

# SCSI

SCSI (pronounced "skuzzy") is an acronym for Small Computer System Interface. SCSI is a device-level interface capable of attaching intelligent peripheral devices such as disk drives, tape drives, scanners, etc. SCSI controllers are capable of attaching either 7 or 15 devices per SCSI bus (depending on the type of adapter). This number will vary depending on the host adapter you have installed. One of these devices, the host adapter (sometimes referred to as the controller), functions as the gateway between the SCSI bus and the system I/O bus (i.e. PCI, EISA, ISA, or MicroChannel).

## Scope

This paper addresses SCSI in a general nature. It is not intended to address any specific IBM product, offering, or implementation. This paper is divided into three sections. The first section will address common SCSI questions. The second section will provide reference material to more deeply address key SCSI characteristics (such as termination, addressing, bus width converters, sample configurations, etc.) The third section will suggest sources for more information on SCSI.

# Common Questions

## When do I terminate my SCSI device? What type of terminator do I use?

First, a technicality; devices on a SCSI bus do not need to be terminated; The SCSI BUS needs to be terminated. Termination must only be applied at the extreme physical ends of the SCSI bus.

Many SCSI devices provide a built in terminator that can be conveniently used when the device is located at the physical end of the SCSI cable. Note that this is not always the same as the last device on the cable since the last device may not be plugged into the last connector. Terminators built into devices can be enabled or disabled by switch or jumper settings. Note that some devices provide jumper settings for 'terminator power' which is NOT the same as enabling the built in terminator (see next question for more information).

Newer IBM Netfinity/PC servers provide a terminator built into the end of the SCSI cable itself. These are usually plugged into the last connector on the cable and 'shrink wrapped' permanently into place or 'press fit' directly onto the cable. In such systems, terminators built into devices (hard disks, tape drives, CD-ROM's, etc.) should **NEVER** be enabled.

A SCSI bus requires a terminator of the same width as the bus itself. In WIDE (16-bit) SCSI, the bus must be terminated with a WIDE (16-bit) 'Active' terminator. Attempting to terminate a 16-bit bus with a NARROW (8-bit) device (CD-ROM, tape drive, etc.) by using a 16- to 8-bit bus converter is **incorrect**. A narrow terminator would only terminate "the low half" of the SCSI bus. The subject of termination is covered in detail in the Reference Material section of this paper.

<b>Important:</b> Terminate SCSI buses, not devices!
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## What is Terminator Power?

SCSI terminators require power in order to operate. At least one SCSI device or controller on a SCSI Bus must be configured to provide Terminator power for proper operation. Terminator power for WIDE (16-bit) SCSI buses must be provided by a WIDE (16-bit) device or controller. It is recommended that only one device (or controller) be configured to supply Terminator power. Note that supplying Terminator power is NOT the same as supplying Termination. Terminator Power will be discussed further in the Reference Material section of this paper.

<b>Important:</b> 'Termination' and 'terminator power' are not the same thing!
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## Where do I put new options on the cable? Is the order on the cable important?

Options can be placed anywhere on the SCSI cable as long as the bus remains properly terminated. Each connector on the SCSI bus is equivalent to any other connector on the same bus. The order in which devices are attached to the cable is irrelevant. Each device is uniquely identified by an 'ID' value that is set via jumpers on the device and **NOT** by its physical position on a cable. In the case of a disk hot swap back plane, SCSI ID's are assigned by hardware on the back plane and correspond to the location where the device is 'plugged in' (refer to your user manual that came with your server for more information).

**Important:** Priority is controlled more by the SCSI ID than the physical location on the bus.

## When can I use a bus width converter?

A bus width converter can be used to attach a NARROW (8-bit) device to a WIDE (16-bit) SCSI bus. The 8-bit device being adapted to attach to a 16-bit bus must NOT be supplying bus termination or terminator power (and not plugged into the last physical connector). Bus width converters are NOT supported on a SCSI bus running at Ultra Speeds. Using a bus width converter to attach a WIDE (16-bit) device to a NARROW (8-bit) bus is NOT recommended and may not function properly. It is important to note that a bus width converter is **not** a terminator.

**Important:** Never terminate a 16-bit bus using an 8-bit device!

## How do external devices affect internal devices? or

## Can I add an external 8-bit device to a 16-bit SCSI adapter?

The PCI Fast/Wide Ultra SCSI adapter is an example of a single channel SCSI adapter that allows device connection both inside and outside the system on a single (same) SCSI bus. Since only one SCSI bus is present, 'ID' values must be unique across all devices (both internal and external) that are attached to the adapter. Ultra speeds are NOT supported on such a configuration since cable lengths will violate limits. Extreme care must be taken when mixing internal and external devices on such a controller. Such a configuration has limitations and complexities in performance, termination, cable length, and topology. Valid examples for this type of configuration are explored in the Reference Material section of this paper.

**Important:** Ultra speeds are not supported when both internal and external devices are on the same bus.

## Can I put faster and slower devices on the same cable? Do the slower devices slow down the faster devices?

Devices of any speed may be placed on a single SCSI bus without degrading the speed of the faster devices. During the boot process, each device on the SCSI bus goes through a process of ‘negotiation’ with the SCSI adapter to determine what transfer speed, bus width, and synchronous offset will be associated with that device. The adapter ‘remembers’ each device’s parameters and uses them whenever communicating with that device. While slow devices do not affect the *speed* of faster devices, they may affect the *latency* or time that a device must wait for access to the bus. A grossly slower device (such as a scanner) attached to a bus full of hard disk drives would be an inefficient configuration. The disk drives would all run at their high data rate but the scanner would have the potential of monopolizing the bus for longer periods of time (due to their slow transfer time) thus making the disk drives ‘wait’ for access to the bus. This, of course, is an extreme example for illustrating a point. For best possible performance, avoid mixing slow devices on the same SCSI bus as disk drives.

**Important:** Each SCSI device negotiates its own speed with the controller during the boot process. The SCSI bus transfer rate does not default to the speed of the slowest device.

## Will my configuration support “ULTRA” speed?

Ultra capability of a SCSI subsystem is quite configuration dependent. Ultra speed requires high signal quality levels. Cable length, number and type of attached devices, cable routing, and termination are major factors in signal quality. Guidelines for Ultra capability are explored in the Reference Material section of this paper.

**Important:** To operate at ultra speed, you must meet several strict guidelines.

## Which SCSI Options will work in my IBM server?

Please refer to the ‘compatibility’ web page located at <http://www.pc.ibm.com/us/compat/>.

# Reference Material

## History

The SCSI standard defines the physical and electrical parameters of a parallel I/O bus used to connect computers and peripheral devices in a daisy-chained fashion. It further defines a set of commands, messages and status information as well as a specific protocol for the exchange of such items. The standard defines support for devices such as disk drives, tape drives, and CD-ROM drives. The original SCSI standard (ANSI X3.131-1986) was approved in 1986. SCSI-2, the second-generation SCSI standard yielding performance and functionality enhancement was approved in January 1994. Currently, further improvements are being developed in the SCSI-3 standard.

