

# Technology Note

## PCI Bus Variation



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# PCI Bus Variation

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## References

### PCI

The PCI bus specification is handled by the PCI-SIG (PCI Special Interest Group), which is an association of numerous industrial actors in the field.

Euresys s.a. is a member of the PCI-SIG (vendor ID h1805).

The web site address of PCI-SIG is <http://www.pcisig.com>

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# Purpose of this Application Note

The purpose of this document is to provide Euresys' customers with some background information on PCI bus variants. This will help them to understand how to match frame grabbers and PC motherboards in order to achieve the expected system performance.

## PCI Variants

### Conventional PCI

The original PCI Revision 1.0 local bus specification was introduced in June 1992. The industrial inception of this technology started with PCI Revision 2.0 in April 1993, which included expansion slots and 66 MHz clock rate support. PCI Revision 2.1 in June 1995 introduced significant improvements related to 66 MHz operation and bandwidth efficiency. In December 1998, the Revision 2.2 clarified some detail issues. The next revision to be issued is Revision 2.3. In this document, the specification for 5 Volt add-in cards is removed, although the specification for 5 Volt system connectors is retained. The final revision of the Conventional PCI bus will be Revision 3.0. The specification for 5 Volt system connectors is removed, which definitely precludes the use of 5 Volt add-in cards. Conventional PCI is characterized by a bus width of 32 or 64 bits, and a clock speed of 33 or 66 MHz. Any combination of width and speed can be found. The vast majority of existing desktop PCs are equipped with Conventional PCI technology.

### PCI-X

PCI-X is a high performance evolution of Conventional PCI. It uses the same hardware structure, which makes it possible to operate a PCI-X add-in card in a Conventional PCI slot, and vice-versa. PCI-X allows for a considerably higher bandwidth than Conventional PCI. It is characterized by a higher clock speed up to 133 MHz, and is usually found in the 64-bit bus width, although the 32-bit width can exist. Revision 1.0 initially issued in July 2000 presently specifies PCI-X as an addendum to Conventional PCI. An improvement to PCI-X is under preparation, and will be specified by PCI-X Revision 2.0. It is intended to extend the clocking capability to 266 and 533 MHz. The PCI-X technology is dedicated to server applications, and is therefore found in many high-end PC motherboards.

### PCI Express

PCI Express availability is expected in 2004. PCI Express will be a replacement for Conventional PCI offering much more flexibility and performance while maintaining software compatibility. The hardware bus structure is substantially different, but the card form factor of the existing desktop enclosures will remain. The connector will change. PCI Express uses a serialized point-to-point technology instead of massive parallel data transportation. The initial standard Revision 1.0 has been released in 2002.

## PCI Performance

### Characterizing Parameters

There are two essential parameters characterizing a PCI bus: the bus width and the clock speed. Both of them directly influence the bus performance.

#### Bus Width

The transmission medium used by the PCI bus is a set of 32 or 64 parallel electrical lines. This figure is called the bus width. An elementary block of 32- or 64-bit data is transferred from a source agent (initiator) to a destination agent (target) within one clock cycle. 32-bit data can be considered as a set of 4 bytes, and 64-bit data can be considered as a set of 8 bytes.

#### Clock Speed

The PCI bus is a synchronous system. This means that each agent connected to a bus is actuated by a clock signal exhibiting the same frequency and phase. For Conventional PCI, the clock speed is 33 or 66 MHz. For PCI-X, the clock speed is 66 MHz or 133 MHz. The data transfer principle used by PCI involves bursts of data transmitted at the clock speed. The pair of agents exchanging data are called "good citizens" when they cooperate to realize long data bursts. The clock speed is an indication of the data throughput capability of the bus, but high performance transfer is subordinated to the good citizenship of all intervening agents, including the motherboard itself.



