

When comparing this circuit with a simple n-MOS or p-MOS transistor, the important point to notice is that the only time when there is a flow of electricity between the 5-V line and ground is when the state of the transistors is switched. This is the only moment in which energy is consumed. When the output has been set and the circuit has stabilized, there is no energy consumption except for charge leaks at the gate. In this design the gate is like a small capacitor that has to be replenished or depleted at each change of state.

In 1963, Frank Wanlass and C. T. Sah, engineers at Fairchild, applied for a patent on CMOS technology. Although CMOS electronic elements are slower than bipolar transistors, they consume 10 times less power, and many more transistors can be integrated on a chip when the power requirements are reduced. The introduction of CMOS technology therefore paved the way for VLSI (very large scale integration) chips. In 1991, Frank Wanlass received the Solid-States Circuits Award from the **Institute of Electrical and Electronics Engineers** for “pioneering contribution to high-speed dynamic memory design and cell technology.”

FURTHER READING

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Motherboard

In a **personal computer** (PC), the motherboard is the base onto which the main electronic components, such as the processor and memory, are soldered. Expansion boards are connected to the motherboard by inserting them into expansion slots. Motherboards for **IBM PC**-compatible computers are dominant in the microcomputer industry.

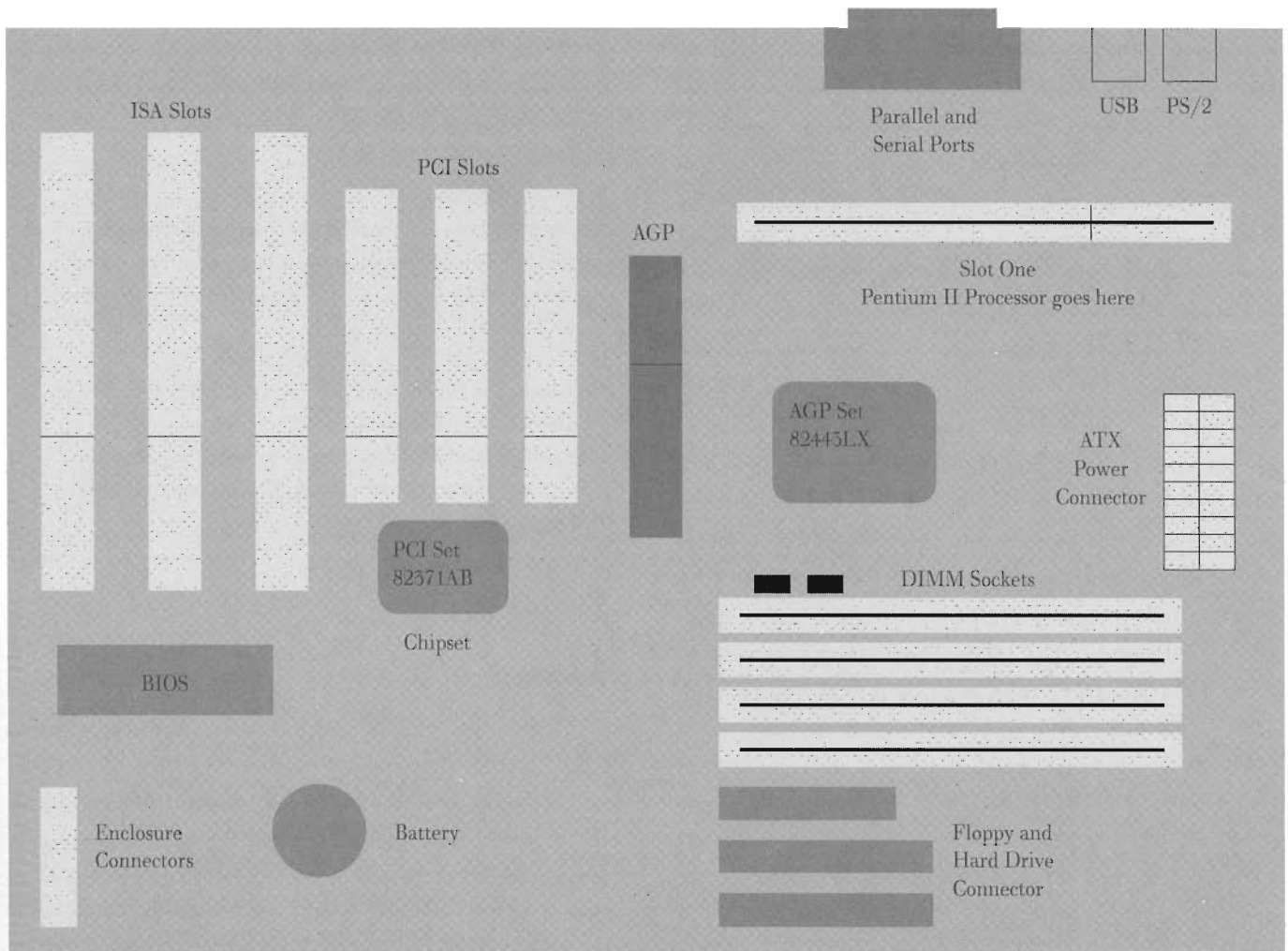
The figure shows an example of a commercial motherboard. The processor (a **Pentium II**) is

