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SUBJECT: A NOVEL METHOD FOR MEASURING HOLE-STORAGE CHARGE IN DIODES

To: See Distribution List

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Abstract: Hole-storage charge in most diodes can be measured by a new method. A constant current is applied to a condenser through the diode, and the condenser is then allowed to discharge through the diode in the reverse direction. The reverse current through the diode (while the condenser is discharging) occurs in two stages. In the first stage the current is quite high, and the stored holes are discharged. In the second stage the diode reverse current discharges the condenser at a very slow rate. The change in charge on the condenser during the first stage provides a measure of the hole-storage charge. This method is described in more detail in the following paper.

Introduction:

Reverse-recovery of crystal diodes has long been known to be a problem in magnetic-core shift registers of the single-core-per-bit type. In such circuits the core acts as a current source that charges either a delay line or a capacitor through a crystal diode. The diode prevents the stored charge from leaking off of the capacitor after the core completes its switching. An equivalent circuit for this type of operation is shown in Fig. 1.

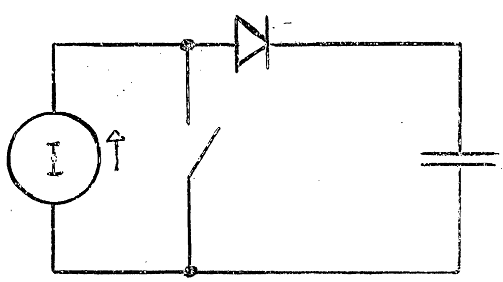

Figure 1

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In early shift registers attempts were made to use alloy junction diodes. These diodes were found to have such poor recovery characteristics that nearly half of the charge on the capacitor was lost through reverse-recovery current in the diode. This difficulty suggested the recovery test to be described.

Test Method

In order to determine the value of a diode, for applications in which the voltage across the unit was reversed immediately subsequent to passage of forward current, it was decided to test the diode in a standard circuit which would put it under roughly equivalent conditions. The circuit of Fig. 2 was devised to allow ease of measurement and maximum flexibility. This device applies a constant current through the diode to a capacitor of any desired capacitance, for any desired amount of time. The current generator is then shorted out and the capacitor allowed to discharge through the back resistance of the diode. The amount of charge lost from the condenser can be measured by simply noting the change in voltage across the condenser. Moreover, the observation does not require fast response oscilloscopes as in many other tests.

Theoretical Basis

The amount of "hole storage" in a forward biased diode is a function of the amount of time in saturation and the magnitude of the saturation current.[1] By supplying a variable current for a variable amount of time this device allows one to make tests for a large range of saturation conditions. Moreover, a correct choice of time and capacity can provide simulation of many actual situations.

When the diode is saturated, the distribution of holes in the base is roughly as shown in Fig. 3a. Upon reversal of the voltage across the diode, the current becomes limited by the end resistance of the diode only. (Fig. 3b.) This high current continues for a very short time. The current then decreases rapidly, and is a function of the initial forward current only.[2] In a very short time the current becomes roughly equal to the normal reverse current of the particular diode (Fig. 3c.) When this condition prevails, the charge that was stored in the diode is just about completely dissipated. This means that the change in the voltage on the capacitor can be used to measure the total charge that was stored in the diode. This discharge may take place within a very short span of time, say 0.2 microseconds or less. However, the response of the oscilloscope need not be that fast, becuase one needs to measure only the eventual charge on the capacitor which changes very slowly.

1. Jones, Nolan T., "Minority Carrier Storage in Diodes and Transistors", Thesis, August, 1954.
2. Kingston, Robert H., "Switching Time in Junction Diodes and Junction Transistors", Proc. I.R.E. Vol. 42, No. 5, May, 1954.