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## Data Rate

At a given time, an initiator agent is transferring data with a target agent. This transaction cannot last more than a few microseconds, as another agent may request its own transfer resources. An arbitration process successively assigns the bus ownership to all requesting agents in such a way that all pending transactions are satisfied. The practical data rate over the bus is the effective transfer rate for all transactions averaged over a substantial period of time. The data rate is expressed in Megabytes per second (MB/s). The peak data rate is a theoretical figure which is only reached during a very short amount of time inside a data burst. The practical data rate is always lower than the peak data rate. Achieving sustained full speed bursts is a way for the practical data rate to approach the peak data rate. However, other considerations, such as transaction arbitration latencies, limit the usability of the peak data rate. Dictated from experience, a practical data rate in excess of some 70% of the peak data rate should not be expected. The terms “bandwidth” and “throughput” are used as equivalent to “data rate”.

## PCI Bandwidth Summary

PCI variant	Clock speed	Bus width		Peak data rate	Practical data rate
Conventional PCI only	33 MHz	32 bits	4 bytes	132 MB/s	90 MB/s
		64 bits	8 bytes	264 MB/s	180 MB/s
Conventional PCI or PCI-X	66 MHz	32 bits	4 bytes	264 MB/s	180 MB/s
		64 bits	8 bytes	528 MB/s	360 MB/s
PCI-X only	133 MHz	32 bits	4 bytes	532 MB/s	360 MB/s
		64 bits	8 bytes	1064 MB/s	720 MB/s

The peak data rate is obtained by arithmetically multiplying the clock speed and the number of bytes making up the data width. The practical figures supplied in this table should be considered as a “rule of the thumb” when evaluating system performance. The real performance essentially depends on systems characteristics, and should be validated on a real system.

# Number of Slots

## The PCI Bus as a Set of Slots

All desktop and server PC motherboards can accommodate additional internal hardware to fulfill special peripheral functions, such as frame grabbers. The prevalent way to achieve this is the peripheral bus, namely the PCI bus. The PCI bus exposes several so-called slots connected in parallel, enabling the insertion of add-in cards on a one-per-slot basis to implement the additional peripheral functions. For electrical reasons, any PCI bus has a limited number of slots. The standard defines how many slots a given PCI bus is allowed to expose. Modern motherboards may exhibit more than one bus, possibly with different attributes. The following applies to each individual bus provided by the motherboard.

## Maximum Slot Summary

PCI variant	Clock speed	Practical data rate
Conventional PCI only	33 MHz	Four
	66 MHz	Two
PCI-X	66 MHz	Four
	133 MHz	Two

For operation at 66 MHz, PCI-X is preferred to Conventional PCI, as the number of available slots is double. This is a key technical feature conveying a strong justification for PCI-X.



# Signaling Voltage

## Definition

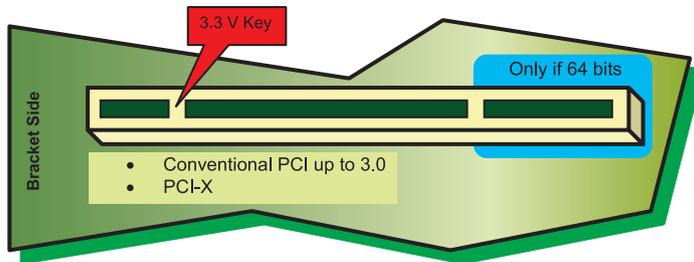
The digital data transmission through the PCI bus operates under certain voltage levels defining the low and high logic states. For technological reasons, it has been adequate to consider two systems in this respect. These are the 5 Volt signaling environment and the 3.3 Volt signaling environment. The signaling environments cannot be mixed. This means that all add-in cards linked to a PCI bus must adopt the signaling voltage imposed by the motherboard.

The 5 Volt system is older, and tends to be replaced by the 3.3 Volt system. This signaling voltage migration is the main motivation for the latest revisions of Conventional PCI from 2.2 to 3.0.

## Slot Variants

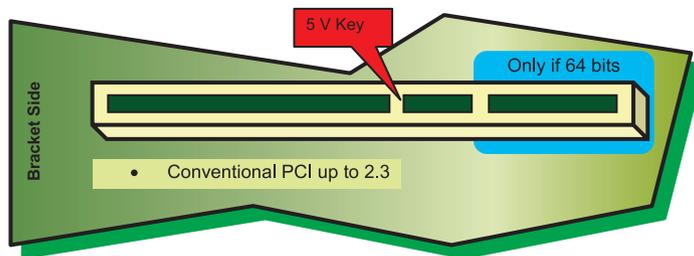
The system connectors (or slots) can be of the 3.3 Volt or 5 Volt type. All slots of a particular PCI bus are identical, reflecting the signaling voltage (3.3 Volt or 5 Volt) imposed by the motherboard.

