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A UNIQUE VARIABLE WIDTH PULSE INTEGRATOR

by Arthur L. Newcomb, Jr. (Langley) 66 33370

Many servo-mechanisms employ sensing devices which produce pulses proportional in width to system rate and/or position. In these applications, tight system control is dependent on fast, accurate and reliable conversion of these pulses to a voltage which is proportional in magnitude to the width of the pulse. Accuracy of system control may also require an output which is relatively free of ripple components over a wide range of duty cycle.

A circuit fulfilling these requirements has been developed and is presently being used in an infrared sensing spacecraft attitude sensor (horizon scanner) having a scan rate of about two per second. A pulse is developed at this repetition rate whose width is directly proportional to spacecraft attitude displacement from the local vertical. The duty cycle of this pulse ranges from 0.06% to about 60%. The spacecraft control system requires that the output furnish spacecraft rate in addition to position information.

AUTHOR

Other applications might include conversion of voice modulated variable width pulses (VWP) and reconversion of telemetered VWP intelligence for more accurate analog signals over low bandwidth channels.

The basic principle of the circuit may be demonstrated using a DPDT relay which is switched on the trailing edge of the input pulse (figure 1). The charging circuit (input) is connected to capacitor C_1 while the high impedance output circuit "reads" capacitor C_2, which was charged on the previous cycle. When the next pulse occurs capacitor C_1 is charged. When the pulse ends, the relay is again switched and the process is repeated.

Relays, however, have disadvantages in that they cannot be switched instantaneously, they require relatively large amounts of power (usually a function of switching speed) and they are generally bulky in comparison to other circuit components. The circuit shown in figure 2 is all solid state, requires only about 600 milliwatts of power and employs a constant current charging source to provide a linear output. Switching is accomplished using the multivibrator formed by Q_4 and Q_5 which is trigge[illegible] on the trailing edge of the input pulse. Low level SCR's (500 milliamp[illegible] continuous rating with at least 10 amp surge rating) SC_1 and SC_2 ste[illegible]

HC $1.00
MF .50

the input pulse to the proper capacitor by being alternately biased on by the multivibrator. At the end of each input pulse the capacitor which is next to be charged is unloaded of its previous charge by a shunted SCR (SC_3 and SC_4). These SCR's are triggered by the same multivibrator through C_5 and C_8. The diodes D_3 and D_4 prevent the capacitors from discharging through the charge circuit.

The constant current charge source is formed by Q_2, Z_1, Z_2, R_7, and R_8. R_5 and R_6 are zener bias resistors. This circuit insures that the output voltage is more nearly linear with respect to the input pulse's width (within less than 2% below 80% of maximum usable output voltage). The maximum output voltage, which is controlled by the constant current source, is one half of the difference between the supply voltage and the zener voltage of Z_1 and Z_2 (which have equal value). The capacitors C_1 and C_2 are read by the high impedance emitter follower (Q_6) through the diodes D_7 and D_8 which are connected in an OR configuration.

Ripple content is strongly affected by the drop-out voltage of the discharging SCR's (SC_3 and SC_4) and the degree to which they are matched. Charging diodes D_3 and D_4 and the zener reference diodes Z_1 and Z_2 should also be matched. The drop-out voltage of SC_3 and SC_4 may also create an offset of the output voltage, but in differential forms of the circuit (as used in the horizon scanner) this effect is negligible.

The only requirement made of the input pulse is that it have a fall time sufficiently fast to trigger the multivibrator (less than 2 microseconds) and an amplitude great enough to saturate Q_1 (greater than 1 volt).

Charge parameter calculations are shown in figure 3a. A synchrogram of circuit waveforms appears in figure 4 and an oscilloscope photo of the operating circuit is shown in figure 5. Figure 6 shows the integrators response to a step function input indicating the range of linear operation.