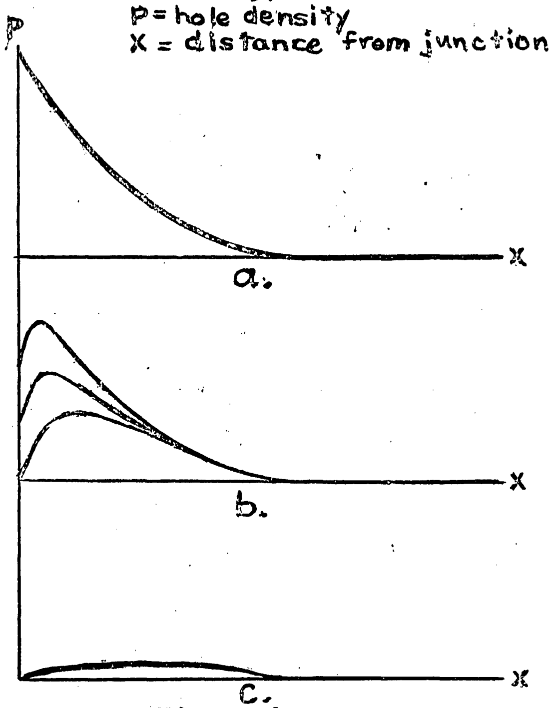

Figure 3

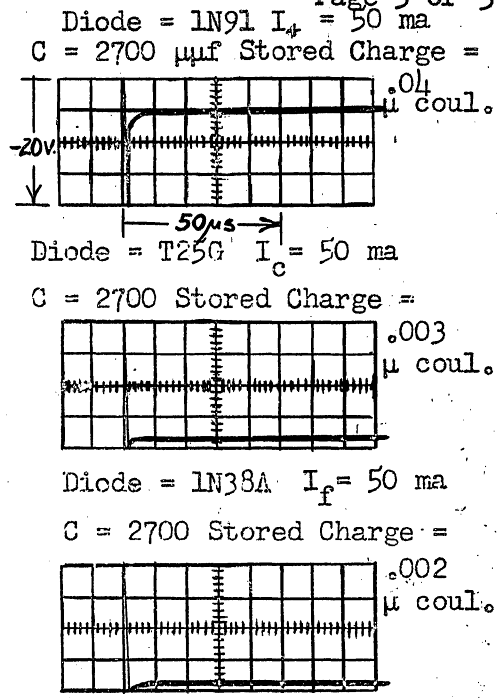

Figure 4

It might be noted that the lifetime of holes in the material has not been mentioned. Usually, the lifetime of holes in the diode is long compared to the time required to discharge the diode in this manner. However, certain types of diodes may achieve very good recovery characteristics by dint of an artificially reduced lifetime. In such diodes, the results of this test would be relatively meaningless as a measure of the total stored charge, but would still reveal the operation to be expected under certain circuit conditions. Moreover, the lifetime must be taken into account when any diode is used in a circuit which causes the diode to recover very slowly.

Circuit Operation

The circuit, as shown in Fig. 2, is quite conventional in operation. The variable width pulse generator supplies a voltage pulse which serves the dual purpose of turning on the current generator (6CD6) and turning off the switching diode (T5). When the voltage of the pulse generator returns to ground (from some negative value) the condenser, C, has been charged to some negative voltage and now discharges through the test diode, the switching diode, and the internal impedance of the pulse generator. The relay and relay driver (5965) are operated some time after the charging and discharging of the condenser through the test diode, in order to bring the initial charge on the condenser back to zero before the next test cycle. The pulse generator is a Rutherford. Typical waveforms are shown in Fig. 4 and show the relative recovery characteristics of various types of diodes. Finally, it might be noted that a certain amount of the recovery is due to capacity, and this cannot be differentiated from hole storage by the above method.