## Background

The SCSI-1 standard and its addendum defined an 8-bit bus width and 5 MHz bus speed that resulted in 5MB (million bytes) per second maximum transfer rate with a maximum cable length of 6 meters. The SCSI-1 standard contained many optional commands and features that made device interoperability difficult.

SCSI-2 addressed the interoperability problem of SCSI-1 by defining a set of 18 basic SCSI commands called the Common Command Set (CCS) which would become the minimum set of commands supported by all peripherals. This provided a level of compatibility unrealized with SCSI-1. In addition to formal support for CCS, SCSI-2 provided enhanced performance and reliability options and additional definitions for other devices such as CD-ROM drives, tape drives, removable drives, and optical drives. SCSI-2 enabled a number of enhancements:

- **Fast SCSI:** This high-speed transfer protocol doubles the maximum speed of the bus to 10 MHz, resulting in a 10MB per second transfer rate on the standard 8-bit bus but with a cable length reduction to 3 meters.
- **Wide SCSI:** Widening the bus to 16-bits provided two distinct advantages. It doubled the amount of data that could be transferred per cycle, which resulted in 10 MB per second transfer rate with SCSI-1 bus speed. In addition it allowed 16 devices per SCSI bus vs. the 8 device maximum for SCSI-1.
- **Fast and Wide SCSI:** Combining the 16-bit data transfer capability of Wide SCSI with the 10 MHz data rate of FAST SCSI resulted in a blazing 20 MB/sec transfer rate with up to 3 meters of cable.
- **Active Termination:** Termination is an important technical consideration in setting up a SCSI bus. SCSI-2 defined the use of active termination, which provides reliable termination

of the bus signals at the higher FAST bus speed. SCSI-1 used a less expensive but poorer passive termination which was unacceptable for FAST bus speeds. In depth coverage of termination is provided in a dedicated Termination section later in this paper.

- **Tagged Command Queuing:** One of SCSI's strengths is its ability to send multiple commands to a device without waiting for a previous command to complete. This capability provides several benefits. A device without queuing capability will always have idle time between the completion of its last command and the receipt of its next command. Queuing eliminates this idle time by allowing the next command to be ready for execution upon current command completion. Queuing allows commands to be completed 'out of order'. Out of Order execution allows a device such as a disk drive to optimize its head movements based on knowledge of queued commands.
- **Differential:** Differential SCSI is an optional electrical specification for the SCSI bus. Differential busses and devices are incompatible with the 'Standard' and much more common 'single ended' busses. Differential SCSI is less susceptible to noise and allows for greater cable lengths but at substantial cost. PC Server and Netfinity typically do not use Differential SCSI. Differential SCSI should not be confused with what is currently being called Low Voltage Differential SCSI (LVDS) which is a new twist on Differential but which is compatible with 'single ended' (see *Ultra-2 SCSI*).

It is important to note that one of the important criteria for SCSI-2 was backward compatibility with SCSI-1 products. A large percentage of SCSI-1 disk drives and controllers available prior to the ratification of SCSI-2 implemented the CCS command set and thus were SCSI-2 compliant devices. *It is a very common misconception that the SCSI bus transfer rate defaults to the rate of the slowest device connected to it. The fact is that each device reaches an 'agreement' with the controller through a process called 'negotiation' where bus speeds and bus widths are agreed upon.*

The unratiified SCSI-3 specification is further addressing performance. Many products exist that support these advanced features.

- **Ultra SCSI:** This further redoubles the SCSI bus speed to 20MHz but with a reduction to 1.5 meters of maximum cable length.
- **Wide Ultra SCSI:** Coupling the double bus speed of Ultra with Wide resulted in a 40MB per second maximum transfer rate with a maximum of 1.5 meters of cable.
- **Ultra-2 SCSI:** This is sometimes referred to as LVD or LVDS SCSI. This further redoubles the SCSI bus speed to 40MHz but with a new electrical interface and termination requirement. The LVD (Low Voltage Differential) signaling interface provides the signal quality of Differential but with a compatibility mode that allows interoperability with non LVD drives or controllers. In this compatibility mode all LVD advantages such as longer cable distance and higher bus speed are forfeited. Cable limitations for Ultra-2 are not clear at this time but substantial improvements are expected.

- **Wide Ultra-2 SCSI:** Coupling the redoubled bus speed of Ultra 2 with Wide results in an 80MB per second maximum transfer rate.

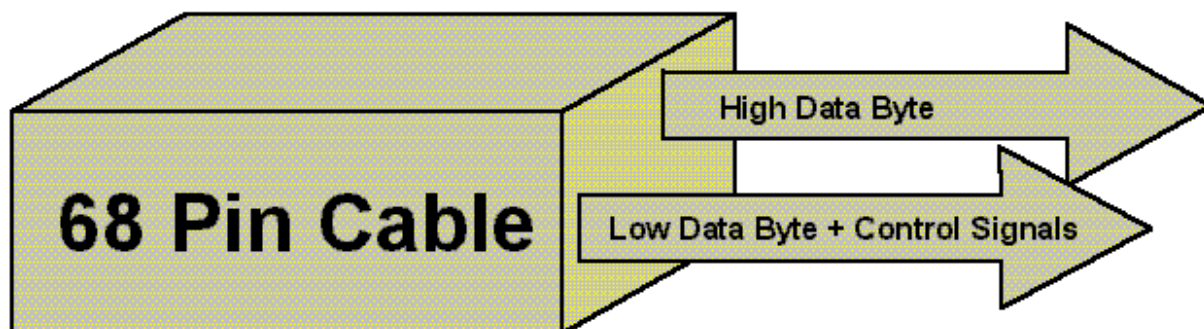
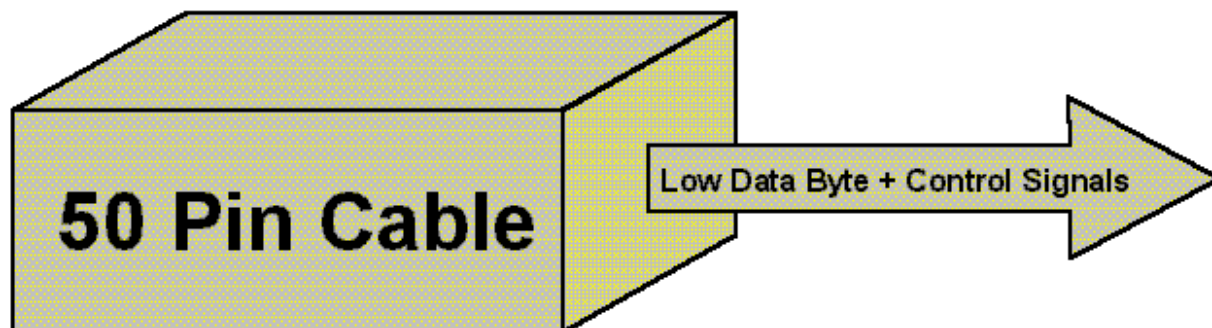
Bus Name	Max Data Rate	Max Bus Speed	Bus Width	Max Total Cable Length
SCSI 1 or 2	5 MB/sec	5 MHz	8-bits (1 Byte)	6 Meters
FAST	10 MB/sec	10 MHz	8-bits (1 Byte)	3 Meters
FAST WIDE	20 MB/sec	10 MHz	16-bits (2 Bytes)	3 Meters
ULTRA	20 MB/sec	20 MHz	8-bits (1 Byte)	1.5 Meters
ULTRA WIDE	40 MB/sec	20 MHz	16-bits (2 Bytes)	1.5 Meters
ULTRA 2	40 MB/sec	40 MHz	8-bits (1 Byte)	25 Meters
ULTRA 2 WIDE	80 MB/sec	40 MHz	16-bits (2 Bytes)	25 Meters

