Digital Computer Laboratory
Massachusetts Institute of Technology
Cambridge, Massachusetts

SUBJECT: CIRCUIT FOR MEASURING SWITCH TIME, RISE TIME, ETC. (SWITCH-TIME COMPARATOR)

To: All Engineers

From: B. Gurley

Date: May 11, 1953

Abstract: Use of the switch-time comparator with an oscilloscope makes possible rapid time measurements in the range 0 - 10 microseconds with an accuracy of 0.5 percent +.01 microseconds.

General Description and Operation

The unit is a delayed-pulse generator with an output pulse delayed 3 to 15 microseconds with respect to the input pulse. The output is applied to the CRT cathode of an oscilloscope to obtain a blanking or an intensifying marker.

To measure a time interval, the delay increment dial (helipot dial) is set to zero and the initial delay is varied by means of the zero-set control until the marker coincides with the beginning of the interval. The delay increment dial is then rotated until the marker now coincides with the end of the interval. The time in microseconds is read directly from the dial (100 dial units = 1 microsecond).

Any delays necessary to bring the beginning of the interval within range of the zero-set control (the initial delay is variable from 3 to 5 microseconds) must be provided externally. The use of delay lines and/or delay line panels whenever possible is recommended because of their greater stability compared to that of delay multivibrators.

Accuracy

The delay increment, as indicated on the helipot dial, is accurate within 0.5% + 0.01 microsecond after calibration. The stability over a period of a few days seems sufficinet to maintain this accuracy. The stability over a period of weeks is not yet known and so the calibration should be checked periodically.

Figure 2 shows the effect of separately changing (a) filament voltage, (b) complete tube compliment, (c) frequency. It can be seen that the unit stays within the stated accuracy under conditions of reasonable tube variations and PRF rate to 5 kc.

Circuitry

Figure 1 is the schematic diagram of the switch time comparator. Figure 3 shows several wave forms each at maximum and at minimum setting of

the delay increment dial (except 3a which is at maximum and minimum zero set).

V1 (the 7AK7) is a screen-coupled phanastran.* The action is initiated by a positive pulse on the suppressor grid. The plate voltage, e_p, (see 3a and b) first drops e_1 volts (which is equal to the negative step on the grid) and then falls at a constant rate, $\frac{e_2 + e_1}{RC}$ volts per second, where e_2 is the grid return voltage, R is R_9, and c is $C_4 + C_5 + C_6$. When $e_p = K e_2$ (the voltage at the tap of R16), diode V_{2b} conducts. The conduction of V_{2b} places the load R13 in the plate of V_1 causing a break in the slope and shortening the duration. Since this loading takes place as the output signal is generated, the accuracy is not affected. R13 is chosen small so as to minimize and flatten the signal from displacement current through the diode (see Figure 3f). The signal across R13 is amplified in V_3 which triggers the blocking oscillator, V_{4b}. The top portion of the signal at the cathode of V_{4b} is used by the output tube, resulting in a 35 volt, 0.06 microsecond signal at the CRT cathode.

Since the difference in pick-off voltages at delay increment settings of 0 and t microseconds is $(1-k)e_2$ volts, the delay increment

$$t = (1-k)e_2 \frac{RC}{e_2 + e_1} \text{ seconds,}$$

or

$$t = (1-k) \frac{RC}{1 + e_1/e_2}, \text{ where}$$

$$.5 \leq k \leq 1 \text{ and } e_1/e_2 < 0.1.$$

The above equation, together with the fact that delays occuring in the pulse forming circuits should be mearly independent of delay increment setting, explain the good stability of the circuit. The PRF sensitivity is indicated by changes in voltage levels, etc. This sensitivity to PRF could be reduced at the expense of some increased circuit complexity.

Calibration

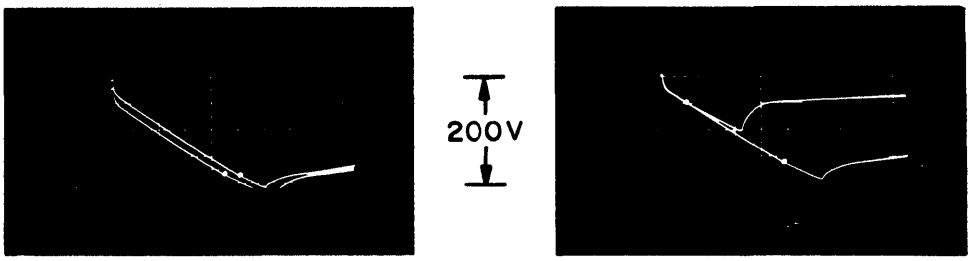
The calibration is done with a Tektronix Type 180 time mark generator and a pulse generator which can be synchronized with the type 180. Using the sweep magnifier of the scope, it is possible to resolve about .003 microsecond.

