENGTH -- THIS CONFIGURATION ONLY LIKELY TO WORK WITH BACKPLANES WITH 4 OR FEWER DEVICES PER BACKPLANE -- PROBABLE NUMBERS SAME AS FOR 4” STUBS						

Rule 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) (20/20/10 pF / 0.1 meter)

All length data in meters.

7. Mixed width operation

SCSI is specified to operate with any of three data path widths: 8 bit, 16 bit, and 32 bit. This document 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 section.

7.1. Architectural Options

This section describes four different ways to configure mixed width bus segments. Each requires separate consideration and each must adhere to the wiring tables shown in 13.1.1.

7.1.1. 16 bit main path

7.1.1.1. Async, slow, 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.

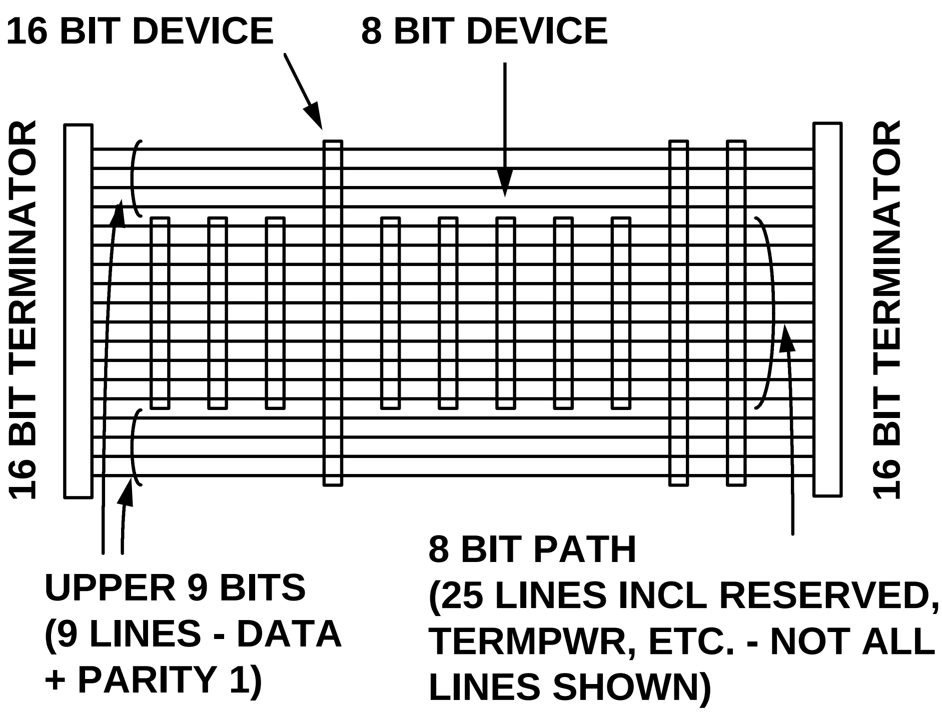

Figure 2 - Mixed width connections using 16 bit main path

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 8 8-bit devices in between. One could have 14 8 bit devices in between but this case could not work since there are only 8 address bits available on 8 bit devices and only 8 devices can be addressed. In this case there is 8 times the individual device loading skew on the data lines. Measurements have shown that a typical delay induced by a single device is 0.5 ns. The one way timing skew in this worst case situation is therefore approximately 4 ns. This is larger than the timing skew produced by the cable media itself and could be responsible for data errors in the upper 9 bits if not treated.

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 pin connector while the 8 bit device will require a 50 pin 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 pin capacitance of the 8 bit device. Of course not all 8 bit devices have the same pin capacitance but a reasonable approximation is from 10 to 20 pF.

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

If one is using round cable (either shielded or unshielded) for the 16 bit path it is possible to use the 50 pin 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 readily 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 pin high density connectors for the round cable and use the scheme described above within the connector converter device.

One also needs to consider the TERMPOWER distribution for this case. The 16 bit path has 4 conductors available for the TERMPOWER. These 4 lines should be connected together by the 8/16 bit connector converter and passed to the TERMPOWER lines on the 8 bit side. There is an issue however on the 8 bit side because the single ended and differential TERMPOWER requirements are different. The single ended uses only one TERMPOWER line while the differential uses two lines.

The risk is that some older single ended devices may ground one of the pins used for differential TERMPOWER. If one of these devices is attached it will connect the TERMPOWER line to ground and disable the entire bus. The simple solution is to connect only the single ended TERMPOWER line from the 8 bit side to the 4 lines on the 16 bit side. This connector converter will therefore work for both single ended and differential applications.

For the differential case any TERMPOWER sources on the 8 bit devices will only use one TERMPOWER 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.

7.1.1.2. Fast-40 case

When using fast-40 LVD or HVD the structure described in 7.1.1.1 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 fairly 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 specifically 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.

7.1.2. 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 7.1.1. The risks in this configuration are mainly that the upper data and parity bits in the 16 bit devices will not be pulled to the negation state at all times.

If the upper bits are not set to a negated state the 16 bit devices may think that other 16 bit devices are arbitrating for the bus (since the upper data bits are asserted) and will fail. One must provide some electrical means for setting these bits. One simple way for single ended devices is to add a high value resistor (say 100K) to the 5V or 3V supply. This will keep the signals negated and will not significantly increase the device loading if the device is used in a wide application. For differential devices one 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.

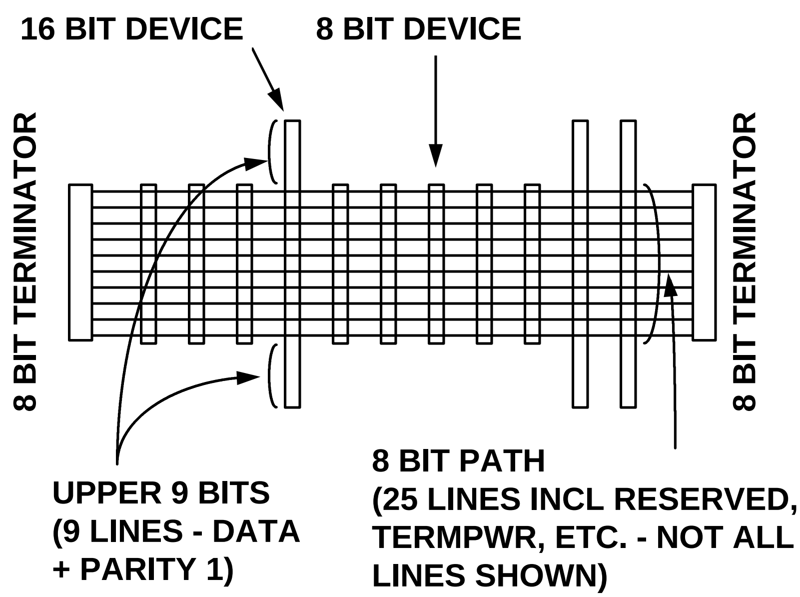

Figure 3 - Mixed width connections using 8 bit main path

7.1.3. Single 16 bit path and single 8 bit path

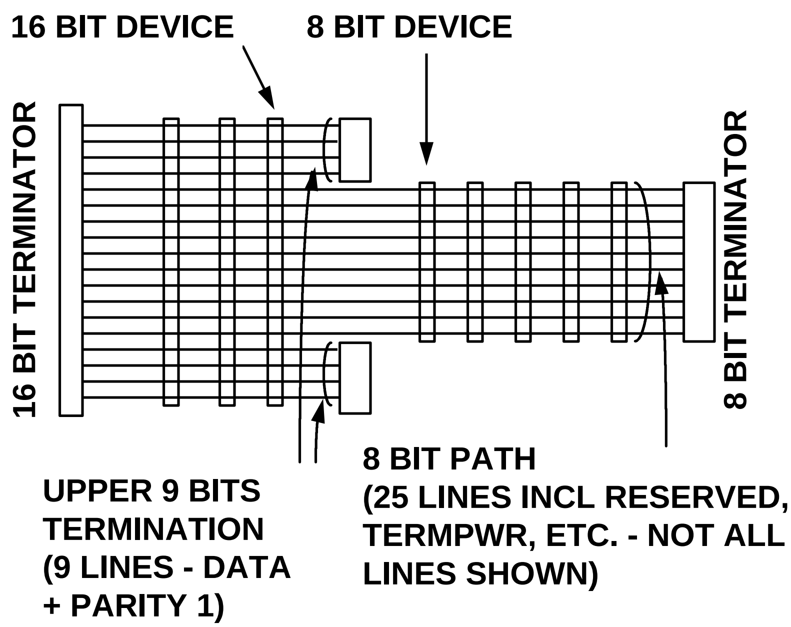

Figure 4 - Mixed width using a single 8bit and a single 16 bit path

7.1.4. Multiple 8 or 16 bit paths

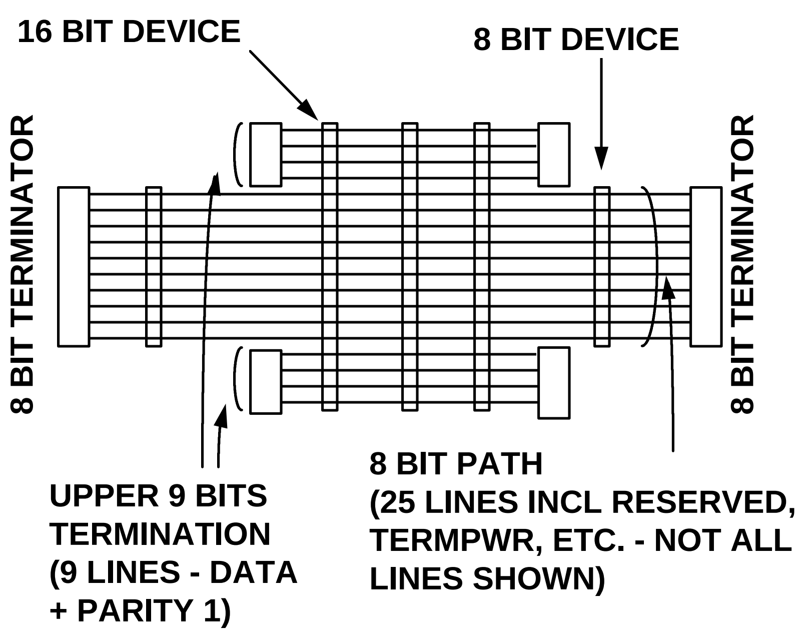

Figure 5 - Mixed width configuration with two 8 bit paths and one 16 bit path

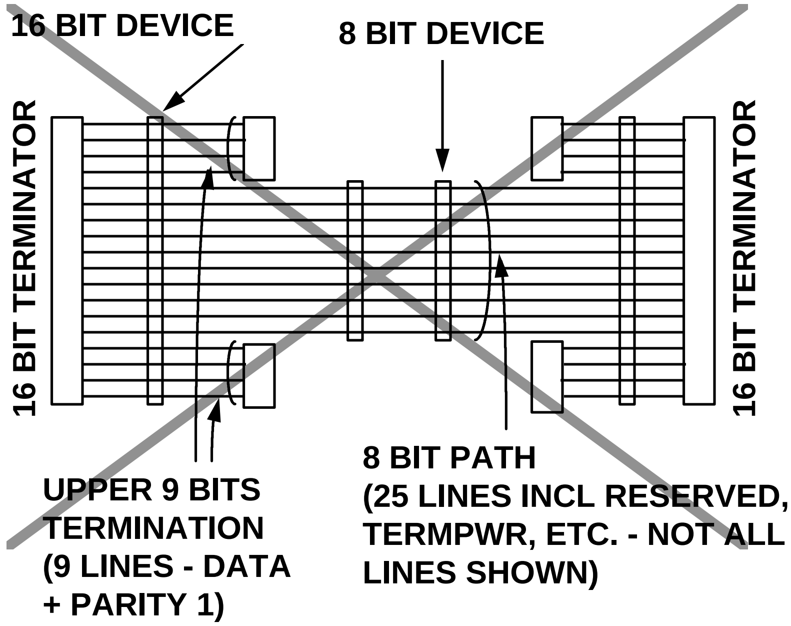

Figure 6 - Illegal mixed width configuration with two 16 bit paths

8. 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 ID’s on all ports, fully participate in SCSI arbitration and messaging, and are “devices” in the SCSI sense. The following sections describe both types of expander.

8.1. Simple expanders

The following features are desirable properties of simple bus expanders:

- Minimal propagation delay budget is consumed during arbitration
- No SCSI ID's, no arbitrations can be initiated, no messages originating with the expander can be sent (messages sent from initiators and targets could be read if desired)
- Retransmitted signal timing skew (both delay and hi/lo) are no worse than from a valid SCSI device
- Does not interfere with the REQ/ACK offset count
- Min/Max pulse widths are maintained
- A reset filter is required
- Powered expanders shall retransmit reset assertions from one segment to the other regardless of the state of any other SCSI signals on either side
- Placement of the initiator and targets with respect to the simple expander is arbitrary
- TERMPOWER is 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)
- DIFSENS line is not electrically or logically connected between segments being coupled
- Transmission mode (SE/LVD, etc.) changes on one segment causes the expander to issue a SCSI bus RESET on the other side

