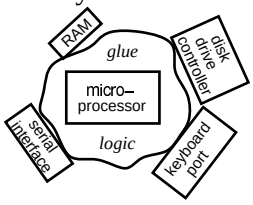
Introduction to Microprocessor Systems

The Microprocessor System

A *microprocessor* is an IC (integrated circuit) that contains most of the digital logic required to implement a computer except for memory and I/O (input/output) devices. This course describes how to interface a microprocessor to memory and I/O devices to make a *microcomputer*.

Exercise: An ad describes a computer system as having a "16 Megabytes of RAM, a Pentium CPU, and a 2 Gigabyte hard disk". What parts of the microcomputer are being described?

Memory and I/O devices usually can't be connected directly to the microprocessor. The logic circuits required to interface the microprocessor and other chips is often called *glue logic*. This additional logic can vary from none in the case of *microcontrollers* (microprocessors that contain on-chip memory and I/O devices) to "intelligent" peripheral interfaces that are as complex as the microprocessor itself. A large part of this course is devoted to the design of such circuits. The next section lists some common functions required to interface the microprocessor and its peripheral chips. These are the circuits that we will study in this course.



Common Support Circuits

Clocks and Reset Circuits

Microprocessors use a fixed frequency clock to synchronize the operation of their internal logic. This clock signal is usually generated by a quartz-crystal controlled oscillator.

The processor must be initialized to a known state when power is first applied or when the system "crashes." Most microprocessors require external circuits to detect the power-on condition or external resets.

Buffers

In larger systems the microprocessor must be connected to more chips than the microprocessor chip's electrical specifications allow. ICs called *buffers*, *bus drivers* or *transceivers* are used between the microprocessor and the other chips.

Latches

Some microprocessors reduce the number of pins required on the chip by using the same pin for two purposes, such as using the same pins first as part of the address bus and then as part of the data bus. An external chip (a latch) is required to temporarily hold the address bus value.

Address Decoders

Since microprocessors can usually address more memory than an individual memory chips contains, there has to be external logic to select the appropriate memory chip for a given address. This function is called address decoding.

Wait State Generators

The access-, hold-, and setup-times of memory and I/O devices often exceed the values provided by the microprocessor's read and write cycles. Circuits are used to force the processor to "wait" one or more clock cycles to extend the durations of read or write cycles.

Interrupt Controllers

I/O devices that require immediate attention can interrupt a program's normal execution by asserting an *interrupt* signal to the microprocessor. When a system has several sources of interrupts it is useful to be

able to distinguish between them and to ensure that higher-priority interrupts are recognized first.

Timers and Counters

It's often useful for programs to be able to measure elapsed time so they can compute the time of day and measure intervals between events. Timers are counters driven from a clock and whose value can be read by the CPU. Timers are often used to generate periodic interrupts to allow an operating system to switch between tasks.

I/O Interfaces

I/O interfaces are used to read and write data to storage and I/O devices such as keyboards, printers, disk drives, etc. *Serial* interfaces transfer one bit at a time while *parallel* interfaces transfer several (typically 8) bits at a time. A typical serial interface is the "RS-232" serial interface. Typical parallel interfaces include the "Centronics" (printer), IDE, SCSI and GPIB interfaces.

DMA Controllers and Bus Arbitration

DMA (Direct Memory Access) allows peripherals to directly read or write memory or other peripherals on the system bus independently of the CPU. Special logic is required to ensure that only one device at time tries to use the bus.

DRAM Refresh

Dynamic RAM (a type of Random-Access Memory) stores data as electric charge in a capacitor. DRAM requires that every memory cell's content be "refreshed" periodically by recharging the capacitor. Circuits are required to ensure that the DRAM contents are periodically refreshed.

Cache Memory

Many modern microprocessors require faster access to memory than is possible with inexpensive memory devices. Fast auxiliary memories called cache memories are used to store the contents of frequently used memory locations and thus improve the overall performance of the system.

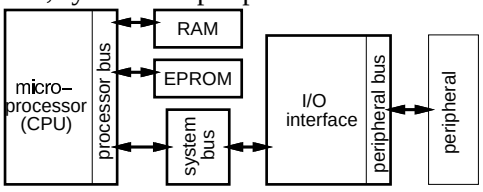
Exercise: A PC is composed of a motherboard containing the microprocessor and two plug-in PCB (printed circuit board) cards, one a memory card and the other a high-performance I/O card. Which of the above circuits would we likely find on each of the three boards?

Buses

A *bus* is a group of related signals. Most microprocessor systems include several buses:

- The signals appearing on the pins on the microprocessor chip are called the *processor bus*.
- Many microcomputers allow peripherals and memory to be placed on physically separate PC cards which plug into connectors on a "motherboard" or "backplane." The signals on these connectors are called the *system bus*. Examples of system buses include the ISA, VME, and PCI buses.
- Peripherals (such as modems or disk drives) are connected to the computer using different connectors. The signals on these connectors are called the *peripheral bus*. Some common peripheral buses include the RS-232 serial interface and the SCSI (Small Computer Systems Interface) bus.

These buses are often further divided into smaller buses. For example, the pins on the microprocessor and system bus can be grouped into a data bus, an address bus, a control bus, and a utility bus. A large part of this course is devoted to the study of typical processor, system and peripheral buses.



Exercise: Draw boxes on the diagram above that show which parts would be inside the CPU chip, on the motherboard and inside the case in a typical PC.

Exercise: The same ad talks about a "PCI motherboard, EIDE hard drive, plus serial and parallel ports." What types of buses do these refer to? How about a "32-bit address bus"?