Signed B. Gurley
B. Gurley

Approved DRB
D. R. Brown

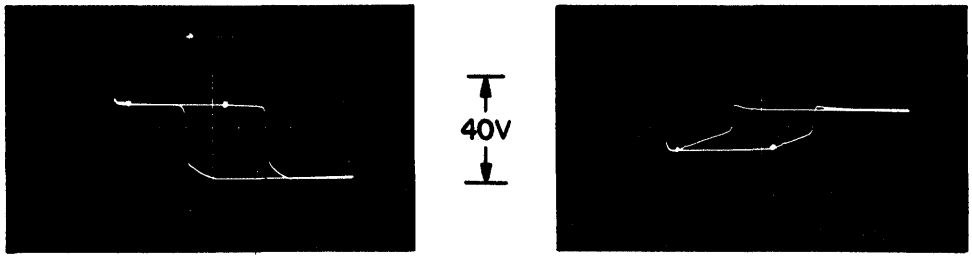
BG/djd
Drawings attached:
A-55055, SA-54831, D-54559

* See vol. 19 Radiation Lab. Series - McGraw-Hill



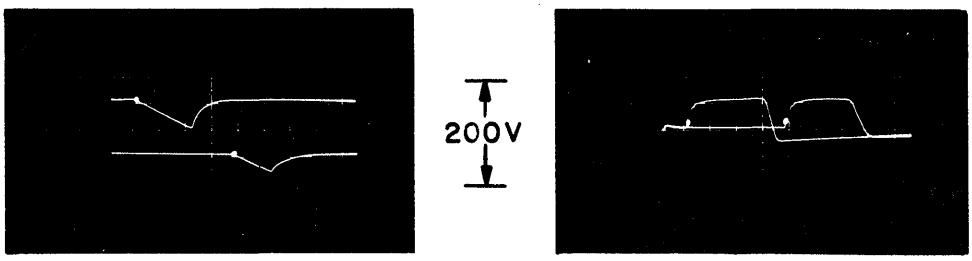
a) 7AK7 PLATE
AT EXTREMES OF ZERO
SET CONTROL (R 10)

