Radechon Storage Tube Circuits

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Summary—Since a signal of about 20 volts must be applied to the storage target of the developmental Radechon either as a means for switching from write to read condition or, in a less preferred mode of operation, as an input writing video signal, this signal must be separated from the much smaller (about 30 millivolt) reading output signal. In the older barrier grid storage tube design, these signals were separated by taking the output from a collector of the secondary electrons from the target. However, experience has shown that separation in the external circuit is simpler in over-all operation. Several circuits have been used in the many applications of the tube. For applications in which switching time is available, relays are best. In special cases, short-time-constant clipping circuits suffice. Radio-frequency (r-f) signal separation provides short access time for the operation of a few tubes. Crystal diode switches are simple, and a self-balanced double cathode follower circuit provides very linear output. Each of these methods is described.

The Signal Separation Problem

THE Radechon, a developmental barrier grid storage tube,[1,2] comprises a single electron gun and a storage target. In its operation during writing, either the input video writing signal is impressed upon the plate at about 10 volts peak to peak, or it is applied to the control grid while a 20-volt square pulse is applied to the plate. In either case, the screen must be held at a fixed potential.[3] The reading output signal is a current of which about 2 microamperes is modulated so that for the usually required 5-megacycle bandwidth, the input capacitance of the output amplifier, and ten to one high peaking, the output voltage is about 30 millivolts. Several methods that have been used to keep this low-level output signal separate from the high-

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* Decimal Classification: R138.31.

[1] A. S. Jensen et al., "Barrier Grid Storage Tube and Its Operation," *RCA Review*, Vol. IX, No. 1, pp. 112-135, March, 1948.

[2] Arthur S. Jensen, "The Radechon, a Barrier Grid Storage Tube," *RCA Review*, Vol. XVI, pp. 197-215, June, 1955.

[3] As far as the writing and reading processes are concerned, the signal need only be applied between screen and plate irrespective of how the potential of either changes with respect to ground. However, if the screen potential is allowed to change, there is a small but perceptible change in deflection sensitivity that reduces the resolution.

level signals that are on the plate and the deflection plates are described below.

In all these circuits, it is important that the output circuits be well shielded. For this purpose a shield electrode, designed to provide adequate electrostatic shielding within the tube between the target structure and the electron gun with its deflection plates, is brought out on a ring seal.

SECONDARY EMISSION METHOD

The earlier tube designs[1] solved this signal separation problem by collecting the secondary electron current on a well-shielded collector,

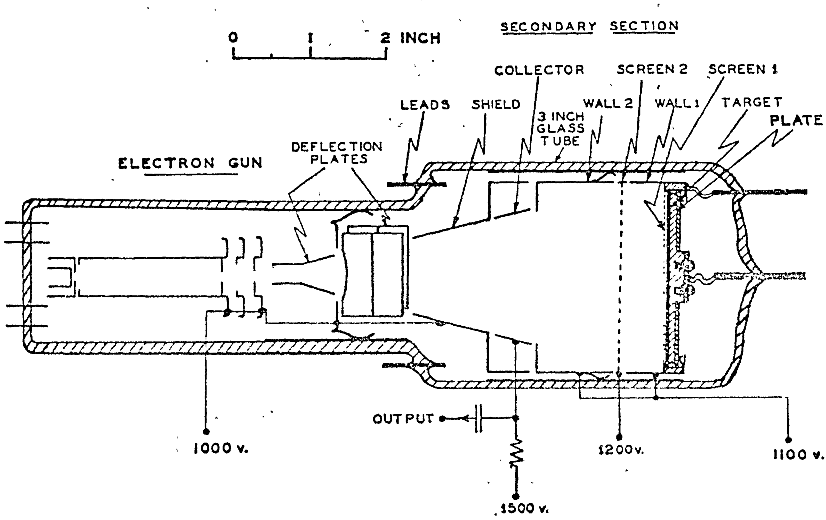
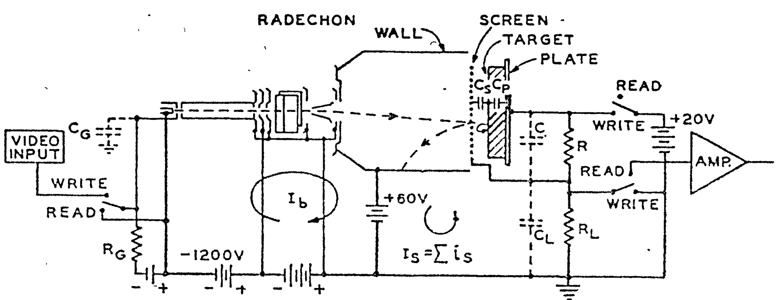


Fig. 1—STE-S type Radechon storage tube.

which then was the output electrode. The output amplifier measured the modulation which was impressed by the stored charge pattern upon this secondary electron current. However, this posed a difficult shading problem. It was difficult to design an electron optical system that collected the secondary electrons equally well from all areas of the target and yet used a small collector with little capacitance to other electrodes. A second screen improved the shading but made the adjustment of electrode potentials even more critical. It became evident that the complication might be better located in the external circuits.