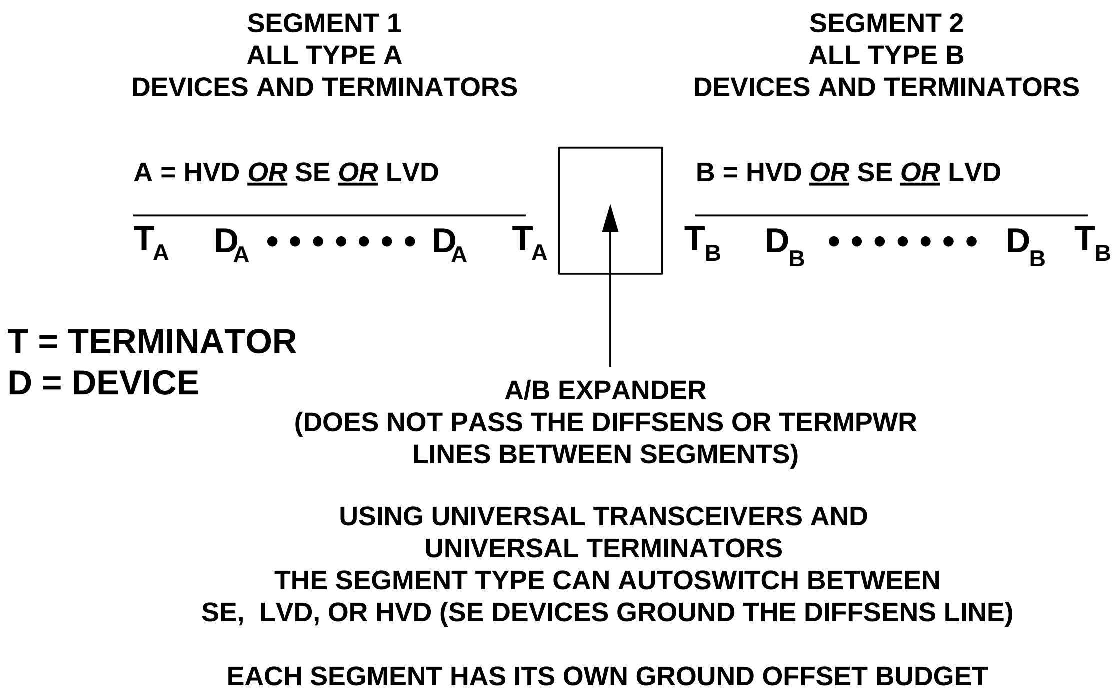

Figure 7 - A two segment domain using a single expander circuit

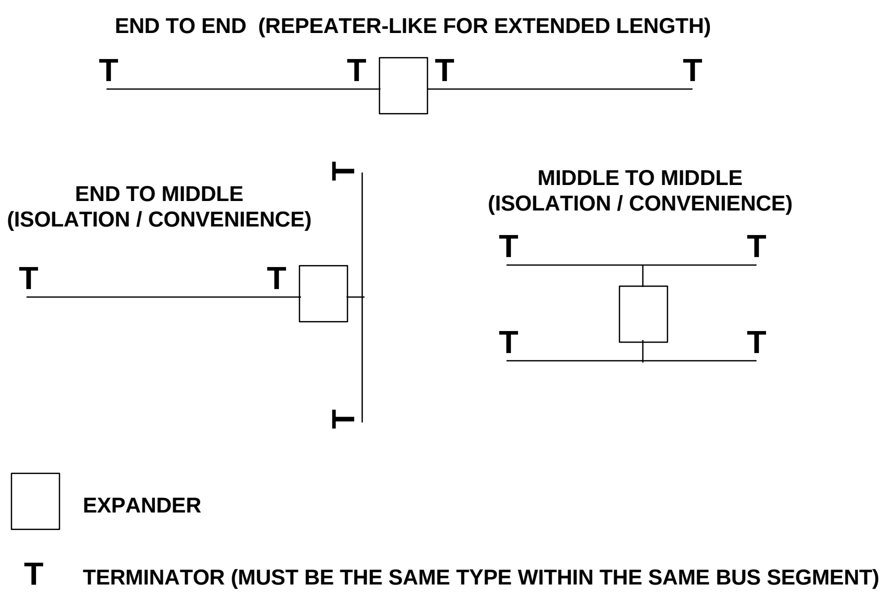

Figure 8 - Three ways to couple bus segments together with expanders

8.1.1. 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. single ended to HVD).

This kind of expander may be very useful in existing systems where dramatic domain length increases may be achieved simply by inserting a single homogeneous expander in the right place. Such a condition exists, for example in a domain where several single ended 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 single ended 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 a lot 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.

8.1.2. 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 universal 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.

8.1.3. Domain parameters using simple expanders only

Figure 9 shows some examples of domains that may be built using only simple expanders. The parameters of the domain that must be maintained are discussed in this section. [Ed note: need to consider the domain parameters when using bridging expanders.]]

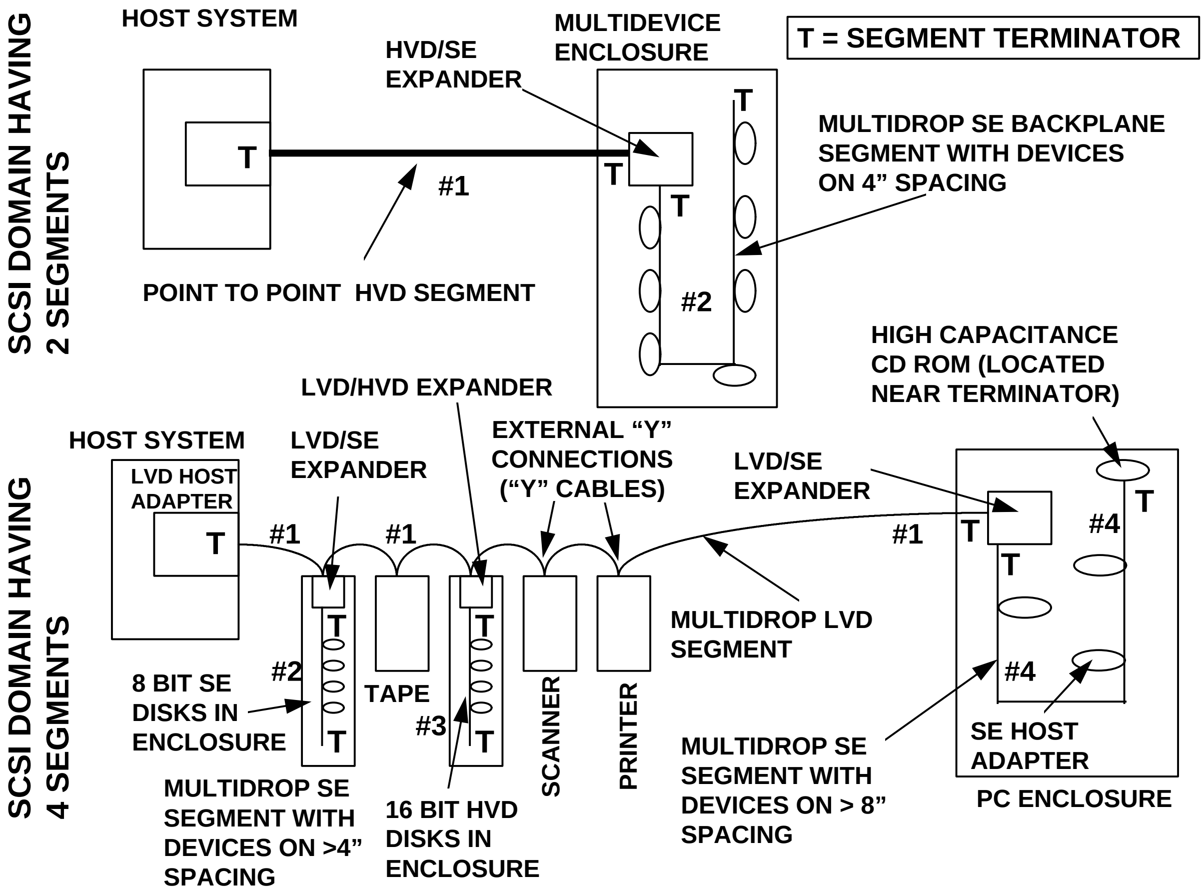

Figure 9 - Examples of domains using simple expanders

8.1.4. General rules for SCSI domains using only simple expanders

The rules are summarized in section 8.1.4.1 followed by detailed discussion for each in the subsequent sections.

8.1.4.1. Rule summary

Valid SCSI domains must 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.

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 must 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 ID’s if they wish to participate in arbitration. It is suspected that this condition may exist in old “fishfinder” applications.

4. The number of addressable devices shall not exceed 16 unless the domain contains LUN bridges (not considered in this document).

5. Acyclic tree architecture must be observed: this is the leaf/branch structure where 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 Ultra Fast-20 rates with a maximum domain propagation time this is a minimum offset of 18. See Table 6.

8.1.4.2. Rule 1

Rule 1 is explored in detail in section 6.

8.1.4.3. Rule 2

Rule 2 relates to intermediate segments which can 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
16 bit	slow (“fast” 5) sync
	fast (fast-10) sync
	fast-20 sync
	fast-40 sync
	fast-100 sync

Configurations may exist where it may appear that Rule 2 is satisfied but that actually violates Rule 1. An example of such a configuration is shown in Figure 10.

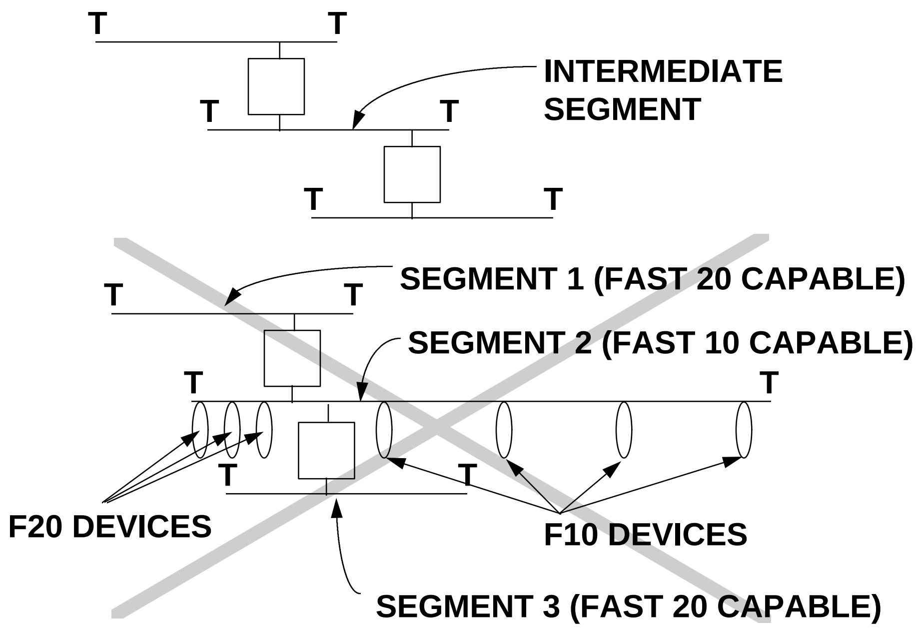

Figure 10 - Intermediate segments and performance ranking

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 therefore 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 sitting like good SCSI citizens 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 considered 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 DIFSENS 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 devices are intended to simplify the inventory and part number proliferation issues and are not intended to support dynamic transmission mode changes.)

8.1.4.4. Rule 3

8.1.4.4.1.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 of driver population 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.

Conditions exist where one may avoid waiting the entire domain round trip time by not having a detectable glitch pass through the expander. This document will not describe how these expanders are implemented but expanders do exist that have this “glitch eating” feature. If glitches are not propagated through the expanders and the conditions described in 8.1.4.4.2 do not apply, the round trip domain signal propagation time is 800 ns. The one way domain propagation time is 400 ns.

8.1.4.4.2.Effects of slow response to BUS FREE

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. 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 Fast20. The new number in SPI-2 is 1600 ns. Therefore domains that contain only SPI-2 compliant devices are not affected by this section.

For almost all other domains It is also generally recommended to ignore this 300 ns limit (since it usually does not apply to real devices) and use either 200 or 400 ns for developing specific implementations.

However, the conditions where it does apply are defined in Figure 11.

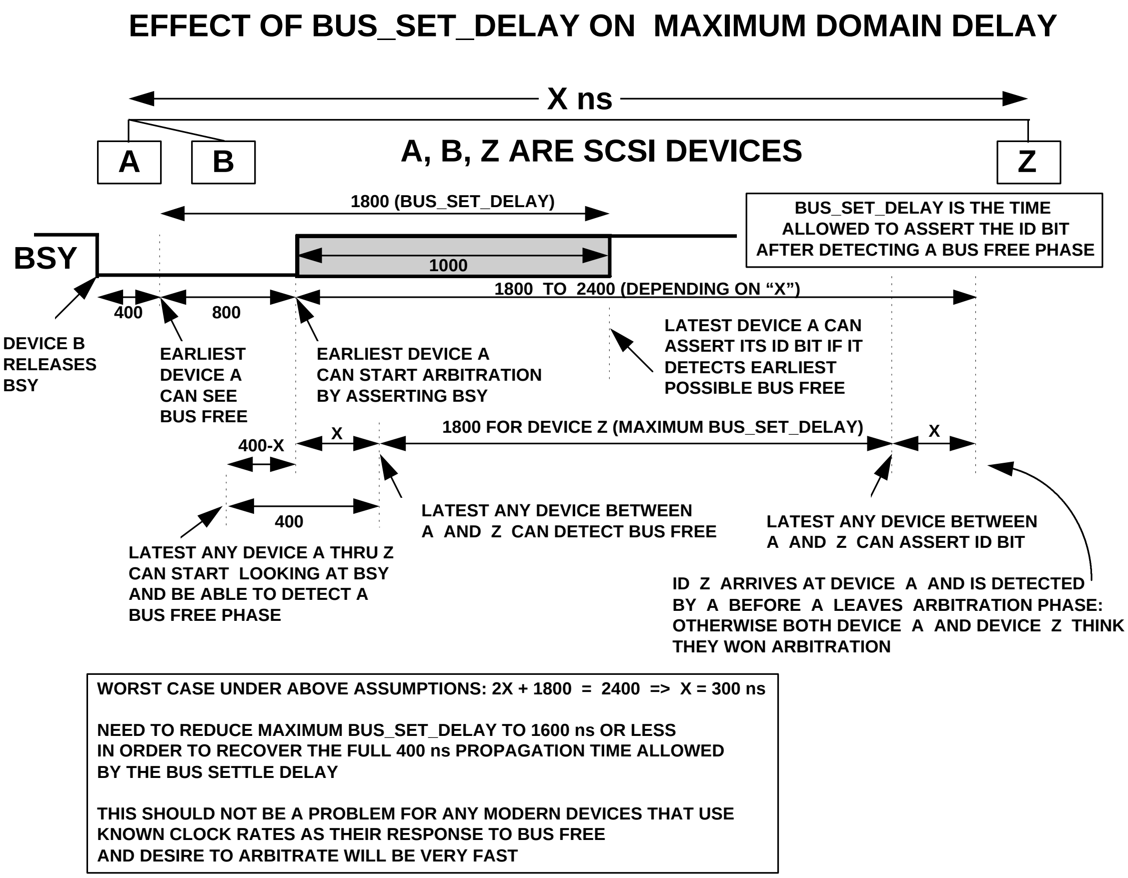

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Figure 11 - Explanation of the BUS_SET_DELAY issue

The reader is invited to study Figure 11 as a purely verbal explanation is ineffective by comparison and therefore is not provided.

8.1.4.4.3. 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 must be counted as part of the 400 ns budget between those devices.

The delay varies widely depending on the implementations. Care must be exercised when considering expanders to understand exactly 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 generally only apply to one of the expanders at time. There is therefore, a need to specify the single expander delay, Tds and the expander series pair delay, Tdp.

Delays for SE/DF expanders are generally much longer than the delays through SE/SE versions. This is caused by the additional propagation time through the differential 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 and therefore the effects are confined to single segments. Using “glitch eating” expanders does not allow one segment’s delays to be passed on to the next. This is indeed fortunate since the propagation time through differential transceivers can be significant and would directly 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 single ended or differential interface. On the other hand, since many protocol chips offer both single direct single ended and differential transceiver options it is very likely that the propagation delay through the differential 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 a lot of margin built into 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.