b) 7AK7 PLATE



c) 7AK7 SUPPRESSOR

d) 7AK7 GRID



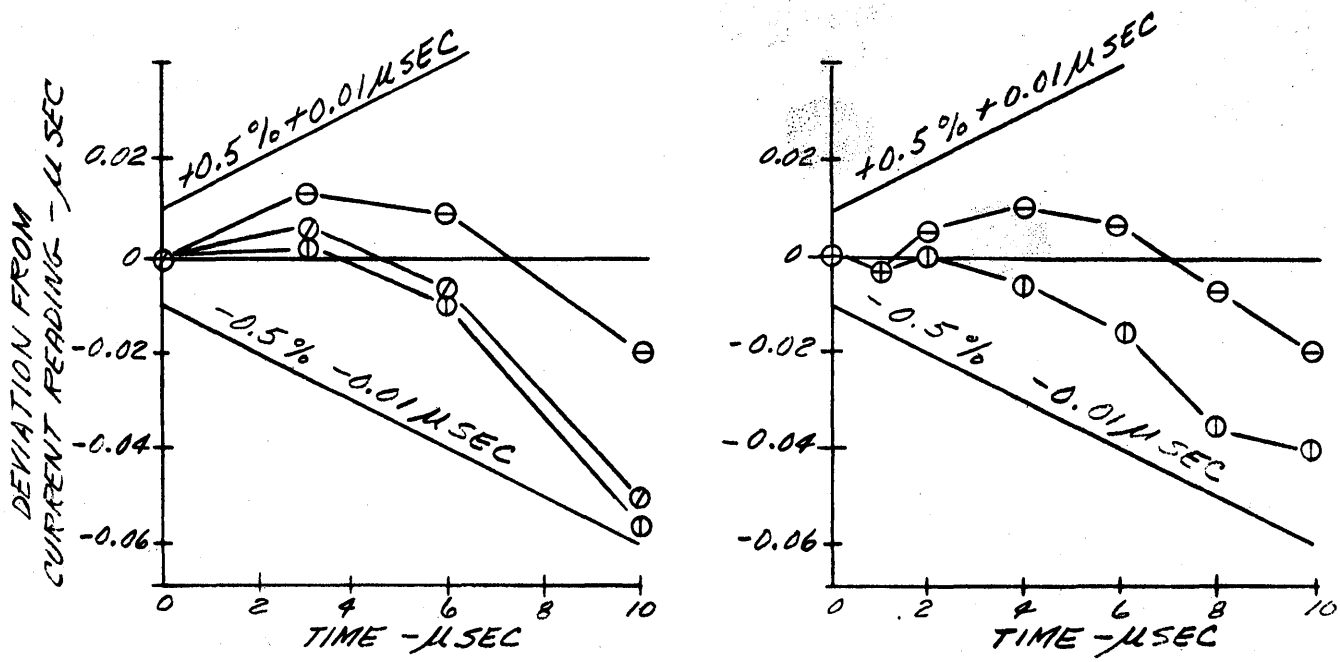
e) V_{2b} (PICK-OFF DIODE) PLATE

f) V_{3a} (AMPLIFIER) PLATE

EACH WAVEFORM (EXCEPT a) IS TAKEN AT 0 AND AT 10 MICROSEC. ON THE DELAY INCREMENT DIAL, THE INTERVAL BETWEEN THE TWO INTENSITY MARKERS IS THUS 10 MICROSEC. (EXCEPT a, WHICH IS THE SAME SWEEP SPEED AS THE OTHERS).