Table 1: SCSI Bus Widths and Data Rates

NOTE: The ‘Max Total Cable Length’ includes ALL cables on the SCSI bus (internal, external, and wire traces on the controller card (assume 6-12 inches for the controller card)). SCSI bus “Repeaters” may be used to extend cable lengths beyond these specified lengths.

## The SCSI Bus

The SCSI bus has two physical ‘variations’ or ‘widths’. The 8-bit (or Narrow) SCSI bus is made up of a single byte (8-bits) of data and a set of control signals. It is cabled by a 50 pin cable. The 16-bit (or WIDE) SCSI bus is an extension of the 8-bit (or Narrow) bus containing all the same signals plus an additional byte of data. It is cabled by a 68 pin cable.



## SCSI ID's

SCSI ID's are used to uniquely identify each device on the SCSI bus. A SCSI bus may have as many ID's as the number of bits in the width of the bus. An 8-bit (or Narrow) SCSI bus has 8 possible ID's ranging in value from 0 to 7; while a 16-bit (or WIDE) SCSI bus has 16 possible ID's ranging in value from 0 to 15. Devices may be assigned any ID in the range but controllers should be limited to ID's 0 through 7 to insure proper operation with any 8-bit (or Narrow) devices that might be installed. The default ID assigned to the host adapter and boot device varies with adapter implementation (see your controller documentation for more information).

ID values not only identify the device or controller but also determine the 'priority' that a device or controller receives on the bus. ID's 0-7 are the highest priority with 7 being the highest; followed by 8-15 with 15 being the highest. SCSI ID priority is as follows:

**Important:** SCSI ID's define priority, not physical location on the cable.

HIGH -----PRIORITY-----LOW

7 6 5 4 3 2 1 0 15 14 13 12 11 10 9 8



# Termination

Termination is an extremely important requirement of the SCSI bus. It is beyond the scope of this paper to explain the technical aspects as to why termination is required but it should be stressed that it is extremely important to the proper operation and reliability of a SCSI configuration. High-speed SCSI busses require high quality signals. Termination directly affects the 'quality' of the electrical signals on the SCSI bus (especially at the higher speeds). Furthermore, the quality of the signal directly affects the reliability of SCSI bus operation.

SCSI termination comes in two variations; Passive and Active. Passive termination uses very simple resistor networks powered directly by the "Term Power" signal on the SCSI bus. Such a configuration worked in SCSI-1 configurations but is unacceptable in today's high-speed SCSI configurations. Active termination was introduced in the SCSI-2 standard. Active termination uses voltage regulation in addition to a different resistor network connection to achieve superior transmission characteristics.

SCSI termination also comes in two 'sizes': Narrow (8-bit) and Wide (16-bit). The Narrow terminator is a 50 pin device and only terminates the Low Data byte and bus control signals. The Wide terminator is a 68 pin device and terminates the Low Data byte and the bus control signals that make up a Narrow bus, plus the additional High Data byte of Wide SCSI.

Termination of a SCSI bus is achieved by placing special termination circuits at both ends of the bus. Termination must not be applied at any other points on the SCSI bus. More than two terminators on a SCSI bus may overload the electrical drivers of the devices and result in damage. Improper termination can manifest itself in various ways, most of which occur intermittently!

<p><b>Important:</b> Every SCSI bus must have 2 terminators (no more, no less); one at both physical ends of the bus.</p>
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Properly terminating a SCSI bus is probably one of the most confusing aspects of SCSI. One of the most common misconceptions is that *devices and controllers* are what require termination. It is the *SCSI bus* that must be terminated, **not** the *device*. One 'buzz phrase' that is used in SCSI circles is **'Terminate busses, not devices'**.

In general, Terminators exist in several forms.

- Built into devices or controllers
- Assembled permanently onto cable end
- Plug in's for last cable connector

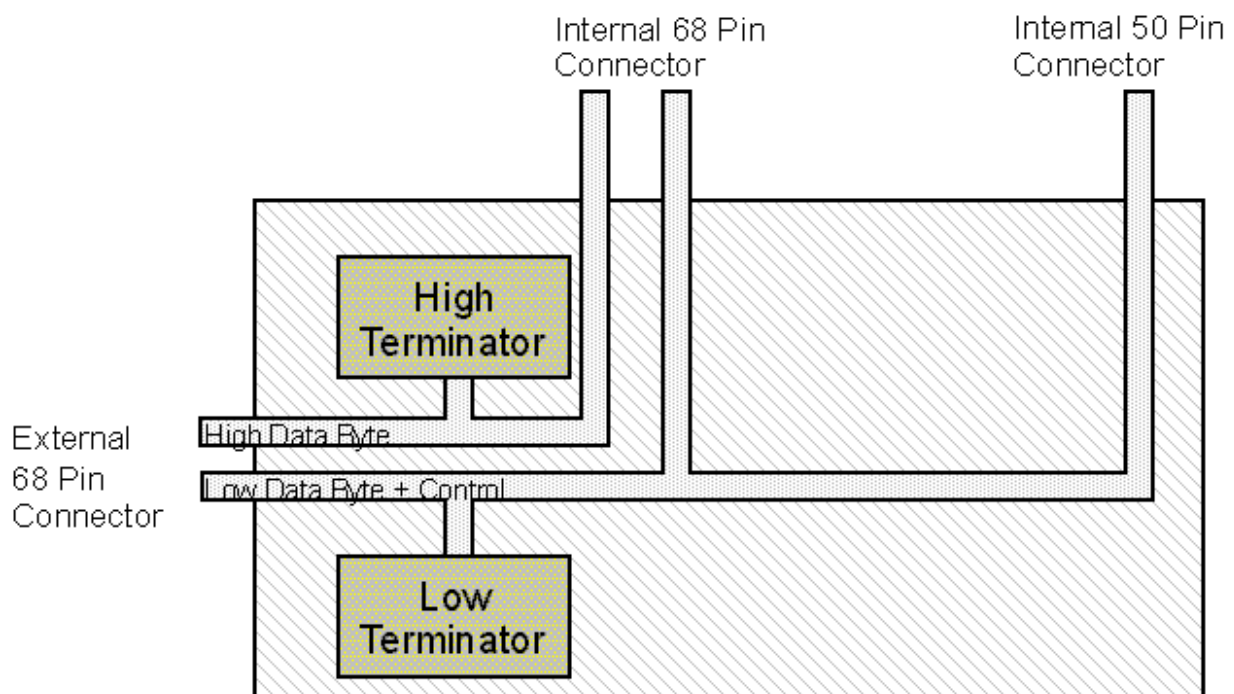
- Built into external bus width converters

