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THE SINGLE SHOT MULTIVIBRATOR

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THE SINGLE SHOT MULTIVIBRATOR

This application note offers an effective design guide for a widely used transistor circuit - The Single Shot Multivibrator. The circuit utilizes the unique advantages of the Raytheon 2N 440 Germanium fusion alloy NPN transistor. Results indicate high reliability under operating conditions of -50 C to +70 C, and extremely short rise and fall times were obtained using this circuit.

THE SINGLE SHOT MULTIVIBRATOR

A. CIRCUIT DESCRIPTION:

A conventional circuit for a mono-stable flip-flop or single-shot is shown in Figure 1.

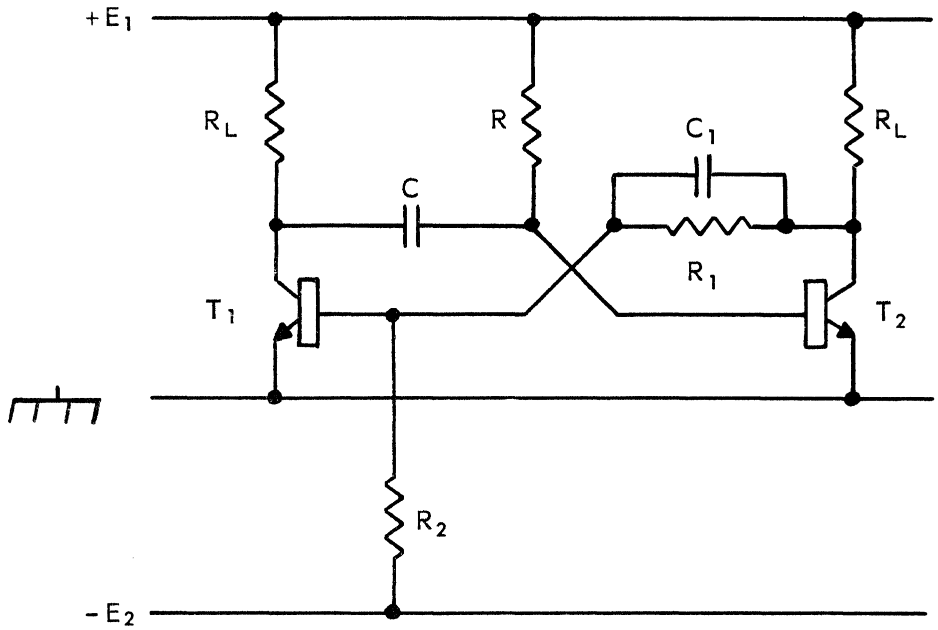


FIGURE I

The stable state for this circuit is: T_2 conducting and T_1 cutoff. Capacitor C is then charged to $(E_1 - V_b)$ volts, if V_b is the base-emitter voltage of T_2.

When the circuit is triggered into its alternate state, C will discharge through R until the base of T_2 is again forward biased and the circuit flips back to its stable state.

Thereby the voltage across R will drop exponentially from $E_1 + (E_1 - V_b) = (2E_1 - V_b)$ to $(E_1 - V_b)$. If collector-emitter voltage of a saturated transistor and the effects of storage charge are neglected in these calculations, the pulse width can be shown to be:

$$T = RC \ln \left(\frac{2E_1 - V_b}{E_1 - V_b} \right)$$

B. DESIGN CONDITIONS:

Limiting values for the resistors R, R_1 and R_2 can easily be found from the conditions for saturation and cutoff of the transistors.

T_1 Cutoff

The condition is:
$$\frac{-R_1}{R_1+R_2}E_2 + \frac{R_2}{R_1+R_2}V_s + \frac{R_1 R_2}{R_1+R_2}I_{co} < 0$$

dividing by:
$$\frac{R_1 R_2}{R_1+R_2}$$

gives:
$$-\frac{E_2}{R_2} + \frac{V_s}{R_1} + I_{co} < 0$$

If we neglect the collector-emitter saturation voltage V_s, the condition becomes:

$$-\frac{E_2}{R_2} + I_{co} < 0$$

$$\text{or} \qquad R_2 < \frac{E_2}{I_{co}} \tag{2}$$

We have to take for I_{co} the max. value at the highest temperature and make the estimate on the high side to compensate for the neglection of V_s.