Charge components may be chosen to provide operation over very wide duty cycle ranges. Pulse widths used with the components specified in figure 2 have ranged from about 500 microseconds up to 0.3 seconds with a corresponding linear output voltage. Lower repetition rates than 2 pulses per second may be used but may make it necessary to incorporate a higher input

[redacted]

impedance output circuit such as a Darlington emitter follower. Repetition rates up to 10,000 pps will operate the multivibrator reliably and with proper changes in charge parameters the circuit may be successfully used at these narrow pulse widths. The use of more sensitive SCR's for SC_3 and SC_4 will reduce the necessary values of the coupling capacitors C_5 and C_8 and the commutating capacitors C_6 and C_7. These changes directly affect the maximum operating repetition rate of the circuit. Figure 3b shows a method of approximating these values.

The circuit is more at home, however, at the low repetition rates where it supplies fast, accurate response to the nearest input pulse. The output therefore represents an integral function of the input, on a single pulse basis, or an RMS equivalent of a series of evenly spaced pulses. The output is in no way a function of repetition rate and is affected only by variations in input pulse width.

Several testing programs conducted over the past year involving the previously mentioned horizon scanner have proven the circuit's capability of operating over long periods of time with reliability and stability.

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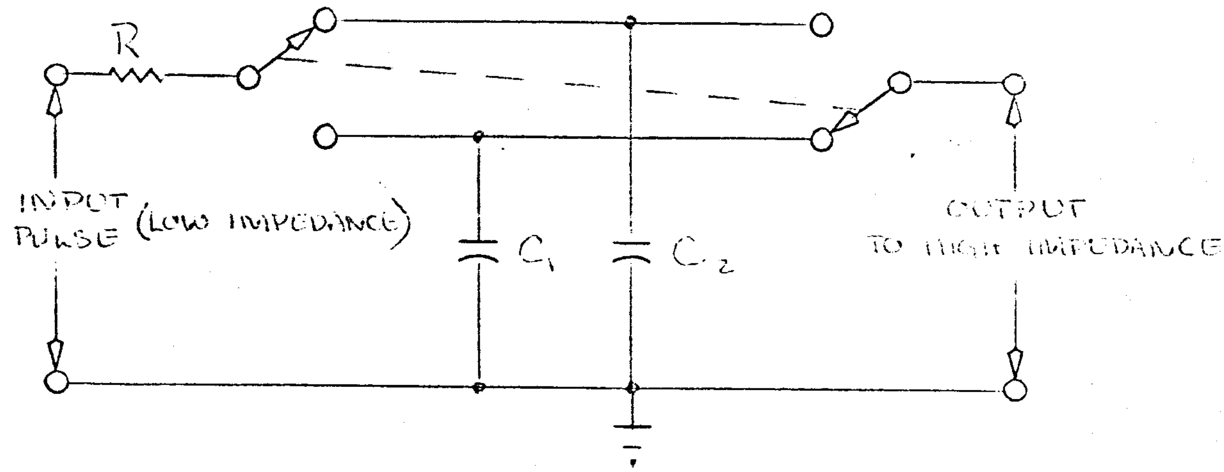
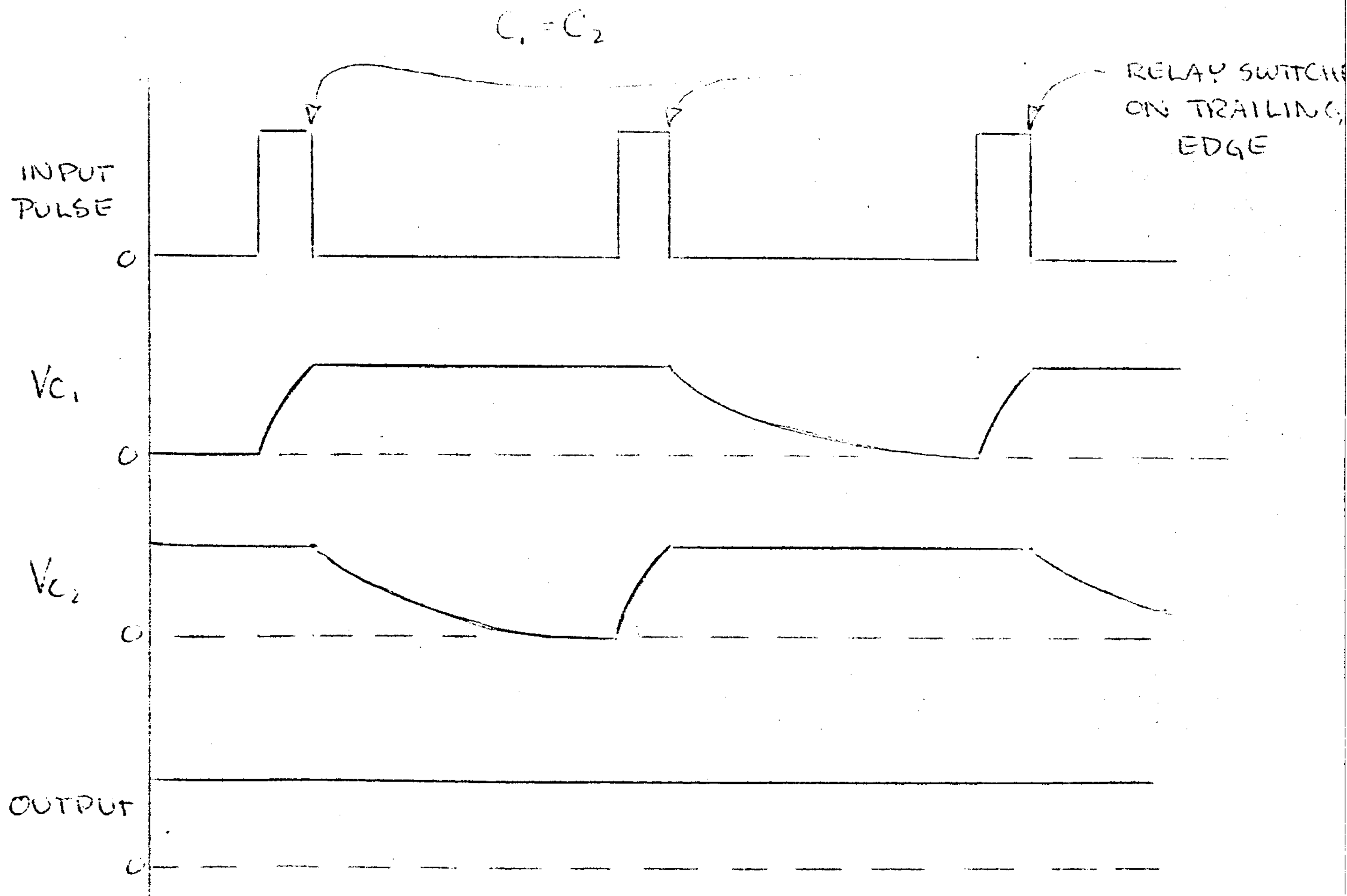
BY [illegible] DATE 8-28-64
CHKD. BY [illegible] DATE

SUBJECT Relay Switching Method

SHEET NO. 1 OF 1
JOB NO.





