Sine of the Times: THE EARLY OSCILLOSCOPES

by Greg Grant

In 1897, Karl Ferdinand Braun developed the Oscilloscope and, for the first time, electrical and radio engineers could see what was happening in an electrical circuit.

For the next forty years, however, the new invention would be regarded as little more than an exotic tool with very limited applications.

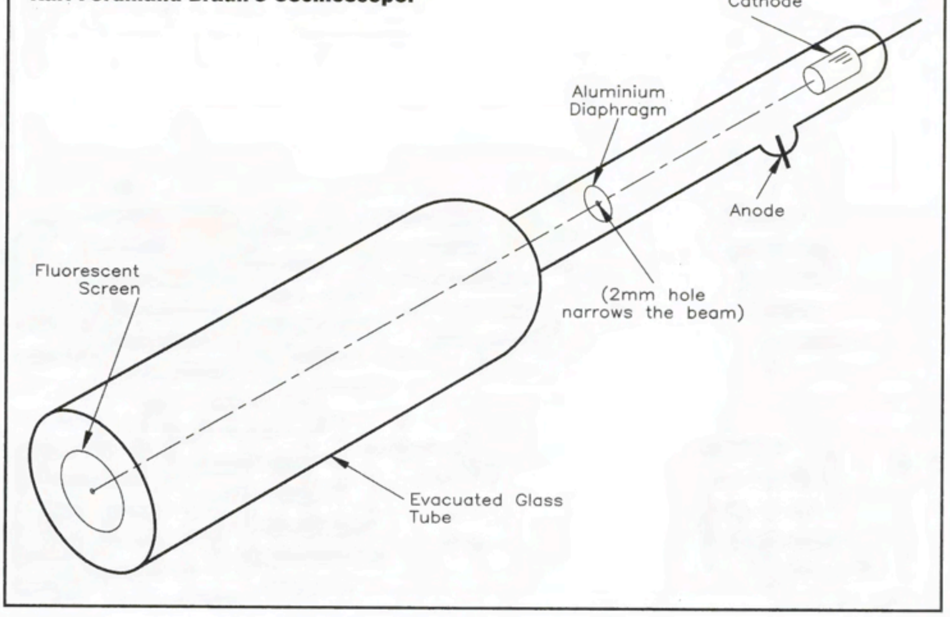
The oscilloscope was a child born of scepticism. The German physicist, Karl Ferdinand Braun, had considerable reservations concerning two, late nineteenth century discoveries. To begin with, there was Heinrich Hertz's revelation that electromagnetic waves existed, the mathematical base for this phenomenon having been established as early as 1865 by James Clerk Maxwell. Secondly – and to Braun, more disturbingly, – there was Wilhelm Roentgen's discovery of X-rays, a revelation that appeared to set physics off in an entirely new direction.

It was as a result of these doubts that Braun decided to begin his own investigation into this burgeoning field of radiation. However, he chose to look into neither X-rays nor electromagnetic radiation but Cathode Rays, which had an even longer, equally mystifying history.

The Nature of Cathode Rays

This aspect of physics began in 1855 when the German inventor, Heinrich Geissler, developed the Mercury Air pump. With it, he produced tubes that enclosed what was, for those days, a good vacuum. These tubes, some of which are shown in Photo 1, illustrated the colourful effects one could create by discharging electricity through rarefied gases.

Figure 1. The ultimate development of the Hittorf and Crookes Tubes: Karl Ferdinand Braun's Oscilloscope.



In 1858, the German physicist-mathematician, Julius Plucker, forced an electric current through a Geissler Tube. This produced a beam which, Plucker discovered, could be bent when a magnetic field was located close to the tube. Therefore, whatever was happening within the vacuum, there was no doubt that an electric charge was involved.

Eleven years later, Plucker's former student, Johann Hittorf, took another look at this phenomenon. Having made his own version of Geissler's Tube, he established that the glow came from the negative pole, or cathode, and moved in a straight line towards the positive pole, or anode. He established this because an object placed in the way of the rays cast a shadow.

