speed and low cost per bit was invented at the Massachusetts Institute of Technology in 1950. The 'core' memory used 'tori' (rings) of iron threaded onto a grid of intersecting wires. By passing a current through a wire threading through a ring of iron, the metal became magnetised. There are two possible directions of the magnetic field in the ring and these are used to represent the two binary states, 0 and 1. The direction of the ring's magnetism can be 'flipped' by an appropriate current. And just as a current induces magnetism, the reverse also occurs: when the direction of magnetism 'flips', a small but detectable reverse current is induced. The magnetic field will flip only when a current above a certain threshold is used. By supplying just over half the threshold current through a vertical wire and the other half through a horizontal wire, only one torus (ring) in the lattice will receive sufficient current to flip.

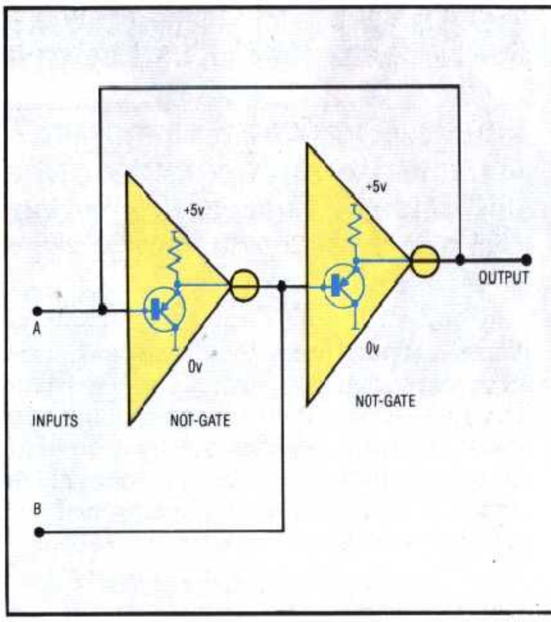
The diameter of the individual rings was eventually reduced from about four millimetres (1/6th inch) to several hundreths of a millimetre, thus reducing the power needed to write data into a cell. Information was read out of a particular memory cell by attempting to flip it. By watching for an induced current it could be discovered whether the cell had flipped or not and hence its original state could be deduced. However, this method of reading set all the cells to one magnetic state, so after each reading the data had to be rewritten.

With large-scale integration of transistors onto a single chip, one of the earliest means of holding data — in use since ENIAC — has been revived: the 'flip-flop'. A flip-flop is a device that is stable in one of two states — and is hence referred to as being 'bistable'. It is constructed out of two electronic switches joined back to back, with the output of each switch fed into the input of the other. In this way a pulse can be 'trapped' in the flip-flop until it is needed.

Each bit requires two switching devices, and the early valve flip-flops were expensive, unreliable and frequently burnt out. However, with integrated circuits, in which hundreds of thousands of transistor switches are built into a single chip, the flip-flop is once again important.

'Static' RAM chips, found in all early home computers, contain thousands of bistable circuits — one for each bit. Most of the newer machines, however, feature 'dynamic' RAM. The user won't notice any difference, but dynamic RAM is faster and cheaper to build. It is really like an array of capacitors, each of which can store an electrical charge. The problem is that a stored charge tends to leak away, so the contents need to be 'refreshed' thousands of times every second by special circuitry built into the chip.

The most recent kinds of memory to become available are 'bubble' and optical laser memories. The latter are similar to the discs that are used for storing music or video films and are read by a laser beam. In bubble memory, tiny magnetic domains or bubbles are created within a chip of magnetic material. These bubbles can be moved around in loops and the presence or absence of a bubble represents a binary 1 or 0. The loops are kept small to give rapid access time. Their density is potentially so high that this kind of memory may come to replace the present moving-surface cassette and disk systems.



Flip-Flop

The flip-flop is the basis of most forms of semiconductor memories, and is constructed from two invertors or NOT-gates (the actual circuit of transistors and resistors is shown in blue). The output of each invertor is connected to the input of the other. If the A is set to logic 1, then the output will be a 1. If input B is set to 1 then the output will be 0. Because this circuit has two stable states, it is sometimes called a 'bistable'

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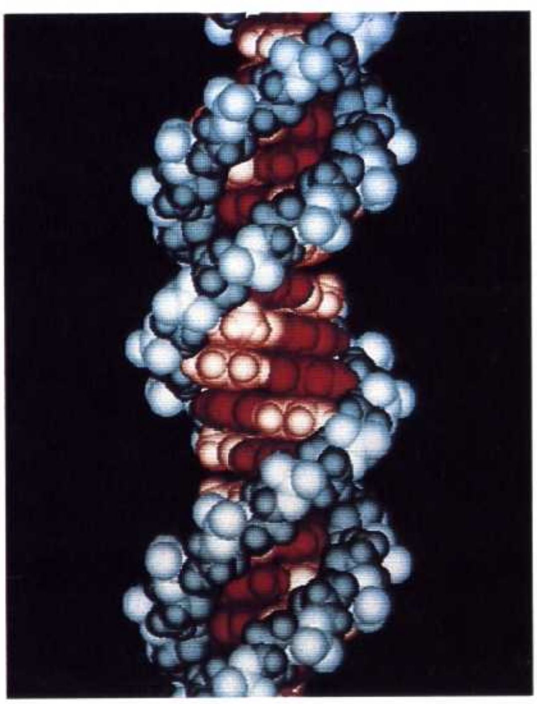
Cryogenic memories may yet become available. At temperatures near to absolute zero, electrical resistance in a medium all but disappears to give what is called superconductivity, and it then becomes theoretically possible to store a charge equivalent to that of a single electron. The charges on which the present type of chip memories operate are very small but each is still equivalent to a few million electrons. With the superconductivity obtained by cooling these memory media to cryogenic temperatures in baths of liquid helium, the speed and capacity of memories leap far beyond anything obtained by present systems.



Biotechnology
Even though microelectronics has reached an incredible level of miniaturisation, every operation in a semiconductor memory will involve the flow of many thousands of electrons. Scientists are already trying to devise memories that work at molecular level i.e. with individual electrons, and this comes under the heading of biotechnology rather than microelectronics. It is known, for example, that the structure of a DNA molecule stores the genetic code that controls the way in which our bodies grow. It will be many years, however, before we can reproduce this effect in usable form