Wm H. Gossard

Monostable Multivibrator Design

How to calculate values for a circuit generating rectangular pulses of constant amplitude and duration in response to triggering pulses whose shape and frequency vary

By G. FRANKLIN MONTGOMERY,
Ionospheric Research Section, Central Radio Propagation Laboratory, National Bureau of Standards, Washington, D. C.

THE monostable cathode-coupled multivibrator, shown in Fig. 1, is a circuit which generates a rectangular pulse of constant amplitude and duration in response to a triggering pulse whose shape and frequency may vary. Excellent descriptions of the operation of this flip-flop circuit have appeared before.[1,2] The purpose of this paper is to develop a method which will allow the designer to choose several parameters, such as plate-supply voltage and pulse length, and then calculate the necessary circuit values in logical fashion.

In the circuit of Fig. 1, a positive rectangular pulse is produced at the plate of triode (1) when the grid of triode (2) is properly triggered; a corresponding negative pulse is produced at the plate of triode (2). The action is as follows: It is assumed that triode (1) is normally conducting and that sufficient bias is developed across R_K to cut off plate current in triode (2). If a short positive trigger pulse of sufficient amplitude is now applied to the grid of (2), plate current will start in (2), and the drop across R_2 will be transferred to the grid of (1). The drop in the grid potential of (1) will decrease the common cathode potential and increase the drop across R_2; if the gain of (2) is sufficient, the grid of (1) will be driven beyond cutoff. Triode (2) will now remain conducting until the coupling capacitor C has discharged sufficiently to raise the grid potential of (1) to the cutoff point. Plate current will then start in (1), the regenerative action just described will proceed in the opposite sense, and the circuit will be restored to its original condition.

If the circuit is designed to generate a pulse of length T, it will not, of course, function properly unless successive trigger pulses are spaced by intervals somewhat greater than T. The additional time is necessary to allow C to recharge through R_2, R_K, and the grid-cathode resistance of (1). Most designs will operate with a trigger separation as small as 2T.

Negative output voltages are available at both the plate of (2) and the common cathode, but the pulse length is much more sensitive to loading at these points than at the plate of (1). It is for this reason that the positive pulse amplitude at the plate of (1) has been chosen as a design parameter.

The design method to be described is exact except for the assumption of instantaneous transitions of plate current between conduction and cutoff. The calculated pulse duration will be in error because of this assumption; the error will be serious only for pulses less than several microseconds long.

The symbols used in the step-by-step method are defined in the following list:

- C = coupling capacitance in farads.
- E_B = supply potential in volts.
- E_C = grid bias in volts.
- E_O = output pulse amplitude at plate of (1) in volts.
- E_P = plate to cathode potential in volts.
- E_T = required amplitude of trigger pulse in volts.
- E_2 = plate to cathode potential of (2) in volts.
- e = base of natural logarithms, 2.718.
- I_P = plate current in amperes.
- I_1 = plate current of (1) in amperes.
- I_2 = plate current of (2) in amperes.
- R = grid leak resistance in ohms.
- R_K = cathode resistance in ohms.
- R_1 = load resistance of (1) in ohms.
- R_2 = load resistance of (2) in ohms.
- S = ratio of peak grid-cathode potential to cutoff bias of (1).
- T = pulse duration in seconds.

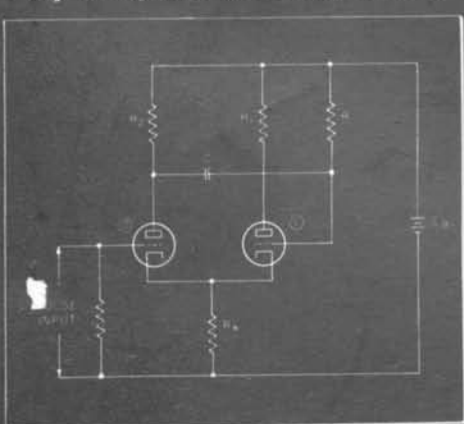
Fig. 1: Diagram of the multivibrator circuit

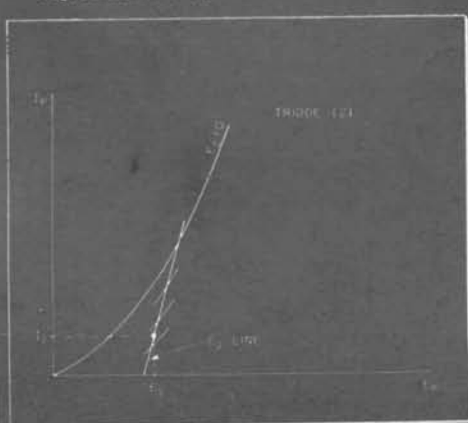
Fig. 2: Triode (2) plate curve construction

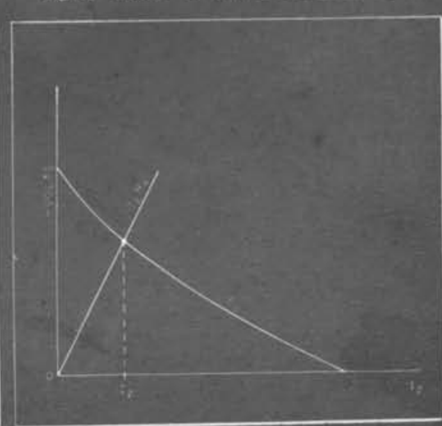
Fig. 3: Triode (2) bias-curve construction

θ_1 = negative ratio of plate voltage to grid voltage for cut-off of (1).

