PC BUSES

The PC's bus is the circuitry that ties all the devices on your motherboard together. The bus concept is to: "extend and link the signals of your system"; however, you have to know what it means to understand it.

In this section we will discuss:

- Bus Basics
- Bus Types
- Multiple Buses
- Bus Standards

BUS BASICS

To understand a PC's bus, you must be aware that a computer has many components such as a Central Processing Unit (microprocessor), clocks, storage devices, input/output devices, etc. These devices must be linked together to perform a function. The 'bus' (or should I say 'BUSES'?) provides a highway for passing information between the devices on the system.

Since this is not an electrical engineering level tutorial, let me say that the bus ties these devices together, so that a signal from your keyboard is displayed on your screen (CRT); a record from a file on a hard disk drive is read into memory and processed at the direction of your CPU; a file is sent to a printer for printing, etc. SO, electrical signals representating information flows along the bus from one device to another.

Your computer may contain several types of buses, among them are:

1. CPU bus or 'system' bus.
2. An address bus
3. Memory bus
4. I/O or Expansion Bus

and they are all located on the motherboard! There is a new bus called the "Universal Serial Bus" that connects to the motherboard, and some consider the wires between the connector and the devices attached to it to be the bus.

When we speak of the 'bus', most of us are speaking of the 'expansion' bus.

Most external devices and storage devices will be connected to the I/O bus through the a local bus. External devices are usually connected to "expansion" cards or controllers which are placed in an "expansion" bus slot located on the motherboard. Electronic circuitry connects the expansion slots together and connect to the system bus. Each of the expansion slots have an address, used to route information to a particular expansion card installed in the expansion slot. Other devices also have addresses such as the keyboard, the memory, etc.

Buses have many factors that affect their performance and that must be considered and solved for them to function:

- Data Sharing
- Addressing
- Power
- Timing
- Flow Control
- System Control

BUS TYPES

There are several "bus" standards, among them are:

- Industry Standard Architecture (ISA).
- Micro Channel Architecture (MCA)
- Enhanced Industry Standard Architecture (EISA)
- Peripheral Component Interface (PCI)
- VESA Bus
- Universal Serial Bus

The most popular in the newer models of PCs are PCI and combinations of PCI and others.

Now, bus size (number of binary bits) greatly affects the performance of your computer. The first microprocessors in 1971, had a 4 bit bus, later models introduced 8, 16, 32, and 64 bit buses. Most of the early buses had a speed of 8.25MHz, where current buses operate at higher levels such as 66MHz (all multiples of 8.25Hz.)

BUS SIZES

Intel Processors

Model	Year	Register Bits	Bus Bits	Physical Address
4004	1971	4	4	1k
8008	1972	8	8	16k
8080	1974	8	8	64k
8085	1974	8	8	64k
8086	1978	16	16	1M
8088	1980	16	8	1M
80186	1982	16	16	1M
80188	1982	16	16	1M
80286	1982	16	16	16M
80386	1985	32	32	4GB
80386SX	1988	32	16	4GB
80486 DX, DX2 SX, DX4	1989	32	32	4GB
Pentium	1993	64	64	4GB
Pentium Pro	1995	64	64	4GB

ISA BUS

The Industry Standard Architecture (ISA) was approved in 1987 by a committee of the IEEE (Institute of Electrical and Electronic Engineers) formally approved the ISA standard.

The ISA bus is actually an 8 bit or 16 bit bus, and operates at 8.25 mhz, or approximately 4MB transfer rate with the 8 bit bus, and 8 mb/s throughput maximum with the 16-bit bus. The expansions slots on a PC's motherboard usually allow for both a 8 or 16 bit ISA card to be connected. This is not the most efficient size, and the ISA standard is being replaced gradually with EISA and PCI buses.

You may notice that most buses operate at a sub-multiple of the actual system clock speed. For instance, 8.25 is one fourth the speed of a 33mhz system. The sub-multiples of speed is how a bus clock and system can maintain synchronous operations.

This graphic shows a ISA 16-bit expansion card and its interface to a 16-bit ISA expansion slot. A 16 bit card has the two sets of connector pins as shown. An 8-bit card would only have the set of pins to the right of the cut in the card.

ISA expansion buses come in Plug-and-Play (PnP) versions. PnP works without modification to an ISA bus. However, most advanced systems with ISA will modify the configuration by adding a single slot specific signal to each bus connector.

EISA PC BUSES

The Enhanced Industry Standard Architecture (EISA) was developed was developed in 1988 by a group of nine companies including AST Research, Compaq Computer Corporation, Epson, Hewlett-Packard, NEC, Olivetti, Tandy, Wyse, and Zenith.

It was to be a 32-bit design to increace the capabilities of ISA, and to compete with the 32-bit design of the Micro Channel Architecture (MCA). With this increase in bus width and using an 8.33 MHz clock, the EISA can reach a theoretical 33 MB/s transfer rate. MCA at this time responded with a bus clock rate of 20Mhz and a 'potential' bus transfer of 160MB/s far outstripping the EISA. However, the EISA development group responded by beginning work on an EISA-2 specification that will move data at a potential transfer rate of 132 MB/s.