8.1.4.4.4. Sample calculations

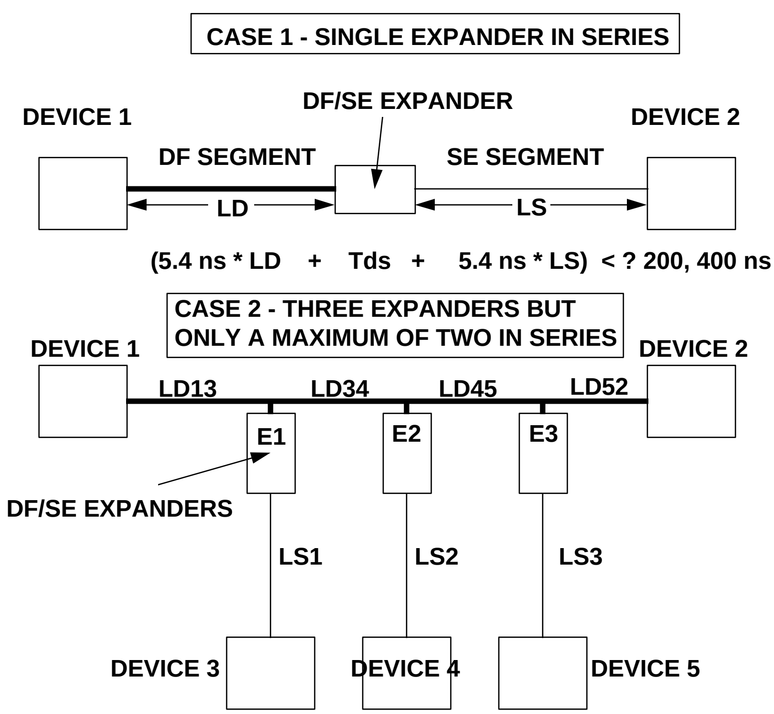

Figure 12 - Two configurations for domain delay calculations

Figure 12 shows two sample SCSI domain configurations. In case 1 the delay calculations are shown in the figure. For the more complex case 2 one must 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, one usually can easily see where the limiting case will be 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)

8.1.4.5. Rule 4

Without special expanders that remap the SCSI ID's to LUN's (LUN bridges 8.2.2) there are only a maximum of 16 data bit lines everywhere in the domain and therefore the number of initiators plus the number of targets cannot exceed 16 for the entire domain.

8.1.4.6. Rule 5

Since each line must 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 is asserting the 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 therefore 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 lock up 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 lock up risk.

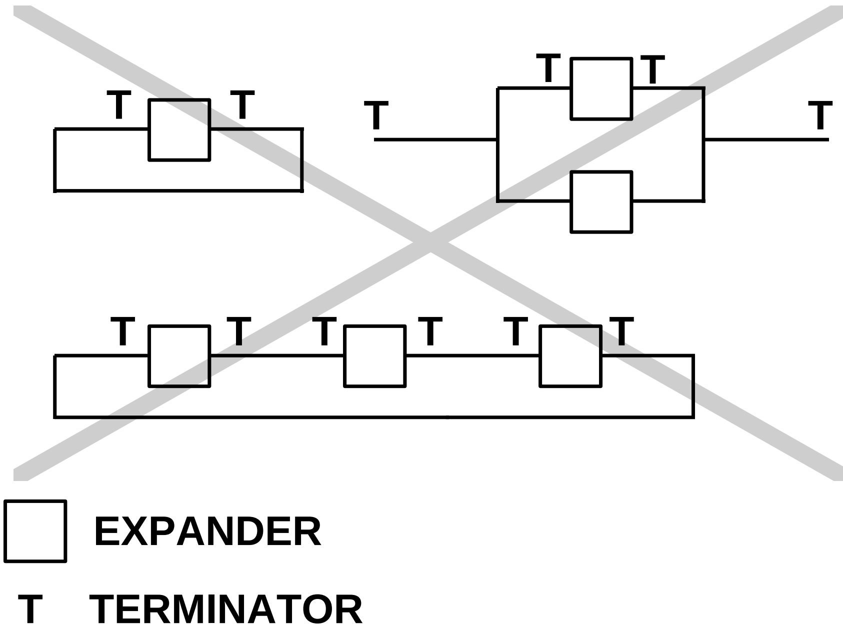

Figure 13 - Examples of illegal loops

8.1.4.7. Rule 6 (REQ/ACK offset)

The REQ/ACK offset is the difference between the number of ACK's(REQ's) sent and the number of REQ's(ACK's) received 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 REQ's and ACK's should be the same. [If this return to zero is not detected it is an indication of very serious problems and should be immediately corrected before using the domain for any critical work.]

When the first ACK(REQ) is sent one must wait a minimum of one round trip time before the first REQ(ACK) can be received from the remote device. This round trip time includes the data processing time at the remote device. ACK's(REQ's) will continue to be issued until the offset counter reaches the maximum REQ/ACK offset level that was negotiated.

If the maximum offset level is reached, the sending device must wait until it sends or receives a decrementing ACK before issuing another REQ. To keep the sending device operating with maximum performance one should never reach the maximum value in the offset counter.

The receiving device should be able 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 expanders.

The minimum desirable offset value is given by:

$$OF_{min} = [\{2x \text{ one way domain delay}\} / \{ACK (REQ) \text{ period}\}] + \text{ processing overhead}$$

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

Table 6 - Minimum REQ/ACK offset levels for max 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
100	Fast 100	10	12
200	Fast 100	10	22
300	Fast 100	10	32
400	Fast 100	10	42
500	Fast 100	10	52
600	Fast 100	10	62
700	Fast 100	10	72
800	Fast 100	10	82

8.2. 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 **Error! Reference source not found.**.

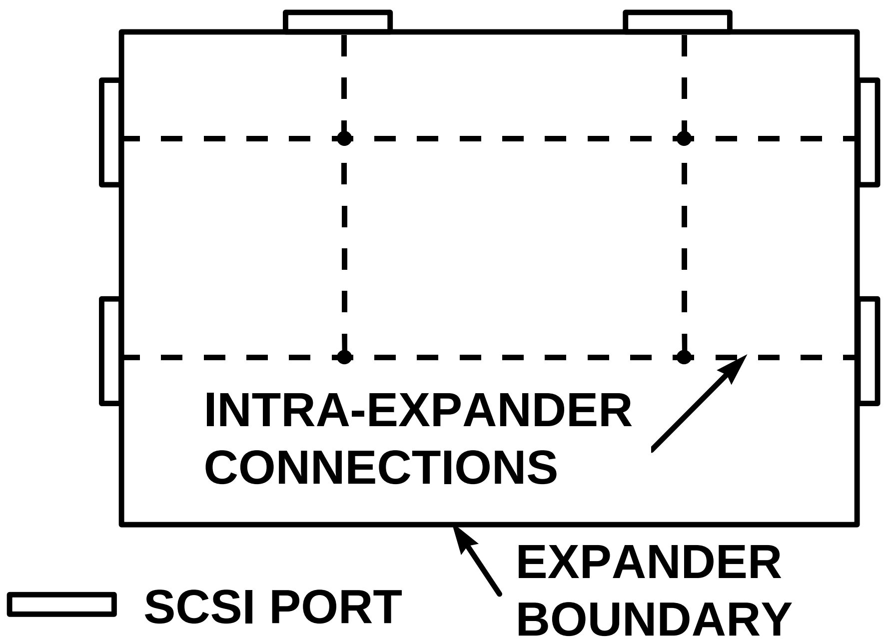

Figure 14 - General bridging expander

It is not the intent of this document to describe general bridging expanders since the number of possibilities are quite diverse. For example, the boundary in **Error! Reference source not found.** 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.

8.2.1. 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. Therefore, we will not consider two port caching expanders further in this document. 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 8.2.4 (Switching expanders).

8.2.2. Logical unit bridges

The bridging expander of primary focus in this document is the address enhancing expander or the "LUN Bridge". The requirements for LUN bridges form the balance of this section.

Logical unit bridges (LUN bridges) described in this document 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 document.

Up to 900 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.

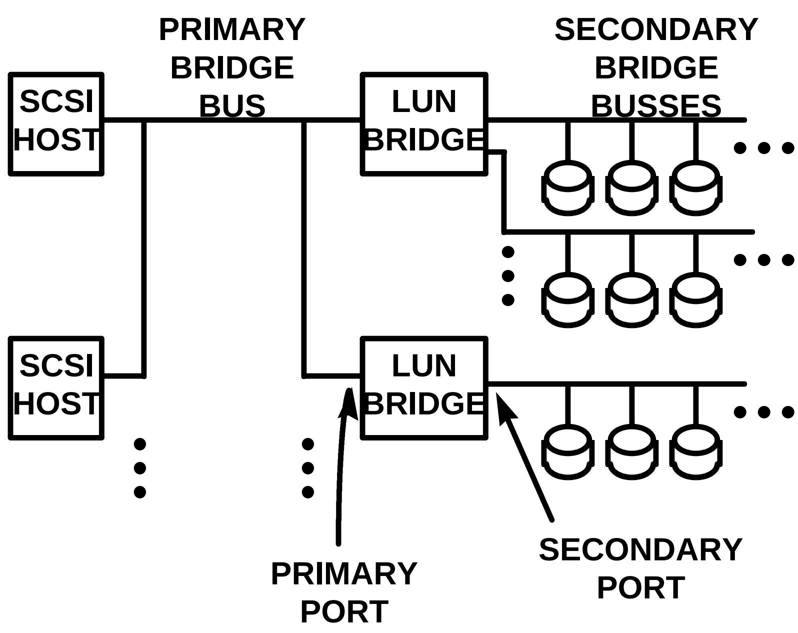

Figure 15 - Case 1 LUN bridge architecture

SCSI devices on a primary bridge bus (which may contain simple expanders) each has a unique SCSI ID (0 to 15). SCSI devices on a secondary bridge bus each has a unique ID (0 to 15). The ID's on a secondary bridge busses 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 LUN's 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 ID5 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.

The arbitration process used in the simple expanders described in section 8.1 may be used with Case 1 LUN bridges. This solves the RESELECTION timing issue.

Primary and secondary busses may contain simple expanders with multiple segments. The overall domain configuration rules are the same as for simple expanders (section 8.1.4) except that the device count limit is changed to that specified in this section.

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

- A Case 1 LUN bridge is a special case of a bridging expander (**Error! Reference source not found.**) that has one primary port and one or more secondary ports
- Only one LUN bridge port on each secondary bridge bus
- Primary bridge busses have one or more initiators
- Secondary bridge busses have no initiators on the secondary bus other than the LUN bridge. This includes devices that use the AEN or COPY commands.
- The LUN bridge shall be assigned LUN (0) under its primary bridge bus ID to enable direct communication to the LUN bridge. (This will require a new device type code.) The LUN bridge shall support 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)
- The speed negotiations shall be done 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 appropriately. between the host and the target devices.
- A REPORT LUN's 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 shall be available to the host through the REPORT LUN's 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 ASC______ [TBD]

- Minimal propagation delay budget is consumed during arbitration by the LUN bridge

- Retransmitted signals shall comply with the requirements for a valid SCSI device

- Does not interfere with the REQ/ACK offset count

- A SPI reset filter (low pass) is required

- TERMPOWER is not directly connected between the segments being coupled

- DIFFSENS line is not electrically or logically connected between segments being coupled

- Transmission mode (SE/LVD, etc.) changes on a primary bridge bus causes the LUN bridge to issue a SCSI bus RESET on all secondary busses. A transmission mode change on a secondary bridge bus causes the LUN bridge to issue a reset only for the secondary bridge bus that caused the transmission mode change

8.2.3. Unsupported configurations

8.2.3.1. 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.

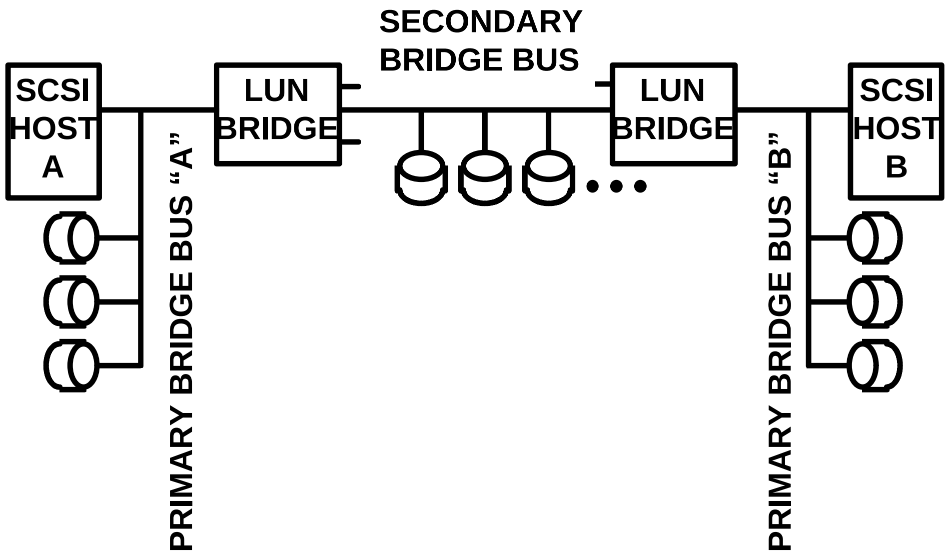

Figure 16 - Unsupported Case 2 configuration

8.2.3.2. 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)

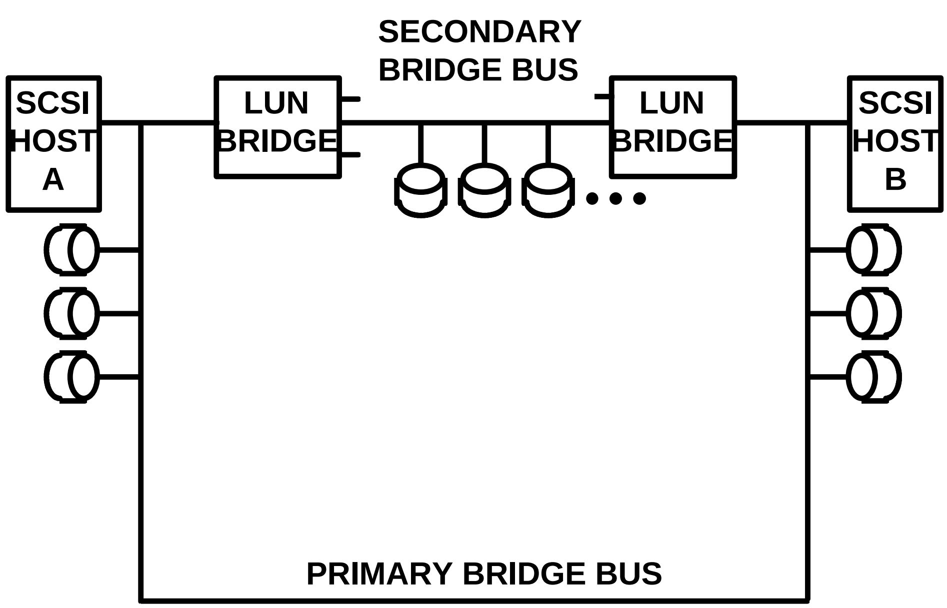

Figure 17 - Unsupported Case 3 configuration

8.2.4. 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 section. 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/LUN's 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 the concept of a SCSI domain to include switch ports in addition to the ID/LUN's on the switch ports. [SCSI domains are defined as the set of SCSI devices that are addressable from an initiator or target.]