BY Newcomb DATE 8-28-64

CHKD. BY ____ DATE ____

SUBJECT Variable Width Pulse Integrator

SHEET NO. 1 OF 2

JOB NO. ____

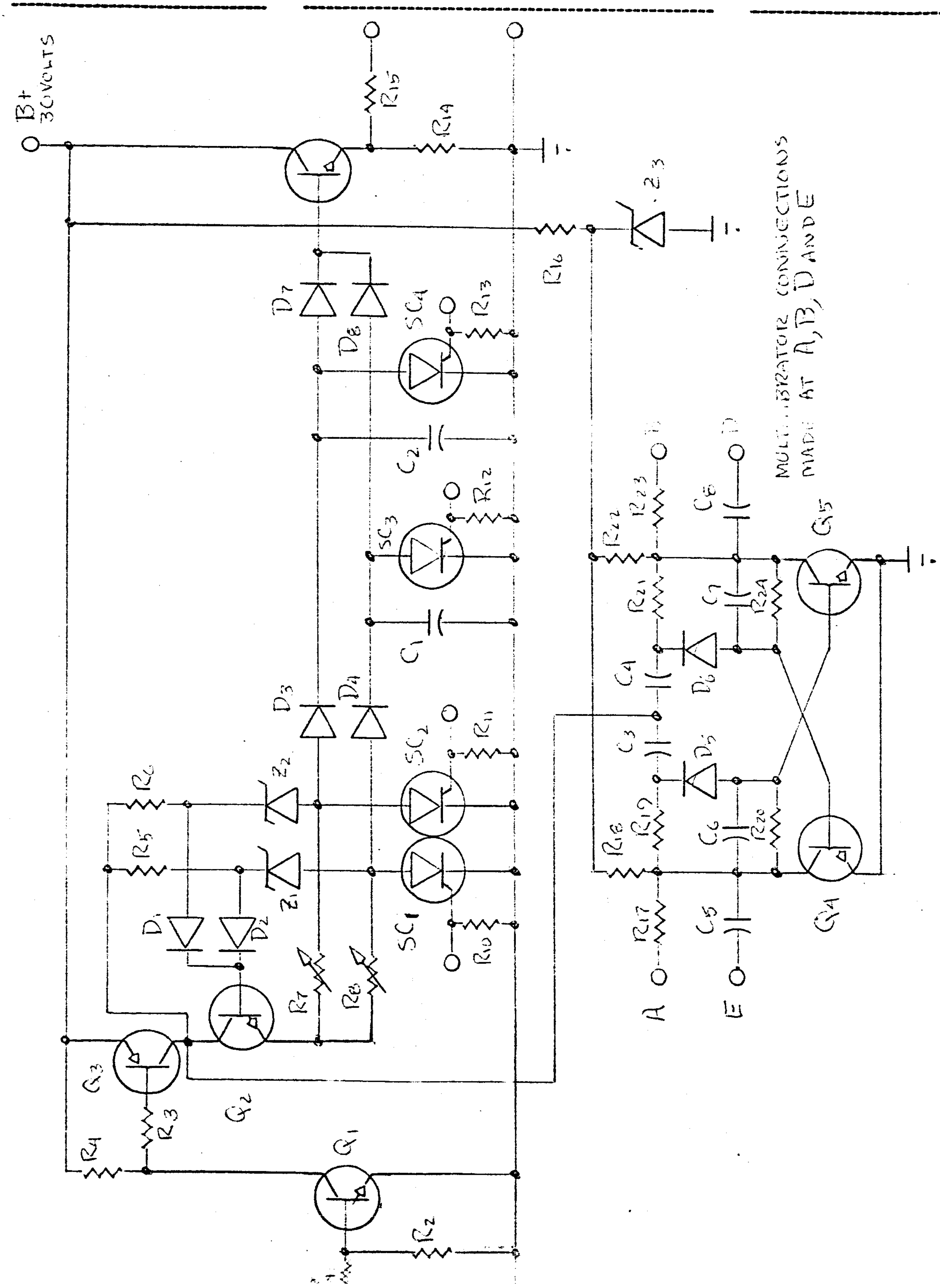


FIGURE 2

BY ________ DATE 8-28-64 SUBJECT ________ SHEET NO. 2 OF 2
CHKD. BY ________ DATE ________ VWP INTEGRATOR JOB NO. ________

COMPONENT VALUES

RESISTORS (OHMS)

