Analog Electronics Circuit

Course Code	**BEEE3021**

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Bias Stabilization

Source & References*:*

The materials presented in this lecture has been taken from various books and internet websites. This instruction materials is for instructional purposes only.

Referred book: R. Boylestad, Electronic Devices and Circuit Theory, 11th edition, Prentice Hall.

BIAS STABILIZATION

- The stability of a system is a measure of the sensitivity of a network to variations in its parameters.
- The operating point of a transistor amplifier shifts mainly with changes in temperature, since the transistor parameters — *β*, I_{CO} *and* V_{BE} *are functions of* temperature.

β: increases with increase in temperature

$|V_{BE}|$: decreases about 2.5 mV per degree Celsius (°C) increase in temperature

I_{CO} (reverse saturation current): doubles in value for every 10°C increase in temperature

Variation of Silicon Transistor Parameters with Temperature

T (°C)	I_{CO} (nA)	β	V_{BE} (V)
−65	0.2×10^{-3}	20	0.85
25	0.1	50	0.65
100	20	80	0.48
175	3.3×10^{3}	120	0.3

Stability Factors $S(I_{CO})$, $S(V_{BE})$, and $S(\beta)$

$$S(I_{CO}) = \frac{\Delta I_C}{\Delta I_{CO}}$$

$$S(V_{BE}) = \frac{\Delta I_C}{\Delta V_{BE}}$$

$$S(\beta) = \frac{\Delta I_C}{\Delta \beta}$$

BIAS STABILIZATION .. $S(I_{CO})$

- **Stability Factor *S*:-** The stability factor *S, as the change of collector current with respect to the reverse saturation* current, keeping β *and VBE constant. This can be written as:*

The Thermal Stability Factor : S_{Ico}

$$S_{Ico} = \left.\frac{\partial I_c}{\partial I_{co}}\right|_{V_{be},\ \beta}$$

This equation signifies that I_c Changes S_{Ico} times as fast as I_{co}

Differentiating the equation of Collector Current $I_C = (1+\beta)I_{co} + \beta I_b$ & rearranging the terms we can write

$$S_{Ico} = \frac{1+\beta}{1-\beta\,(\partial I_b/\partial I_C)}$$

- It may be noted that Lower is the value of S_{Ico} better is the stability

BIAS STABILIZATION .. $S(I_{CO})$

Fixed-Bias Configuration

$$S(I_{CO}) \cong \beta$$

Emitter-Bias Configuration

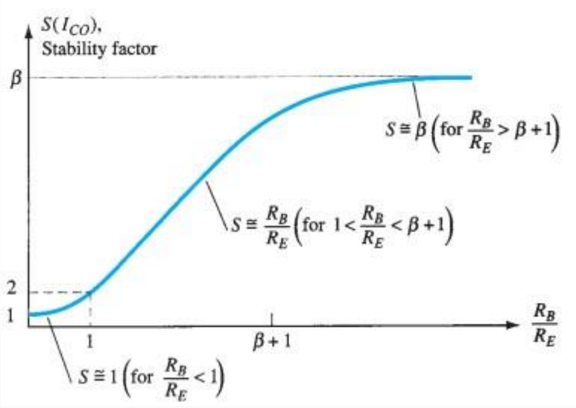
$$S(I_{CO}) \cong \frac{\beta(1 + R_B/R_E)}{\beta + R_B/B_E}$$

$$S(I_{CO}) \cong \beta \quad R_B/R_E \gg \beta$$

$$S(I_{CO}) \cong 1 \quad R_B/R_E \ll 1$$

$$S(I_{CO}) \cong \frac{R_B}{R_E}$$

R_B/R_E ranges between 1 and $(\beta + 1)$



Voltage-Divider Bias Configuration

$$S(I_{CO}) \cong \frac{\beta(1 + R_{Th}/R_E)}{\beta + R_{Th}/R_E}$$

Feedback-Bias Configuration ($R_E = 0\ \Omega$)

$$S(I_{CO}) \cong \frac{\beta(1 + R_B/R_C)}{\beta + R_B/R_C}$$

Physical Impact

$$I_B = \frac{V_{CC} - V_{BE}}{R_B}$$

$$I_C = \beta I_B + (\beta + 1)I_{CO}$$

the level of I_C would continue to rise with temperature, with I_B maintaining a fairly constant value—a very unstable situation.

