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TRANSISTOR BIAS STABILTY AS A FUNCTION OF β_F VARIATIONS

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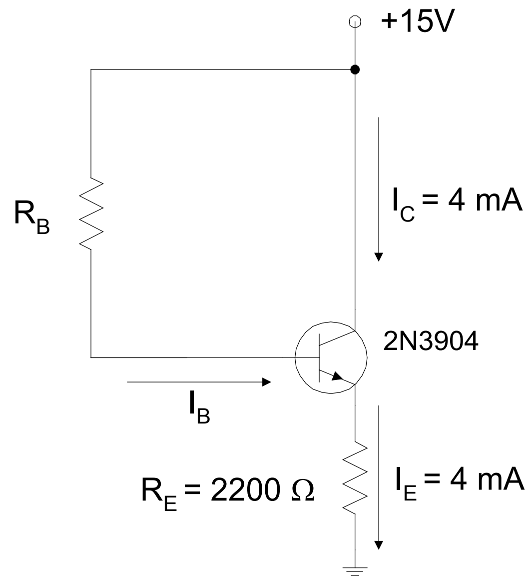

Figure 1: Single resistor transistor biasing circuit.

$$\beta_F = 100; \qquad I_C = \beta_F I_B; \qquad I_E = (\beta_F + 1) I_B; \qquad I_E \approx I_C$$

$$I_B R_B + 0.7V + I_C R_E = V_{CC}$$
$$I_B R_B + 0.7V + \beta_F I_B R_E = V_{CC}$$
$$I_B (R_B + \beta_F R_E) = V_{CC} - 0.7V$$