## Terminating the PCI Fast/Wide and PCI Fast/Wide Ultra Adapters

The PCI Fast/Wide and Fast/Wide Ultra adapters provide three connectors on which SCSI cables can be attached.

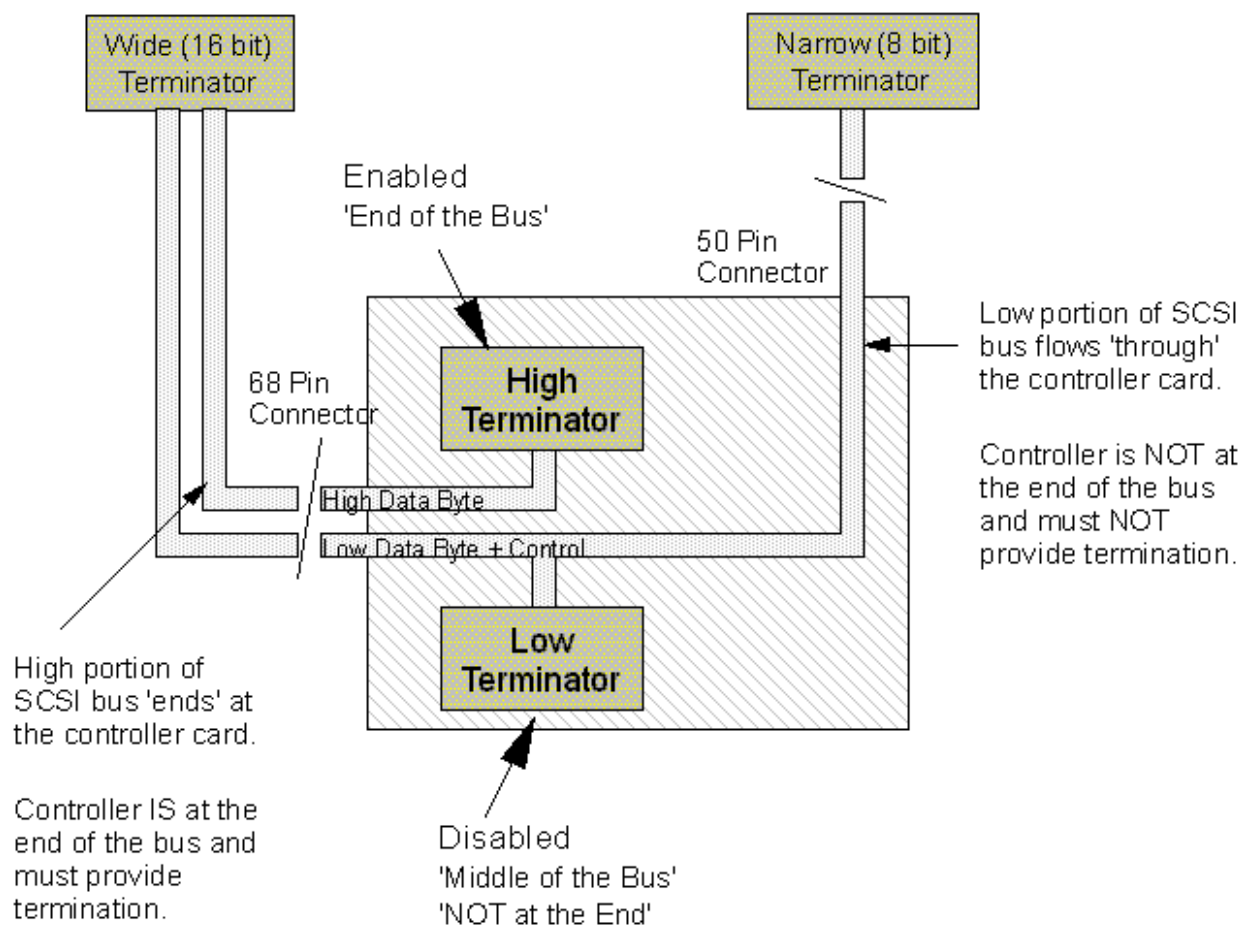
- 68 Pin External
- 68 Pin Internal
- 50 Pin Internal

A **maximum** of two (out of the three) connectors may have cables attached in a valid configuration. The following diagram shows how the SCSI bus connectors and terminators are logically configured.



Both the PCI Fast/Wide and PCI Fast/Wide Ultra adapters contain built-in SCSI bus terminators for use when the adapter is at one physical end of the SCSI bus (i.e. you are using only internal or only external devices). The design of the controller allows for individual control of the low and high bus portions of the terminators.

Individual control of the high and low portions of the terminator is required due to the capability of the controller to support both Wide and Narrow SCSI cables on a single SCSI bus. When a Wide and Narrow cable are simultaneously attached to the controller, the high and low portions of the SCSI bus are in different 'configurations'. The following diagram illustrates this situation:



In addition to manual control, the PCI Fast/Wide Ultra adapter provides an “automatic” termination mode that properly configures the low and high bus terminators based on which connectors have SCSI cables attached. The Automatic mode should always be selected for

normal operation. With the PCI Fast/Wide adapter, the high and low terminators must be configured manually.

The following table indicates the proper settings for the High and Low bus terminators. These are the settings that result from use of ‘automatic’ termination mode on the PCI Fast/Wide Ultra adapter:

External 68 pin Connector Used	Internal 68 pin Connector Used	Internal 50 pin Connector Used	High Terminator	Low Terminator
Yes	No	No	Enabled	Enabled
No	Yes	No	Enabled	Enabled
No	No	Yes	Enabled	Enabled
Yes	Yes	No	Disabled	Disabled
No	Yes	Yes	Enabled	Disabled
Yes	No	Yes	Enabled	Disabled

## Terminator Power

The SCSI standard defines a ‘signal’ on the SCSI cable, which supplies power for the terminators. At least one SCSI controller or device must be configured to provide terminator power to this cable wire.