RELAY CIRCUIT

In certain applications which do not require rapid switching from write to read and vice versa, the relay circuit of Figure 2 has proven the most satisfactory. During writing, the load impedance (R_L, C_L) is shorted out so that the screen is held firmly at ground potential, while the switching voltage is developed across R and the target input capacitance C, the sum of all the C_s and C_p in series (about 1000 micromicrofarads). The resistor R is chosen so that this time constant is smaller than the allowable switching time. Video input is applied to the control grid. During reading, the plate is disconnected from the switching voltage source, the load impedance is placed between the target structure and ground, and the target structure is connected to the output amplifier. The load impedance time constant is chosen to match the required output bandwidth, except that increased low-frequency signal-to-noise ratio[4] can be obtained by using a large time constant at the input and high peaking later in the amplifier.



$\frac{1}{C} = \sum \frac{1}{C_S} + \frac{1}{C_P}$; $C = 1000\mu\mu fd.$

$\sum C_S + C_P = 8000\mu\mu fd.$; $C_S + C_P = 0.18\mu\mu fd/\text{SPOT}$

$C_L = 5\mu\mu fd.$; $C_G = 7.4\mu\mu fd.$

Fig. 2—Schematic relay circuit.

During writing, the average voltage of the target structure is one half the applied switching voltage. Upon switching back to the read condition, this appears as a large transient across the load impedance. An improved circuit (Figure 3) balances the impedance of R and the target input capacitance by the equivalent network R_2C_2, but requires another relay and additional switching power, and adds to the load capacitance. However, even with fixed circuit values, this reduces the switching transient to the order of magnitude of the stored output signal.

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[4] For disturbances and noise not generated by the beam, and at the expense of high frequency disturbance and noise.

Radio-Frequency Signal Separation System

A method of signal separation identical to that used in some other storage tubes[5-8] has been applied successfully to the Radechon.[9,10] In this system, writing is accomplished as before with either a steady beam and the video applied to the plate, or a switching signal on the plate and the video applied to the control grid. During reading, the beam is keyed on by driving it above cutoff with an r-f oscillator. The stored charge pattern on the target modulates the r-f variations of the beam which are amplified by the output band-pass r-f amplifier, the stored signal modulation being detected, as in any receiver following the i-f amplifier. However, the lower frequency switching or video

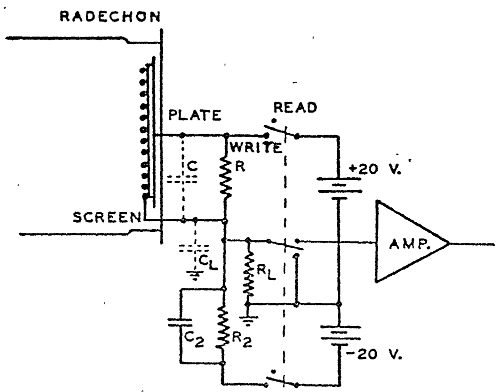

Fig. 3—Improved relay circuit.

signals applied to the plate are rejected by the output amplifier. Appropriate filters are required at the plate, and shielding around the target section of the Radechon and the output amplifier is extremely important. The ring seal internal shield has proven satisfactory in this method of operation.

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[5] L. Pensak, "The Graphechon—A Picture Storage Tube," *RCA Review*, Vol. IX, p. 59, March, 1949.

[6] L. E. Flory, J. E. Dilley, W. S. Pike, and R. W. Smith, "A Storage Oscilloscope," *RCA Review*, Vol. XII, pp. 220-229, June, 1951.

[7] S. H. Dodd, H. Klemperer, and P. Youtz, "Electrostatic Storage Tube," *Elec. Eng.*, Vol. 69, pp. 990-995, November, 1950.

[8] A. J. Lephakis, "An Electrostatic-Tube Storage System," *Proc. I.R.E.*, Vol. 39, pp. 1413-1415, November, 1951.

[9] Personal communication from F. M. Gager, E. N. Zettle, and G. K. Jensen of the Naval Research Laboratory, Washington, D.C.

[10] Personal communication from N. I. Korman and W. V. Goodwin of Engineering Products Division, RCA, Moorestown, N. J.