R_1, R_2, R_4, R_5, R_6 ....100K
R_3, R_{17}, R_{23} 10K
R_7, R_8 ....10K LIN. POT.
$R_9, R_{14}, R_{20}, R_{24}$ 47k
R_{10}, R_{11} 4.7K
R_{12}, R_{13}, R_{16} 3.3K
R_{15} 1K
R_{18}, R_{22} 2.7K

CAPACITORS (FARADS)

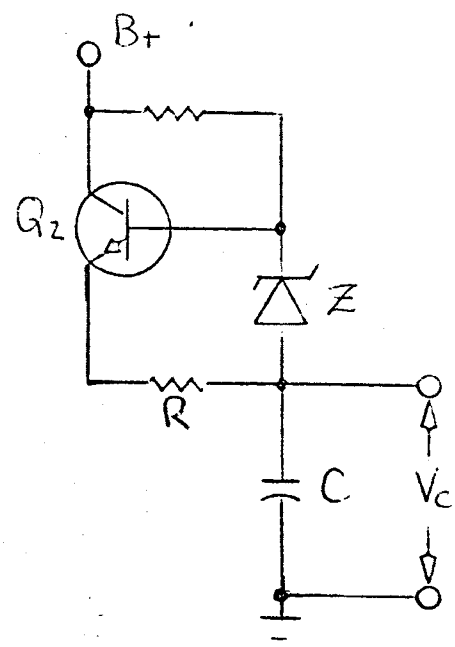
C_1, C_2 ....47μ @ 35VDC
C_3, C_4 ....100p
C_5, C_6, C_7, C_8 .....1000p

DIODES

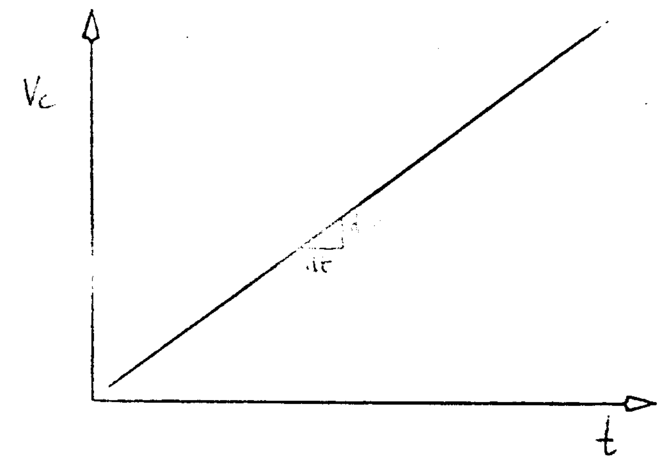
$D_1 - D_8$ 1N38
Z_1, Z_2 ....1N758 (10v)
Z_3 ....1N759 (12v)

SEMICONDUCTORS

Q_1, Q_2, Q_6 ....2N697
Q_3 ....2N722
Q_4, Q_5 ....2N1711



EQUIVALENT CIRCUIT



DESIRED CHARGE RATE

$$\frac{dv}{dt} \quad \frac{\text{VOLTS}}{\text{SECOND}}$$

$$v_c = \frac{1}{C}\int i\,dt$$

$$\frac{dv_c}{dt} = \frac{I}{C} = \frac{V_z}{RC} \qquad \text{WHERE} \quad I = \frac{V_z}{R}$$