In 1876, another German researcher, the physicist Eugen Goldstein, repeated Hittorf's experiment and drew the same conclusions, naming the phenomenon Cathode Rays. By the end of that decade, the British electrical engineer, C. F. Varley, demonstrated that cathode rays could equally well be deflected by an electrostatic field.

In 1880, the British physicist and scientific editor, William Crookes, demonstrated that cathode rays travelled in straight lines and, as well as casting a shadow, could also drive a small wheel, provided they struck the wheel on its edge! Crookes, like Hittorf, made his own, improved version of Geissler's origination, the Crookes Tube and, from his investigations with it, concluded that cathode rays were a stream of electrically charged particles.

A decade later, the Irish physicist, George Stoney, put forward the idea that electricity, like matter, existed as fundamental particles. Furthermore, he thought that such particles carried the same electrical charge and suggested they be called Electrons.

Four years later, the French physicist, Jean-Baptiste Perrin, demonstrated that when cathode rays struck a cylinder, it slowly gained a large negative potential. This was the deciding factor: cathode rays were a stream of negative particles. It was at this juncture that Braun entered the picture.

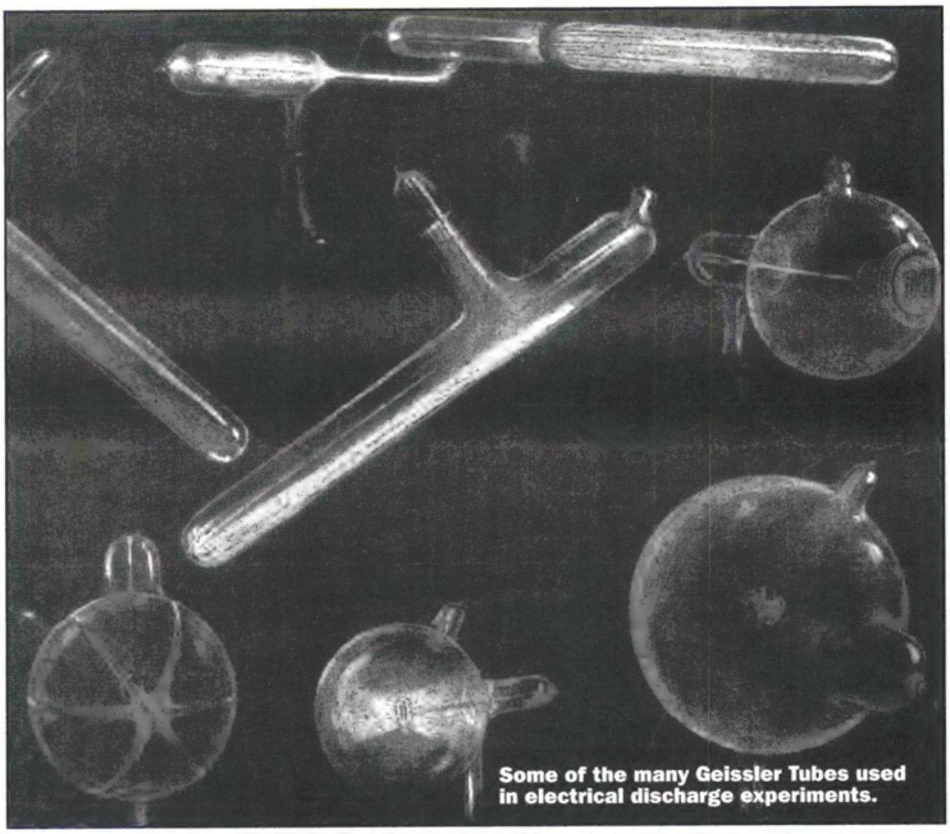
The Braun Tube

The earliest cathode ray tube, made by Braun at the University of Strasbourg, is shown in Figure 1.

Measuring 45 × 8cm, it consisted of an aluminium cathode, a diaphragm of the same material with a 2mm hole at its centre and finally, a mica screen coated with a phosphorescent colour.