- emitter-bias configuration

$$I_B \downarrow = \frac{V_{CC} - V_{BE} - V_E \uparrow}{R_B}$$

$$I_B \downarrow = \frac{V_{CC} - V_{BE} - V_{R_C} \uparrow}{R_B}$$

$$\beta R_E \gg 10 R_2$$

The most stable of the configurations

BIAS STABILIZATION .. $S(V_{BE})$ & $S(\beta)$

Fixed-Bias Configuration

$$S(V_{BE}) \cong \frac{-\beta}{R_B}$$

$$S(\beta) = \frac{I_{C_1}}{\beta_1}$$

$$S(V_{BE}) \cong \frac{-\beta/R_E}{\beta + R_B/R_E}$$

$$S(\beta) = \frac{\Delta I_C}{\Delta\beta} = \frac{I_{C_1}(1 + R_B/R_E)}{\beta_1(\beta_2 + R_B/R_E)}$$

$$S(V_{BE}) \cong \frac{-\beta/R_E}{\beta} = -\frac{1}{R_E}$$

$$S(V_{BE}) = \frac{-\beta/R_E}{\beta + R_{Th}/R_E}$$

$$S(\beta) = \frac{I_{C_1}(1 + R_{Th}/R_E)}{\beta_1(\beta_2 + R_{Th}/R_E)}$$

$$S(V_{BE}) = \frac{-\beta/R_C}{\beta + R_B/R_C}$$

$$S(\beta) = \frac{I_{C_1}(R_B + R_C)}{\beta_1(R_B + \beta_2 R_C)}$$

Summary

$$\Delta I_C = S(I_{CO})\Delta I_{CO} + S(V_{BE})\Delta V_{BE} + S(\beta)\Delta\beta$$

For fixed-bias

$$\Delta I_C = \beta\Delta I_{CO} - \frac{\beta}{R_B}\Delta V_{BE} + \frac{I_{C_1}}{\beta_1}\Delta\beta$$

General Conclusion:

The ratio R_B/R_E or R_{Th}/R_E should be as small as possible with due consideration to all aspects of the design, including the ac response.

BIAS STABILIZATION .. $S(V_{BE})$ & $S(\beta)$

$$S(V_{BE}) = \frac{\Delta I_C}{\Delta V_{BE}}$$

Fixed-Bias Configuration

$$S(V_{BE}) \cong \frac{-\beta}{R_B}$$

$$S(\beta) = \frac{I_{C_1}}{\beta_1}$$

Emitter-Bias Configuration

$$S(V_{BE}) \cong \frac{-\beta/R_E}{\beta + R_B/R_E}$$

$\beta \gg R_B/R_E$

$$S(V_{BE}) \cong \frac{-\beta/R_E}{\beta} = -\frac{1}{R_E}$$

$$S(\beta) = \frac{\Delta I_C}{\Delta \beta} = \frac{I_{C_1}(1 + R_B/R_E)}{\beta_1(\beta_2 + R_B/R_E)}$$