T_1 Saturated

The condition required for T_1 to be saturated is: $I_{b1} > \frac{I_{c1}}{h_{FE}}$

where h_{FE} is the DC current gain at I_{c1}.

$$I_{c1} = \frac{E_1 - V_s}{R_L} = \frac{E_1}{R_L} \text{ if we neglect } V_s$$

and
$$I_{b1} = \frac{E_1 - V_b}{R_1 + R_L} - \frac{E_2 + V_b}{R_2}$$

Substituting the values of I_{c1} and I_{b1}, the condition becomes

$$\frac{E_1 - V_b}{R_1 + R_L} - \frac{E_2 + V_b}{R_2} > \frac{E_1}{R_L h_{FE}}$$

Solving for R_1 yields:

$$R_1 < R_L \left[\frac{hFE}{1 + \frac{V_b}{E_1 - V_b} + \frac{hFE\, R_L}{R_2}\left(\frac{E_2 + V_b}{E_1 - V_b}\right)} - 1 \right] \tag{3}$$

T_2 Cutoff

In deriving the formula for the pulse width, I_{co} has been neglected. The effect of I_{co} is the same as of a voltage I_{co} R in series with R. The voltage across R will then drop exponentially from $(2E_1 - V_b - I_{co}R)$ to $(E_1 - V_b)$ and the pulse width will be:

$$T^1 = RC \ln\left(\frac{2E_1 - V_b - I_{co}R}{E_1 - V_b}\right) \qquad (4)$$

At room temperature the influence of I_{co} can usually be neglected. But if the circuit is to operate at temperatures up to $+70^{\circ}C$, the influence of I_{co} may be severe, and the circuit will even cease to operate if $I_{co}R = E_1$.

This sets an absolute maximum for R

$$R < \frac{E_1}{I_{co}}$$

T_2 Saturated

The condition is the same as for T_1 with $R_2 \rightarrow \infty$ so that:

$$R < R_L\left[\frac{hFE}{1 + \dfrac{V_b}{E_1 - V_b}} - 1\right] \qquad (5)$$

C. EXAMPLE: (See attachment)

D. MEASUREMENTS:

The actual circuit used for the measurements is that of Figure 2.

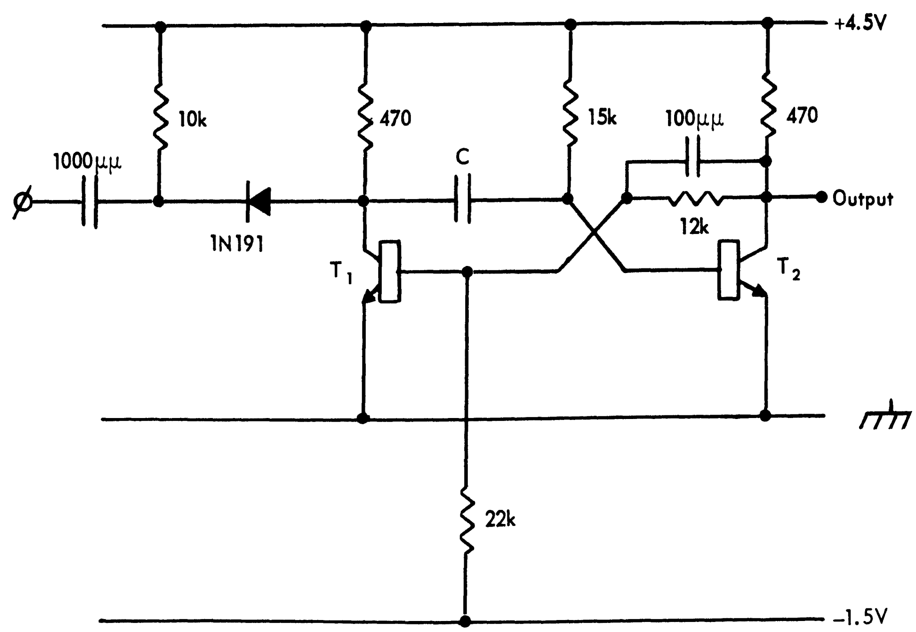


FIGURE 3

FIGURE 2

The measured pulse width vs. capacitance curve is a straight line through the origin.

