behaviour and properties of the flow of current automatically make an 'adder'.

Even very complicated mathematical functions often find very simple solutions in elementary circuits (an example is 'integration' — finding the area under a curve). Analogue computers aren't 'programmed' like digital machines; instead, a circuit has to be constructed that models the program to be solved. All the available components are mounted on the back of a 'patchboard', on the front of which are plugs and sockets to wire the components together. A patchboard looks rather like an old-fashioned telephone switchboard.

In an analogue computer the varying voltages or currents are used to represent physical quantities such as force or velocity, and the 'values' of electrical components represent things like the mass of a car, or the strength of its springs. But in a digital computer all data is represented with strings of pulses, five volts for binary 1 and zero volts for binary 0. Here lies a further distinction between analogue and digital computers: in one information can be stored in a way that caters for continuously changing quantities but in the other data is stored in 'discrete', or individual, units.

Some home computers (for example, the BBC Micro) have a socket for analogue input. In general, when digital computers deal with analogue information, such as a temperature or force, they first have to convert the data into digital form.

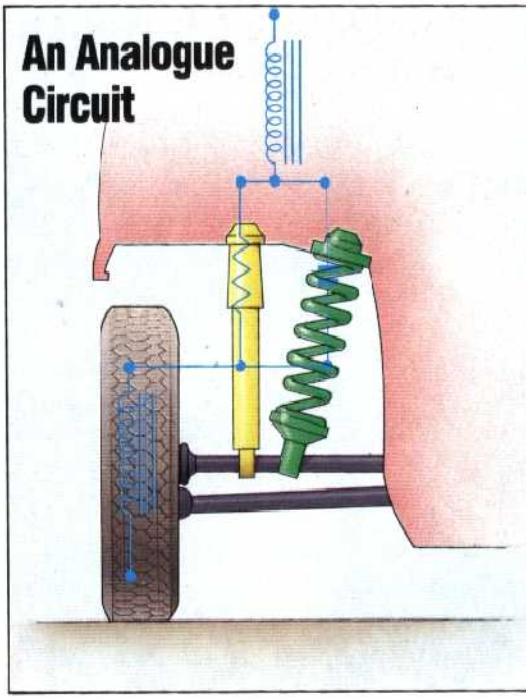
The big advantage of digital systems is that information can be processed or transmitted without loss of quality. If a five volt pulse is put through an electrical circuit it may well be affected by the distortion that is inherent in any circuit and come out, perhaps, as 4.9 volts. In an analogue system, in which voltage fluctuations represent changes in information, this might mean the difference between a singer's voice being an A or an A flat. But in a digital system, in which there are only two possible signals, five volts or zero, any signal close to five (for example 4.9) is automatically recognised and regenerated as a pure five volts. So errors are corrected and do not accumulate. By contrast, the accumulation of errors as the signal passes through successive circuits is one of the disadvantages of the analogue computer.

However, the analogue computer does reap an advantage from representing quantities as varying values of a voltage or current. It means that an input condition can change rapidly and the system will reflect the consequent changes immediately. No time is needed for coding the data into binary pulses, processing it and finally decoding it again to give the output.

This characteristic is very important in applications where rapid responses are essential. For example, an automatic pilot has to respond to a sudden gust of wind during a landing, when there is no time to do lengthy computations, even at the speed with which modern digital computers operate. Sensors detect the sudden gust, generating a relatively small output voltage. The autopilot circuit responds instantly with a relatively large output voltage change, which automatically operates the wing flaps to keep the plane in trim.

Analogue computers are used in many areas of industrial control where complex systems have to be delicately managed with fine and continuous adjustment, as in an industrial chemical plant. But they remain less well known than their digital counterparts. Though simple analogue computers are sometimes used in schools for teaching purposes, the type of application to which they are suited means that we are unlikely ever to see an analogue home computer. Thirty years ago it looked like a close race between the analogue and the digital computer. Analogue computers will always have their uses but as digital computers get bigger and faster they will increasingly dominate the market.

An Analogue Circuit



Car suspension systems consist of a spring and a damper. The spring absorbs the sudden shock of hitting a bump and then the oscillations of the spring are dissipated by the damper. The engineers have to select the best size of spring and damper to give the most comfortable ride over different road surfaces at different speeds. An electrical circuit can be used to represent the arrangement of spring, damper, car body and wheel. A fluctuating voltage is applied at one end to represent the bumps on the road and the size of the electrical components is varied until the output voltage is as smooth as possible

KEVIN JONES

Chinese Whispers

The way in which a message gets distorted in a game of Chinese Whispers has a strong parallel with the cumulative errors in an analogue circuit

In a digital circuit, only a limited number of messages (effectively 1 or 0) can be passed. So if any distortion does arise, it can easily be identified and eliminated at the next stage