The Z550M:
an unusual counter valve (ca. 1959)

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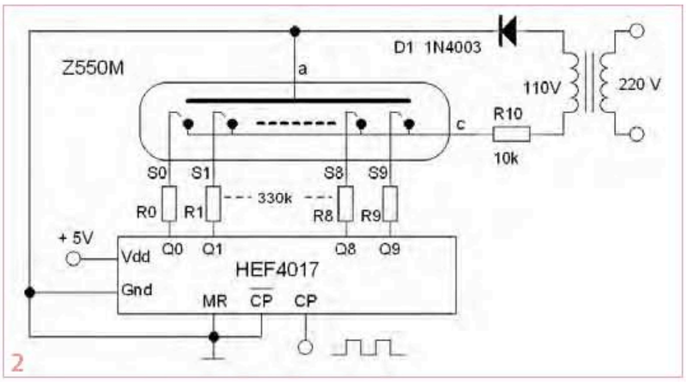
The first version of the popular Nixie valves launched by Burroughs in 1954 had the disadvantage that a transistor with a fairly high breakdown voltage was needed to drive the valve. Such transistors were very difficult to manufacture in the early day of transistor technology, when transistors were still made from germanium. To allow glow discharge valves to be operated directly by low-voltage transistor circuits, a pair of researchers at the Philips Research Lab, Theo Botden and Martinus van Tol, developed the Z550M around 1959. A few examples with different markings are shown in **Figure 1**.

The Z550M consists of a small disc-shaped plate – the anode – with cutouts for the numerals 0 to 9. A set of ten interconnected cathodes is located behind the numerals. A starter electrode is located close to each cathode. A rectified AC voltage is applied between the anode and the cathodes (see the standard application diagram in **Figure 2**). It takes only 5 V on a starter electrode to initiate a glow discharge behind the desired numeral and cause the numeral to light up (**Figure 3**).

In order to understand the operation of the Z550M, you first need to know something about the characteristics of glow discharge valves. A glow discharge valve has two electrodes, usually made from nickel or molybdenum, in an atmosphere of neon gas at a pressure of a few centimetres Hg. If the voltage between the two electrodes is less than the striking voltage, no current will flow. If the voltage is gradually increased, the gas will break down at a certain voltage. This striking voltage depends on many factors, such as the product of the pressure of the neon gas and the distance between the electrodes. The striking voltage is directly dependent on this product. Once the gas has broken down, a current will flow, and it is limited only by a resistor connected in series with the valve. As a result, the voltage across the valve decreases to the maintaining voltage.



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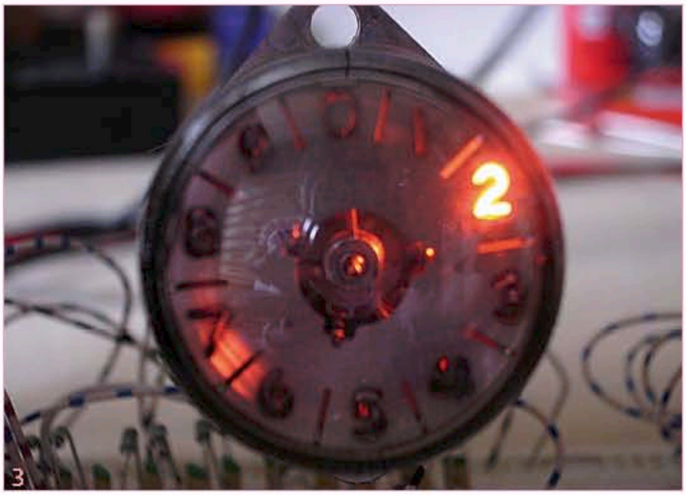
If you ignore the starter electrodes in Figure 2, you can clearly see that if the supply voltage is gradually increased, at a certain point the gas between one of the cathodes and the anode will break down. The voltage across the valve will then drop immediately to the maintaining voltage, with the result that the other numerals remain dark. The numeral will remain lit until the next zero crossing of the supply voltage. The distance between the starter electrodes and the cathodes is much less than the distance between the cathodes and the anode, so the striking voltage of the starter electrodes is lower than the striking voltage between the cathodes and the anode. If a slightly elevated voltage (such as a voltage supplied by a transistor or a logic gate) is applied to one of the starter electrodes, the initial gas breakdown will occur there. The high resistance in series with the starter electrode limits the current that must be supplied by the drive circuit to a few tens of milliamperes. It turns out that this small discharge is able to initiate a larger discharge between the associated cathode and the anode.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Obviously, this principle can only work if the striking voltages of the various starter electrodes differ by less than 5 V. This proved to be not so easy to achieve. Fortunately, experience gained from decades of research on glow discharge valves at the Philips Research Lab came in handy here. An extensive research programme focussing on glow discharges was initiated immediately after the lab was founded in 1914. Already before the Second World War, this resulted in several important new products such as fluorescent lamps, low-pressure sodium lamps for street lighting, and high-pressure mercury lamps for applications such as film projectors.