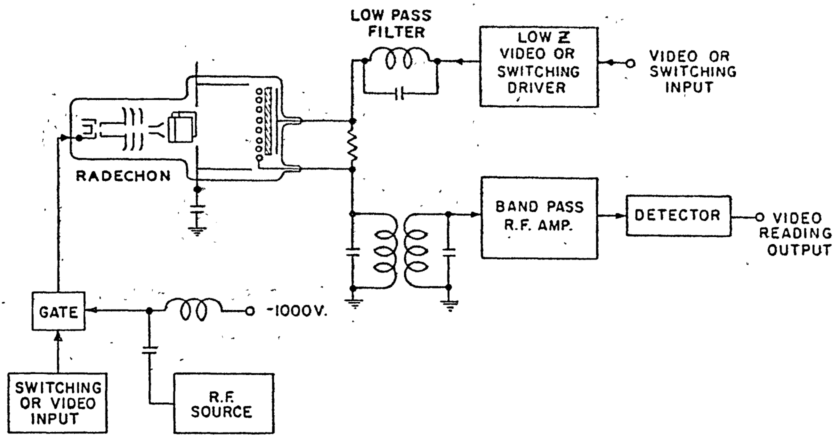

Fig. 4—Radio-frequency signal separation system.

Crystal Diode Circuit

Crystal diodes may be used as switches in the place of the relays of Figure 2 with a considerable gain in the speed of operation, but somewhat of a loss in efficiency of signal separation because the front resistance of the diode is not less than 25 ohms. One of several[11]

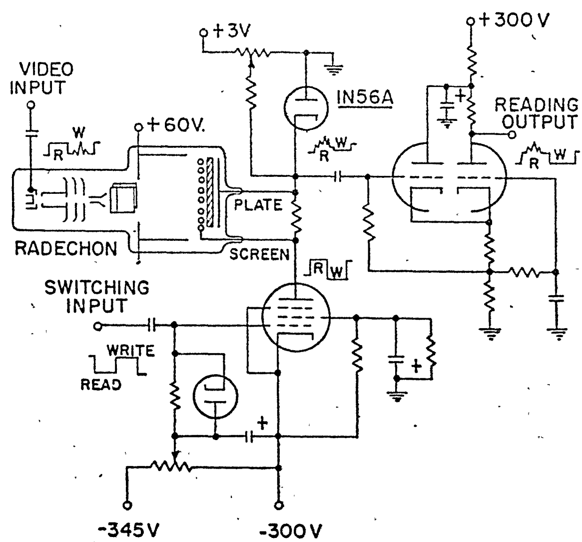

Fig. 5—Crystal output circuit.

[11] E. W. Bivans and J. V. Harrington first devised and used this and similar circuits in their investigations in connection with a binary digit storage system at the Air Force Cambridge Research Laboratories, Cambridge, Massachusetts: E. W. Bivans and J. V. Harrington, "An Electronic Storage System," *Proc. I.R.E.*, Vol. 38, No. 2, p. 205 (Conv. abstract No. 118), February, 1950.

successful circuits of this type is shown in Figure 5. During writing the pentode and crystal diode are both conducting, holding the target structure at a low impedance while the switching voltage is applied across it. Some of this switching voltage does appear on the input of the amplifier, however, since the crystal diode's forward resistance forms an appreciable part of the potential divider in the pentode's plate circuit. During reading, the pentode is driven beyond cutoff, the crystal diode is not conducting, and the entire target structure and the amplifier input are at a high impedance from ground so that current signals from the tube may be amplified. Ordinarily, the simple back resistance of the crystal diode is not sufficient, but, at the expense of adding a small pedestal to the output signal, the crystal diode may be back biased as shown and its resistance increased. It is advisable to have clipping circuits in later stages to remove this injected pedestal and the residual switching signal. If the time is available in the system's application, it is well to have a keyed clamp set the zero signal level after the reading switch has operated and before the reading beam is turned on.

The version of the circuit shown here is undesirable in some applications since it applies the switching voltage to the screen instead of the plate, thus reducing the tube resolution somewhat.[3] Furthermore, the nonlinear characteristic of the crystal diode is a distinct disadvantage if absolute measurements are to be made on the output signal. Fortunately, the majority of practical applications do not require this.

DOUBLE CATHODE FOLLOWER CIRCUIT

The search for an output circuit with a linear characteristic which would enable the measurement of reliable tube data for publication led to a circuit whose steady and reliable operation with good signal separation recommends it for more general use. In the double cathode follower circuit (Figure 6) the screen is dynamically held at a fixed potential. The lower pentode cathode follower feeds electrons into the screen as fast as they are taken out by the upper pentode. This operation is satisfactory even during the rise of the switching signal since both tubes are being operated over their transfer characteristic in the same direction at the same time. This feature is more important than the matching of the tubes. Unmatched tubes have been used with good results for separating the output signal from the switching signals, but it has not been successful in the separation from video input signals applied to the plate. The switching signal transient is about the same size as the output stored signal (Figure 7).