$$\therefore \quad RC = \frac{V_z}{\frac{dv_c}{dt}}$$

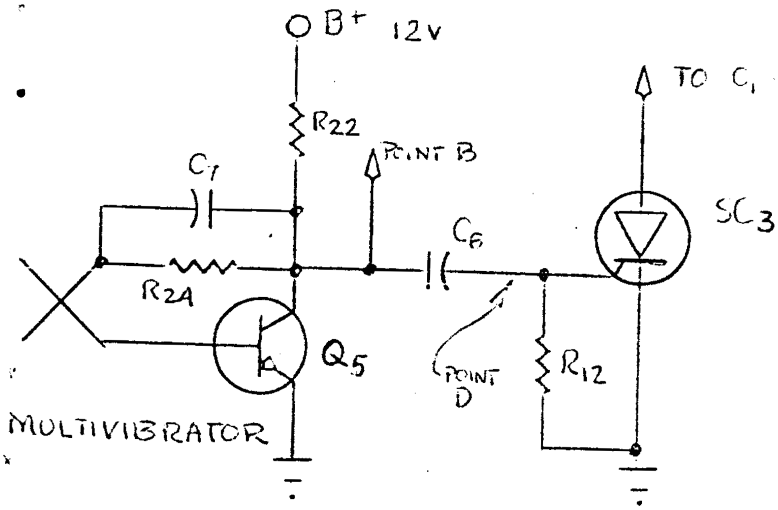
FOR LINEAR OPERATION

$$V_{c\,MAX} = V_{B+} - 2V_z$$

BY Newcomb DATE 10-1-64
CHKD. BY [illegible] DATE

SUBJECT
PARAMETERS CALCULATIONS

JOB NO.