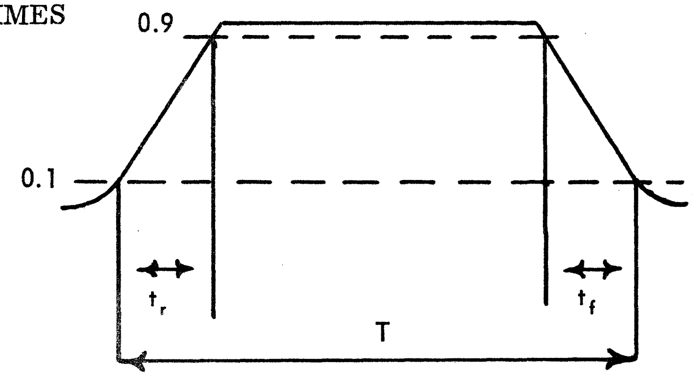
$T = 10400$ C sec. at + 25°C   C in farads
$T = 9300$ C sec. at + 70°C

The calculated curve for this circuit is:

$T = 10740$ C sec.

The difference with the measured curve is only 3.3%. At +70°C the pulse width is $12\frac{1}{2}$% down, which is within the predicted range.

RISE AND FALL TIMES



tr = 0.24 μsec.
tf = 0.16 μsec.

FIGURE 3

TRIGGER AMPLITUDE

The required trigger amplitude varies with the pulse width (see graph) and also slightly with the repetition rate. In the graph, the minimum required trigger amplitude is plotted as a percentage of the pulse amplitude vs. the pulse width.

DRIVER STAGE

The trigger pulses can also be applied via a driver stage instead of the diode network as in Figure 2.

The advantages are:

- minimum pulse width 0.5 μsec compared with 2 μsec for the diode network

- shorter rise time, (0.08 μsec); the fall time does not change

- higher repetition rates (up to 750 kcs), Example:

$E_1 = 4.5V$	$R_L + 470\Omega$	T_1	Raytheon NPN units (such as 2N440)
$E_2 = 1.5V$		T_2	$hFE = 100$ @ 1 mA
$V_b = 0.2V$			Alpha Cutoff = 11 mcs

1) First a maximum value for R_2 is found with (2). Here we have to use the maximum value for I_{co} at the highest temperature. Let this be $+70^oC$.

At 25^oC I_{co} max. = $4\,\mu A$ for the units in question, and I_{co} doubles for every 12^oC. This gives for I_{co} at 70^oC:

$$I_{co}\,(70^oC) = 54\,\mu A$$

As pointed out, the estimate has to be made on the high side and we will take $60\,\mu A$.

Substitute in: (2) $\longrightarrow R_2 < \dfrac{1.5}{60 \times 10^{-6}} = 25000\,\Omega$

The nearest lower standard value is: $R_2 = 22\,k\Omega \pm 10\%$

2) The next step is to calculate R_1 with (3). Here we have to take the minimum value for h_{FE} at the lowest temperature. Let this be -50^oC. At this temperature h_{FE} will drop roughly a factor of 2 compared with the value at room temperature.

With $h_{FE} = 40$ we find:

$$R_1 < 28R_L = 13.2\,k\Omega$$

Let $R_1 = 12\,k\Omega \pm 10\%$

3) A minimum value for R is found with (5). Again we take $hFE = 40$ which gives:

$$R < 17.5\,k\Omega$$

The nearest lower standard value would be:

$$R = 15\,k\Omega \pm 10\%$$

4) We have to check, however, whether the influence of I_{co} is not too severe at 70^oC.

The pulse width will be narrowed by a factor

$$\frac{T'}{T} = \frac{\ln\left(\dfrac{2E_1 - V_b - I_{co}\,R}{2\,E_1 - V_b}\right)}{\ln\left(\dfrac{2E_1 - V_b}{E_1 - V_b}\right)} \qquad (6)$$

With $I_{co} = 60\,\mu A$ at 70^oC the factor is 85% for $R = 15\,k\Omega$, which means a reduction of maximum 15%.