SCSI switches constitute a separate SCSI device type.

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.

Error! Reference source not found. shows one set of data paths established by the switch for specific tasks. **Error! Reference source not found.** shows the same switch servicing a different set of tasks that need a different set of data paths.

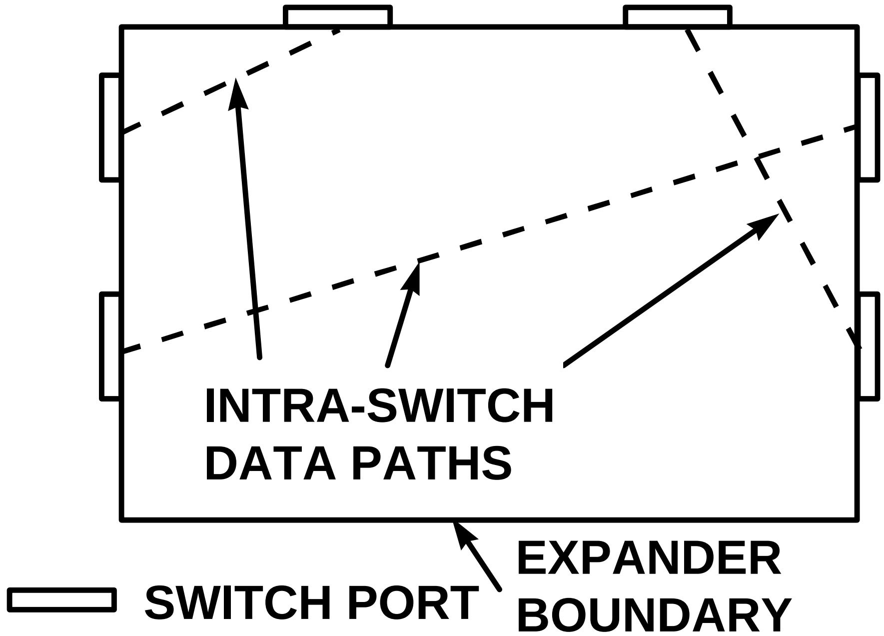

Figure 18 - One set of data paths in a SCSI switch

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

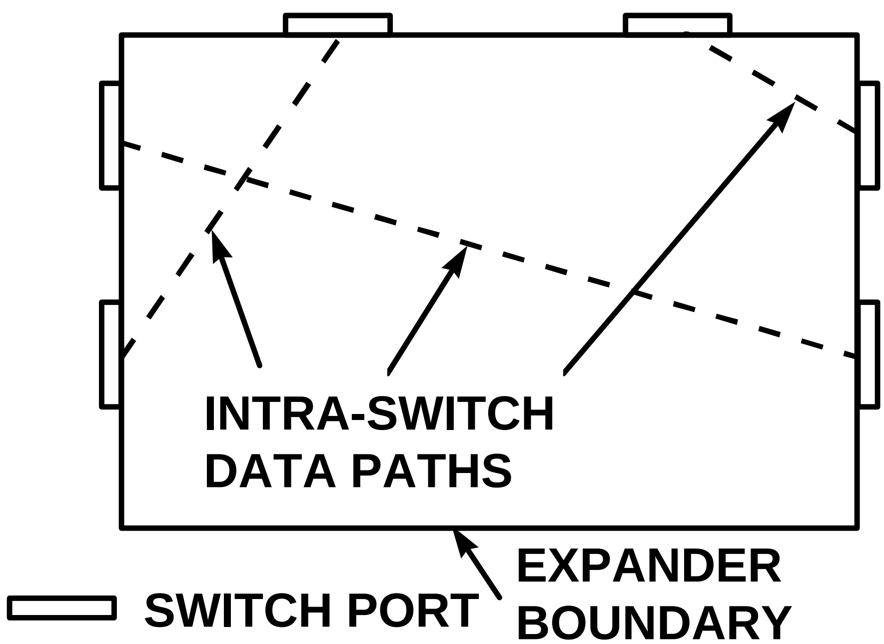

Figure 19 - Another set of data paths in the same SCSI switch

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 document.

Requirements on switches include:

- TERMPWR shall not be directly connected between switch ports
- DIFFSENS shall not be connected electrically or logically between switch ports
- RESETS shall not be 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)
- Switches may supply TERMPWR to attached busses
- The REPORT LUN's command shall be supported by every switch port under LUN(0) for reporting the configuration and status of attached devices, switch status, and port status.
- Switches are responsible for avoiding deadlock between ports.

9. Dynamic reconfigurations of domains

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

9.1. Addition and removal of devices

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

9.1.1. Framework of device addition and removal process

This section describes the stages that must be considered during the addition, removal or operational state change of SCSI devices.

SCSI HOT PLUGGING

- **THE FIRST SECTION OF THIS DOCUMENT DESCRIBES THE STEPS INVOLVED IN REMOVING AND INSERTING SCSI STORAGE DEVICES ON ACTIVE BUSSES**

- **A STRUCTURED APPROACH IS USED WHERE EVERY STEP IN THE PROCESS IS EXAMINED IN DETAIL**

- **BOTH THE HARDWARE AND THE SOFTWARE IMPLICATIONS ARE SPECIFIED**

SCSI DEVICE HOT PLUGGING

THERE ARE TWO END STATES INVOLVED WITH SCSI HOT PLUGGED DEVICES:

1. OPERATIONAL STATE (ES1)

FULLY SECURED IN THE ENCLOSURE, FULLY POWERED, FULLY CONNECTED TO ALL SCSI BUS AND GROUND PINS, PHYSICALLY STATIC (EXCEPT FOR HDA), ENABLED TO PARTICIPATE IN ALL ACTIVITIES ALLOWED BY THE DESIGN OF THE DEVICE AND SYSTEM

2. STORED STATE (ES2)

UNPOWERED, ELECTRICALLY DISCHARGED, PHYSICALLY STATIC, LOGICALLY UNPROGRAMMED, PHYSICALLY SEPARATED FROM THE BUS AND THE SYSTEM ENCLOSURES THAT CONTAIN THE BUS PORTS

SCSI DEVICE HOT PLUGGING

- 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 OR DAMAGING ANY DATA IN THE SYSTEM OR IN THE DEVICE BEING MOVED

- THE DEVICE BEING MOVED IS TERMED THE OBJECT DEVICE IN THIS DOCUMENT

- OBJECT DEVICES ARE OUTGOING OBJECT DEVICES IF THEY ARE GOING FROM ES1 TO ES2

- OBJECT DEVICES ARE INCOMING OBJECT DEVICES IF THEY ARE GOING FROM ES2 TO ES1

- AS SOON AS ANY PART OF AN END STATE CONDITION IS NO LONGER VALID THE OBJECT DEVICE IS SAID TO BE IN TRANSITION

SCSI DEVICE HOT PLUGGING

- THE SCSI BUS THAT DIRECTLY CONNECTS TO AN OBJECT DEVICE IS TERMED THE MAIN BUS FOR THAT DEVICE
- SOME LEVEL OF DISRUPTION TO THE ACTIVITIES ON THE MAIN BUS MUST OCCUR REGARDLESS OF THE HOT PLUGGING PROCESS USED
- IN ONE EXTREME HOT PLUGGING PROCESS, THE MAIN BUS MUST BE SHUT DOWN COMPLETELY FOR PARTS OF THE OBJECT DEVICE TRANSITION
- IN A MINIMALLY DISRUPTIVE HOT PLUGGING PROCESS, EXTRA COMMUNICATIONS ACROSS THE MAIN BUS ARE STILL NECESSARY (TO INFORM THE OBJECT DEVICE OR OTHER DEVICES ON THE MAIN BUS OF THE IMPENDING END STATE CHANGE)

SCSI DEVICE HOT PLUGGING

- SINCE THE MOST DEMANDING APPLICATIONS REQUIRE MINIMAL DISRUPTION TO THE MAIN BUS ACTIVITIES THE SCSI DEVICE HOT PLUGGING PROCESSES DESCRIBED WILL FOCUS ON THIS CASE

- IT WILL BE POINTED OUT HOW 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 DISRUPTION IS HIGHLY APPLICATION DEPENDENT BUT IT IS VITAL TO HAVE THE DEVICE PROPERTIES, THE APPLICATION REQUIREMENTS, AND THE HOT PLUGGING PROCESS BE CONSISTENT WITH EACH OTHER

SCSI DEVICE HOT PLUGGING

FRAMEWORK FOR INCOMING OBJECT DEVICES

STORED END STATE

TRANSITION OUT OF STORAGE CONTAINER

TRANSITION BETWEEN STORAGE CONTAINER AND SERVICE ENCLOSURE

INITIAL TRANSITION INTO SERVICE ENCLOSURE PHYSICAL CONSTRAINTS

TRANSITION TO STATE IMMEDIATELY PRIOR TO MAKING ELECTRICAL CONTACT WITH ANY SERVICE ENCLOSURE ELECTRICAL PINS

TRANSITION FROM NO ELECTRICAL CONTACT TO FULL ELECTRICAL CONTACT

DEVICE INITIALIZATION AND SPIN UP

FIRST DEVICE COMMUNICATIONS

FINAL START UP COMMUNICATIONS

OPERATIONAL END STATE

SCSI DEVICE HOT PLUGGING

FRAMEWORK FOR OUTGOING OBJECT DEVICES

OPERATIONAL END STATE

COMMUNICATIONS TO BEGIN REMOVAL FROM THE ACTIVE BUS

ALL BUS TRAFFIC TO OUTGOING OBJECT DEVICE CEASED

DEVICE SPIN DOWN

TRANSITION FROM FULL ELECTRICAL CONTACT TO NO ELECTRICAL CONTACT

TRANSITION FROM STATE IMMEDIATELY AFTER MAKING ELECTRICAL DISCONNECT TO READY FOR FINAL REMOVAL FROM SERVICE ENCLOSURE

FINAL REMOVAL FROM SERVICE ENCLOSURE PHYSICAL CONSTRAINTS

TRANSITION BETWEEN SERVICE ENCLOSURE AND STORAGE CONTAINER

TRANSITION INTO STORAGE CONTAINER

STORED END STATE

9.1.2. Electrical considerations for device insertion and removal

Hot plugging details:

This section describes details of the mechanics and issues that operate during the insertion and removal of devices when using the SCA-2 connector system

9.1.2.1. 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.

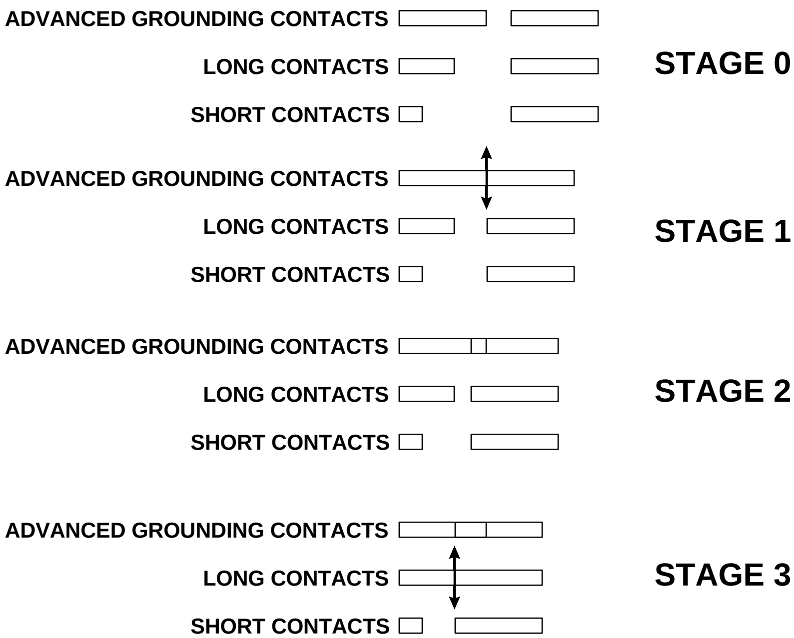

Figure 20 - Stages 0 thru 3 for the insertion process

<u>Stage 0 - No contacts mated (Figure 20)</u>

Issues, effects, comments

Mechanical stresses, vibration, electrical activity limited to possible enclosure to device "skin" ESD for devices with electrically exposed "skins".

<u>Stage 1 - First advanced grounding contact electrical activity (Figure 20)</u>

Issues, effects, comments

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

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

Issues, effects, comments

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

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

Issues, effects, comments

Stage 2 issues still in effect for all cases

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

No effect, no arcing, least disruptive case

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

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 contact ground pin mates after which the return current is shared between the AGC and the long contact ground pin.

Note that 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 pin 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)

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 contact ground pin mates

Note that 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 pin that mates.

If the next pin 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.

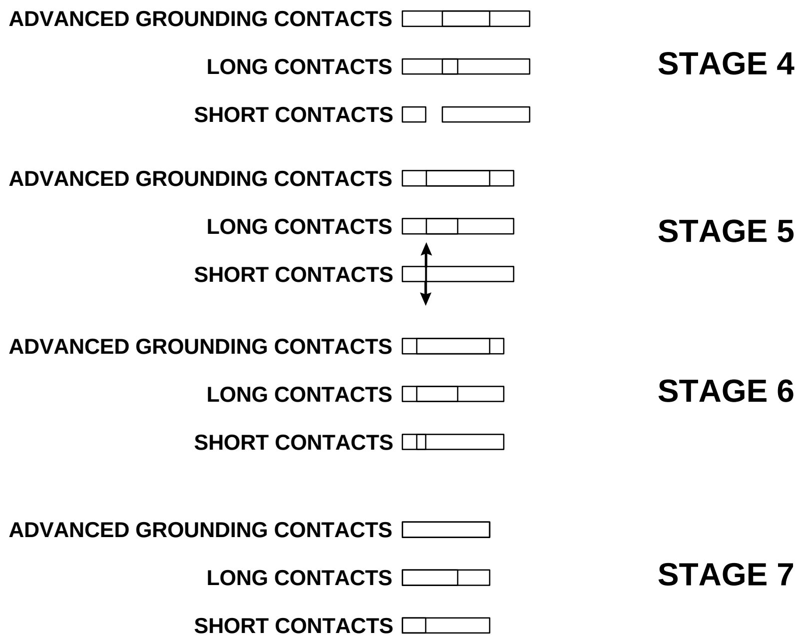

Figure 21 - Stages 4 thru 7 for the insertion process

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

Issues, effects, comments

Stage 2 issues still in effect

Possible power loading transients due to wiping action

Power decoupling capacitors charging

Logic becoming powered (non necessarily reliable in this stage)

All SCSI pins set to high impedance state (should always be in this state during all parts of stage 4)

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

Issues, effects, comments

Stages 2 and 4 issues still in effect

Low power transients seen on active SCSI lines of operating bus segment due to charging of device pins - very little radiation due to low power - no detectable glitches expected if the ACG contacts operate properly and the SCSI pins 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 must 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 pins

No reliable sequencing between SCSI signals and power

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

Issues, effects, comments

Stages 2 and 4 issues still in effect

Logic inputs stabilize

Power stabilizes

No reliable detection that all pins are in Stage 6 from connector behavior alone

No device operation should be attempted in this stage

Stage 7 - All contacts fully seated (Figure 21)

Issues, effects, comments

Stages 2, 4, and 6 issues cease

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

9.1.2.2. Removal

This section will show the removal procedure at the same level of detail as section 9.1.2.1.