The Braun Tube had been a gradual development, its creator modifying it so that the spot formed by the particle stream shifted in accordance with the electromagnetic field set up by the varying mains current applied to the field coil. In fact, the spot formed a wobbly vertical line.

When Braun placed a rotating mirror in front of the screen, a horizontal movement was added, and the mains current sine wave could be clearly seen. It was for this reason that the Braun Tube came to be called an Oscilloscope, because its electron beam could follow, and therefore display, current and voltage oscillations.



Some of the many Geissler Tubes used in electrical discharge experiments.

Courtesy: The Ann Ronan Picture Library.

Braun had created his tube principally for experimental purposes, and from observing the mains current variations of the local power station, he took to investigating the alternating current of the Strasbourg telephone exchange (50 complete vibrations per second), the curve produced by a tuning fork and the phenomenon of Lissajous Figures.

In 1899, Braun's assistant, Jonathan Zenneck, developed horizontal deflection, making the rotating mirror unnecessary. The basic oscilloscope was now in place. Yet, as late as 1911, there was not a single beam-deflection device on the market. Why?

Further Developments

It is difficult for many people, brought up in a world overloaded with communicative equipment, to realise that such devices are a quite recent development. At this time, amplifiers and oscillators did not exist and so there was no demand to produce the oscilloscope commercially. Nevertheless, a number of researchers world-wide continued to develop them further.

In 1902, Cornell University's Harris J. Ryan manufactured a 13cm diameter tube, but experienced problems with high voltage leakage. Three years later, the Austrian physicist, Artur Wehnelt, suggested that Braun's cold cathode cylinder be replaced by a lime-coated platinum filament.

Wehnelt had carried out fundamental research into thermionic emission from platinum wires coated with a variety of oxides such as calcium, barium and strontium and discovered that, in a vacuum, such wires emitted more electrons per square centimetre than platinum alone. His work considerably improved vacuum valve efficiency and he later developed the Wehnelt Cylinder, which enabled oscilloscope beam current to be controlled, thus giving sharp-point focusing. This was the first of a number of small, yet very significant, developments in thermionic tube technology.

The watershed year in electronic developments, however, was 1912, when Lee de Forest, H. B. van Etten and Charles V. Logwood of the Federal Telegraph Company began working on amplifier design, centred on de Forest's triode valve. Before the year was out, the United States (US) government's Bureau of Standards tested the team's three-valve amplifier and found that it had a gain of 120! Here was another indicator of the way things were moving, in that the amplifier was designed by a team. True, lone inventors and originators would still come forward with stunning ideas and designs but, increasingly, they would become an endangered species.

In September 1912, Edwin H. Armstrong developed the first oscillatory circuit, his Regenerative design, which had considerable, near-immediate, success.

It was followed shortly afterwards by similar circuits, designed by such greats of the profession as Germany's Meissner, Britain's Round and Canada's Fessenden.

In 1915, the General Electric Company's Irving Langmuir applied for a patent for what he termed a 'Getter', for producing a high vacuum in cathode ray tubes and valves. He also discovered the Space Charge around a valve's cathode which, in turn, led to his developing thoriated tungsten as a valve heater, thus further improving electron emission. Shortly, thoriated tungsten became the standard heater material of the vacuum tube industry.

Four years later, William G. Housekeeper patented the Housekeeper Seal, a method of sealing metals through glass. He did this by tapering a piece of copper strip to a feather edge and then sealing the glass to the edge of the taper. Since the expansion of copper is 165×10^{-7}m/°C compared to glass's 52×10^{-7}m/°C, this technique equalised the contraction/expansion difference between the two substances. The electrical industry could now manufacture large diameter seals using such materials as high purity copper.

1923, however, saw one of the greatest developments where the oscilloscope was concerned: the Tipless Tube. In this version of Braun's creation, evacuation was done from the base, the tip being protected by the base itself. A magnesium getter was also incorporated, to absorb any residual air still lingering after evacuation.