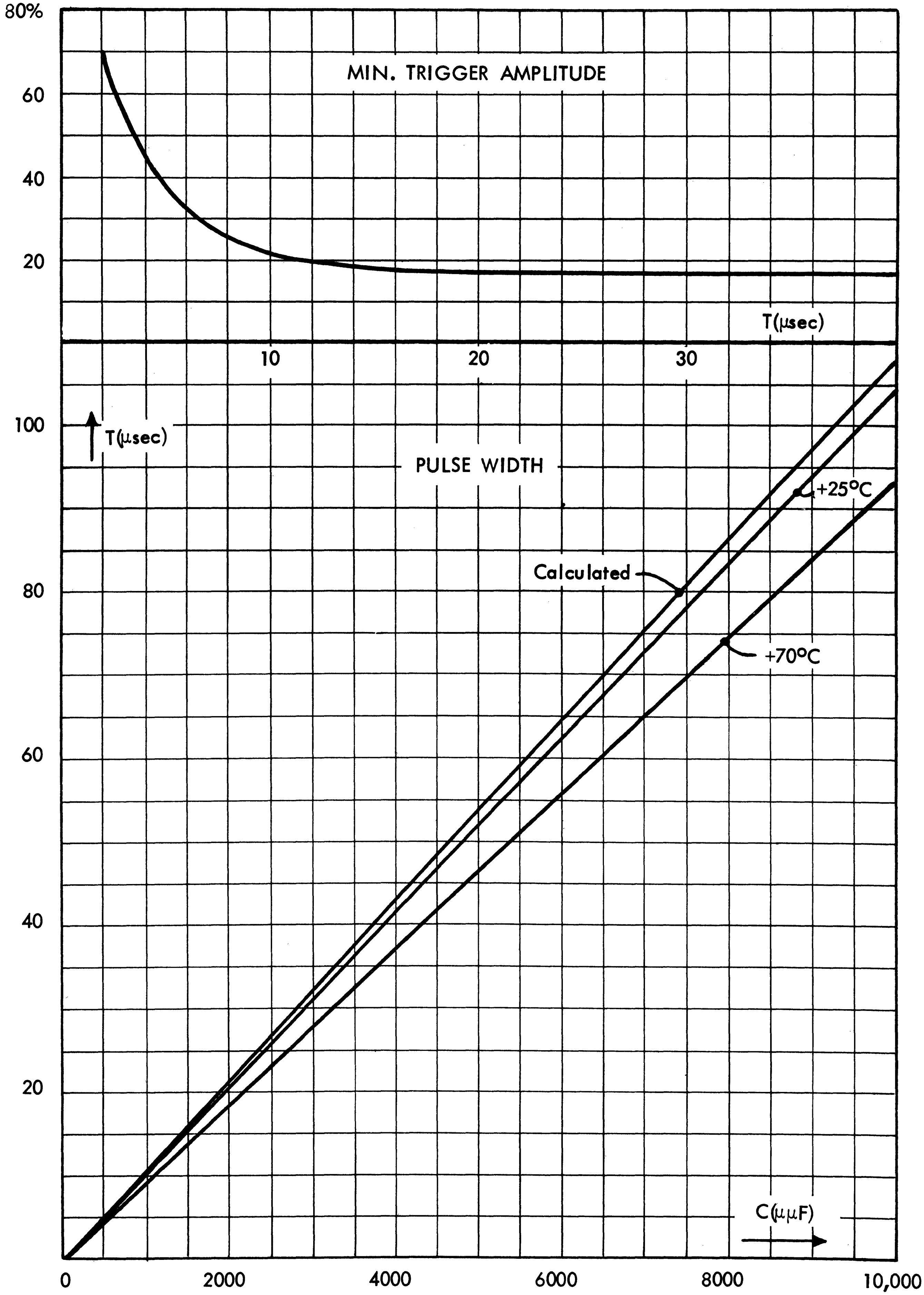

80%
60
40
20
MIN. TRIGGER AMPLITUDE
T(μsec)
10
20
30
100
T(μsec)
PULSE WIDTH
+25°C
Calculated
80
+70°C
60
40
20
C(μμF)
0
2000
4000
6000
8000
10,000

FIGURE 4