9.1.3. Logic input states during transitions

In sections 9.1.2.1 and 9.1.2.2 it was noted that conditions exist where the input logic state is not defined and may have nearly arbitrary values. This sections provides more detail on the required actions of receivers in this state. [details to be added].

9.1.4. Operational state changes for devices

This section describes the process and procedures for changing the operational state of a SCSI device that does not directly result from a physical disconnection. Examples of operational state changes are stopping 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. [need more detail here]

9.2. Reconfiguration of bus segments

9.2.1. Addition and removal of bus segments

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

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

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

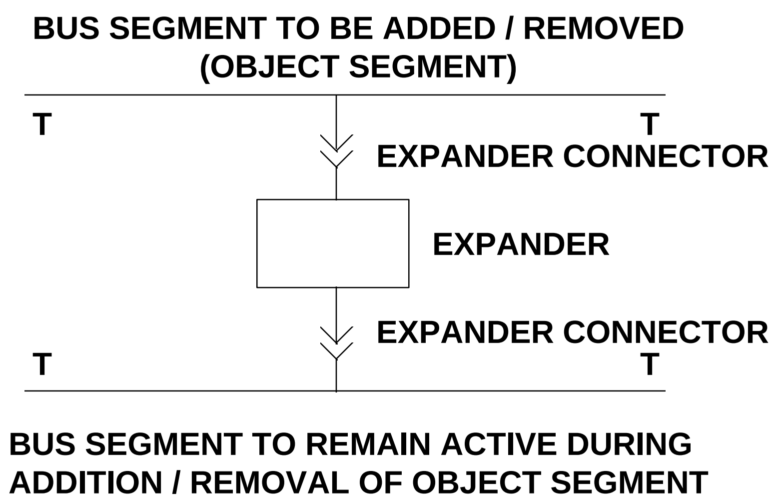

Figure 22 - Dynamic addition / removal of a bus segment

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. This includes any “background polling” activity. The expander may continue to drive the object segment as a result of traffic on the active segment

At this point there are four options:

1. disable the powered expander and separate the active segment connector
2. remove the power from the expander and separate the active segment connector or
3. separate the active segment connector or
4. leave the expander in place with power on and separate the object segment connector

[following needs editing]
Option 1 requires that the expander power down “gracefully” without inducing any glitches on the active segment. Option 1 should not be used if the expander supplies TERMPWR to the either segment.

Option 2 requires that any activity from the active segment side, which may include times when only some of the pins are mated, not cause any devices on the object side to leave the high impedance state.

Option 3 requires that the terminators for the object segment remain powered while the connector is being separated and provision must be made in the expander to set all input signals to the negated state on the object segment side during and after the connector separation. Option 3 requires a connector that has all signal pins and DIFFSENS break before the TERMPWR pin breaks if the object connector supplies TERMPWR to the object segment. The expander shall not assert RESET on the active segment side as a result of any changing of the DIFFSENS signal on the object side. [this point needs discussion] 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 basic requirement is that the signals at the active segment connector remain in the high impedance state until the devices on the object segment have been initialized (see section xxxx).

The segment addition process is essentially the reverse of the removal process using one of the following.

1. the object segment is assembled to the expander and the unpowered expander is then connected to the active bus segment connector.. The object segment TERMPWR is turned on, the expander is next powered on and the object segment devices are initialized.
2. the unpowered expander is connected to the active bus segment without the object segment attached. The object segment is then connected to the expander, object segment TERMPWR is applied, and the expander is powered on and the object segment devices are initialized.
3. the expander is attached to the active bus segment connector and then powered on (if not already powered on before the attachment. The TERMPWR is then applied to the object segment and the object segment connector is mated. Devices on the object segment are then initialized.

All options require the expander to power cycle without driving the active bus segment.

Option 3 requires the TERMPWR pin to mate before any signal or DIFFSENS pin if TERMPWR is supplied to the object segment by the expander.

9.2.2. Operational state changes for segments

This section describes the process and procedures for changing the operational state of a bus segment that does not directly result from a physical disconnection. 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. Changing the powering to segment termination is also an operational state change. [need more detail here]

10. Topologies and configuration rules for dynamically reconfigurable domains

10.1. Initiator and target placement and population requirements

10.2. Initialization sequences for segments

This section describes the allowed initialization and quiescing sequencing that is required to support the addition, removal, and operational state changes of bus segments within a domain.

10.3. Domain power considerations

This section deals with the power implications when system reconfigurations are done.

11. 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 section deals with the case where the TERMPWR lines are used to supply power to the terminators.

11.1. Wire effects

The options and complexity of TERMPWR distribution have grown fairly dramatically 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 must get its power only through the TERMPWR lines in the bus. Fortunately 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 section 12 for discussions of ground distribution. If there is more than a few millivolts of ground shift one will need to reduce the lengths even more (except in the extremely 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 for minimum source voltage delivered to the TERMPWR lines are 2.8, 2.94, and 4.25 volts. 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 - TERMPWR source voltages

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

11.1.1. Single ended

The SPI standard requires that single ended terminators source current to the signal line whenever the voltage on that line falls below 2.5 volts. This is a minimal condition that is used in the calculations in this section. 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 volts). On the other hand, since the negated signal is not as large, 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.

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 volt is required and the normal expectation is that single ended linear regulated terminators need 4.0 volts 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 volts 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 170 feet. The present SCSI standards are written assuming the case of 3 connectors, a 4.25V source and a 4.0 V terminator with a single 28 gauge TERMPWR line. This gives the 10.8 feet in Table 8.

The two conductor case represents using both TERMPWR lines for single ended TERMPWR distribution as specified for the narrow differential cases. This requires connecting both lines to the same pin normally used for supplying the terminator BEFORE getting to the terminator. The connection may be done in the cable assembly backshell, on the printed circuit board between the cable assembly and the terminator or at the terminator pins. Single ended 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 done. Similar comments apply at the source side.

Table 8 - TERMPWR single ended 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	5.3	3.2	2	10.6	6.4	4
4.25 V	2.7 V	68.4	41.1	25.7	136.9	82.1	51.3
4.25 V	4.0 V	5.8	3.5	2.17	11.6	7	4.4
NARROW - 3 CONNECTORS							
2.8 V	2.7 V	3.6	2.1	1.3	7.1	4.3	2.7
2.94 V	2.7 V	10.3	6.2	3.9	20.6	12.4	7.7
4.25 V	2.7 V	73.4	44.1	27.5	146.9	88.1	55.1
4.25 V	4.0 V	10.8	6.5	4.1	21.6	13	8.1
WIDE - 15 CONNECTORS							
		4-28	4-30	4-32			
2.8 V	2.7 V	5	3	1.86		f	
2.94 V	2.7 V	20.7	12.4	7.8			
4.25 V	2.7 V	167.7	100.6	62.9			
4.25 V	4.0 V	21.8	13.1	8.2			
WIDE - 3 CONNECTORS							
2.8 V	2.7 V	10	6	3.7			
2.94 V	2.7 V	25.7	15.4	9.6			
4.25 V	2.7 V	172.7	103.6	64.8			
4.25 V	4.0 V	26.8	16.1	10.1			
ALL LENGTHS IN FEET				-- = DOES NOT WORK			

Clearly there are a wide variety lengths possible and a large number of traps. For example, 3.3 volt battery powered devices simply cannot run narrow SCSI at the lower end of the battery voltage spec.

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

11.1.2. Low voltage differential (LVD)

LVD terminators require voltages no lower than 3.0 V and current of at least 0.5 A per wide terminator. This is similar to the 2.7V / wide case in Table 8 since the voltage requirement is 10% higher but the current is slightly more than 10% lower.

11.1.3. Multimode SE/LVD

For this case the terminators require voltages no lower than 3.0 V (if the SE mode uses regulators that can use 3.0V) and current of at least 0.65 A per wide terminator. If the SE mode requires 4.0 V the voltage requirement goes to 4.0V. A separate table is needed to show this case (To be done in the future)

11.1.4. High voltage differential

The HVD case requires at least 4.0 V and 1.0 A 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 separate table is needed to show this case (To be done in the future).

11.2. Mixed power configurations

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

11.2.1. High voltage / Low voltage

11.2.2. Power on / Power off segments

Expanders shall propagate reset under all powered up conditions. This allows the bus to be reset due to catastrophic events on one side that could lock up the expander. [should be added to expander requirements section]

11.3. Terminator considerations

11.4. TERMPWR source placement

12. Grounding and ground distribution

This section explores the not-so-obvious issues with achieving grounding in SCSI systems. When operating under extended configurations the effects of improper grounding are more likely to be manifested

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 section provides guidance on the proper usage of the lines presently identified as “grounds” in the SCSI standards.

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 single ended signals. Every single ended signal (except for Term Power) is paired with a ground line. The signal return is the return path for the signal circuit.

The shield ground provides the EMC integrity between external enclosures.

12.1. Single ended systems

In the single ended 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 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.

12.2. 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 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.

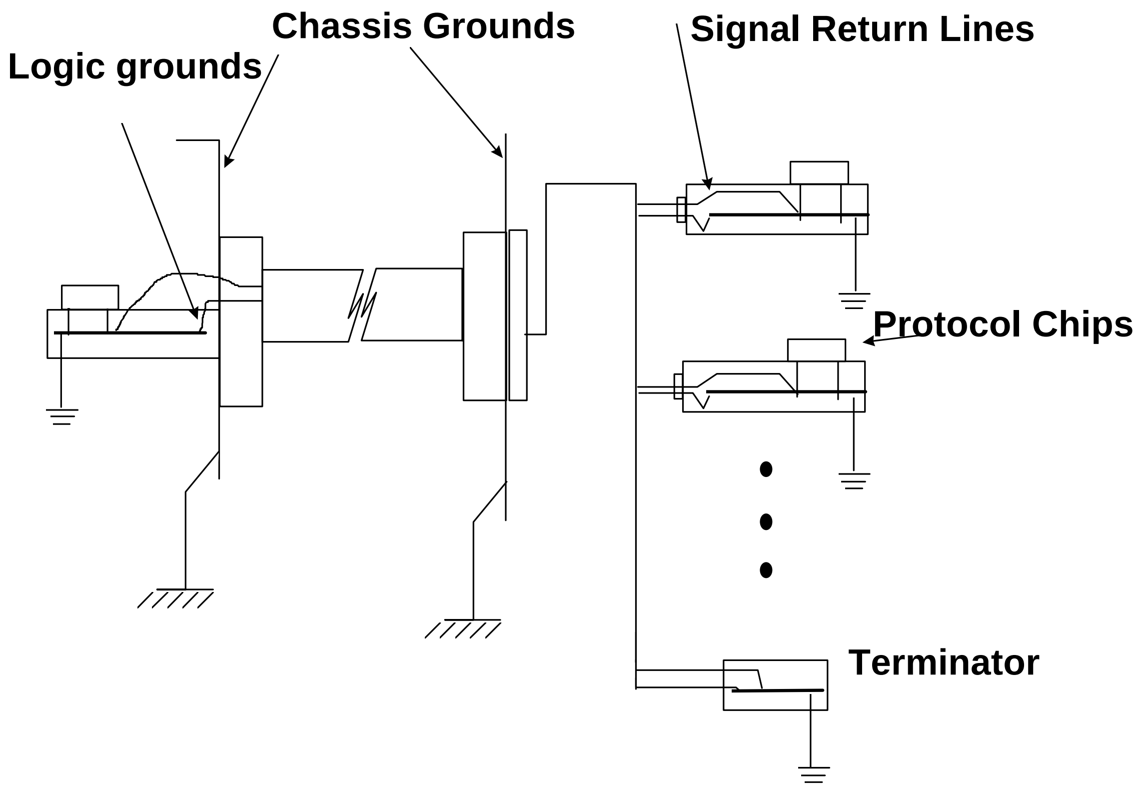

Figure 23 - Examples of various ground points

12.3. Shield connections

The shield shall have 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 termination around the connector. 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.

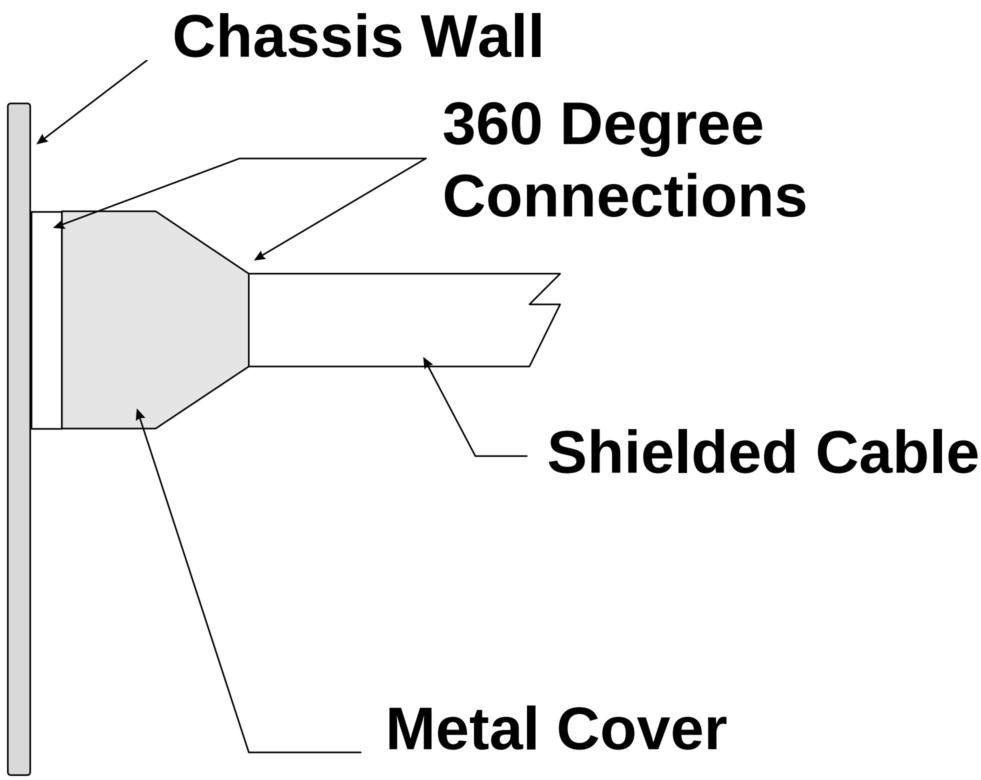

Figure 24 - Shield connection details

12.4. System considerations:

All SCSI systems are direct coupled and are therefore 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 section 12.4.2.

