The Tektronix 7250 Transient

Pushing analogue oscilloscope techniques to their limits

Recently, an interesting and rather heavy (60 kg!) oscilloscope-like instrument (Figure 1) was donated to the Historic Collection of the Faculty of EEMCS by the Reactor Institute Delft. Though the instrument looks like an "overweighted" digital oscilloscope, it appeared to be an instrument hiding a remarkably interesting component, namely a scan-converter tube. In this contribution we will discuss this device in more detail, in particular in relation to the physical limitations faced by traditional oscilloscopes.

Conventional CRT oscilloscope high frequency limitations

The basic analogue oscilloscope consists of a Cathode Ray Tube (CRT), a linear time base (sweep) generator and a signal amplifier (Figure 2). The electron gun (cathode) of the CRT emits electrons. These electrons are accelerated and focused on a phosphoric screen, thereby producing a small visible spot. The time base, or sweep generator, is connected to the horizontal deflection plates causing the electron beam to move linearly with time from left to right. In contrast, the signal under study, after being properly amplified, is fed to the vertical deflection plates. The trigger system takes care of the synchrony between the waveform under study and the start of the sweeps. In this way the waveform of the signal is displayed on the screen.

Figure 1. *The Tektronix 7250 Transient Digitizing Oscilloscope*

The central part of an oscilloscope is the CRT deflection system, of which the bandwidth is limited. At very high frequencies (> 100 MHz) the electric field between the deflection plates changes while the electrons are still passing through that field. The net deflection of the electrons is therefore reduced, and this reduction increases as the frequency of the voltage applied to the deflection plates increases. This effect could be reduced by increasing the speed of the electrons, which would decrease the time during which the electrons are influenced by the deflection plates.

Increasing the speed of the electrons can be accomplished by increasing the voltage of the accelerating electrode. Doing this introduces some new problems, however, such as higher demands on the insulation both outside and inside the tube. Furthermore, when the speed of the electrons is increased, the time that they are under the influence of the deflecting electric field is reduced, which leads to reduced vertical deflection sensitivity and, in turn, to higher demands on the vertical amplifier. In this article we will discuss two interesting developments that led to significant improvements.

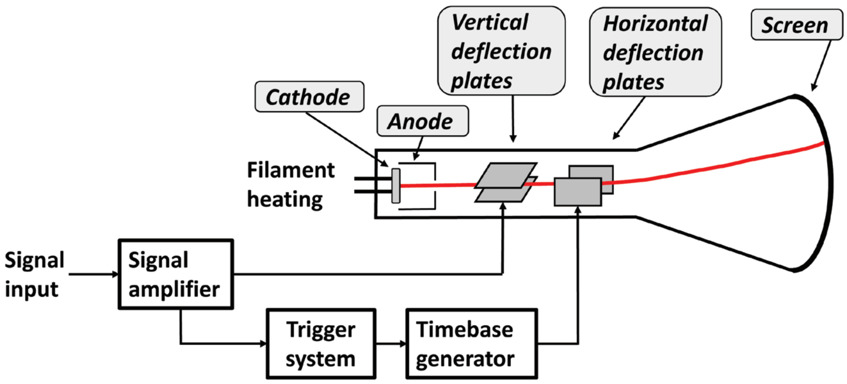

Figure 2. *The Tektronix 7250 Transient Digitizing Oscilloscope*

Digitizing Oscilloscope

Otto Rompelman

Distributed deflection

As has been mentioned above, changes in the electric field of the deflection plates during the passage of electrons leads to a reduction of the bandwidth. This problem was significantly reduced by the development of the so-called distributed deflection assembly [1][2], as illustrated in Figure 3. The basic idea is to split up the deflection plates into a number of smaller segments. Within the tube these segments are interconnected through delaying circuits. The delay per segment is such that it matches with the travelling time of the electrons passing through that segment. The net result is that, during passage, the electrons are subject to the same phase of the deflection voltage. The introduced delay line has to be terminated properly (i.e., by Z in Figure 3) as to avoid unwanted reflections.

This leads to a low impedance as seen by the deflection amplifier, which was problematic with vacuum tube amplifiers. Distributed amplifiers were used to solve this problem, however at some expense (namely some vacuum tubes). Distributed deflection plates were amongst others introduced in the Tektronix 580-series oscilloscopes [4] in the late 1950's with 100 MHz bandwidth and the Tektronix model 454 [5] in 1967 with 150 MHz bandwidth.

