CHARLES WHEATSTONE

A multi-talented Victorian scientist and inventor.

by Ian Sinclair

ONE OF THE curious facts about the way we remember Charles Wheatstone is that the measuring system that bears his name, the Wheatstone Bridge, was not, in fact, his invention, nor did he ever lay any claim to it!

Charles Wheatstone was born in 1802 at Gloucester, and seems to have been educated at rather undistinguished schools, because we have no record of his progress in these days. There seems to have been little about his early life to connect him to electrical engineering, and the first impression he made on the world was in 1829, when he invented, of all things, the concertina, that miniature accordian which became the traditional accompaniment of singing sailors in the Victorian era. His interest was at that time intensely devoted to sound waves, and he is credited with the discovery that sound travels faster in glass or metal rods than in air.

In 1834, his research efforts were rewarded by his appointment as Professor of Experimental Philosophy at Kings College, and he continued his researches into sound. It was at this time, incidentally that he coined a new word: "microphone" — though he didn't invent the device. His most important achievement, however, was the measurement of the speed of electric current along cables.

Not many details of the experiment survive, but from the hints that remain, we can reconstruct the method.

Two spark gaps were connected in series, one at the start of a very long length of cable, and the other at the end of the cable. The idea was that when a high voltage (he seems to have used a capacitor charged from a Wimshurst Generator) is applied to one end of the cable, sparks will be produced across both gaps — but the spark at the far end of the cable will occur slightly later than the one at the start.

A Space In Time

The time difference is not large, however. If we assume, as we know now, that the speed of the current wave in the cable is around 200 million metres per second, or 200 m per microsecond, then it takes a 200 m length of cable to cause a delay of only one microsecond. That's not a lot even by today's standards, and it was unimaginably small in those days. Wheatstone used a method which had already been used to measure the speed of light — a revolving mirror.

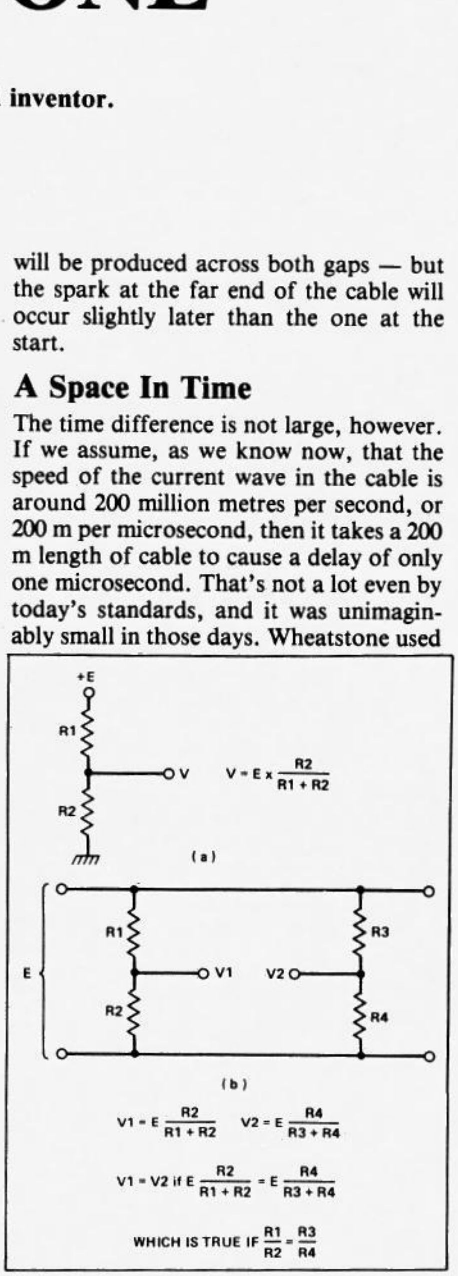

Fig. 1 The 'Wheatstone Bridge'; (a) a simple potential divider; (b) Two dividers connected in a bridge formation.

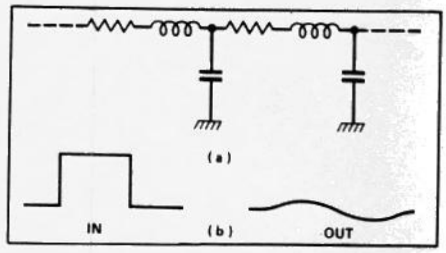

Fig. 2 Cable capers; (a) a long cable can be represented as a set of inductors, capacitors and resistors; (b) their effect is to smooth out pulse waveforms, and this limits the speed of transmission of information.