**Important:** SCSI terminators require power in order to operate. A SCSI bus may be properly terminated, but still not function properly if Terminator Power is not supplied.

Each supplier of Terminator Power must provide isolation and current limiting protection for safety reasons. This is usually done with diodes and fuses or circuit breakers.

Many devices have jumpers or switches to enable or disable the supplying of Terminator Power. Terminator Power is often abbreviated as Term Power or T Power. See your option documentation for details.

It is recommended that controllers always be configured to supply Terminator Power if they offer such capability. Most controllers (ServeRAID, PCI Fast/Wide, PCI Fast/Wide Ultra) supply Terminator power by default. The PCI RAID Adapter (Mylex DAC960) does not supply Terminator power. Configurations with this controller require Terminator power to be supplied by a device other than the controller. See your user documentation for details.

It is recommended that a minimum number of controllers or devices supply Terminator power to a SCSI bus. This recommendation is made for safety reasons to reduce the maximum current that will be carried by the wire in the SCSI cable in the unlikely event of a short circuit condition.

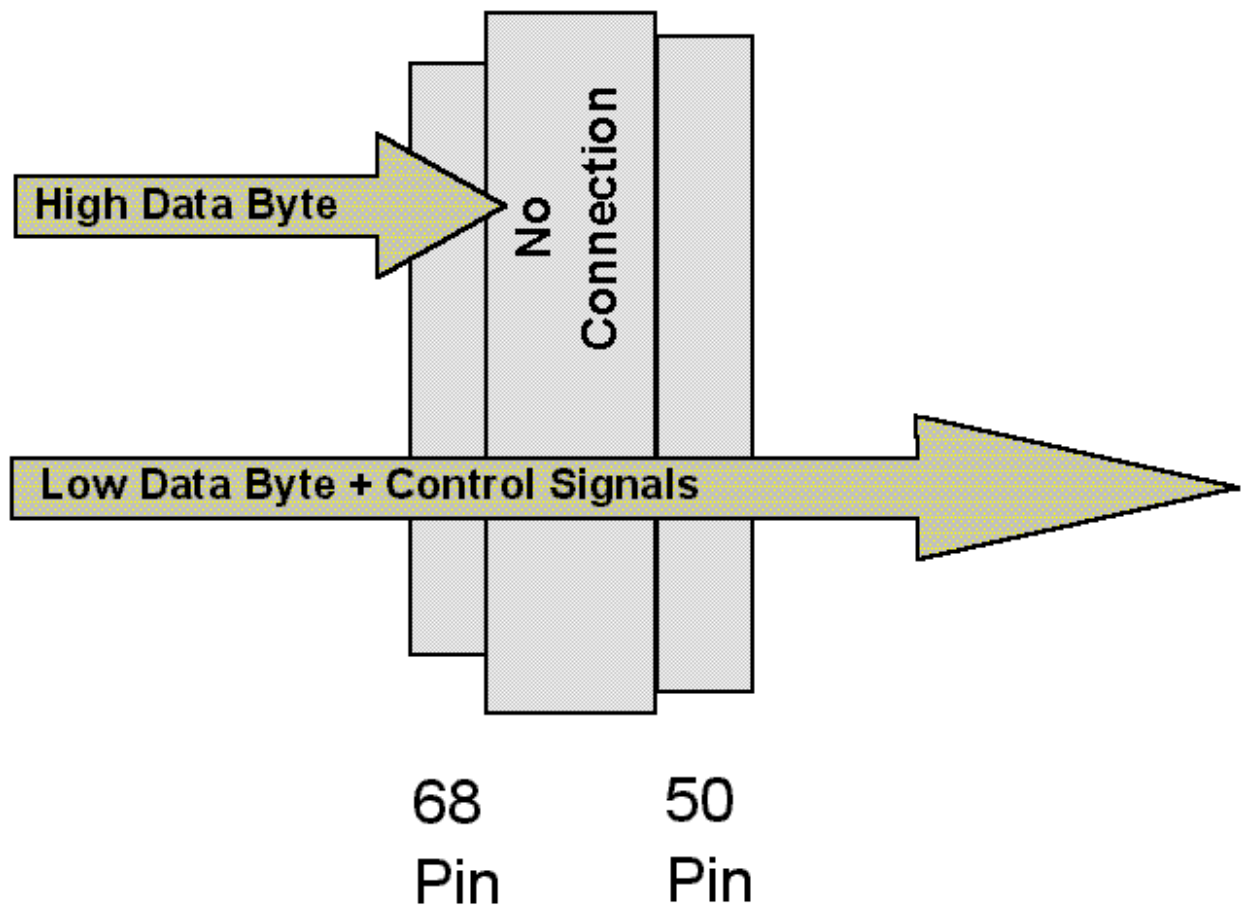
A NARROW (8-bit) SCSI device must not be used to supply Terminator power to a WIDE (16-bit) SCSI bus. A Narrow device is only required to supply sufficient power to operate a pair of Narrow (8-bit) terminators. WIDE (16-bit) terminators require twice the power of their Narrow counterparts and would require more power than a NARROW device would provide. A WIDE (16-bit) device provides sufficient power for WIDE terminators.

Note that supplying Terminator power is NOT the same as supplying Termination. Both proper SCSI bus termination and Terminator power must be present for proper operation.