$$I_B = \frac{(V_{CC} - 0.7V)}{R_B + \beta_F R_E} \qquad (1)$$

$$I_C = \frac{\beta_F (V_{CC} - 0.7V)}{R_B + \beta_F R_E} \qquad (2)$$

$$R_B + \beta_F R_E = \frac{\beta_F (V_{CC} - 0.7V)}{I_C}$$

$$R_B + 100 \times 2200\Omega = \frac{100(15V - 0.7V)}{4mA}$$

$$R_B + 220k\Omega = \frac{1430}{4} \times 10^3 \Omega$$

$$R_B + 220k\Omega = 358k\Omega$$

$$R_B = 138k\Omega$$

Variation of Collector Current with Beta

I_C	β_F
2.9 mA	50
4.0 mA	100
5.0 mA	200
5.4 mA	300
ΔI_C=2.5 mA	

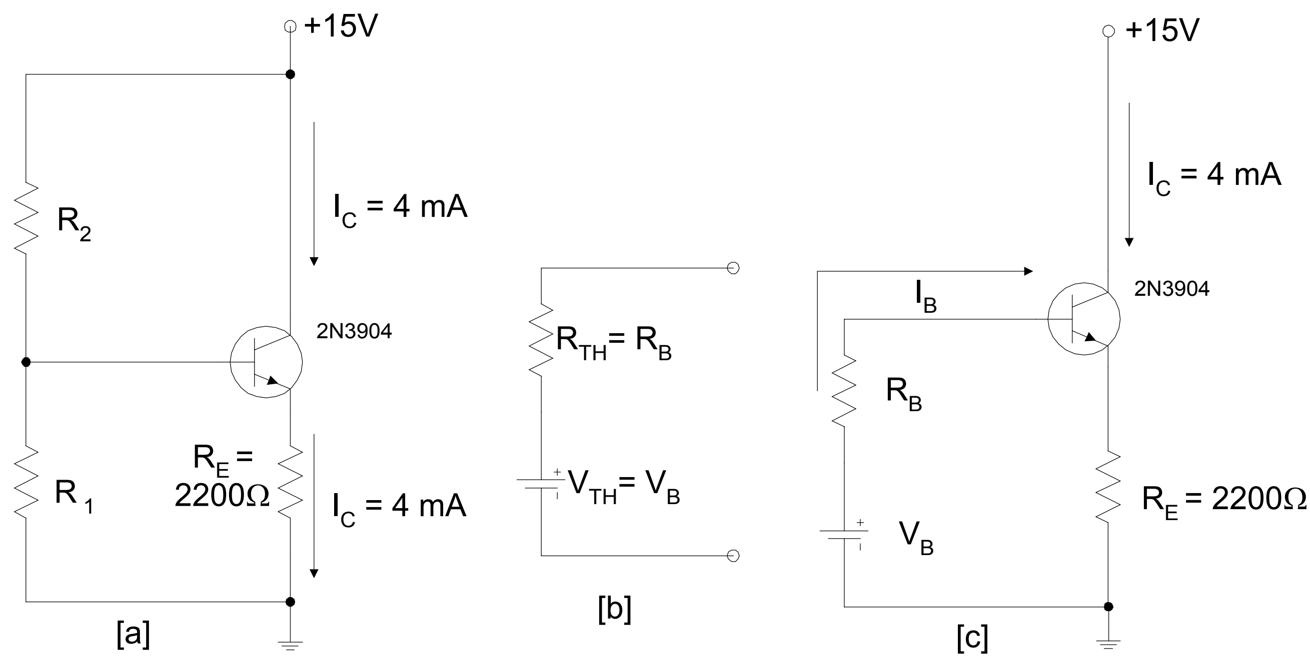

Figure 2: Two-resistor biasing circuit and Thevenin Equivalent for analysis.

$$V_B = \frac{R_1}{R_1 + R_2} \times V_{cc} \qquad (3)$$

$$R_B = \frac{R_1 R_2}{R_1 + R_2} \qquad (4)$$

$$V_B - I_B R_B - 0.7V - I_C R_E = 0$$
$$V_B = I_B R_B + 0.7V + \beta_F I_B R_E$$
$$V_B - 0.7V = I_B R_B + \beta_F I_B R_E = I_B\left(R_B + \beta_F R_E\right)$$

$$I_B = \frac{\left(V_B - 0.7V\right)}{R_B + \beta_F R_E} \qquad (5)$$

$$I_C = \frac{\beta_F\left(V_B - 0.7V\right)}{R_B + \beta_F R_E} \qquad (6)$$

Equation (6) is an equation with two unknowns: V_B and R_B. Analyzing the denominator of equation (6) we note that ***if*** R_B is kept small compared to the product $\beta_F R_E$ then the β_F's in the numerator and denominator will cancel if we can ignore R_B. As a general rule of thumb, keeping R_B no greater than ten times R_E will give good bias stability over a wide range of β_F values. R_B cannot be lowered to zero since the internal impedance of the battery is zero, and thus any AC source that is capacitor-coupled into the transistor stage will be shorted out. We will continue the example using R_B = 22kΩ. Now we can solve eqn. (6) for V_B.

$$4mA \times \left(22k\Omega + 220k\Omega\right) = 100\left(V_B - 0.7V\right)$$
$$4mA \times 242k\Omega = 100V_B - 70$$
$$968 + 70 = 100V_B$$
$$V_B = 10.4V$$

Given V_B= 10.4 V and R_B= 22kΩ, we can now solve equations (3) and (4) for R_1

$$V_B = \frac{R_1}{R_1 + R_2} \times V_{CC}$$

and R_2. $R_1 + R_2 = R_1\left(\frac{V_{CC}}{V_B}\right) = R_1\left(\frac{15V}{10.4V}\right) = 1.45R_1$

$$R_1 + R_2 = 1.45R_1$$
$$0.45R_1 = R_2$$

$$\frac{R_1 R_2}{R_1 + R_2} = R_B = 22k\Omega$$

$$\frac{R_1 \times 0.45 R_1}{R_1 + 0.45 R_1} = 22k\Omega$$

$$\frac{0.45 R_1^2}{1.45 R_1} = 22k\Omega$$

$$0.310 R_1 = 22k\Omega$$

$$R_1 = 70.9k\Omega \qquad use \quad 68k\Omega$$

$$R_2 = 0.45 R_1 = 0.45 \times 70.9k\Omega = 31.9k\Omega \quad use \quad 33k\Omega$$

Check I_C variation with change in β_F using equation (6):

$$I_C = \frac{\beta_F (V_B - 0.7V)}{R_B + \beta_F R_E} \tag{6}$$

$$I_C = \frac{\beta_F (10.4 - 0.7V)}{22k\Omega + \beta_F 2200\Omega}$$

I_C	β_F
3.7 mA	50
4.0 mA	100
4.2 mA	200
4.3 mA	300
ΔI_C=0.6 mA	

Looking at the partial circuit shown in Figure 2c; we can see that our goal is to keep the product of the collector (emitter) current and the emitter resistor constant. This voltage is 8.8 volts for I_C = 4 mA. Note that the 0.7V base-emitter voltage is essentially constant. If we can keep the voltage drop due to I_B R_B as small as possible by keeping R_B small (since we have no control over I_B); then it becomes obvious that the emitter resistor voltage drop is essentially set by the V_B battery voltage minus the base-emitter voltage.