### 3.3 Volt Connector



A bus complying with any PCI variant can exhibit the 3.3 Volt connector.

### 5 Volt Connector

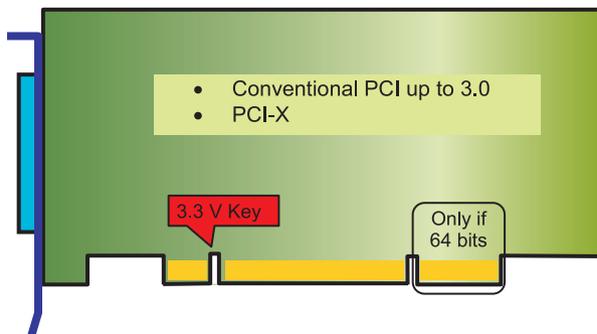


A bus complying with Conventional PCI 3.0 or PCI-X cannot exhibit the 5 Volt connector.

## Add-in Card Variants

A PCI board can be designed to be operated in the 3.3 Volt or 5 Volt environment, or both. In the latter case, it is often called a "universal" card. There are three types of add-in cards featuring an edge connector shape that adequately fits into an allowable system connector.

### 3.3 Volt Add-in Card

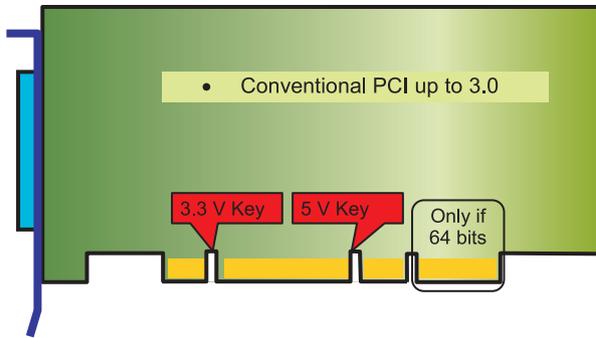


An add-in card complying with any PCI variant can be a 3.3 Volt card.



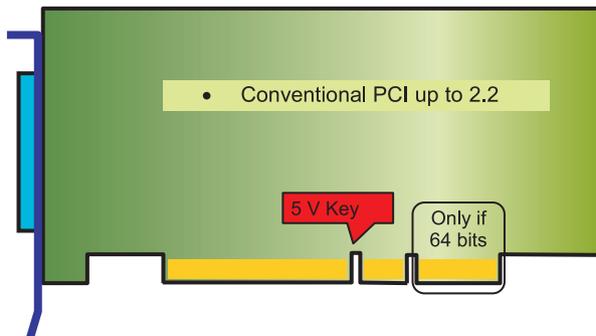
# Technology Note. PCI Bus Variation

## Universal Add-in Card



An add-in card complying with PCI-X cannot be a universal card.

## 5 Volt Add-in Card



An add-in card complying with Conventional PCI 2.3 or 3.0 or PCI-X cannot be a 5 Volt card.