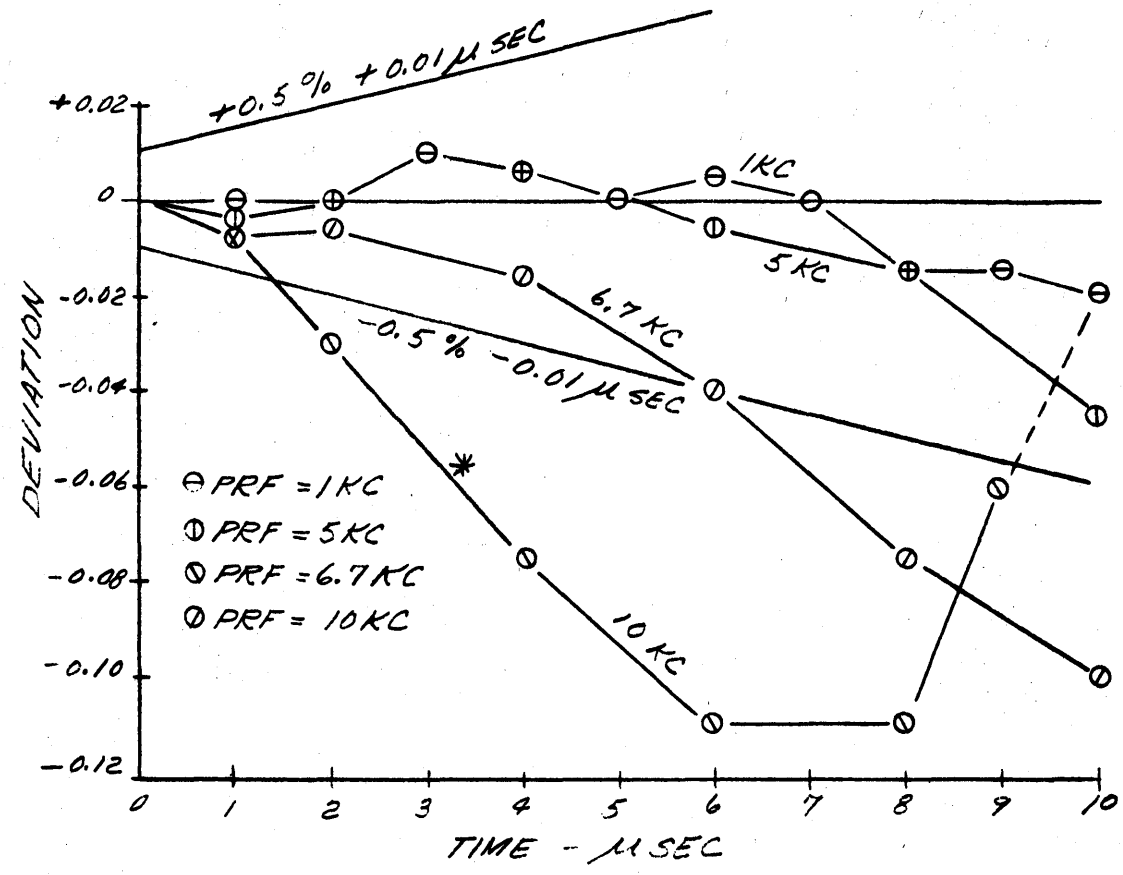
FIG. 3
SWITCH TIME COMPARATOR WAVEFORMS

A-55055



⊖ "NORMAL FILAMENT -5.7V
⊖ V1 ONLY -4.7V
⊖ ALL TUBES -4.8V

⊖ ORIGINAL TUBES
⊖ COMPLETE CHANGE OF TUBES

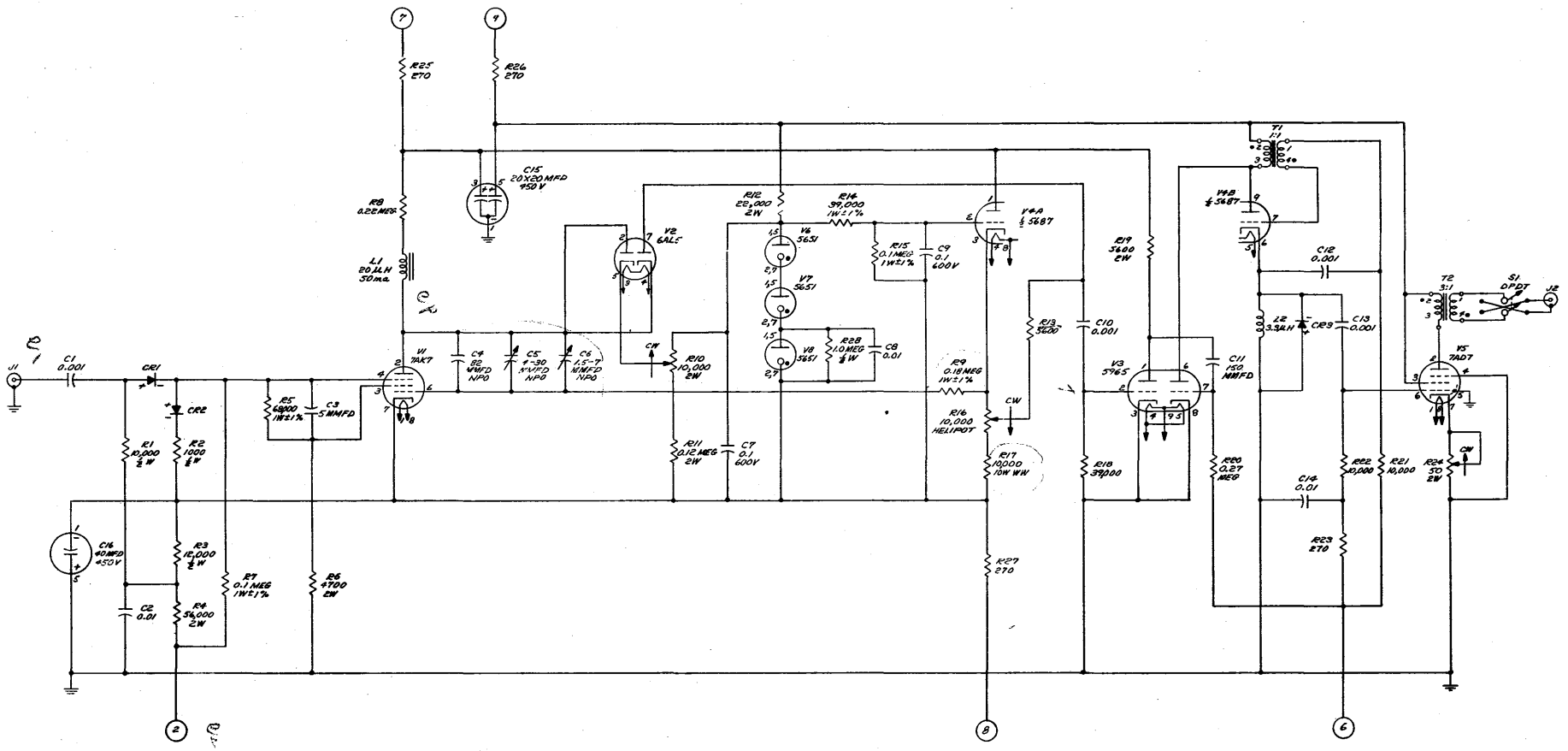


* CONDITIONS AT CALIBRATION FIG. 2

DEVIATION OF SWITCH-TIME COMPARATOR AS FUNCTION OF FILAMENT VOLTAGE, TUBE CHANGE, AND PRF

A-54831

D-54559



NOTES:
UNLESS OTHERWISE SPECIFIED:
A. RESISTORS ARE IN OHMS. 1W ±10%.
B. CAPACITORS ARE IN MICROFARADS.
C. VIDEO CONNECTORS ARE JAN UG-625/U.
D. CRYSTAL RECTIFIERS ARE SYLVANIA TYPE 1N34A.

	MASSACHUSETTS INSTITUTE OF TECHNOLOGY DIGITAL COMPUTER LABORATORY DEPT. OF ELECTRICAL ENGINEERING – D.C.L. PROJECT NO. 6889		
	CIRCUIT SCHEMATIC SWITCH TIME COMPARATOR, TE		
	SCALE ——	DR. CRP 8-11-53	D-54559
	APP.	CK. 9/14/53 APPR.	