In actuallity, neither MCA or EISA had a great influence on the market and the concept of a 'Local Bus' was introduced in 1991 by NEC became the most important concept in buses, and led later to the VESA Local Bus, and the PCI Local Bus. However, there are still a few motherboards available which have EISA bus in conjunction with PCI buses.

PCI BUSES

The Peripheral Component Interface (PCI). This bus was introduced by Intel Corporation in July 1992, a little more than a month before the VESA Local Bus specifications were announced. It was designed primarily for high speed operation of the expansion bus. It was released again as PCI Release 2.0 in May 1993. PCI is the most popular 'bus' in the mid-1990s and is usually combined on a motherboard with an ISA or EISA expansion bus. For example, many motherboards have a number of pure ISA or EISA slots, some PCI slots, and one or more PCI/ISA combination slots.

The PCI bus was originally supposed to be a "local bus", but it is said it is a high speed inter-connection system. However, it runs at superior speed, for instance some of the SCSI interfaces can run up to 40 MB/S transfer rates, although some books indicate the original PCI bus was a 32 bit, 33MHz bus, which could move data at up to 132MBytes/sec as a theoretical maximum - this includes overhead.

The May 1993 release broadened the data path to 64 bits to conform to the Pentium processors release in 1993. Please note the second release of the VESA Local Bus standards did the same.

The PCI standard provides an interface to the ISA, EISA, and MCA buses, but PCI can replace these older buses in a motherboard design. A pure PCI bus machine is possible, but most motherboards for years will still have an interface to ISA and EISA expansion slots.

Remember: Most motherboards have both PCI and ISA, or PCI and EISA, or even PCI and MCA slots. The PCI I/O controller will route traffic from the CPU to the proper bus - either the PCI bus or the ISA/EISA bus.

Some points about the PCI Bus:

1. Intel intended the PCI to be the single industry standard for buses.

2. It was designed for CPUs from 33 MHz clock speeds and up.

3. PCI is basically process or independent.

4. PCI is not a true "local" bus.

5. PCI has 3 flow control signals which enable it to accommodate devices that cannot operate at the full speed of the PCI bus.

6. The version 2.0 release is designed to work in PCs based on the ISA, MCA, and EISA buses.

7. The revised standard defined compatibility so that the same board can be adapted to fit the form factor of an ISA, EISA, or MCA system.

8. The PCI bus is ideal for the Pentium and P6 type machines because it's speed is theoretically 528MB/s at the 66MHz bus speed and 64 bit bus. It appears to work also with the 75 and 83MHz buses being introduced in motherboards.

The PCI Bus has an I/O Controller connected to the CPU. The system is supposed to operate as follows:

1. Signals from the CPU go to the I/O controller for the PCI local bus operations. The controller is between any ISA or EISA controller.

2. The PCI controller examines all signals from the CPU to determine their destination.

3. The PCI controller routes all signals meant for the ISA/EISA/MCA bus to the controller for that bus. The speeds to the ISA/EISA/MCA bus will be at 33MHz, and then slowed to the 8-10MHz range used by the destination bus.

4. The PCI controller routes all signals for the PCI local bus to the local bus adapter slots. The data along this path travels at 33MHZ and is 32 bits.

In effect, the traffic is routed by the I/O controller to the appropriate type of expansion slot for which it is destined. If it is to go to a card in a PCI slot, that is where it is sent. All traffic going to the CPU is collected by the PCI I/O controller and forwarded to the CPU.

PCI buses will probably become the "de facto" bus for the industry. PCI is designed to replace older buses such as ISA, EISA, and MCA. However, you will see PCI/ISA or PCI/EISA mixes for some time - there is a large base of these cards in the world; however, these mixes are already falling by the wayside.

PCI and EISA combinations are becoming more common, and even this combinations will gradually disappear.

VESA Local BUS

The Video Electronics Standard Association (VESA) is a group of PC vendors who developed the VESA local bus. This group developed the standard for the VESA Local BUS (VL Bus) standard and formally announced in August 1992.

It was designed to speed up video displays, but its specification was general enough for other high-speed data transfers.

VESA provided a standardized connector and protocol for local bus expansion system for PCs. VESA also announced a second generation VL Bus standard (Version 2) in 1992. This revision redefined the maximum number of VL Bus slots from 3 in the original specification to 3 slots at 40MHz and 2 slots at 50MHz in a circuit.

Its speed was originally set at up to 50MHz, and is a 32-bit card. VESA cards have two sets of connectors, one set is based on the 16 bit ISA slot, and a second set of 36 pairs of connectors that carry local bus information.