## Bus Width Converters

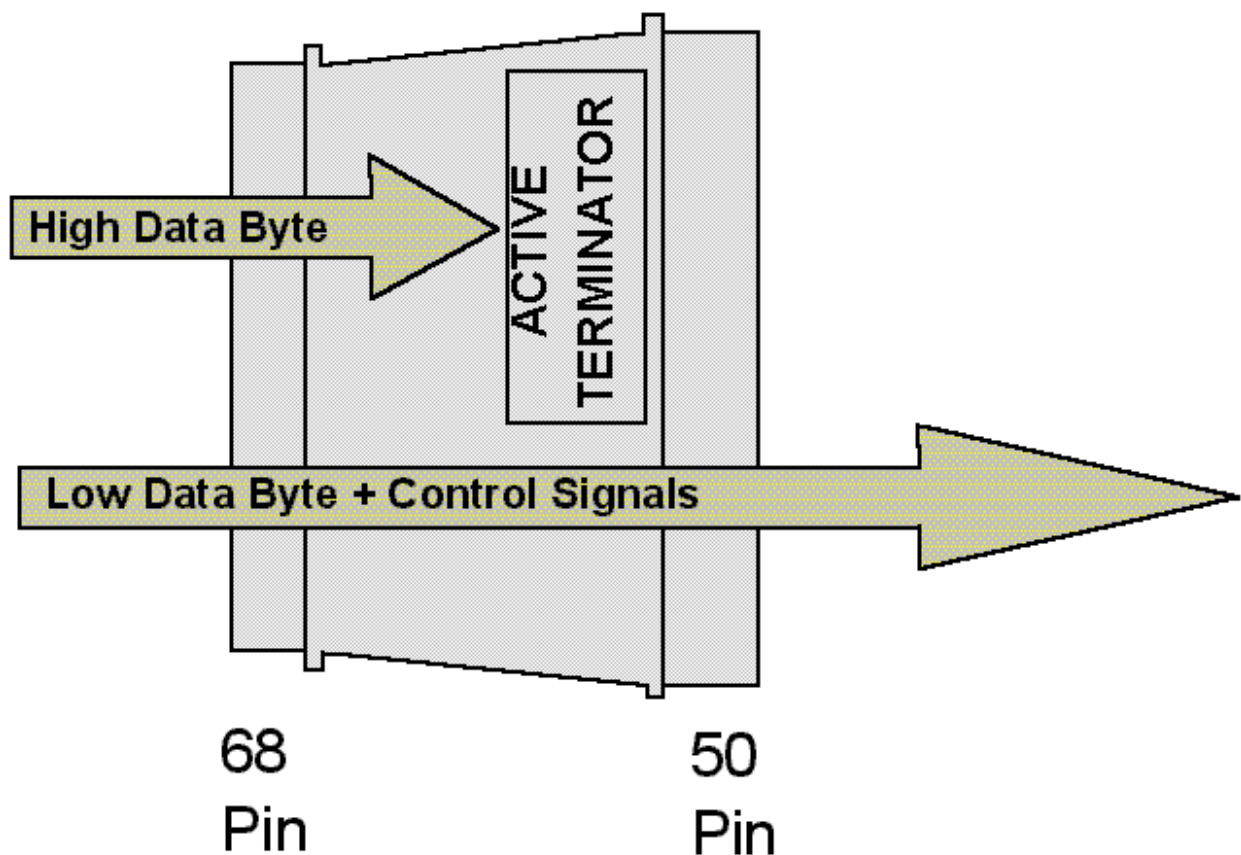
### Internal 16 to 8-bit converter

An internal 16 to 8-bit converter is an industry standard component used to attach a Narrow (8-bit) device to a Wide (16-bit) SCSI Bus. This adapter has a 68 pin connector as its input and a 50 pin connector as its output. The converter 'plugs in' to the 8-bit device and to the 68-pin Wide SCSI ribbon cable. An 8-bit device connected to a 16-bit bus with this converter **MUST NOT** be used to provide bus termination (as this would only terminate 8 out of the 16 bits). Care must be taken to insure that the 8-bit device **DOES NOT** have termination enabled nor should it be configured to supply Terminator power. Ultra speeds are not supported on SCSI busses which have devices attached using a bus width converter.



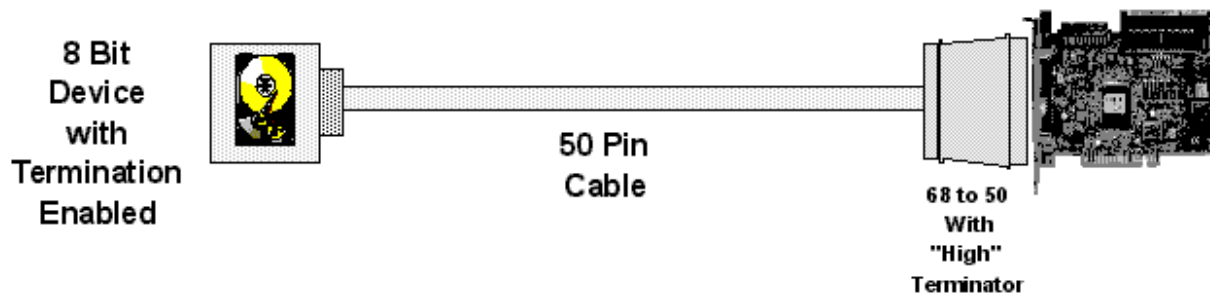
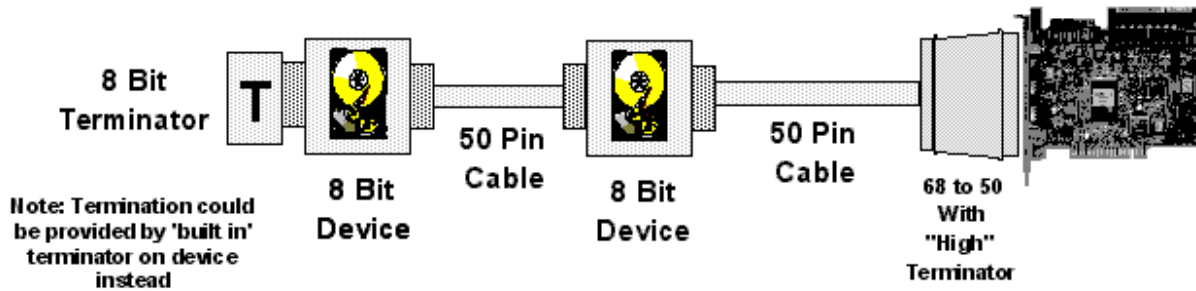
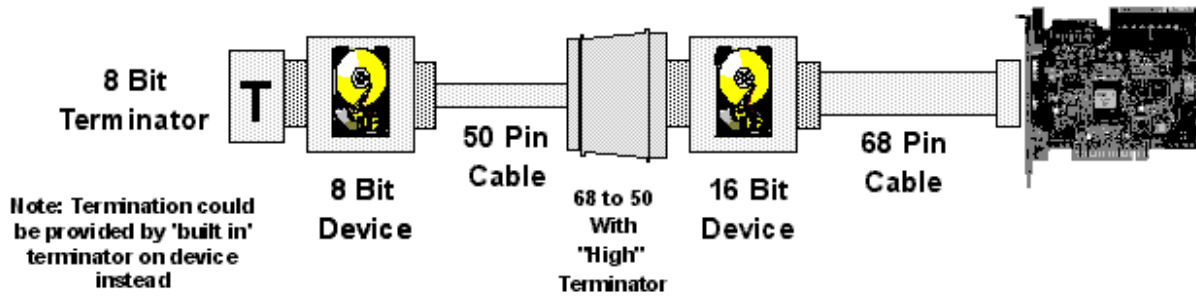
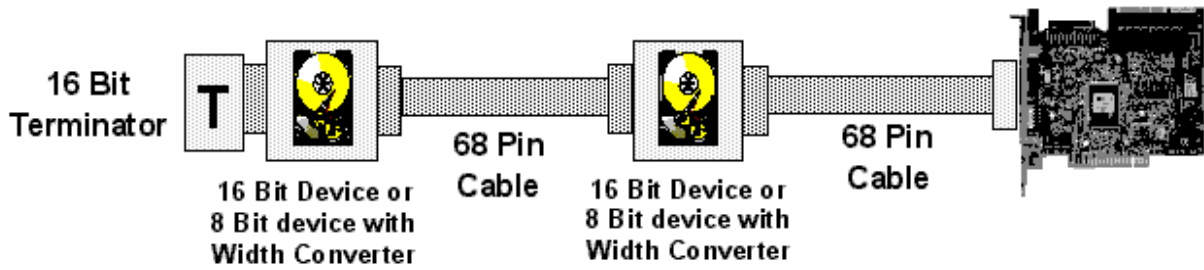
## External 16 to 8-bit converter