In the circuit shown the switching signal is applied to the grids

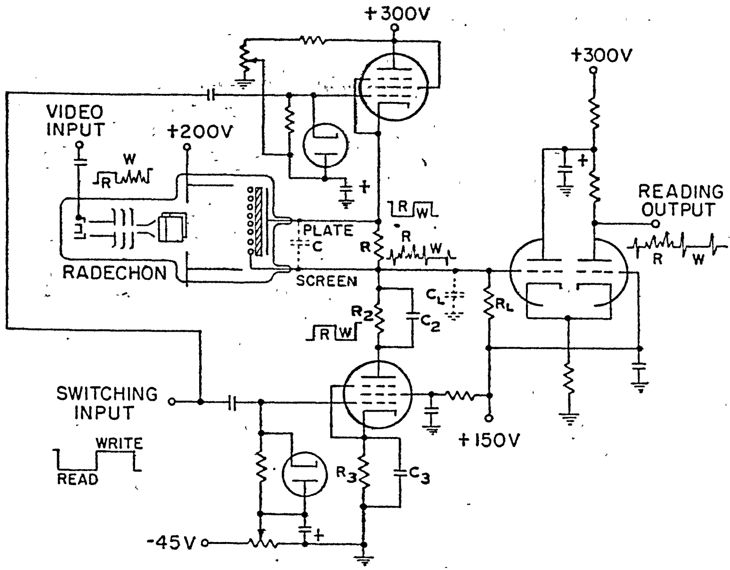

Fig. 6—Double cathode follower circuit.

of both upper and lower cathode followers to turn them on during writing. The switching voltage is then developed across the Radechon target structure. The network R_2C_2 balances that of the resistor R and the Radechon input capacitance C so that, upon cutting off of the cathode followers at the beginning of the reading period, there will be no large switching transient before C discharges. The network R_3C_3 in the cathode of the lower pentode is necessary to provide the same cathode feedback to it as the resistor R and the Radechon target input capacitance C provides to the upper pentode so that both tubes have the same dynamic operating characteristic. A similar network should be in the plate circuit of the upper pentode to balance R_2C_2, but its effect is negligible. All these resistors and capacitors respectively have the same value.

If no switching signal is to appear at the screen during writing, the currents through the two pentodes must be accurately the same. This is accomplished by adjusting their biases as indicated in the diagram. It is obviously impractical to do this manually, but a feedback loop from the output of the amplifier back to the bias source

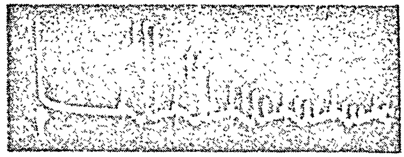

Fig. 7—Six copies of output stored signal following switching transient.

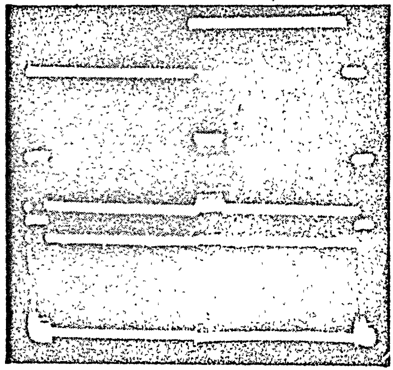

Fig. 8—(*Top*) Switching signal at plate. (*Center*) Input to control grid. First and last bursts are reading gates. Center burst is groups of writing pulses. Blanking applied during fly back. (*Bottom*) Stored output signal from double cathode follower circuit.

for either pentode easily accomplishes this balance. A wide-band feedback loop automatically operates only during writing time since the pentode it controls is cut off thus reducing the loop gain to zero during reading. A slow speed feedback loop, providing essentially d-c bias control must be keyed so that it measures only the writing output otherwise it will respond to the output reading signals. Both types of circuits of conventional design have been operated successfully, both separately and simultaneously. Figure 8 illustrates the balance that can be maintained. The bottom line is the stored signal output of fourteen reading copies following the writing of a group of pulses fourteen times on one single line scan. The output pulses appear very much compressed at the edges. A small discontinuity at the center is the switching transient. Note that the baselines during reading and writing are at approximately the same level, showing good separation of the input switching signal from the output signal.

During the reading period, while the pentodes are cut off, the Radechon load impedance consists of R_L, a known linear resistor which is the grid resistor of the amplifier, and C_L, which is the capacitance to ground of the Radechon target structure, the plate of the lower pentode, the cathode of the upper pentode, the amplifier input and wiring. In all these circuits a cathode-coupled input stage has been used to eliminate Miller-effect capacitance. The heaters of the pentodes were on a d-c supply to prevent hum pick-up at the cathode of the upper pentode. This circuit was used for the measurement of all the data given[2,12] on the Radechons.

[12] A. S. Jensen, "Discharging an Insulator Surface by Secondary Emission Without Redistribution," *RCA Review*, Vol. XIV, pp. 216-233, June, 1955.