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. Sections 12.4.1 and 12.4.3 provides more detail

12.4.1. Ground paths in the SCSI cable

When used with single ended 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 single ended devices is 35 plus the 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).

Therefore: (1) the SCSI cable itself does a very good job of establishing a solid, shielded ground connection between devices and (2) using single ended transmissions increases the amount of copper being used for ground connection by approximately 2x compared to differential.

12.4.2. Building power distribution

SCSI grounding depends on the integrity of the power distribution system in the building. This section 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 section. The issues shown can be readily 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 volt 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).

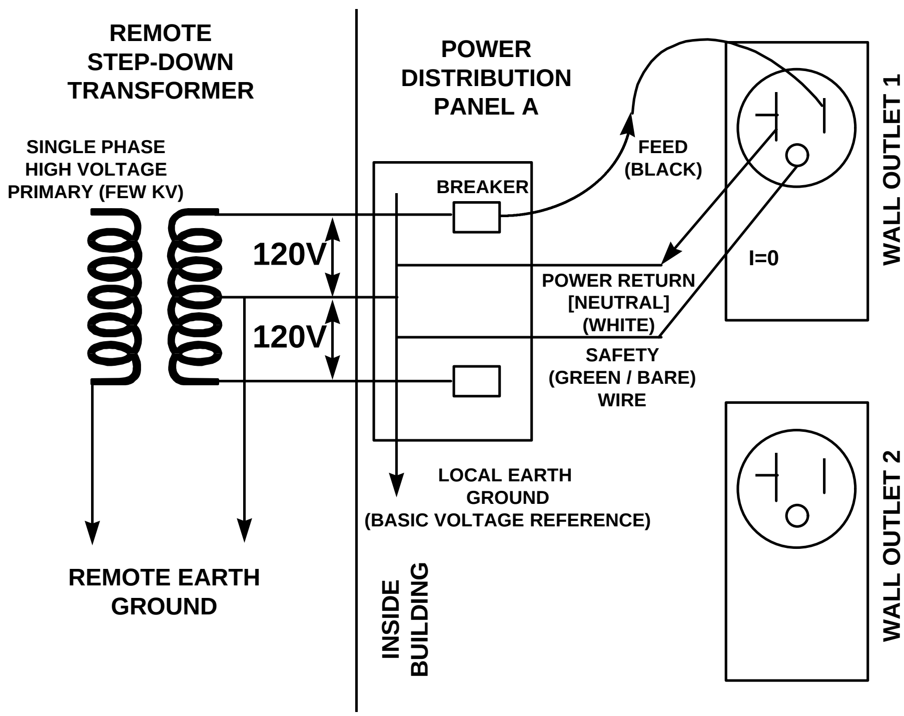

Figure 25 - Basic single phase power distribution system

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 must have gone 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 effectively 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). There will generally be different load imbalances in different distribution panels with resulting different ground current flowing and therefore different actual ground voltages at different distribution panels. Therefore, a single SCSI bus should always take power from the same power distribution panel (even in fault-free conditions).

12.4.3. Ground loops

Ground offsets can also be produced by a.c. induced noise into closed ground paths (loops). This document will not attempt to explore this mechanism except to note that generally 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. Once again, 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.

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

13. References and tables

13.1. SFF-8017 reference

13.1.1. Wiring tables

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1. Scope

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

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

3. General Description

The variety of SCSI (Small Computer System Interface) cabling alternatives means that integrators are facing the need to connect a 16-bit SCSI-3 P-cable (High Density 68-pin) device or connector and an 8-bit A-cable device or connector.

One relatively inexpensive way to make this connection is via a 50-conductor adapter cable which has a SCSI-3 68-pin high density connector on one end and a SCSI-2 50-pin connector (either high or low density) on the other end.

The SCSI-3 Physical Interface standard (X3T9.2/0855D) specifies how to connect an A-cable to a 16-bit P-cable but does not describe how to wire a 68-pin connector if it is being used only for an A-cable connection.

This document specifies the wiring of the 68-pin cable connector in this type of application. Failure to follow this specification can result in TERMPWR (Termination Power) shorts and one likely result is a device failure.

The 50-pin 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-pin connector receptacle is either wired as specified in SCSI-3 if it is a 16-bit P-cable device or as specified in this document if it is an A-cable device.

There is an issue with electrical termination of the 9 unused signal pairs if a 16-bit P-cable wiring is used on the receptacle side of the 68-pin connector. This is especially important if 16-bit devices are connected to an 8-bit bus, since the 9 lines will float to an asserted state for single ended and to an indeterminate state for differential. This electrical condition will prevent a 16-bit device from working even if it is only doing 8-bit transfers, unless wired according to this Specification.

5. Wiring Rules

5.1 Considerations

This specification contains the SCSI wiring rules for a wide range of interconnects that are possible using the presently available standards for SCSI connectors (both in X3T9.2/X3T10 and SFF) i.e. the wiring rules for A-cables and P-cables when used with mixed width and SFF Committee-specified connections.

Connections beyond the simple A-cable, P-cable, and A-cable to P-cable have become possible and likely since the creation of the original specification for the SCSI A-cable in the SCSI-2 specification and the original specification for the SCSI P-cable in the draft SPI (SCSI-3 Parallel Interface) standard. This specification is a comprehensive collection of wiring tables for the new connections that may now exist. There is no support for the SCSI-2 B-cable in this specification.

The starting point is the A-cable and P-cable connections as referenced above in the SCSI-2 and SCSI-3 standards.

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

The term P-cable in this specification means a 68-conductor bus whose lines are functioning as defined in the SCSI-3 SPI standard. Generally the function of the lines is determined by the devices connected to the bus. This specification assumes that the SCSI-2 or SCSI-3 standard devices take precedence over these bus functions.

Line functions that are peculiar to an SFF device are not continued into a standard A-cable or P-cable although these special functions may exist in limited domains (within a notebook computer for example).

This specification does not directly consider the cases where only different SFF connectors may be connected to the same bus. One may assume the bus is functioning as a standard A-cable or P-cable and safely use the wiring tables but since there would be no standard A-cable or P-cable devices to provide the line functions this could lead to inefficient implementations.

The wiring tables specify how to connect either the A-cable or P-cable to the connections listed below.

The two (and only two) terminators on the bus define the ends of the bus. The electrical path forming continuity between these terminators is the bus path. Any other electrical path is a stub path.

There are two basic kinds of connection described: stubbing and bussing.

A stubbing connection occurs when breaking the connection does NOT cause loss of bus continuity from terminator to terminator. A stubbing connection cannot involve any bus termination.

A bussing connection occurs when breaking the connection does cause loss of bus continuity from terminator to terminator. A bussing connection must directly involve bus termination. This is specified in the tables where appropriate.

There are a family of connectors that must be considered. Whether these connectors are high or low density or are shielded or not does not affect these wiring tables. Note however that the 50-pin SCSI-2 connections have different pin numbers depending on the connector contact number set being used.

The low density unshielded SCSI-2 50-pin connector will use 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 pins will use Set 2 or simply the cable conductor number.

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

Connections considered in this specification:

- 50-pin SCSI-2
- 68-pin SCSI-3
- 80-pin SCA (Single Connector Attachment) SFF-8015
- 50-pin SFF-8003
- 68-pin SFF-8003

Also included in this specification are differential pinouts for the SCA and SFF connectors since these are not defined in the source documents.

In space confined situations, such as with PC option panels, one may pass two
single ended A-cables through a single 68-pin SCSI-3 connector. This is done
by commoning grounds and sacrificing three of the reserved lines. The wiring
specification for this connection is also contained in this document.

5.2 Intermix Cases Covered

5.2.1 Single Ended

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

- A-cable with a 68-pin SCSI-3 stubbing connection
- A-cable with a 68-pin SCSI-3 bussing connection
- P-cable with a 50-pin SCSI-2 stubbing connection
- P-cable with a 50-pin SCSI-2 bussing connection
- A-cable with a stubbing 80-pin SCI connection
- A-cable with a bussing 80-pin SCI connection
- P-cable with a stubbing 80-pin SCI connection
- P-cable with a bussing 80-pin SCI connection
- A-cable with a stubbing SFF 50-pin connection
- A-cable with a bussing SFF 50-pin connection
- A-cable with a stubbing SFF 68-pin connection
- A-cable with a bussing SFF 68-pin connection
- P-cable with a stubbing SFF 68-pin connection
- P-cable with a bussing SFF 68-pin connection
- P-cable with a stubbing SFF 50-pin connection
- P-cable with a bussing SFF 50-pin connection
- 2 A-cables with a single 68-pin SCSI-3 stubbing connection
- 2 A-cables with a single 68-pin SCSI-3 bussing connection

5.2.2 Differential

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

- A-cable with a 68-pin SCSI-3 stubbing connection
- A-cable with a 68-pin SCSI-3 bussing connection
- P-cable with a 50-pin SCSI-2 stubbing connection
- P-cable with a 50-pin SCSI-2 bussing connection
- A-cable with a stubbing 80-pin SCI connection
- A-cable with a bussing 80-pin SCI connection
- P-cable with a stubbing 80-pin SCI connection
- P-cable with a bussing 80-pin SCI connection
- A-cable with a stubbing SFF 50-pin connection
- A-cable with a bussing SFF 50-pin connection
- A-cable with a stubbing SFF 68-pin connection
- A-cable with a bussing SFF 68-pin connection
- P-cable with a stubbing SFF 68-pin connection
- P-cable with a bussing SFF 68-pin connection
- P-cable with a stubbing SFF 50-pin connection
- P-cable with a bussing SFF 50-pin connection

5.3 Cross Reference

Table 5-1 identifies the combinations which are specified in Clause 6.

TABLE 5-1 REFERENCE TO SPECIFIED COMBINATIONS

	50-pin SCSI-2	68-pin SCSI-3	80-pin SFF-8015	50-pin SFF-8003	68-pin SFF-8003
Basic Single Ended Cable Pinout	6- 1	6- 3	6- 9	6- 5	6- 7
Basic Differential Cable Pinout	6- 2	6- 4	6- 10	6- 6	6- 8
A-Cable Single Ended Cable Bussing	6- 1	6- 11	N/A	6- 13	6- 17
A-Cable Single Ended Cable Stubbing	6-1	6-11	6-19	6-13	6-17
A-Cable Differential Cable Bussing	6-2	6-12	N/A	6-14	6-18
A-Cable Differential Cable Stubbing	6-2	6-12	6-21	6-14	6-18
P-Cable Single Ended Cable Bussing	N/A	6-3	N/A	N/A	6-15
P-Cable Single Ended Cable Stubbing	6-23	6-3	6-20	6-25	6-15
P-Cable Differential Cable Bussing	N/A	6-4	N/A	N/A	6-16
P-Cable Differential Cable Stubbing	6-23	6-4	6-22	6-26	6-16
Dual A-Cable Single Ended Cable Bussing		6-27			
Dual A-Cable Single Ended Cable Stubbing		6-27			

5.4 Bus Termination

5.4.1 General Applications

For 16-bit devices (devices with a 68-pin SCSI-3 connector) onboard bus termination may be accomplished:

- in the manner specified in the SPI document if the device is providing bus termination for the entire 68-pin connector (end of bus 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 bus segment device applications only)

5.4.2 Specific Precautions

In some application for 16-bit devices special considerations must be taken to ensure proper termination of the unused signals is accomplished.

- 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 (such as when using a cable assembly as specified in Section 5). If the unused pins are not terminated or asserted on board, the required negations or terminations have to be provided in the cable assembly.

If some means of electronic termination is not implemented on the unused lines, the upper data and parity bits may "float" to what appears to be an asserted state and cause device or system operational problems. The unused lines do not have to meet the electrical requirements for SCSI bus termination and may be built of resistors. Resistors of at least 100K ohms should be used to avoid loading the bus.

- high value pull up resistors for single ended.
- high value resistors in a totem pole for differential.

It is recommended that resistors or some alternative form of electronic termination be implemented in all 16-bit devices.

5.5 Rack Mount Considerations

Connectors such as the SFF-8015 SCA (Single Connector Attach) are 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 bussing 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 device (thereby making it a bussing connection) AND there is a local source of TERMPWR for the terminator the connections can be followed if the Reserved lines are not used. NOTE: Such a configuration is not strictly 'legal' since TERMPWR should only be supplied to terminators from the TERMPWR signal (as defined in SCSI-2 and SCSI-3 SPI).

TABLE 6-1 SINGLE ENDED: CONTACT ASSIGNMENTS FOR SCSI-2 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	-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 6-2 DIFFERENTIAL: CONTACT ASSIGNMENTS FOR SCSI-2 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.

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 6-3 SINGLE ENDED: CONNECTOR CONTACTS FOR SCSI-3 P-CABLE
(Applies to both bussing and stubbing connections)

68-pin SCSI-3 Connector Contact and Signal Name	Single Ended P-Cable Conductor Position		68-pin SCSI-3 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 6-4 DIFFERENTIAL: CONNECTOR CONTACTS FOR SCSI-3 P-CABLE

68-pin SCSI-3 Connector Contact and Signal Name	Differential P-Cable Conductor Position		68-pin SCSI-3 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 6-5 SINGLE ENDED: SIGNAL ASSIGNMENTS FOR SFF-8003 A-CABLE

50-pin SFF-8003 Connector Contact and Signal Name	Single Ended A-Cable Conductor Position		50-pin SFF-8003 Connector Contact and Signal Name	
1 GROUND	1	2	-DB(0)	26
2 GROUND	3	4	-DB(1)	27
3 GROUND	5	6	-DB(2)	28
4 GROUND	7	8	-DB(3)	29
5 GROUND	9	10	-DB(4)	30
6 GROUND	11	12	-DB(5)	31
7 GROUND	13	14	-DB(6)	32
8 GROUND	15	16	-DB(7)	33
9 GROUND	17	18	-DB(P)	34
10 GROUND	19	20	GROUND	35
11 5V/3.3V GROUND	21	22	5V/3.3V (Motor)	36
12 12V/5V GROUND	23	24	12V/5V	37
13 TERMPWR	25	26	TERMPWR	38
14 12V/5V	27	28	12V/5V GROUND	39
15 5V/3.3V (Logic)	29	30	5V/3.3V (Return)	40
16 -ADDR #1/GROUND	31	32	-ATN	41
17 GROUND	33	34	SYNC	42
18 GROUND	35	36	-BSY	43
19 GROUND	37	38	-ACK	44
20 GROUND	39	40	-RST	45
21 -ADDR #2/GROUND	41	42	-MSG	46
22 GROUND	43	44	-SEL	47
23 -ADDR #3/GROUND	45	46	-C/D	48
24 GROUND	47	48	-REQ	49
25 VU/GROUND	49	50	-I/O	50

NOTES: (1) The -ADDR #n/GROUND signals shall be externally grounded.
(2) If more than one VU signal is required, the -ADDR #n/GROUND signals shall be used. See SFF-8003 for the recommended circuit to convert an -ADDR #n/GROUND signal to a VU Mode signal.
(3) If the drive does not support on-board terminators, the TERMPWR signals shall not be connected to the drive.
(4) Drives may be built for either 3.3V or 5V Logic.