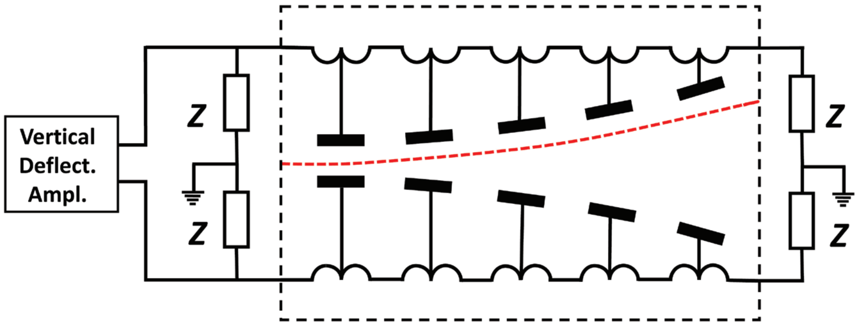

Figure 3. *Distributed deflection assembly; the configuration is 'seen' as a transmission line by the vertical amplifier [2]*

Microchannel plate technology

When increasing the bandwidth of an oscilloscope a new problem arises. High frequency demands lead to high sweep rates and, consequently, to reduced exposure times of the phosphoric screen. The net result is a low light output. To overcome this problem, Tektronix introduced the microchannel plate technology [2][3] in the late seventies of the past century. A microplate acts as an electron multiplier based on secondary emission and is positioned a few millimeters before the phosphoric screen (Figure 4). The microchannel plate consists of a large number of parallel channels at a slight angle with respect to the electron beam. The channel walls are semiconducting, which allows charge replenishment from an external voltage source. Each channel can therefore be considered to be a continuous dynode structure which acts as its own dynode resistor chain. An acceleration voltage of about 1000 V is applied across both sides of the plate. Electrons entering a channel will hit the channel walls and release a cascade of secondary electrons: this process is repeated a number of times, resulting in an enhanced number of accelerated electrons leaving the plate. Finally, an acceleration voltage V_a (10-50 kV) propels the electrons to the phosphor coated screen. The diameter δ of the channels is 25 μm and therefore, the resulting diameter of the micro channel place is about 5 cm.

This technology, in combination with further developments in distributed deflection technology (both horizontal and vertical) and special electron optics, has allowed the bandwidth of the CRT to be increased to about 1 GHz. The CRT at issue was the Tektronix T7100 [6], which was used in the Tektronix 7104 1 GHz oscilloscope, introduced in 1978 [7].

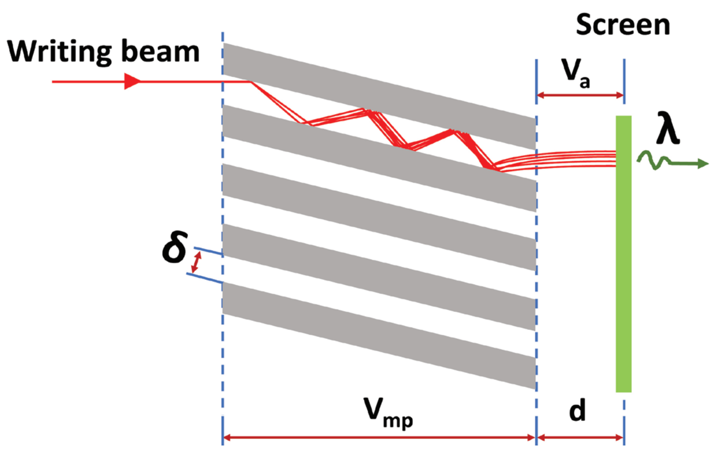

Figure 4. *The microchannel plate: the electron beam is enhanced by repetitive secondary emissions before hitting the phosphoric screen (d ≈ 3 mm)*

Transient recording by means of scan converter technology.

An ordinary oscilloscope is intended to show repetitive waveforms that, when displayed on the screen, are 'fused' by our eyes to a stable image. However, if we are faced with a low duty cycle and single event phenomena, we would need some way of storing the image. This need can be fulfilled by a storage oscilloscope or a transient recorder. When dealing with very rapid phenomena, we have to combine the technologies, as described earlier, with some storage function. In the Tektronix 7250 transient digitizer a so-called scan-converted is used for recording very fast phenomena. The scan-converter at issue is in fact a combination of two vacuum tubes, namely an extremely fast writing tube (including distributed deflection and a microchannel plate) and a reading tube similar to a Vidicon as was used in video cameras [8]. Its principle is illustrated in Figure 5. First the signal under study is applied directly to the vertical plates of the CRT-part (not shown in the figure). To achieve maximum bandwidth, no vertical amplifier is used, resulting in a vertical sensitivity of 5 V full scale.