An external 16 to 8-bit converter is an industry standard component used to attach an external Narrow (8-bit) cable to an external Wide (16-bit) connector (on a controller or expansion unit). This adapter has a 68 pin male connector as its input and a 50 pin connector as its output. Note that this type of converter becomes the 'end' of the high byte portion of the Wide SCSI Bus and therefore **MUST** provide an ACTIVE terminator for these signals. Terminator power must be provided by a device (or controller) attached to the bus segment on the 68 pin side of the bus width converter. Ultra speeds are not supported on SCSI busses with devices attached using bus width converters. This component is not offered by IBM. Refer to your local cable vendor for more information.



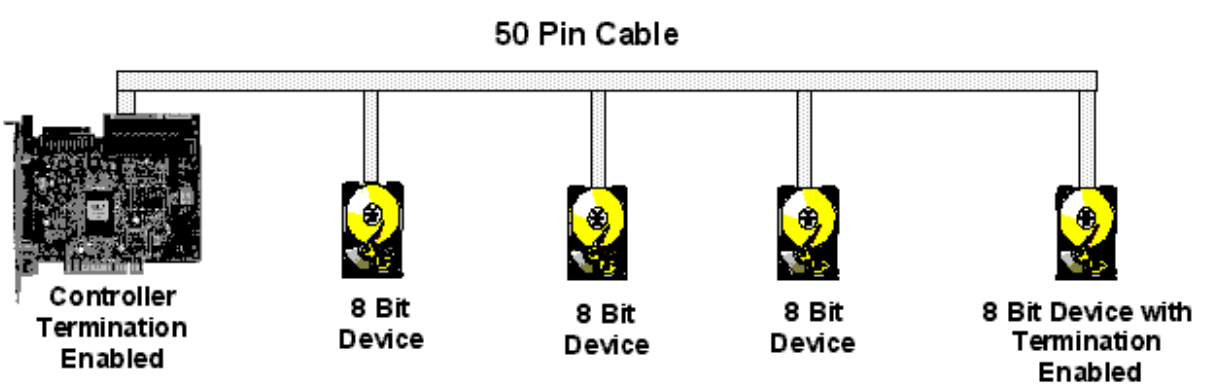
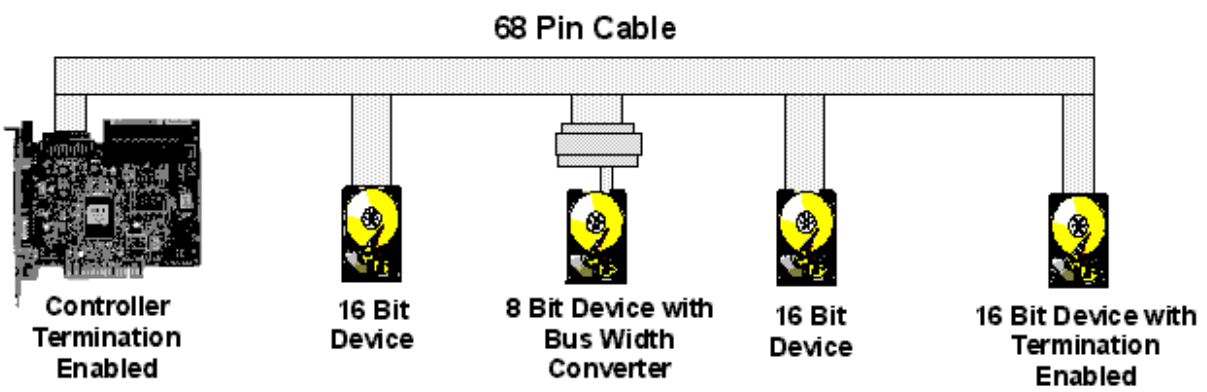
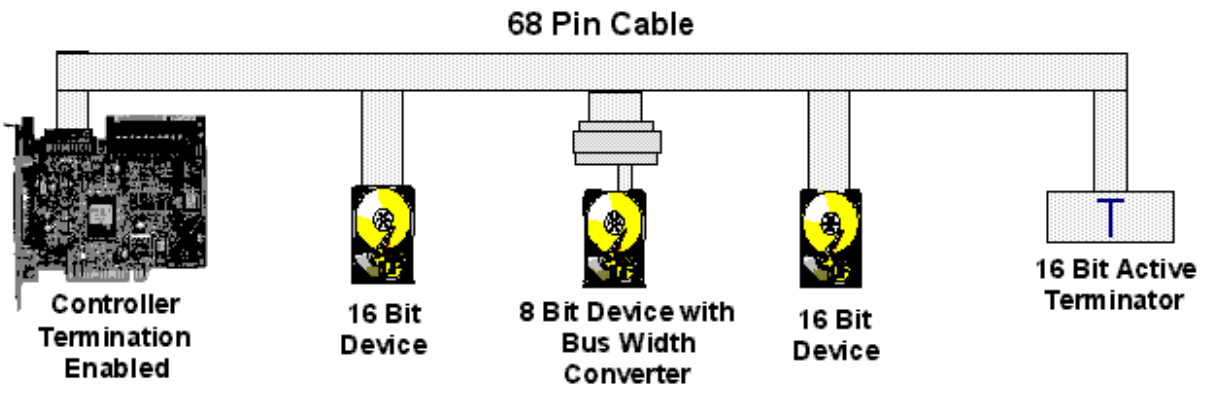
# Configuration Examples