Signed Edmund U. Cohler
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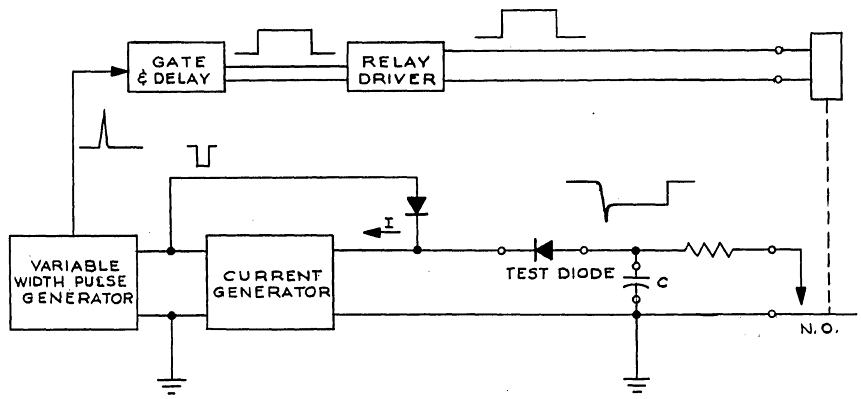
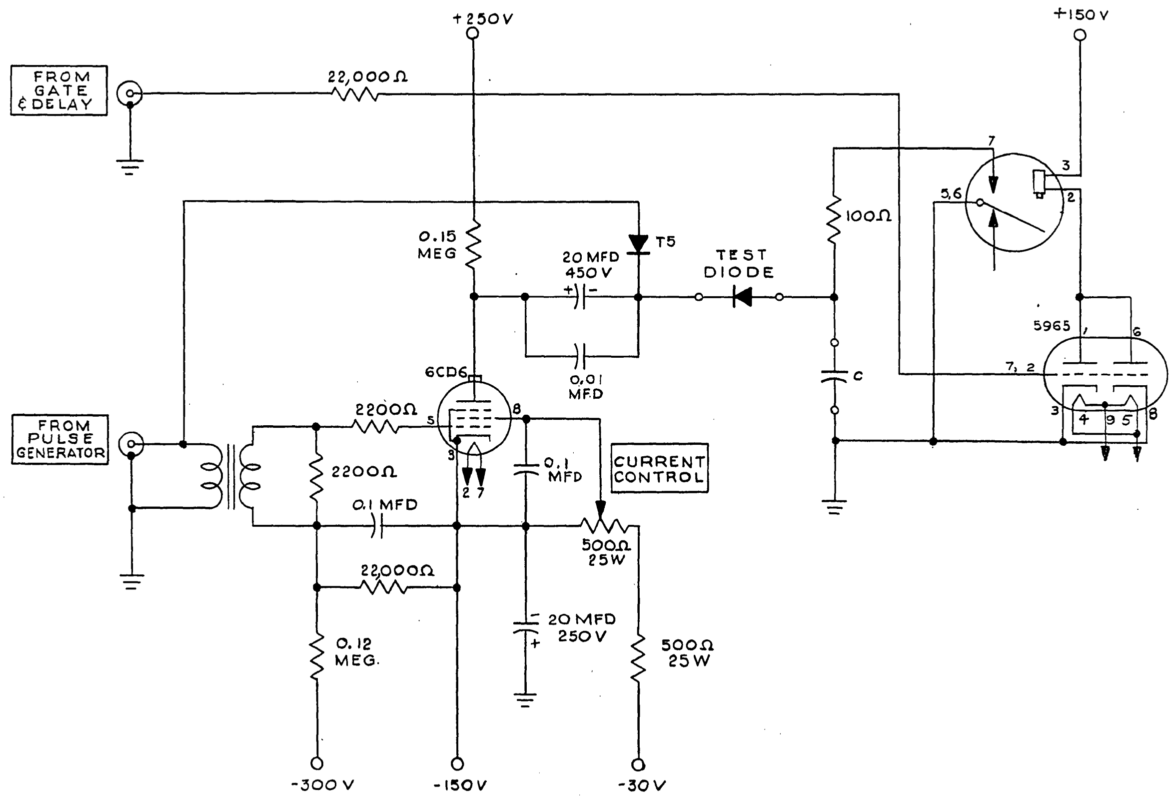


BLOCK DIAGRAM



CIRCUIT FOR DETERMINING REVERSE RECOVERY CHARGE OF DIODES

C-59295