$$T_H = CR = C_8 R_{12}$$

$$T_H = 0.5\mu sec = C_8 (3.3\,K)$$

$$C_8 = \frac{0.5 \times 10^{-6}}{3.3 \times 10^{3}}$$

$$C_8 \geqq 150\,pfd$$

where T_H = MANUFACTURERS SPEC. FOR SCR TRIGGER TIME TO HOLD

R_{12} = VALUE IS SET BY MANUFACTURERS STATEMENT FOR TEMPERATE RANGE OF OPERATION

FOR MOST APPLICATIONS BEST RESULTS ARE OBTAINED WHEN

$$C_7 = C_8$$

BY [illegible] DATE 10-5-64 SUBJECT ______ SHEET NO. 1 OF 1

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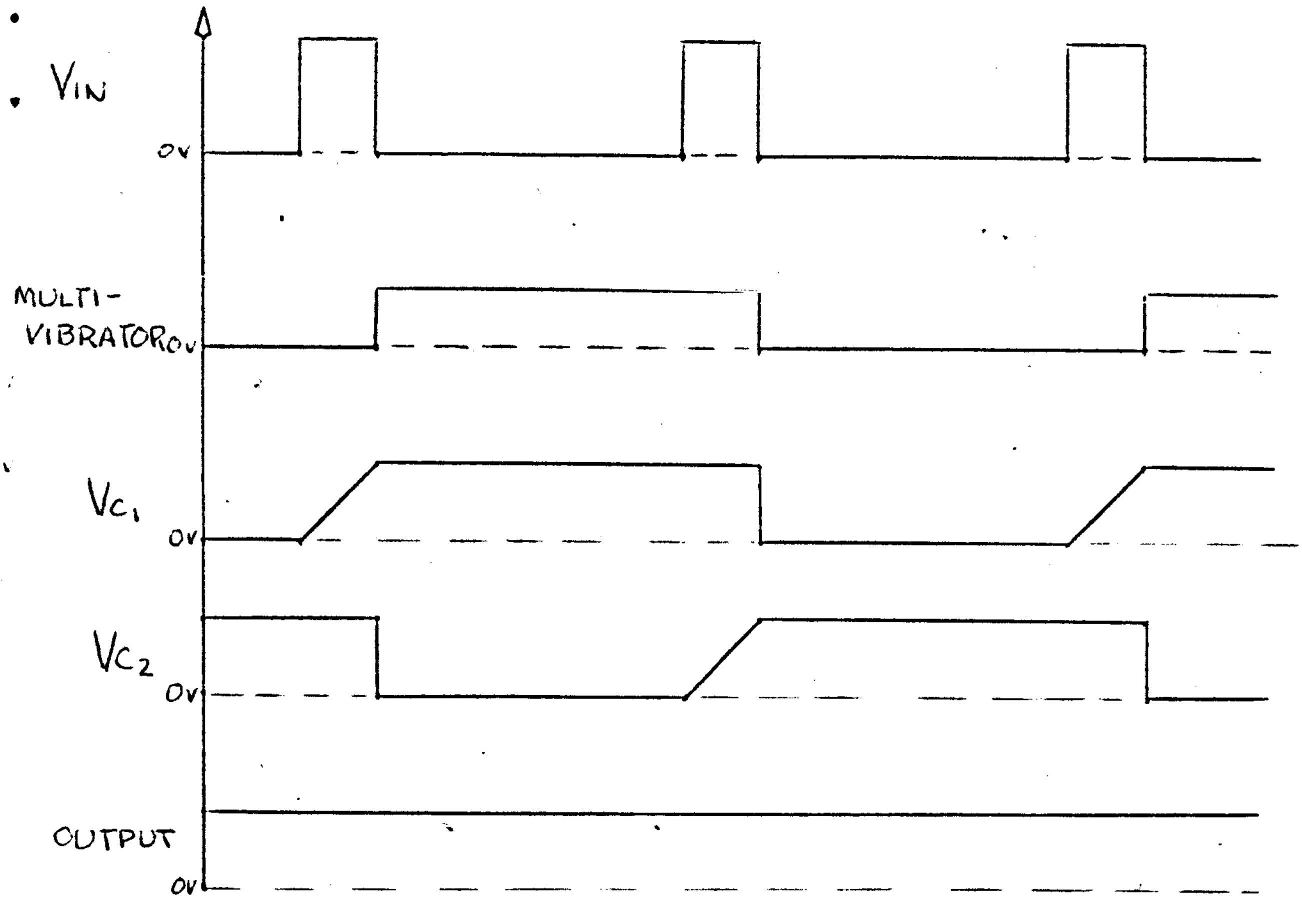
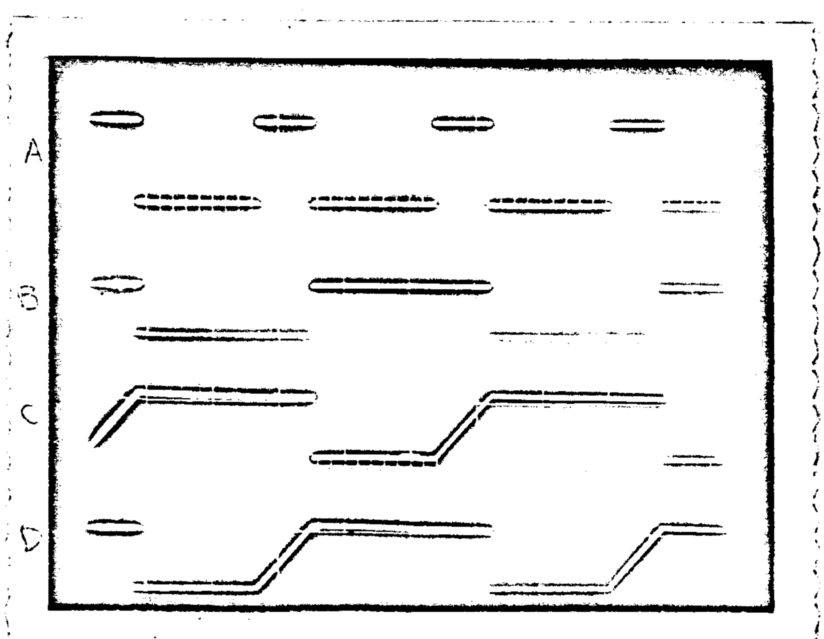