Let me make a few points about the design objectives of the VL Bus before we discuss how it actually works:

1. First, high resolution graphics revealed the inability of the ISA bus to transfer data quickly enough.

2. Early design of local buses were propriatory, and were incompatible.

3. The VESA Local Bus's design allowed other high volume devices such as hard disk drives to use the bus.

4. The VL Bus was designed around the Intel 486 processor's needs.

5. The VL Bus's high speed was its primary selling point. It's maximum speed is 66MHz.

6. At the 33MHz level, with the 32-bit design, the original VL Bus speed was a theoretical 132 mb/s! It had burst mode or non-burst mode. Burst mode means that the bus uses a single address cycle followed by four data cycles.

7. This means it takes 5 clock cycles to transfer four double-words of 32-bits each. So you transfer 4x32bits (128bits) each 5 clock cycles, which translates to about 105 MB/s of real data. The VL Bus is slower in non-burst mode and maxed out at about 66 mb/s because it required an address cycle for each data transfer of 32 bits, which takes 2 clock cycles.

8. VL Bus Version 2.0 allowed 3 40MHz slots and 2 50MHz slots if low capacitance is maintained.

9. VL Bus Version 2.0 defined a 64 bit interface. The wider bus and the higher clock speed will allow for total theoretical throughput of 400MB/s. Of course there are overhead, etc.

10. Boards designed for VL Bus Version 2.0 will work in the original VL Bus slots by specification requirement.The VESA Local Bus is ideal for 486 machines. Why? Because it can handle about everything the 33MHz buses in the 486 machines can throw at it. VESA is much slower than PCI and has trouble with the 66 MHz and higher speed buses in Pentium and P6 type machines.

The VESA operates as follows:

1. The CPU sends signals to the I/O Controller that handles VL-Bus operations. The signals contains code and destination addresses for all the signals to follow.

2. The I/O controller decodes the addresses to determine if the signals are for any of the local-bus adapters.

3. Signals going to non-local bus adapters are sent to the ISA I/O controller. While the signals were passed at 33MHz and 32bits, the ISA controller will convert them to 16 bit, 8 MHz for the ISA BUS.

4. If a signal is for the VESA local bus, the VESA controller sends a signal control signal to the adapter in that slot, telling the adapter to execute the operation requested.

5. Once the adapter starts the operation, the VL controller lets the data for that operation pass directly from the processor to the local bus slot over a 32 bit data path, and at speeds up to 50MHz.

Universal Serial Bus (USB)

The USB is a new bus (first shipped in late 1996) called the "Universal Serial Bus" that connects to the motherboard through a USB port, and some consider the wires between the connector and the devices attached to it to be the bus.

Remember, the PC's bus is the circuitry that ties all the devices on your motherboard together. The bus concept is to: "extend and link the signals of your system"; however, you have to know what it means to understand it.

Well, the motherboard supports a USB port on the motherboard, but you must connect device to the USB interface which is located on the motherboard. Devices such as a USB keyboard may have one or more ports on it to which you connect other USB devices. On most PC's, external devices are usually connected to a "serial" or a "parallel" port, or to an expansion card in an expansion slot. These ports usually take only one device; or you have to have a "interface" card such as a SCSI to which you can hook up to 7 devices.

These ports are relatively slow (115 Kbps with serial ports, and about 2.5 Mbps for parallel ports) and expansion cards are even slower if in an 8 bit ISA slot.

With the advent of the USB concept, you now have the ability (as soon as the devices are commercially available) to hook up to 127 devices off the USB port - if they have USB connections on the devices! Sounds great; however, get realistic for just a moment.

You currently have devices that are not USB compliant, your old motherboard does not have a USB port, and you don't know if there are any companies working on an interface card, with a USB port, which will be available to you.

Even if there are companies working on an interface card that will connect to your current motherboard, it will not work at the speeds envisioned by the developers of the USB specifications. What will the USB standard eventually allow you to do?

1. Connect up to 127 devices thru a single USB port.
2. Speed - Have a total throughput of 1.5MBPs for for some devices such as keyboards, modems, etc., and up to 12 Mbps for printers, monitors, etc. over the single USB port.
3. IRQ's: a single IRQ can handle up to 127 devices through the single USB port!
4. Cable lengths between devices may be up to 5 meters long.
5. A USB keyboard can have multiple USB ports and act as a USB hub.
6. Multiple devices can run at either of the above speeds without conflicts.
7. Peripheral devices can be "hotswappable".
8. Automatic detection and loading of device drivers.
9. Two devices running at either speed can operate without conflicts at the same time.

Well, the parallel and serial ports on a computer, are really connections that are detriments to performance. Their speeds are somewhat limited - 115 Kbps for serial ports and 2.5 Mbps for parallel ports, so the USB should give increased performance.

Larger software companies are currently working on providing drivers for the USB ports such as Windows95 and Windows NT.

Most manufacturers of motherboards have already incorporated USB ports on their products, and these motherboards began shipping in late 1996. The Micronics "Stingray" motherboard is an example.

Just imagine, peripheral devices stacked along every wall of your office, or room at home, only occupying one I/O port, one IRQ, and one DMA address!