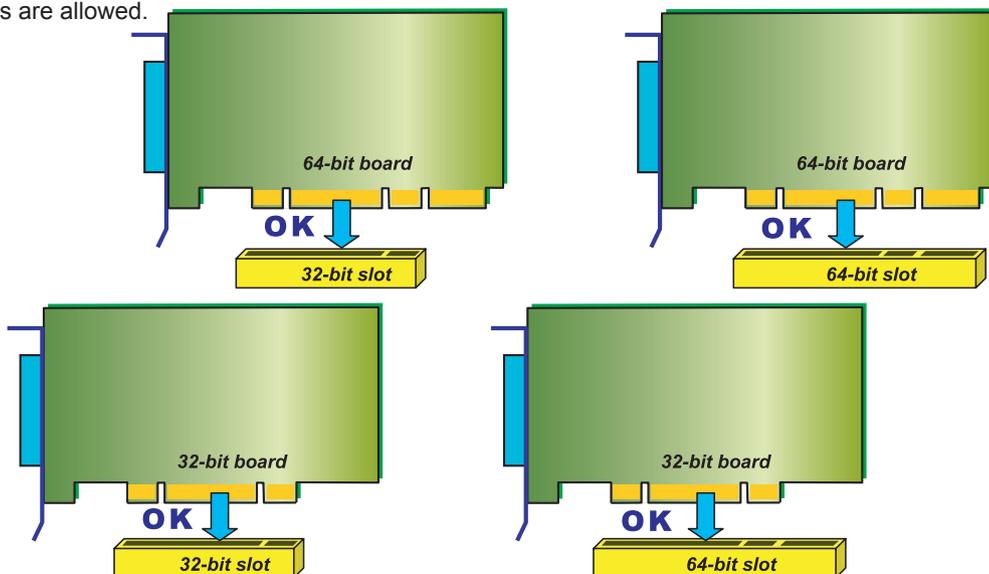
# Interoperability

## General Rules

Whenever it is physically possible to insert an add-in card into a slot, it is allowed. This is true regardless of the keying system and the width of the PCI bus (32 or 64 bits). The 64-bit PCI slots and add-in cards are distinguished by an additional group of contacts. The large degree of compatibility between different variants is a clear advantage of the PCI principle. However, the user should be aware that mating an add-in card of kind A to a slot of kind B may result in an overall loss of performance. Usually, the system performance aligns itself with the weaker device. This important point is discussed in the course of this document.

## Bus Width Interoperability

All combinations are allowed.