θ_2 = same as above for (2).

The calculations and graphic constructions to be made are now listed in order. Derivations of the formulas are given in the appendix.

Given E_B, E_O, T:

1. Choose tube types for (1) and (2). It is not necessary that the triodes be identical, although they are usually so chosen for convenience.

2. Calculate θ_1 and θ_2 from the E_P-I_P curves for the chosen tubes. It is sufficient to calculate these ratios using $E_P = E_B$ and E_C equal to the grid bias at $I_P = 0$.

3. Choose $I_1 R_K > (E_B/\theta_2)$

4. On the E_P-I_P curves for (1), read I_1 at $E_P = E_B - E_O - I_1 R_K$ and $E_C = 0$. I_1 should not exceed the maximum current rating for the tube, and $I_1(E_B - E_O - I_1 R_K)$ should not exceed the allowable plate dissipation. If either quantity is too large, E_B should be decreased.

5. Calculate $R_1 = (E_O/I_1)$

6. Calculate $R_K = (I_1 R_K/I_1)$

7. Choose $S > 1$. Values from 2 to 5 are usually satisfactory.

8. On the E_P-I_P curves for (2), plot

$$E_2 = \left(1 - \frac{S}{\theta_1}\right) E_B - I_1 R_k + \frac{SR_k}{\theta_1} I_2$$

for various values of I_2 (see Fig. 2).

9. Using the intersections of the E_2 line with the I_P curves, plot E_C versus I_2 on a separate graph (see Fig. 3).

10. On the same graph, plot $-I_2 R_K$ versus I_2.

11. Read I_2 at the intersection on Fig. 3, and locate this value on Fig. 2. Read E_2.

12. Calculate $R_2 = (E_B - E_2)/I_2 - R_K$

13. Choose $R >> R_2$, and at least 10^5 ohms.

14. Calculate:

$$C = \frac{T}{R \ln \left[\dfrac{E_B + I_2 R_2 - I_1 R_k}{\left(1 + \frac{1}{\theta_1}\right)(E_B - I_2 R_k)}\right]}$$

where ln indicates the logarithm to the base *e*.

15. Calculate:

$$E_T > \left(1 + \frac{1}{\theta_2}\right) I_1 R_k - \frac{E_B}{\theta_2}$$

This completes the design.

APPENDIX

Supplementary symbols:

E_G = grid potential of (1) during conduction.

E_G' = minimum grid potential of (1) during cutoff.

$e_G(t)$ = instantaneous grid potential of (1) during pulse cycle.

t = elapsed time, starting at time of triggering.

Initially, in order to ensure cut-off of (2), $I_1 R_K > E_B/\theta_2$

If $R >> R_2$; $E_G' = E_G - I_2 R_2$

But if R is greater than about 10^5, the grid-cathode potential of (1) is nearly zero. Therefore:

$E_G = I_1 R_K$

and $E_G' = I_1 R_K - I_2 R_2$ .... (a)

For (1) to be cut off,

$I_2 R_K - E_G' > (E_B - I_2 R_K)/\theta_1$

Use a ratio S; then

$I_2 R_K - E_G' = (S/\theta_1)(E_B - I_2 R_K)$ .... (b)

Substitute (a) for E_G' in (b), and

$I_2(R_K + R_2) = (S/\theta_1)(E_B - I_2 R_K) + I_1 R_K$ .... (c)

Now $E_2 = E_B - I_2(R_K + R_2)$ ..... (d)

Substitute (c) for $I_2(R_K + R_2)$ in (d), and

$$E_2 = \left(1 - \frac{S}{\theta_1}\right) E_B - I_1 R_K + \frac{SR_K}{\theta_1} I_2$$

This is the equation of the line plotted in Fig. 2.

To determine the pulse duration, notice that:

$$e_G(t) = E_B - (E_B - I_1 R_k + I_2 R_2)\, e^{\frac{-t}{RC}}$$

At $t = T$,

$$I_2 R_k - e_G(T) = \frac{E_B - I_2 R_k}{\theta_1}$$

Substitute (e) for $e_G(t)$ in (f), and

$$e^{-\frac{T}{RC}} = \frac{\left(1 + \frac{1}{\theta_1}\right)(E_B - I_2 R_k)}{E_B + I_2 R_2 - I_1 R_k}$$

from which

$$C = \frac{T}{R \ln \left[\dfrac{E_B + I_2 R_2 - I_1 R_k}{\left(1 + \frac{1}{\theta_1}\right)(E_B - I_2 R_k)}\right]}$$

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2. **Waveforms,** B. Chance, McGraw-Hill, 1949, pp. 166-171.

Reprinted from October, 1950, Issue of TELE-TECH

CALDWELL-CLEMENTS, INC. New York, N. Y.