## Valid External Examples



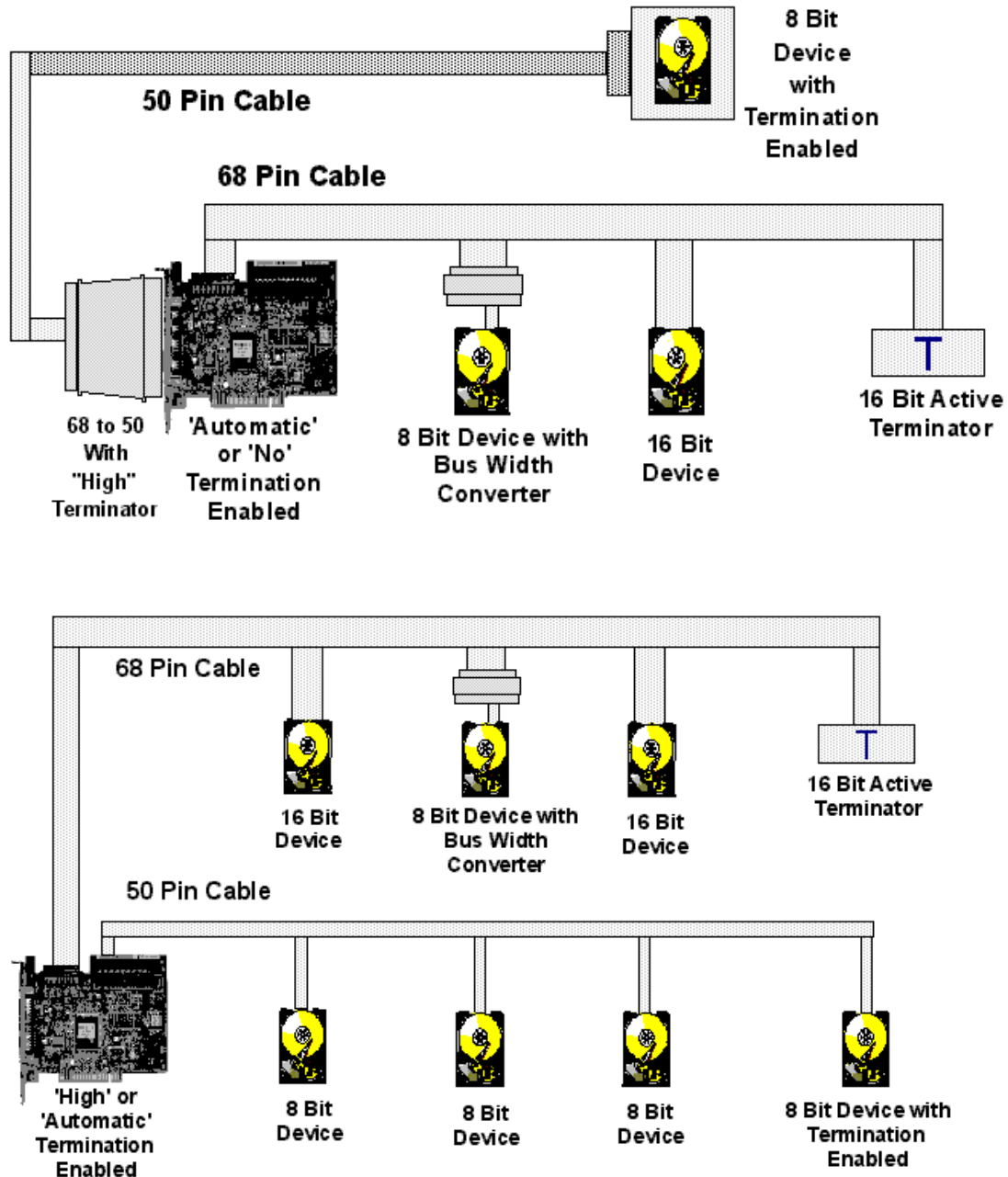


# Valid Internal Examples



## Valid Mixed Internal and External Examples

Mixed internal and external configurations are supported only with the PCI Fast/Wide and Fast/Wide Ultra SCSI controller. This controller has three connectors which only two may be used concurrently. Attempting to use all three connectors concurrently will result in unreliable or non operation. It is recommended that "ULTRA" not be used in any mixed configuration as cable length limitations will very likely be violated. Note that the controller card does not 'know' how long the cables are and will attempt to operate even with an invalid configuration.



## Ultra Guidelines

One of the most commonly asked questions is 'will my configuration run at Ultra speed?' This is not always a simple question to answer. Ultra SCSI speeds stresses the SCSI subsystem to its breaking point. Because of this stress, cable lengths and configuration requirements are limited. One must seriously consider if the perceived benefits of the additional interface speed (which usually provides no noticeable performance improvement) offset the critical nature of the configuration.

Below is a list of guidelines that will assist in creating a configuration that will operate at Ultra speeds:

- Keep cables short (refer to the table on page 7)

- Minimize the number of devices on the bus

- Do not put 'non Ultra' devices (such as CD-ROM's or tapes) on an Ultra Bus

- Do not use bus width converters

- Use Active Terminators

Keeping the cables short is the most important consideration. The SCSI specification allows 1.5 meters of cable with 8 connectors or 3 meters of cable with 4 connectors. Cable length includes ALL wire on the bus (both internal and external). This even includes the length of wire 'traces' on SCSI cards as well as the actual cables. A SCSI adapter can be assumed to have 6 to 12 inches of wire 'traces' which should be subtracted from the maximum allowable cable length. The number of supported connectors includes the one attached to the controller and even the ones not connected to anything! Even an empty connector degrades signal quality.

Every device attached to a SCSI bus results in degradation of the SCSI signal quality. Reducing the number of drives on a SCSI bus results in higher quality signals and more reliable operation.

Non-Ultra devices (such as CD-ROM's, tape drives, and lower speed hard disk drives) may not be designed with sufficient care to insure minimum signal quality degradation. Using devices that have been specifically designed to operate at Ultra speeds provides the highest probability of success in an Ultra configuration. Consider using a separate adapter for lower speed devices.

Please bear in mind that these are only guidelines for Ultra support. For specific information relative to the system that is being configured, please refer to the system documentation or contact the IBM Helpcenter.

## Operating System Device Drivers

SCSI is a standard, in much the same way Ethernet and RS-232 are standards. The SCSI standard defines the electrical characteristics and protocol of the SCSI bus connections but not how the SCSI host adapter appears to the system programs. Thus SCSI host adapters require unique drivers to properly operate in a system. Future industry initiatives such as I2O are attempting to standardize how adapters appear to a system therefore eliminating the need for unique device drivers.

## Other Information Sources

<b>Web Site:</b>	<b>Description:</b>
<a href="http://www.pc.ibm.com/support">http://www.pc.ibm.com/support</a>	Download files, hints and tips, create custom profiles, and frequently asked questions
<a href="http://www.pc.ibm.com/us/compat">http://www.pc.ibm.com/us/compat</a>	Netfinity compatibility information
<a href="http://www.pc.ibm.com/us/netfinity">http://www.pc.ibm.com/us/netfinity</a>	IBM Netfinity home page
<a href="http://www.adaptec.com">http://www.adaptec.com</a>	Adaptec's home page
<a href="http://www.pc.ibm.com">http://www.pc.ibm.com</a>	IBM Personal Systems Group (PSG) home page
<a href="http://www.pc.ibm.com/techconnect">http://www.pc.ibm.com/techconnect</a>	HMMs, white papers, education/certification
<a href="http://www.pc.ibm.com/us/server/sguide">http://www.pc.ibm.com/us/server/sguide</a>	ServerGuide home page
<a href="http://www.redbooks.ibm.com">http://www.redbooks.ibm.com</a>	IBM Redbooks home page
<a href="http://www.training.ibm.com/usedu/">http://www.training.ibm.com/usedu/</a>	IBM PC Institute