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PRACTICAL APPLICATION

- BJT Diode Usage and Protective Capabilities

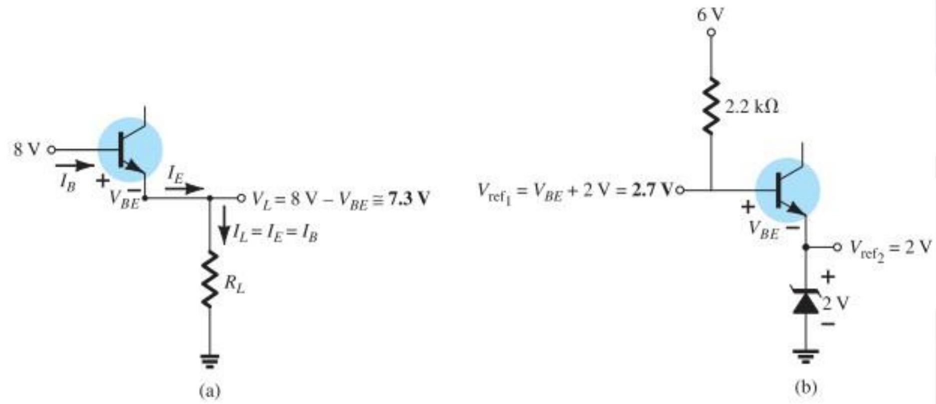

FIG. 4.102
BJT applications as a diode: (a) simple series diode circuit; (b) setting a reference level.

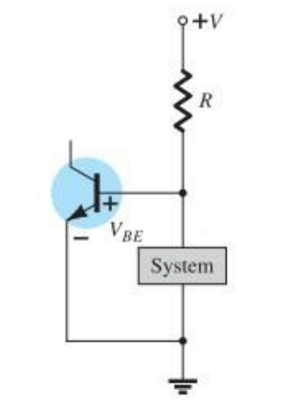

FIG. 4.103
Acting as a protective device.

PRACTICAL APPLICATION

- Relay Driver

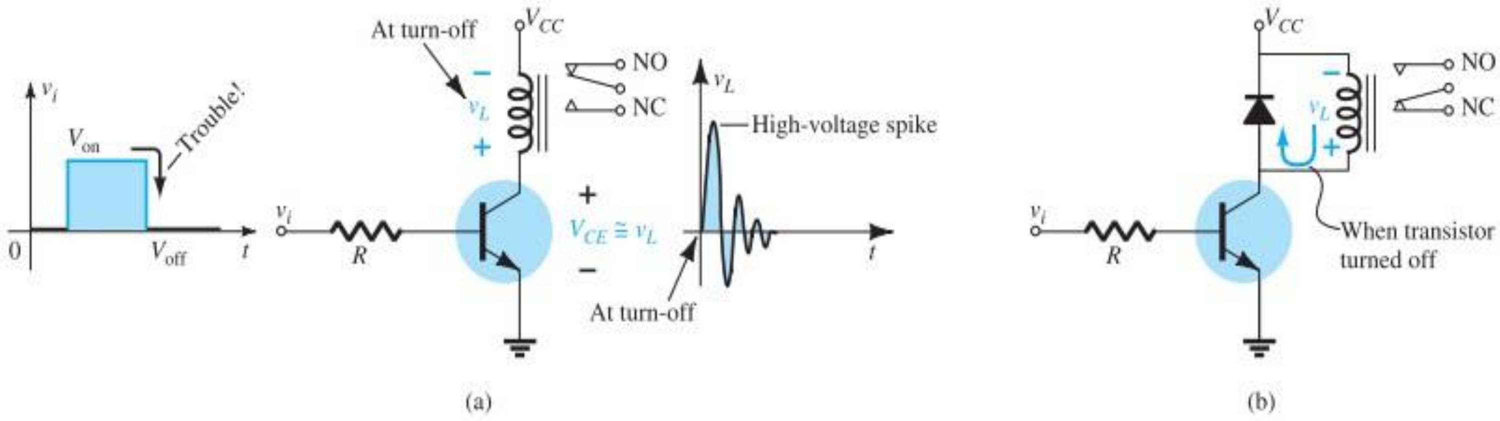

FIG. 4.104

Relay driver: (a) absence of protective device; (b) with a diode across the relay coil.

Thank You