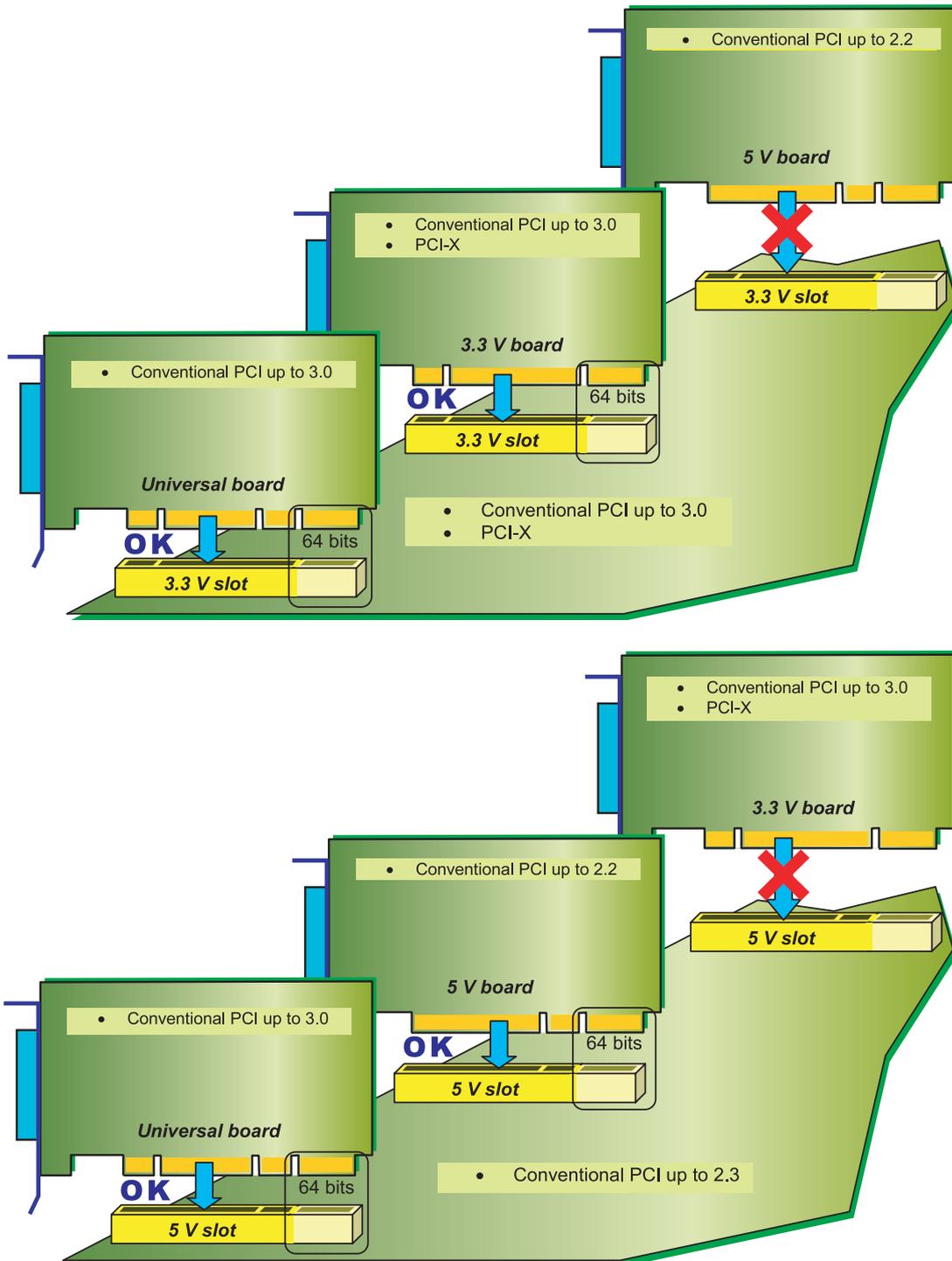


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When using a 64-bit board in a 32-bit slot, the data rate achieved during data transfer is half the data rate achievable if the motherboard bus was 64-bit capable. When using a 32-bit board in a 64-bit slot, the performance of the board is not degraded, but the motherboard bus capability is somehow wasted. The data rate in MB/s related to the board should be counted as double in its contribution to the global bus traffic. These considerations must be taken into account at the system design stage.

### Signaling Voltage Interoperability

There is no way to mix 3.3 Volt and 5 Volt signaling voltage. The problem is solved thanks to the keying system of both the connector and the board.



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### Bus Variant Interoperability

It is now clear that Conventional PCI and PCI-X are interoperable. But the following consideration must be taken into account at the system design stage.

A PCI-X compliant board is able to operate in two modes:

- The PCI-X mode
- The Conventional PCI mode

When working in the Conventional mode, a number of functional features offered by PCI-X are not available.

Slot compliance	Board compliance	Operating mode
PCI-X	All bussed boards are PCI-X	PCI-X
	At least one board is Conventional PCI	Conventional PCI
Conventional PCI	PCI-X	Conventional PCI
	Conventional PCI	Conventional PCI

To fully take advantage of a PCI-X compliant board, one should select a PCI-X compliant motherboard, and avoid occupying other bus slots with Conventional PCI boards. When using a Conventional PCI board in a PCI-X slot, the performance of the board is not degraded.

### Clock Speed Interoperability

The clock speed for a particular PCI bus is unique. It automatically adapts to the slowest clock speed utilized by the system bus and the add-in cards. This is a way to guarantee interoperability, but it can be a critical system consideration, as the data rate performance is proportional to the clock speed. For instance, the data transfer capability of a 66 MHz board installed in a 66 MHz slot will be divided by a factor of two when a 33 MHz board is installed in another slot of the same bus.

Slot clock speed	Board clock speed	Operating speed
133 MHz	All bussed boards are 133 MHz	133 MHz
	At least one board is 66 MHz	66 MHz
	At least one board is 33 MHz	33 MHz
66 MHz	All bussed boards are 66 MHz or higher	66 MHz
	At least one board is 33 MHz	33 MHz
33 MHz	All bussed boards are 33 MHz or higher	33 MHz

## Powering Voltage

Systems that provide PCI connectors are required to provide power supply through four rails: +5V, +3V3, +12V, -12V.

The signaling voltage and the power voltage are not related. All PCI system slots are required to deliver +5V and +3V3 power independently of their 5 Volt or 3.3 Volt signaling system.

However, a few PC systems featuring a PCI bus with 5 Volt signaling environment have been observed with a lacking +3V3 power supply rail. This potentially causes an interoperability issue that does not arise when the PC manufacturer complies with the standard. In order to overcome this issue, all the 5 Volt and universal frame grabbers provided by Euresys do not use the +3V3 power rail. Instead, the necessary power is extracted from the +5V rail.



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