The Early Oscilloscopes

By the mid-1920s, the oscilloscope was becoming more widely known and used more frequently, certainly among scientists. Professor Harold Nordinger of Sweden's Uppsala University first used an oscillograph to investigate lightning strikes on power lines at this time. Britain's National Physical Laboratory also used oscillographs, in the study of waveforms and Lissajous figures, among other things.

By 1931, the American General Radio Company had developed the first oscillograph for general use. A three-piece device, its power supply, sweep circuitry and cathode ray tube were contained in separate enclosures. The first Spectrum Analyser appeared at this time too, developed by the Panoramic Radio Corporation's Marcell Wallace. It was, essentially, a scanning receiver with an upper frequency limit of 35MHz.

In the following year, the German physicist, M. von Ardenne, produced an oscilloscope using a hot cathode and gas filling, for beam focusing. Although this model showed some of the advantages to be got from a high vacuum, it suffered from large spot size, instability and poor modulation.

In America, meanwhile, the Du Mont Laboratories – founded by Dr. Allen B. Du Mont, who developed the 'Magic Eye' tuning indicator in 1931 – began to manufacture oscilloscopes. In 1933, they introduced their Model 130 Oscilloscope with a 13 cm screen, 5kHz sweep and a bandwidth extending from 20Hz to 10kHz. Two years later, the Radio Corporation of America (RCA) produced the first oscilloscope, aimed primarily at the Service Engineer.

Perhaps the most unusual feature of these early oscilloscopes was gas focusing, where argon or helium gas was introduced into the tube at pressures of around 1×10^{-3}mmHg for argon and some 20×10^{-3}mmHg for helium. As the electron beam moved up the neck of the tube, it collided with the gas molecules, ionising them. Since the ions were heavy and slow-moving compared to the beam electrons, they tended to remain in the beam path, forming a positive core to it. When the quantity of positive ions produced equalled the number of electrons in any given area, the mutual repulsive force was neutralised and an increase in the number of ions meant an attractive force on the electrons, bringing them in towards the axis.

The result was spot diameters of between 0·2 and 0·5mm, the focusing being determined by the gas's 'Ionisation Probability,' a function of gas pressure and beam current.

At this time, many engineers in Britain and the U.S. were beginning to see television as a perfectly viable medium, provided a suitable receiving device could be found. The cathode ray tube of the day, however, was not the most satisfactory device for this role!

To begin with, the gas focusing could not be maintained over the range of beam current required to create a picture. Secondly, far better screen phosphors were needed, ones that would produce high efficiency white light. Finally, to achieve a bright trace over several hundred lines, a far more intense beam was required, yet one that would remain sharply focused. This last, of course, required an increase in the tube's final voltage.

All of the above were of great concern in Britain, where Electrical and Musical Industries (EMI), were close to producing the world's first television broadcasting service. Yet, they were by no means in favour of the cathode ray tube. One of the engineers involved, L. F. Broadway, remarked at the time that "we believed the CRT as a display device was only an interim measure. We didn't really believe that this huge vacuum envelope, a cumbersome sort of thing, would last."

That the 'cumbersome thing' not only lasted but went on to inspire development of both the Electron Microscope and the Visual Display Unit (VDU) says much, not only for the engineers involved but above all, for Karl Ferdinand Braun. His generosity in refusing to patent his discovery became, as he intended, a great benefit to science and an even greater one to the world at large. ELECTRONICS

References

From Compass To Computer. The San Francisco Press Inc., San Francisco. Atherton, W. A. (1984). Page 217.

The Day The Universe Changed. Burke, James (1985). BBC Books, London. Page 298.

'On a Method of Demonstrating and Studying the Time Dependence of Variable Currents.' Wiedermann's Annual. Braun, K. F. (1897). Page 1. (Translated from the German by Wendy Song).

Ibid [3], Page 3.

Beam Deflection and Photo Devices. Schlesinger K. and Ramberg E.G. (1961). Proc. IRE. (1962). Page 991.

The Setmakers. Geddes K. and Bussey G. (1991). BREMA, London. Page 227.