inserted in a special slot. Having a slot for the processor is very convenient, since it can be replaced when a better model becomes available. In this way the rest of the **hardware** investment can be preserved. The DIMM sockets are used to plug-in memory chips in DIMM (dual-in-line memory module) packages. In this example there are also some connectors for floppies, hard drives, and parallel and serial ports.

The **BIOS** (basic input output software) is stored in a **ROM** (read-only memory) chip that contains the basic code to control the computer. The battery in the figure is used to keep the computer clock running. Expansion slots are quite prominent in this motherboard: three ISA (industry standard architecture) and three PCI (peripheral component interconnect) slots are present. The AGP (accelerated graphics port) chipset is used to speed up the display of computer graphics on the screen, especially three-dimensional images.

The USB (universal serial bus) is a new kind of “**plug and play**” interface that makes it possible to connect peripherals without having to add an expansion card to the motherboard. USB is a standard developed by several companies, which have made it available to other computer manufacturers free of charge. The power connector takes a set of different voltage levels from the power source and delivers them to all components using metallic lines etched on the motherboard, possibly in several layers. Other types of boards include the daughter card (those that connect to a motherboard), controller cards (used to interface a peripheral to the motherboard), a network interface card (NIC, used to connect the computer to a **local area network**), and video cards (used to control the screen).

There are many parameters that differentiate motherboards, such as the number of processors that can be plugged in, the clock speed, the maximum data transfer rate of the local bus, the BIOS used, and the amount of maximum memory that can be added to the system. Although, in theory, upgrading a computer by buying a new motherboard should be easy, in practice it can be very difficult because there are so many available options, and very detailed knowledge of all the hardware is needed.



Commercial motherboard with a Pentium II processor.

FURTHER READING

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Motorola

Motorola is one of the leading **semiconductor** companies in the United States. It sells a wide variety of electronic products, such as **microprocessors**, cellular telephones, networking equipment, and embedded **analog** and **digital** systems.

When Paul and Joseph Galvin bought out a bankrupt battery firm and founded the Galvin Manufacturing Company on 25 September 1928, they probably never

dreamed that they had just begun what was to become a global leader in electronics. The Galvin brothers set up shop in Chicago with five employees and total assets of around U.S.\$1300. Their first product was a battery eliminator, but it was with automobile radios that they made a fortune. Car radios were not available directly from the manufacturer, and the Galvins's radios were sold and installed through car dealerships. In 1930, the Galvin Manufacturing Company had a net revenue of over U.S.\$287,000. Paul then coined the name *Motorola*, mixing *motion* and *radio*, for the company's line of new products. By 1936, Motorola was well established in the U.S. market as a brand name, and home radios were introduced into the product line shortly thereafter.

During World War II, Galvin Manufacturing Corporation was a supplier of electronics for the war