It should be noted that the introduction of the microplate in fact implies a digitizing process. The number of microplate channels leads to a resolution of 2048 points vertically (11 bits) and 512 points horizontally (9 bits).

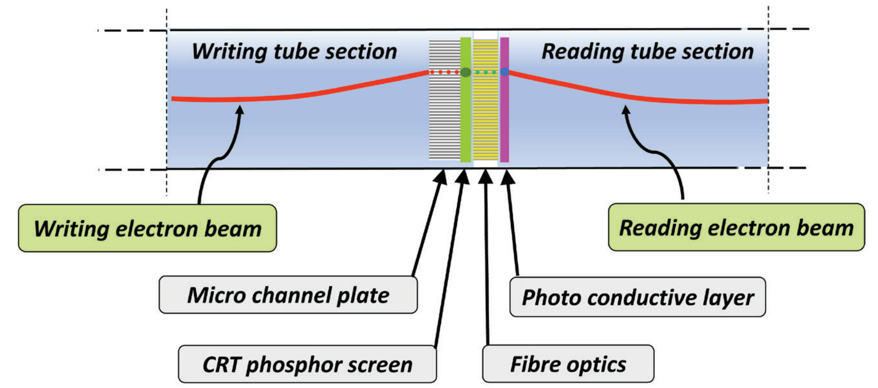

Figure 5. *Basic configuration of the scan-converter tube (deflection system not shown)*

The phosphoric screen, when hit by fast electrons, emits photons which are consequently transported through a fibre optic disc to the photoconductive screen of the reading tube (camera) section of the scan-converter (Figure 6).

In the camera section the photons emitted by the CRT-section hit the photoconductive layer, which releases electrons and leaves a positive charge at that point. The net result is a positive charge image corresponding to the image on the CRT-screen. This image can now be scanned by a reading electron beam. This scanning beam is focused and deflected with magnetic coils, similar to the usual scanning procedure in TV-systems. The photoconductive layer is connected to a high voltage source. Once the scanning electrons hit a charged area of the layer, an electrical signal is generated in the circuit of the conductive layer. After amplification, the signal is converted into a standard pulse which is fed into one location in a digital memory, the location being determined by the deflection information of the reading electron beam (Figure 7).

The memory is made up of CMOS static RAM. These chips were introduced in the mid '70s of the past century. The data can be stored for up to two years using a built-in battery backup. The memory size for one scan corresponds to the physical resolution of the system as discussed before, namely horizontal (time axis) 9 bits and vertical (signal amplitude) 11 bits. The actual memory size is a multiple of this value, enabling the storage of multiple waveforms.

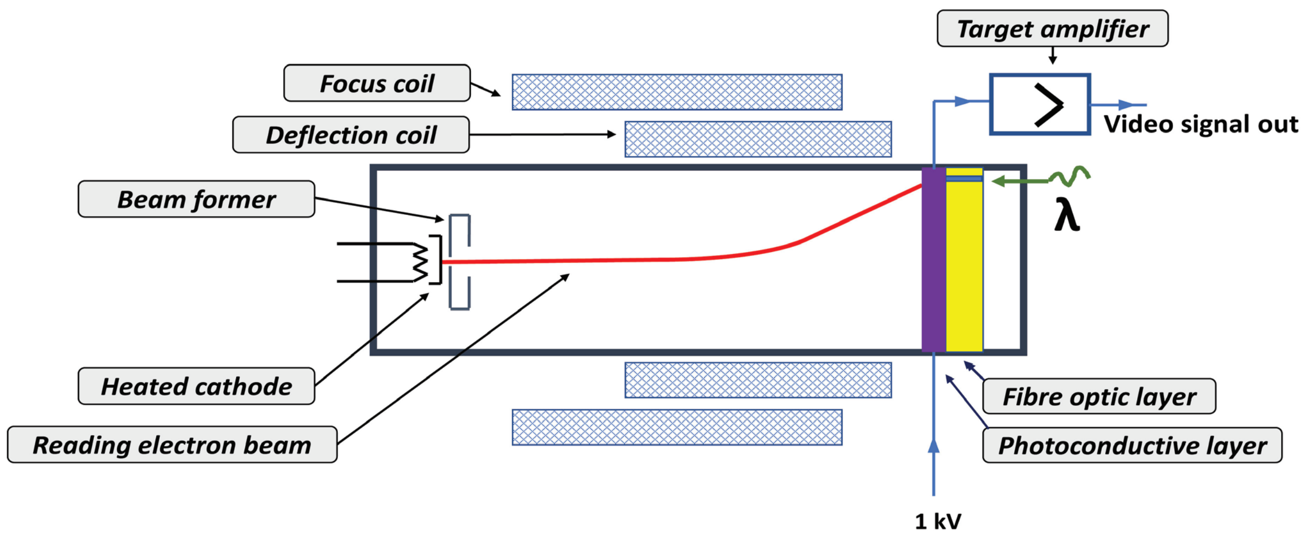

Figure 6. *The camera section of the scan-converter tube; (this section is mirrored when compared to the overall view of figure 5)*