The largest contribution to the development of a fundamental understanding of glow discharges was provided by Frans Penning. In his research, Penning noticed that the striking voltage was strongly dependent on the surface contamination of the cathode. He developed a method for cleaning the cathode by operating the valve for a while with very high current density. The resulting bombardment

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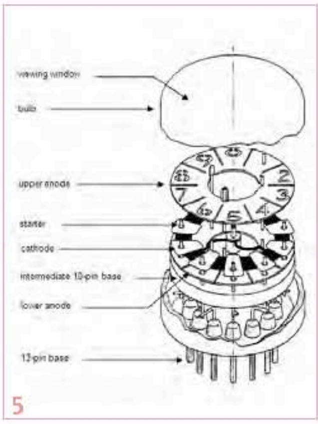

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by gas ions cleaned the cathode in a process called 'sputtering'. A supplementary benefit is that the metal ions released from the cathode in this process bind impurities in the gas, which is called 'gettering'. Penning also discovered that if a tiny amount of argon is added to the neon gas, it is possible to not only reduce the striking voltage but also produce an operating region within which the striking voltage is nearly independent of the gas pressure and the electrode separation. Both techniques were applied to the Z550M, and after a bit of experimenting the desired tolerance range was achieved. **Figure 4** shows a picture of the electrode configuration ultimately determined in the lab.

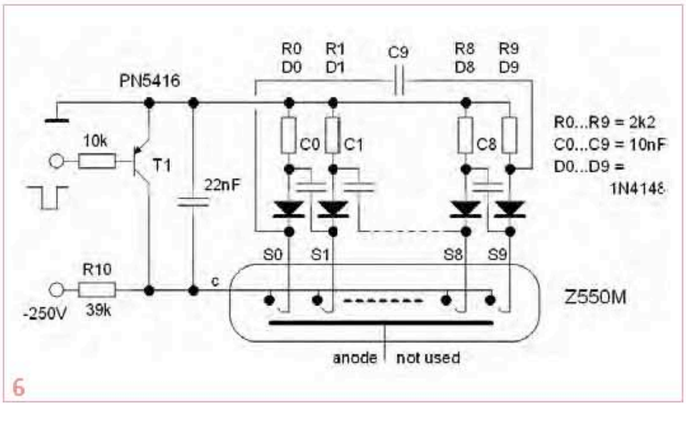
After the feasibility of the Z550M concept had been demonstrated, the project was handed over to a development team in order to make the valve ready for production. The valve was assigned its type number at this time. The development team decided on a somewhat different construction with each starter electrode located in a small hole in the cathode. This made it easier to connect the starter electrodes to the pins of the valve (**Figure 5**). This arrangement also makes the average distance between the starter electrode and the cathode nearly independent of the exact positioning of the starter electrode, which further reduced the spread due to production tolerances. Finally, a small amount of tritium was added to the gas mixture to ensure fast and reliable initiation of the glow discharge. The author's website [1] provides extensive reading material on the history of the development of the Z550M and samples of original lab workbooks.

During this time, Pierre van Vlodrop in the glow discharge valve application lab also got his hands on a few samples of the Z550M. He used the Z550M to build a rather remarkable ring counter in which the starters were used as anodes, as illustrated in **Figure 6** [2]. Here he was able to make good use of the very well defined striking and maintaining voltages (105 V and 85 V, respectively). The operating principle of the ring counter is simple. When the supply voltage is applied, one of the numerals will be triggered at random (for example, 0). The resulting current causes a voltage drop across R10 that is sufficient to keep the other numerals dark. This current also causes a voltage drop of around 10 V over R0, which causes C0 to be charged to 10 V. A negative clock pulse on the base of T1 drives it into conduction, which pulls the supply voltage of the valve to zero and extinguishes the glow discharge. When the supply voltage subsequently rises, starter 1 will have a bias of 10 V relative to the other starters because C0 is the only capacitor with a charge, with the result that that a glow discharge will be initiated in the gas behind the '1' numeral. With each successive clock pulse, the next number in series will light up – simple but effective.

Despite the elegant principles underlying the design of this valve, it never achieved commercial success. Shortly after it was introduced, the BSX21 transistor was developed. With a breakdown voltage (BV_{ceo}) of 80 V, it could be used to drive a Nixie valve directly. In addition, the clockface display was regarded as inconvenient and outmoded, even inside Philips.

The fact that Z550M valves can be found with Philips, Valvo and Mullard markings suggests that they were produced in large quantities in several Philips plants. In fact, the quantities were so small that they were only made in the pilot production plant on the Emmasingel in Eindhoven. The Eindhoven plant simply put different markings on the valves according to the intended destination country in order to make them easier to sell.

Pro Electron was founded in Brussels in 1966 to coordinate the registration of European valve and semiconductor type numbers. The Pro Electron organisation largely followed the Philips system, with the result that the Z550M was rechristened ZM1050.



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Now in 2009, the valves still work very well. However, they do not count as fast now, since the tritium added to the gas mixture to promote fast initiation of the glow discharge has a half-life of 12.5 years, and not much of it is left after 50 years.

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Internet Links

[1] http://www.dos4ever.com/ring/Z550M.html

[2] http://www.dos4ever.com/ring/ring.html

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