SWITCH BOARD

In the last instalment of Workshop we introduced the most important components of electronics: diodes, resistors, capacitors and transistors. In computing, the most significant of these is the transistor. Here, we look at what it does and use it to build some simple logic gates.

Transistors have two essential roles; to act as an amplifier for a signal, or to turn one current on and off under the control of another current. It is this ability to act as an electronic switch that makes them useful in computers. By grouping them together, you can build circuits that store on/off patterns that can be treated by the computer as binary numbers. Other circuits are logic gates that let you add on/off sequences together and so on.

If you build the logic gates described on the page opposite, you'll appreciate that whole computers made out of transistors would be extremely large and expensive machines — as indeed they once were. Small and reasonably priced computers need a further refinement — integrated circuits. These are predefined circuits with hundreds of transistors etched onto a tiny chip of silicon, enclosed in a black plastic case. You can buy simple integrated circuits (known as 'TTL chips') for most jobs. Four AND gates on one chip will cost just a few pence. The chips necessary for complex tasks, such as binary counters, and so on are about 50 pence each.

The practice of placing more and more circuits onto a single chip is often termed 'very large scale integration'. VLSI chips have many thousands of components compressed into them and can do very complex jobs. The microprocessor is such a chip. So are the chips that generate the television display, control the interfaces and provide the range of sound effects that many machines can provide. The principles are the same as those we have used for three simple logic gates. It is only the sheer number of components and complexity of the circuits that differ.

VLSI chips are made from a number of different technologies, depending on a trade-off between economy, performance and power consumption. The type found in most computers are MOS chips (metal-oxide-silicon), while many battery powered portables use CMOS chips (complementary metal-oxide-silicon), which are slower but use far less power.

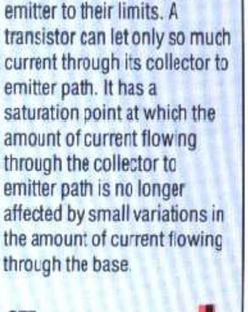
In the next instalment of Workshop we'll build a half adder, based on the circuit described on page 33 of the Computer Science series.

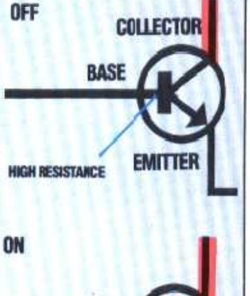
Transistors As Amplifiers

A transistor has three parts, known as a base, collector and emitter. Three wires, each connected to one of these, run out through the casing of the transistor. Typically, the base is used to control a current flowing from the collector to the emitter. If a current is applied to the base, a current can flow from the collector to the emitter. A changing current applied to the base causes the resistance of the collector to emitter path to vary in unison. By feeding a large current into the collector and varying it with a small current through the base, the emitter produces a large signal that varies exactly as the small signal. The transistor has been used to amplify the small signal.

Transistors As Switches

Switching with a transistor involves using the properties of the base, collector and emitter to their limits. A transistor can let only so much current through its collector to emitter path. It has a saturation point at which the amount of current flowing through the collector to emitter path is no longer affected by small variations in the amount of current flowing through the base.



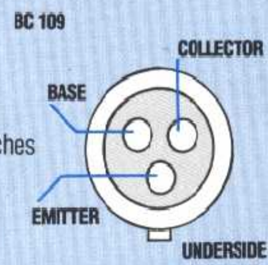


Building The Logic Gates

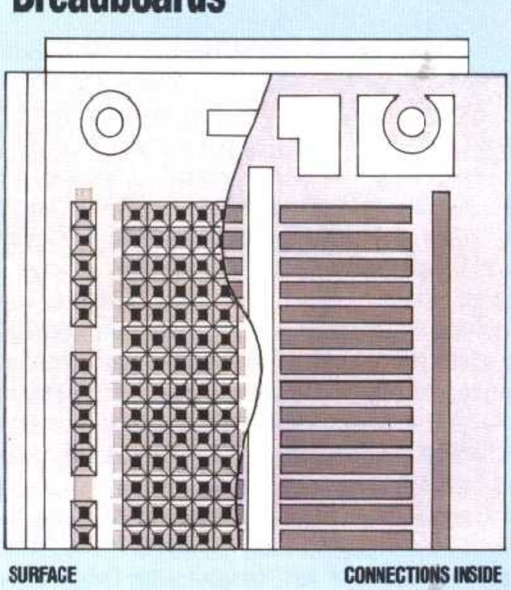
These simple circuits (right) illustrate the way the transistor's switching ability can be used to build logic gates. You can build each one in turn using the same set of components and a breadboard. It is important to realise that the actual switching is 'solid-state', in other words it has no moving parts. In these examples the inputs to the circuits are push buttons with LEDs (light emitting diodes). In a computer, the inputs to such circuits would be the outputs from other circuits. Once you've built and understood these gates, you might even like to try building a more complex circuit by feeding the output of one gate into another.

What You Need

1 Breadboard (Experimentor 300 or similar)
2 BC109 transistors
2 Red LEDs
1 Green LED
3 500 ohm resistors
2 15K ohm resistors
2 Push-to-make switches
1 9 volt battery
1 Battery clip
Short lengths of wire



Breadboards



Breadboards provide a simple way to experiment with circuits like these without having to take the time and trouble to solder the components. The breadboard is a re-usable base into which components can be securely plugged. The metal grips for the components act as conductors, so each group of five holes is electrically connected. With this matrix, it's easy to transfer simple circuits onto the board, using short pieces of wire to connect separate groups of holes. The board illustrated here is larger than you need at present but it will be useful for future projects.

KEVIN JONES