TABLE 6-6 DIFFERENTIAL: SIGNAL ASSIGNMENTS FOR SFF-8003 A-CABLE

50-pin SFF-8003 Connector Contact and Signal Name	Differential A-Cable Conductor Position		50-pin SFF-8003 Connector Contact and Signal Name	
1 +DB(0)	1	2	-DB(0)	26
2 +DB(1)	3	4	-DB(1)	27
3 +DB(2)	5	6	-DB(2)	28
4 +DB(3)	7	8	-DB(3)	29
5 +DB(4)	9	10	-DB(4)	30
6 +DB(5)	11	12	-DB(5)	31
7 +DB(6)	13	14	-DB(6)	32
8 +DB(7)	15	16	-DB(7)	33
9 +DB(P)	17	18	-DB(P)	34
10 DIFFSENS	19	20	GROUND	35
11 5V/3.3V GROUND	21	22	5V/3.3V (Motor)	36
12 12V/5V GROUND	23	24	12V/5V	37
13 TERMPWR	25	26	TERMPWR	38
14 12V/5V	27	28	12V/5V GROUND	39
15 5V/3.3V (Logic)	29	30	5V/3.3V (Return)	40
16 +ATN	31	32	-ATN	41
17 GROUND	33	34	SYNC	42
18 +BSY	35	36	-BSY	43
19 +ACK	37	38	-ACK	44
20 +RST	39	40	-RST	45
21 +MSG	41	42	-MSG	46
22 +SEL	43	44	-SEL	47
23 +C/D	45	46	-C/D	48
24 +REQ	47	48	-REQ	49
25 +I/O	49	50	-I/O	50

NOTES: (1) The -ADDR #n/GROUND signals shall be externally grounded.
(2) If more than one VU signal is required, the -ADDR #n/GROUND signals shall be used. See SFF-8003 for the recommended circuit to convert an -ADDR #n/GROUND signal to a VU Mode signal.
(3) If the drive does not support on-board terminators, the TERMPWR signals shall not be connected to the drive.
(4) Drives may be built for either 3.3V or 5V Logic.

TABLE 6-7 SINGLE ENDED: SIGNAL ASSIGNMENTS FOR SFF-8003 P-CABLE

68-pin SFF-8003 Connector Contact and Signal Name	Single Ended P-Cable Conductor Position		68-pin SFF-8003 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 5V/3.3V GROUND	29	30	5V/3.3V (Motor)	49
16 12V/5V GROUND	31	32	12V/5V	50
17 TERMPWR	33	34	TERMPWR	51
18 TERMPWR	35	36	TERMPWR	52
19 12V/5V	37	38	12V/5V GROUND	53
20 5V/3.3V (Logic)	39	40	5V/3.3V (Return)	54
21 -ADDR #1/GROUND	41	42	-ATN	55
22 GROUND	43	44	SYNC	56
23 GROUND	45	46	-BSY	57
24 GROUND	47	48	-ACK	58
25 GROUND	49	50	-RST	59
26 -ADDR #2/GROUND	51	52	-MSG	60
27 GROUND	53	54	-SEL	61
28 -ADDR #3/GROUND	55	56	-C/D	62
29 GROUND	57	58	-REQ	63
30 -ADDR #4/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

NOTES: (1) The -ADDR #n/GROUND signals shall be externally grounded.
(2) If more than one VU signal is required, the -ADDR #n/GROUND signals shall be used. See SFF-8003 for the recommended circuit to convert an -ADDR #n/GROUND signal to a VU Mode signal.
(3) If the drive does not support on-board terminators, the TERMPWR signals shall not be connected to the drive.
(4) Drives may be built for either 3.3V or 5V Logic.
(5) 8 bit drives which are connected to the SFF P-Cable shall leave the following signals open: -DB(Pl) and - DB(8) through -DB(15). All other signals shall be connected as defined.

TABLE 6-8 DIFFERENTIAL: SIGNAL ASSIGNMENTS FOR SFF-8003 P-CABLE

68-pin SFF-8003 Connector Contact and Signal Name	Differential P-Cable Conductor Position		68-pin SFF-8003 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 5V/3.3V GROUND	29	30	5V/3.3V (Motor)	49
16 12V/5V GROUND	31	32	12V/5V	50
17 TERMPWR	33	34	TERMPWR	51
18 TERMPWR	35	36	TERMPWR	52
19 12V/5V	37	38	12V/5V GROUND	53
20 5V/3.3V (Logic)	39	40	5V/3.3V (Return)	54
21 +ATN	41	42	-ATN	55
22 GROUND	43	44	DIFFSENS	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

NOTES: (1) The -ADDR #n/GROUND signals shall be externally grounded.

(2) If more than one VU signal is required, the -ADDR #n/GROUND signals shall be used. See SFF-8003 for the recommended circuit to convert an -ADDR #n/GROUND signal to a VU Mode signal.

(3) If the drive does not support on-board terminators, the TERMPWR signals shall not be connected to the drive.

(4) Drives may be built for either 3.3V or 5V Logic.

(5) 8 bit drives which are connected to the SFF P-Cable shall leave the following signals open: -DB(Pl) and - DB(8) through -DB(15). All other signals shall be connected as defined.

TABLE 6-9 SINGLE ENDED: SIGNAL ASSIGNMENTS FOR SFF-8015 SCA

80-pin SFF-8015 Connector Contact and Signal Name	Cable conductor numbers are not applicable.	80-pin SFF-8015 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 6-10 DIFFERENTIAL: SIGNAL ASSIGNMENTS FOR SFF-8015 SCA

80-pin SFF-8015 Connector Contact and Signal Name	Cable conductor numbers are not applicable.	80-pin SFF-8015 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 6-11 SINGLE ENDED: 68-PIN SCSI-3 CONNECTION & SCSI-2 A-CABLE
(Applies to both bussing and stubbing connections)

68-pin SCSI-3 Connector Contact and Signal Name			Single Ended A-Cable Conductor Position and Signal Name				68-pin SCSI-3 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 SFF connector pin 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 6-12 DIFFERENTIAL: 68-PIN SCSI-3 CONNECTION & SCSI-2 A-CABLE
(Applies to both bussing and stubbing connections)

68-pin SCSI-3 Connector Contact and Signal Name	Differential A-Cable Conductor Position and Signal Name	68-pin SCSI-3 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(L) -DB(L) 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 SFF connector pin 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 6-13 SINGLE ENDED: 50-PIN SFF-8003 CONNECTION & SCSI-2 A-CABLE
(Applies to both bussing and stubbing connections)

50-pin SFF-8003 Connector Contact	Single Ended A-Cable Conductor Position	50-pin SFF-8003 Connector Contact

and Signal Name		and Signal Name			and Signal Name
1 GROUND		1 GROUND	-DB(0) 2		-DB(0) 26
2 GROUND		3 GROUND	-DB(1) 4		-DB(1) 27
3 GROUND		5 GROUND	-DB(2) 6		-DB(2) 28
4 GROUND		7 GROUND	-DB(3) 8		-DB(3) 29
5 GROUND		9 GROUND	-DB(4) 10		-DB(4) 30
6 GROUND		11 GROUND	-DB(5) 12		-DB(5) 31
7 GROUND		13 GROUND	-DB(6) 14		-DB(6) 32
8 GROUND		15 GROUND	-DB(7) 16		-DB(7) 33
9 GROUND		17 GROUND	-DB(P) 18		-DB(P) 34
10 GROUND		19 GROUND	GROUND 20		GROUND 35
11 5V/3.3V GROUND	X	21 GROUND	GROUND 22	X	5V/3.3V (MOTOR) 36
12 12V/5V GROUND	X	23 RESERVED	RESERVED 24	X	12V/5V 37
13 TERMPWR	X	25 OPEN	TERMPWR 26		TERMPWR 38
14 12V/5V	X	27 RESERVED	RESERVED 28	X	12V/5V GROUND 39
15 5V/3.3V (LOGIC)	X	29 GROUND	GROUND 30	X	5V/3.3V (RETURN) 40
16 -ADDR #1/GROUND	Y	31 GROUND	-ATN 32		-ATN 41
17 GROUND		33 GROUND	GROUND 34	X	SYNC 42
18 GROUND		35 GROUND	-BSY 36		-BSY 43
19 GROUND		37 GROUND	-ACK 38		-ACK 44
20 GROUND		39 GROUND	-RST 40		-RST 45
21 -ADDR #2/GROUND	Y	41 GROUND	-MSG 42		-MSG 46
22 GROUND		43 GROUND	-SEL 44		-SEL 47
23 -ADDR #3/GROUND	Y	45 GROUND	-C/D 46		-C/D 48
24 GROUND		47 GROUND	-REQ 48		-REQ 49
25 VU/GROUND	Y	49 GROUND	-I/O 50		-I/O 50

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

Y = If ADDR # is present then signal is Not Connected, otherwise it is connected as Ground.

No Reserved line functions are possible if used as a bussing connection

TABLE 6-14 DIFFERENTIAL: 50-PIN SFF-8003 CONNECTION & SCSI-2 A-CABLE
(Applies to both bussing and stubbing connections)