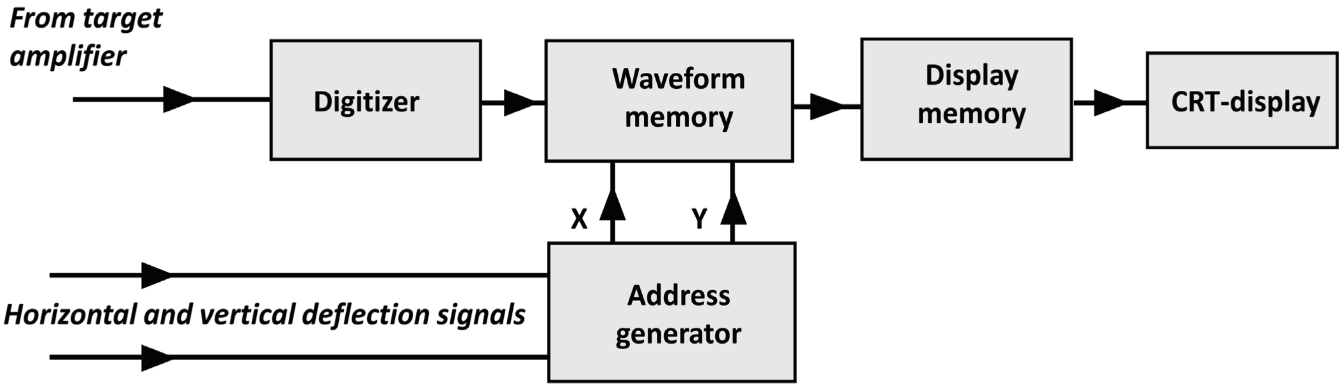

Figure 7. *Data storage and display*

Concluding remarks

The application of the scan converter technology in the Tektronix 7250 has led to an instrument with a bandwidth of 6 GHz enabling the recording of 50 ps rise-time phenomena. The absence of vertical amplifiers leads to a sensitivity of 5 V full scale. Because of the absence of a vertical amplifier and due to the delay line character of the vertical deflection system, the input impedance is 50 Ω. The input connectors are located at the rear side of the instrument. Sweep rates range from 1 µs to 50 ps per division. The instrument is suited for analysing both single shot and repetitive signals. An external trigger signal is required. The sweep delay (delay between trigger signal and actual start of the time base generator) is widely programmable.
Obviously, the use of a digital memory enables detailed data analysis options such as cursor-controlled measurement of signal values. Also, automatic rise time (10% - 90 %), peak-to-peak time and delay times can be assessed. All results are shown numerically displayed on the screen. The stored waveform has a much higher resolution that can then be displayed on the screen. This allows zooming in on details of the stored waveform. Finally, the memory contents may be read out on a plotter or can be transferred to other equipment with the at that time usual GPIB-protocol. Further details can be found in the instrument leaflet [9] and the VintageTek website [10].

Interestingly, the 7250 was originally developed by the French company Intertechnique (Division Systèmes Militaires et Transmissions) and introduced around 1985 as the IN7000 Oscilloscope Numérique. In the Tektronix 7250 service manual it is mentioned, that occasionally within the instrument texts are in French [11]. Furthermore, various parts (e.g., printed circuit boards) are provided with French inscriptions. The instrument was rebranded by Tektronix for sale in the USA.

Now that sampling devices with over 1 G-samples/sec have become available (see e.g. [12]), instruments like this have become obsolete.

Acknowledgement

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References

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[3] see: https://w140.com/tekwiki/wiki/Micro-channel_plate_CRT
[4] see: https://w140.com/tekwiki/wiki/580-series_scopes
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[12] see: https://www.ti.com/data-converters/adc-circuit/high-speed/rf-sampling.html

An interesting original ‘promotion video’ on the 7250 can be found at:
https://www.youtube.com/watch?v=fS6WOx5X8zM
or by scanning the QR-code.