The mirror was small, and turned at a very high, steady, measurable speed. The light from the first spark would reflect from the mirror, and so would the light from the second spark — but in the short interval between these sparks, the mirror would have turned so that the reflected images, which would coincide if the mirror had not turned, seemed to separate. The faster the mirror was rotated, the greater was the separation. From the separation of these images, Wheatstone could work out the angle through which the mirror had turned and, knowing the rotating speed, he could also find the time it had taken to cover this angle. This was the time between the two sparks, and from this he could find the speed of the current in the cable.

The method worked (using several kilometres of cable) and Wheatstone was able to announce a value for the speed of electric current in a cable.

This work on the speed of current, however, led Wheatstone to become interested in sending signals through cables, the work which was to occupy him for the rest of his life. He was elected a Fellow of the Royal Society in 1836, at a time when he was working with William Fothergill Cooke on a telegraph system which was to be standard on railways all over the world for more than a century.

Getting The Needle

Wheatstone's aim was to produce a telegraph signalling system which could be used by relatively unskilled operators, but which could handle a lot of information. His first efforts used a 6-wire system which operated three needles (using electromagnets), but this was quickly superseded by a 6-wire, 5-needle system.

Each of the five needles was operated by an electromagnet which was connected between one of the five signal wires and the sixth (ground return) wire. Current in one direction would turn the needle clockwise, current in the opposite direction would turn the needle anticlockwise; the needles were spring-loaded to ensure that they returned to the central position when the magnets were not energized, and also that the angle of deflection was proportional to the current passing through in the electromagnet. The principle was that a digit could be selected by pointing a needle at it, and a letter could be selected by pointing two needles so that they intersected. It may look slow and clumsy, but remember that it only needed looking at to receive the message and Morse code, which in any case needs a trained operator, was still a thing of the future.

Wheatstone and Cooke's telegraph system was eagerly adopted by railways all over the world as the railway boom of the 1840-1860 period got under way and, in Britain at least, the name of Wheatstone became almost synonymous with telegraphy. Wheatstone then became deeply immersed in submarine telegraph — the use of underwater cables — and this involved the measurement of large resistance values. The solution that he adopted actually was an invention by Samual Christie to be known as the Wheatstone Bridge."

The principle, like that of so many good inventions, was simple. If we connect two resistors in series, the voltage across one resistor depends on the ratio of its resistance to the total resistance of the pair. If we use *two* pairs of resistors, then the voltages at their junctions (Figure 1) are equal when the ratios of the resistances are equal. Since this equality, which determines that no current will flow between the points, is easy to detect, and can be detected using very sensitive instruments, it forms a much better system for measuring high-value resistors than the use of Ohm's law. The delightful point about the bridge system is that no *measuring* instrument is needed. All we need is a sensitive galvanometer (which need not be calibrated) to read zero when the voltages are equal, and some resistors of known value.

From Cables To TV

Wheatstone's use of the bridge circuit was another step forward in telegraph technology and led to the first successful transatlantic cable being laid in 1866. This was a remarkable event, not simply because it linked the telegraph systems of two major continents, but because of the other advances which it sparked off. During his work on high resistance measurements, Wheatstone had used the element selenium as a resistor material, and found that its resistance value altered according to the brightness of the light striking it. This discovery set off the research on image transmission that led to TV. In addition, the integration effect of capacitance, inductance and resistance in a long cable (Figure 2) led to the analysis, by Oliver Heaviside, of the effect of capacitance and inductance on signals and particulalry on pulses, in cables — work which was later to be of inestimable value in radar engineering.

Wheatstone was knighted in 1868, a just recognition of his pioneering efforts which covered a huge range of activies not mentioned here. One of these was the stereoscope, which allowed the viewer to see three-dimensional pictures. Another was the use of electromagnets as field magnets in dynamos, a development which changed the dynamo from laboratory device to engineering plant, and led to the large-scale use of electricity (a power source regarded at the time with as much superstitious dread as nuclear power is now).

Wheatstone also amused himself with ciphers, cryptographs and his first love, music. He died in Paris in 1875, too soon to see some of the most exciting results of his work, but with the satisfaction of knowing that he had made a lasting contribution to many fields.

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