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

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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. 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 $R_c$ 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 $R_c$; 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 $R_c$, $R_k$, and the grid-cathode resistance of (1). Most designs will operate with a trigger separation as small as 2$T$.

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 this 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.
- $E_p =$ output pulse amplitude at plate of (1) in volts.
- $E_t =$ plate to cathode potential in volts.
- $I_p =$ plate current in amperes.
- $I_t =$ plate current of (2) in amperes.
- $R =$ grid leak resistance in ohms.
- $R_k =$ cathode resistance in ohms.
- $R_l =$ load resistance of (1) 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
\( \theta = \) negative ratio of plate voltage to grid voltage for cutoff of (1).
\( \theta_s = \) 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 \( E_R, E_O, T \):
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 \( \theta \), and \( \theta_s \), from the \( E_P-I_P \) curves for the chosen tubes. It is sufficient to calculate these ratios using \( E_P = E_R \) and \( E_C \) equal to the grid bias at \( I_P = 0 \).
3. Choose \( I, R_K > (E_R/\theta) \).
4. On the \( E_P-I_P \) curves for (1), read \( I \), at \( E_P = E_R - E_O - I.R_K \) and \( E_C = 0 \). \( I \) should not exceed the maximum current rating for the tube, and \( I (E_R - E_O - I.R_K) \) should not exceed the allowable plate dissipation. If either quantity is too large, \( E_R \) should be decreased.
5. Calculate \( R_s = (E_O/I) \)
6. Calculate \( R_K = (I, R_K/I) \)
7. Choose \( S > 1 \). Values from 2 to 5 are usually satisfactory.
8. On the \( E_P-I_P \) curves for (2), plot
\[
\epsilon = (1 - \frac{3}{\theta^1}) \epsilon_R - \frac{\epsilon_R}{\theta^2} \]
for various values of \( I \) (see Fig. 2).
9. Using the intersections of the \( E \) line with the \( I_P \) curves, plot \( E_C \) versus \( I \), on a separate graph (see Fig. 3).
10. On the same graph, plot \( -I, R_K \) versus \( I \).
11. Read \( I \), at the intersection on Fig. 3, and locate this value on Fig. 2. Read \( E \).
12. Calculate \( R_s = (E_R - E_c)/I - R_K \)
13. Choose \( R > R_s \), and at least 10 ohms.
14. Calculate:
\[
C = \frac{T}{\ln \left( \frac{\epsilon_R - \frac{1}{\theta^1} \epsilon_R - \frac{\epsilon_R}{\theta^2}}{(1 + \frac{1}{\theta^1}) (\epsilon_R - \frac{\epsilon_R}{\theta^2})} \right)}
\]
where \( \ln \) indicates the logarithm to the base e.
15. Calculate:
\[
E_c > \left( 1 + \frac{1}{\theta^1} \right) \epsilon_R - \frac{\epsilon_R}{\theta^2}
\]
This completes the design.

**APPENDIX**

Supplementary symbols:
- \( E_G = \) grid potential of (1) during conduction.
- \( E_G' = \) minimum grid potential of (1) during cutoff.
- \( e(t) = \) instantaneous grid potential of (1) during pulse cycle.
- \( t = \) elapsed time, starting at time of triggering.

Initially, in order to ensure cutoff of (2), \( I, R_K > E_R/\theta \).
If \( R > R_s; E_G' = E_G - I.R_s \);
But if \( R \) is greater than about 10 ohms, the grid-cathode potential of (1) is nearly zero. Therefore:
\[
E_G = I.R_K
\]
and \( E_G' = I.R_K - I.R_s \).

For (1) to be cut off,
\[
I.R_K - E_G' > (E_R - E_O)/\theta
\]
Use a ratio \( S \); then
\[
I.R_K - E_G' = (S/\theta) (E_R - I.R_K)
\]
Substitute \( (a) \) for \( E_G' \) in \( (b) \), and
\[
I. (R_K + R_s) = (S/\theta) (E_R - I.R_K) + I.R_K
\]
Now \( E_c = E_R - I.(R_K + R_s) \) \( \ldots (d) \)
Substitute \( (c) \) for \( I. (R_K + R_s) \) in \( (d) \), and
\[
E_c = (1 - \frac{3}{\theta^1}) \epsilon_R - \frac{\epsilon_R}{\theta^2} + \frac{3R}{\theta^1} \epsilon_R
\]
This is the equation of the line plotted in Fig. 2.

To determine the pulse duration, notice that:
\[
e(t) = \epsilon_R - (\epsilon_R - \frac{1}{\theta^1} \epsilon_R + \epsilon_R - \frac{\epsilon_R}{\theta^2}) \sim \epsilon_R
\]
At \( t = T \),
\[
I. \epsilon_R - \epsilon_R (T) = \epsilon_R - \frac{1}{\theta^1} \epsilon_R
\]
Substitute \( (c) \) for \( e(t) \) in \( (f) \), and
\[
T \frac{R}{\epsilon_R} = \left( \frac{1}{\theta^1} \right) (\epsilon_R - \frac{\epsilon_R}{\theta^2})
\]
from which
\[
C = \frac{T}{\ln \left( \frac{\epsilon_R + \frac{1}{\theta^1} \epsilon_R - \frac{\epsilon_R}{\theta^2}}{(1 + \frac{1}{\theta^1}) (\epsilon_R - \frac{\epsilon_R}{\theta^2})} \right)}
\]

**REFERENCES**