FIGURE 4 SYNCHROGRAM OF CIRCUIT WAVEFORMS



TIME SCALE 0.2 SEC/CM

A. INPUT PULSE 20 V/CM
MUST BE > 1 VOLT

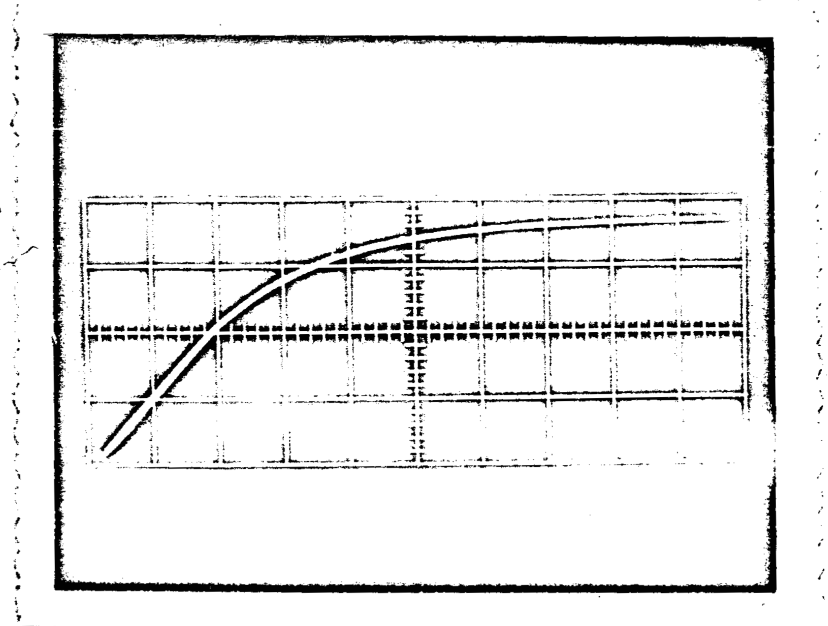
B. MULTIVIBRATOR 10 V/CM

C. V_{C_1}
D. V_{C_2}
5 V/CM

FIGURE 5 OPERATING WAVEFORMS

BY Newcomb DATE 5 Oct 64 SUBJECT SHEET NO. OF

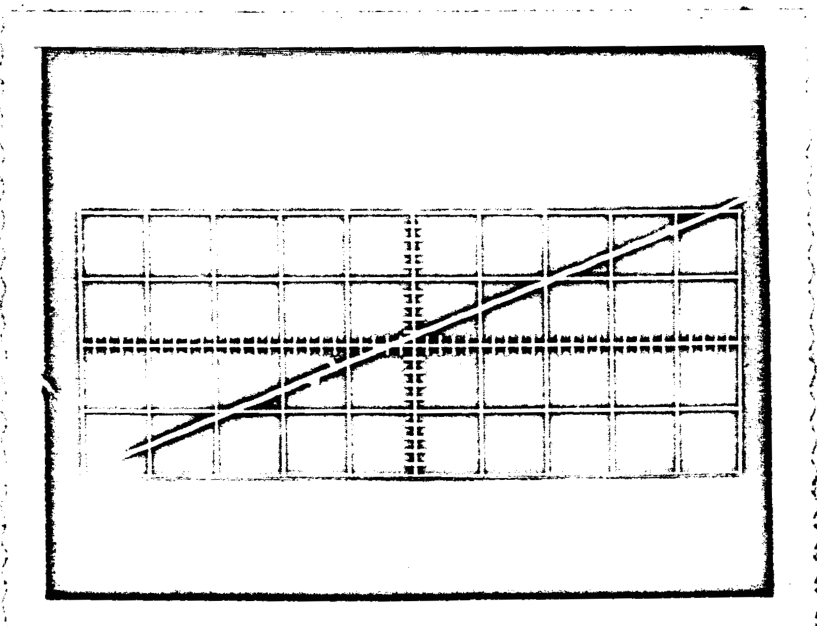
CHKD. BY DATE JOB NO.



INTEGRATOR OUTPUT

TIME 0.2 SEC/CM

5 VOLTS/CM



INTEGRATOR OUTPUT

TIME 400 MILLISECONDS FULL SCALE

2 VOLTS/CM

FIGURE 6 LINEARITY OF RESPONSE TO STEP FUNCTION