50-pin SFF-8003 Connector Contact and Signal Name	Differential A-Cable Conductor Position and Signal Name		50-pin SFF-8003 Connector Contact and Signal Name
1 +DB(0)	1 +DB(0)	-DB(0) 2	-DB(0) 26

```
|  2 +DB(1)             |  3 +DB(1)   -DB(1)     4 |    -DB(1)          27 |
|  3 +DB(2)             |  5 +DB(2)   -DB(2)     6 |    -DB(2)          28 |
|  4 +DB(3)             |  7 +DB(3)   -DB(3)     8 |    -DB(3)          29 |
|  5 +DB(4)             |  9 +DB(4)   -DB(4)    10 |    -DB(4)          30 |
|  6 +DB(5)             | 11 +DB(5)   -DB(5)    12 |    -DB(5)          31 |
|  7 +DB(6)             | 13 +DB(6)   -DB(6)    14 |    -DB(6)          32 |
|  8 +DB(7)             | 15 +DB(7)   -DB(7)    16 |    -DB(7)          33 |
|  9 +DB(P)             | 17 +DB(P)   -DB(P)    18 |    -DB(P)          34 |
| 10 DIFFSENS           | 21 DIFFSENS GROUND    20 |    GROUND          35 |
| 11 5V/3.3V GROUND  X  | 19 GROUND   GROUND    22 |  X 5V/3.3V (Motor)  36 |
| 12 12V/5V GROUND   X  | 23 RESERVED RESERVED  24 |  X 12V/5V           37 |
| 13 TERMPWR            | 25 TERMPWR  TERMPWR   26 |    TERMPWR          38 |
| 14 12V/5V          X  | 27 RESERVED RESERVED  28 |  X 12V/5V GROUND    39 |
| 15 5V/3.3V (Logic) X  | 31 GROUND   GROUND    32 |  X 5V/3.3V (Return) 40 |
| 16 +ATN               | 29 +ATN     -ATN      30 |    -ATN            41 |
| 17 GROUND             | 33 GROUND   GROUND    34 |  X SYNC             42 |
| 18 +BSY               | 35 +BSY     -BSY      36 |    -BSY            43 |
| 19 +ACK               | 37 +ACK     -ACK      38 |    -ACK            44 |
| 20 +RST               | 39 +RST     -RST      40 |    -RST            45 |
| 21 +MSG               | 41 +MSG     -MSG      42 |    -MSG            46 |
| 22 +SEL               | 43 +SEL     -SEL      44 |    -SEL            47 |
| 23 +C/D               | 45 +C/D     -C/D      46 |    -C/D            48 |
| 24 +REQ               | 47 +REQ     -REQ      48 |    -REQ            49 |
| 25 +I/O               | 49 +I/O     -I/O      50 |    -I/O            50 |
+-----------------------+--------------------------+-----------------------+
     X = Signal is Not Connected i.e. no connection between the SFF
         connector pin and the respective cable conductor.
No Reserved line functions are possible if used as a bussing connection
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TABLE 6-15 SINGLE ENDED: 68-PIN SFF-8003 CONNECTION & SCSI-3 P-CABLE
(Applies to both bussing and stubbing connections)

68-pin SFF-8003 Connector Contact and Signal Name	Single Ended P-Cable Conductor Position and Signal Name	68-pin SFF-8003 Connector Contact and Signal Name
1 GROUND	1 GROUND -DB(12) 2	-DB(12) 35
2 GROUND	3 GROUND -DB(13) 4	-DB(13) 36
3 GROUND	5 GROUND -DB(14) 6	-DB(14) 37
4 GROUND	7 GROUND -DB(15) 8	-DB(15) 38
5 GROUND	9 GROUND -DB(P1) 10	-DB(P1) 39
6 GROUND	11 GROUND -DB(0) 12	-DB(0) 40
7 GROUND	13 GROUND -DB(1) 14	-DB(1) 41
8 GROUND	15 GROUND -DB(2) 16	-DB(2) 42
9 GROUND	17 GROUND -DB(3) 18	-DB(3) 43
10 GROUND	19 GROUND -DB(4) 20	-DB(4) 44
11 GROUND	21 GROUND -DB(5) 22	-DB(5) 45
12 GROUND	23 GROUND -DB(6) 24	-DB(6) 46
13 GROUND	25 GROUND -DB(7) 26	-DB(7) 47
14 GROUND	27 GROUND -DB(P) 28	-DB(P) 48
15 5V/3.3V GROUND X	29 GROUND GROUND 30	X 5V/3.3V (Motor) 49
16 12V/5V GROUND X	31 GROUND GROUND 32	X 12V/5V 50
17 TERMPWR	33 TERMPWR TERMPWR 34	TERMPWR 51
18 TERMPWR	35 TERMPWR TERMPWR 36	TERMPWR 52
19 12V/5V X	37 RESERVED RESERVED 38	X 12V/5V GROUND 53
20 5V/3V (Logic) X	39 GROUND GROUND 40	X 5V/3.3V (Return) 54
21 -ADDR #1/GROUND Y	41 GROUND -ATN 42	-ATN 55
22 GROUND	43 GROUND GROUND 44	X SYNC 56
23 GROUND	45 GROUND -BSY 46	-BSY 57
24 GROUND	47 GROUND -ACK 48	-ACK 58
25 GROUND	49 GROUND -RST 50	-RST 59
26 -ADDR #2/GROUND Y	51 GROUND -MSG 52	-MSG 60
27 GROUND	53 GROUND -SEL 54	-SEL 61
28 -ADDR #3/GROUND Y	55 GROUND -C/D 56	-C/D 62
29 GROUND	57 GROUND -REQ 58	-REQ 63
30 -ADDR #4/GROUND Y	59 GROUND -I/O 60	-I/O 64
31 GROUND	61 GROUND -DB(8) 62	-DB(8) 65
32 GROUND	63 GROUND -DB(9) 64	-DB(9) 66
33 GROUND	65 GROUND -DB(10) 66	-DB(10) 67
34 GROUND	67 GROUND -DB(11) 68	-DB(11) 68

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

NOTE: Not recommended for bussing connections due to loss of Reserved line continuity.

TABLE 6-16 DIFFERENTIAL: 68-PIN SFF-8003 CONNECTION & SCSI-3 P-CABLE
(Applies to both bussing and stubbing connections)

68-pin SFF-8003 Connector Contact and Signal Name			Differential P-Cable Conductor Position and Signal Name				68-pin SFF-8003 Connector Contact and Signal Name		
1	+DB(12)		1	+DB(12)	-DB(12)	2		-DB(12)	35
2	+DB(13)		3	+DB(13)	-DB(13)	4		-DB(13)	36
3	+DB(14)		5	+DB(14)	-DB(14)	6		-DB(14)	37
4	+DB(15)		7	+DB(15)	-DB(15)	8		-DB(15)	38
5	+DB(P1)		9	+DB(P1)	-DB(P1)	10		-DB(P1)	39
6	+DB(0)		13	+DB(0)	-DB(0)	14		-DB(0)	40
7	+DB(1)		15	+DB(1)	-DB(1)	16		-DB(1)	41
8	+DB(2)		17	+DB(2)	-DB(2)	18		-DB(2)	42
9	+DB(3)		19	+DB(3)	-DB(3)	20		-DB(3)	43
10	+DB(4)		21	+DB(4)	-DB(4)	22		-DB(4)	44
11	+DB(5)		23	+DB(5)	-DB(5)	24		-DB(5)	45
12	+DB(6)		25	+DB(6)	-DB(6)	26		-DB(6)	46
13	+DB(7)		27	+DB(7)	-DB(7)	28		-DB(7)	47
14	+DB(P)		29	+DB(P)	-DB(P)	30		-DB(P)	48
15	5V/3.3V GROUND	X	11	GROUND	GROUND	12	X	5V/3.3V (Motor)	49
16	12V/5V GROUND	X	42	GROUND	GROUND	32	X	12V/5V	50
17	TERMPWR		33	TERMPWR	TERMPWR	34		TERMPWR	51
18	TERMPWR		35	TERMPWR	TERMPWR	36		TERMPWR	52
19	12V/5V	X	37	RESERVED	RESERVED	38	X	12V/5V GROUND	53
20	5V/3V (Logic)	X	59	GROUND	GROUND	60	X	5V/3.3V (Return)	54
21	+ATN		39	+ATN	-ATN	40		-ATN	55
22	GROUND		41	GROUND	DIFFSENS	31		DIFFSENS	56
23	+BSY		43	+BSY	-BSY	44		-BSY	57
24	+ACK		45	+ACK	-ACK	46		-ACK	58
25	+RST		47	+RST	-RST	48		-RST	59
26	+MSG		49	+MSG	-MSG	50		-MSG	60
27	+SEL		51	+SEL	-SEL	52		-SEL	61
28	+C/D		53	+C/D	-C/D	54		-C/D	62
29	+REQ		55	+REQ	-REQ	56		-REQ	63
30	+I/O		57	+I/O	-I/O	58		-I/O	64
31	+DB(8)		61	+DB(8)	-DB(8)	62		-DB(8)	65
32	+DB(9)		63	+DB(9)	-DB(9)	64		-DB(9)	66
33	+DB(10)		65	+DB(10)	-DB(10)	66		-DB(10)	67
34	+DB(11)		67	+DB(11)	-DB(11)	68		-DB(11)	68

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

NOTE: Not recommended for bussing connections due to loss of Reserved line continuity and no TERMPWR return path in cable (except for shell).

TABLE 6-17 SINGLE ENDED: 68-PIN SFF-8003 CONNECTION & SCSI-2 A-CABLE
(Applies to both bussing and stubbing connections)

68-pin SFF-8003 Connector Contact and Signal Name			Single Ended A-Cable Conductor Position and Signal Name				68-pin SFF-8003 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	5V/3.3V GROUND	X	19	GROUND	GROUND	20	X	5V/3.3V (Motor)	49
16	12V/5V GROUND	X	21	GROUND	GROUND	22	X	12V/5V	50
17	TERMPWR	X	23	RESERVED	RESERVED	24	X	TERMPWR	51
18	TERMPWR	X	25	OPEN	TERMPWR	26		TERMPWR	52
19	12V/5V	X	27	RESERVED	RESERVED	28	X	12V/5V GROUND	53
20	5V/3V (Logic)	X	29	GROUND	GROUND	30	X	5V/3.3V (Return)	54
21	-ADDR #1/GROUND	Y	31	GROUND	-ATN	32		-ATN	55
22	GROUND		33	GROUND	GROUND	34	X	SYNC	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	-ADDR #2/GROUND	Y	41	GROUND	-MSG	42		-MSG	60
27	GROUND		43	GROUND	-SEL	44		-SEL	61
28	-ADDR #3/GROUND	Y	45	GROUND	-C/D	46		-C/D	62
29	GROUND		47	GROUND	-REQ	48		-REQ	63
30	-ADDR #4/GROUND	Y	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 SFF connector pin and the respective cable conductor.
Y = If ADDR # is present then signal is Not Connected, otherwise it is connected as Ground.
* = 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.

NOTE: Not recommended for bussing connections due to loss of Reserved line continuity.

TABLE 6-18 DIFFERENTIAL: 68-PIN SFF-8003 CONNECTION & SCSI-2 A-CABLE
(Applies to both bussing and stubbing connections)

68-pin SFF-8003 Connector Contact and Signal Name			Differential A-Cable Conductor Position and Signal Name				68-pin SFF-8003 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)		3	+DB(0)	-DB(0)	4		-DB(0)	40
7	+DB(1)		5	+DB(1)	-DB(1)	6		-DB(1)	41
8	+DB(2)		7	+DB(2)	-DB(2)	8		-DB(2)	42
9	+DB(3)		9	+DB(3)	-DB(3)	10		-DB(3)	43
10	+DB(4)		11	+DB(4)	-DB(4)	12		-DB(4)	44
11	+DB(5)		13	+DB(5)	-DB(5)	14		-DB(5)	45
12	+DB(6)		15	+DB(6)	-DB(6)	16		-DB(6)	46
13	+DB(7)		17	+DB(7)	-DB(7)	18		-DB(7)	47
14	+DB(P)		19	+DB(P)	-DB(P)	20		-DB(P)	48
15	5V/3.3V GROUND	X	1	GROUND	GROUND	2	X	5V/3.3V (Motor)	49
16	12V/5V GROUND	X	49	GROUND	GROUND	50	X	12V/5V	50
17	TERMPWR	X	23	RESERVED	RESERVED	24	X	TERMPWR	51
18	TERMPWR		25	TERMPWR	TERMPWR	26		TERMPWR	52
19	12V/5V	X	32	GROUND	GROUND	22	X	12V/5V GROUND	53
20	5V/3V (Logic)	X	27	RESERVED	RESERVED	28	X	5V/3.3V (Return)	54
21	+ATN		29	+ATN	-ATN	30		-ATN	55
22	GROUND		31	GROUND	DIFFSENS	21		DIFFSENS	56
23	+BSY		33	+BSY	-BSY	34		-BSY	57
24	+ACK		35	+ACK	-ACK	36		-ACK	58
25	+RST		37	+RST	-RST	38		-RST	59
26	+MSG		39	+MSG	-MSG	40		-MSG	60
27	+SEL		41	+SEL	-SEL	42		-SEL	61
28	+C/D		43	+C/D	-C/D	44		-C/D	62
29	+REQ		45	+REQ	-REQ	46		-REQ	63
30	+I/O		47	+I/O	-I/O	48		-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 SFF connector pin 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.

NOTE: Not recommended for bussing connections due to loss of Reserved line continuity.

TABLE 6-19 SINGLE ENDED: 80-PIN SFF-8015 CONNECTION TO SCSI-2 A-CABLE
(Applies to stubbing connection)

80-pin SFF-8015 Connector Contact and Signal Name			Single Ended A-Cable Conductor Position and Signal Name				80-pin SFF-8015 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(PO)		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(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 SFF connector pin 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.

NOTE: See also 5.5 Rack Mount Considerations

TABLE 6-20 SINGLE ENDED: 80-PIN SFF-8015 CONNECTION TO SCSI-3 P-CABLE
(Applies to stubbing connection)

80-pin SFF-8015 Connector Contact and Signal Name			Single Ended P-Cable Conductor Position and Signal Name				80-pin SFF-8015 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 SFF connector pin 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.

NOTE: See also 5.5 Rack Mount Considerations

TABLE 6-21 DIFFERENTIAL: 80-PIN SFF-8015 CONNECTION TO SCSI-2 A-CABLE
(Applies to stubbing connection)

80-pin SFF-8015 Connector Contact and Signal Name			Differential A-Cable Conductor Position and Signal Name				80-pin SFF-8015 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(PO)		20	-DB(P)	+DB(P)	19		+DB(PO)	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(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 SFF connector pin 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.

NOTE: See also 5.5 Rack Mount Considerations

TABLE 6-22 DIFFERENTIAL: 80-PIN SFF-8015 CONNECTION TO SCSI-3 P-CABLE
(Applies to stubbing connection)

80-pin SFF-8015 Connector Contact and Signal Name			Differential P-Cable Conductor Position and Signal Name				80-pin SFF-8015 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(PO)		30	-DB(P)	+DB(P)	29		+DB(PO)	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(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 SFF connector pin 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.

NOTE: See also 5.5 Rack Mount Considerations

TABLE 6-23 SINGLE ENDED: 50-PIN SCSI-2 CONNECTION TO SCSI-3 P-CABLE
(Applies to stubbing connection)

50-pin SCSI-2 Connector Contact and Signal Name			Single Ended P-Cable Conductor Position and Signal Name				50-pin SCSI-2 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 SFF connector pin and the respective cable conductor.

TABLE 6-24 DIFFERENTIAL: 50-PIN SCSI-2 CONNECTION TO SCSI-3 P-CABLE
(Applies to stubbing connection)

50-pin SCSI-2 Connector Contact and Signal Name			Differential P-Cable Conductor Position and Signal Name				50-pin SCSI-2 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 SFF connector pin and the respective cable conductor.

TABLE 6-25 SINGLE ENDED: 50-PIN SFF-8003 CONNECTION TO SCSI-3 P-CABLE
(Applies to stubbing connection)

50-pin SFF-8003 Connector Contact and Signal Name			Single Ended P-Cable Conductor Position and Signal Name				50-pin SFF-8003 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	5V/3.3V GROUND	X	31	GROUND	GROUND	32	X	5V/3.3V (MOTOR)	36
12	12V/5V GROUND	X	33	TERMPWR	TERMPWR	34	X	12V/5V	37
13	TERMPWR		35	TERMPWR	TERMPWR	36		TERMPWR	38
14	12V/5V	X	37	RESERVED	RESERVED	38	X	12V/5V GROUND	39
15	5V/3.3V (LOGIC)	X	39	GROUND	GROUND	40	X	5V/3.3V (RETURN)	40
16	-ADDR #1/GROUND	Y	41	GROUND	-ATN	42		-ATN	41
17	GROUND		43	GROUND	GROUND	44	X	SYNC	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	-ADDR #2/GROUND	Y	51	GROUND	-MSG	52		-MSG	46
22	GROUND		53	GROUND	-SEL	54		-SEL	47
23	-ADDR #3/GROUND	Y	55	GROUND	-C/D	56		-C/D	48
24	GROUND		57	GROUND	-REQ	58		-REQ	49
25	VU/GROUND	Y	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 SFF connector pin and the respective cable conductor.

TABLE 6-26 DIFFERENTIAL: 50-PIN SFF-8003 CONNECTION TO SCSI-3 P-CABLE
(Applies to stubbing connection)

50-pin SFF-8003 Connector Contact and Signal Name			Differential P-Cable Conductor Position and Signal Name				50-pin SFF-8003 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		
12	12V/5V GROUND	X	11	GROUND	GROUND	12	X	12V/5V GROUND	39
1	+DB(0)		13	+DB(0)	-DB(0)	14		-DB(0)	26
2	+DB(1)		15	+DB(1)	-DB(1)	16		-DB(1)	27
3	+DB(2)		17	+DB(2)	-DB(2)	18		-DB(2)	28
4	+DB(3)		19	+DB(3)	-DB(3)	20		-DB(3)	29
5	+DB(4)		21	+DB(4)	-DB(4)	22		-DB(4)	30
6	+DB(5)		23	+DB(5)	-DB(5)	24		-DB(5)	31
7	+DB(6)		25	+DB(6)	-DB(6)	26		-DB(6)	32
8	+DB(7)		27	+DB(7)	-DB(7)	28		-DB(7)	33
9	+DB(P)		29	+DB(P)	-DB(P)	30		-DB(P)	34
10	DIFFSENS		31	DIFFSENS	GROUND	32		GROUND	35
11	5V/3.3V GROUND	X	33	TERMPWR	TERMPWR	34	X	X5V/3.3V (Motor)	36
13	TERMPWR		35	TERMPWR	TERMPWR	36		TERMPWR	38
14	12V/5V	X	37	RESERVED	RESERVED	38	X	12V/5V	37
16	+ATN		39	+ATN	-ATN	40		-ATN	41
17	GROUND		41	GROUND	GROUND	42	X	SYNC	42
18	+BSY		43	+BSY	-BSY	44		-BSY	43
19	+ACK		45	+ACK	-ACK	46		-ACK	44
20	+RST		47	+RST	-RST	48		-RST	45
21	+MSG		49	+MSG	-MSG	50		-MSG	46
22	+SEL		51	+SEL	-SEL	52		-SEL	47
23	+C/D		53	+C/D	-C/D	54		-C/D	48
24	+REQ		55	+REQ	-REQ	56		-REQ	49
25	+I/O		57	+I/O	-I/O	58		-I/O	50
15	5V/3.3V (Logic)	X	59	GROUND	GROUND	60	X	5V/3.3V (Return)	40
		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 SFF connector pin and the respective cable conductor.

Y = If ADDR # is present then signal is Not Connected, otherwise it is connected as Ground.

TABLE 6-27 SINGLE ENDED: SCSI-3 68 PIN CONNECTOR TO DUAL SCSI-2 A-CABLE
(applies to stubbing and bussing connections)

BUS 1 50-pin SCSI-2 Connector Contact and Signal Name (Set 2)			68 PIN SCSI-3 Connector Contact and Signal Name				BUS 2 50 PIN SCSI-2 Connector Contact and Signal Name (Set 2)		
			BUS 1			BUS 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 pin connector pin.

Note: pins 17 and 51 on the 68 pin 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 RAID applications
Note: A 34 pair "P" cable CANNOT provide a dual "A" cable function.