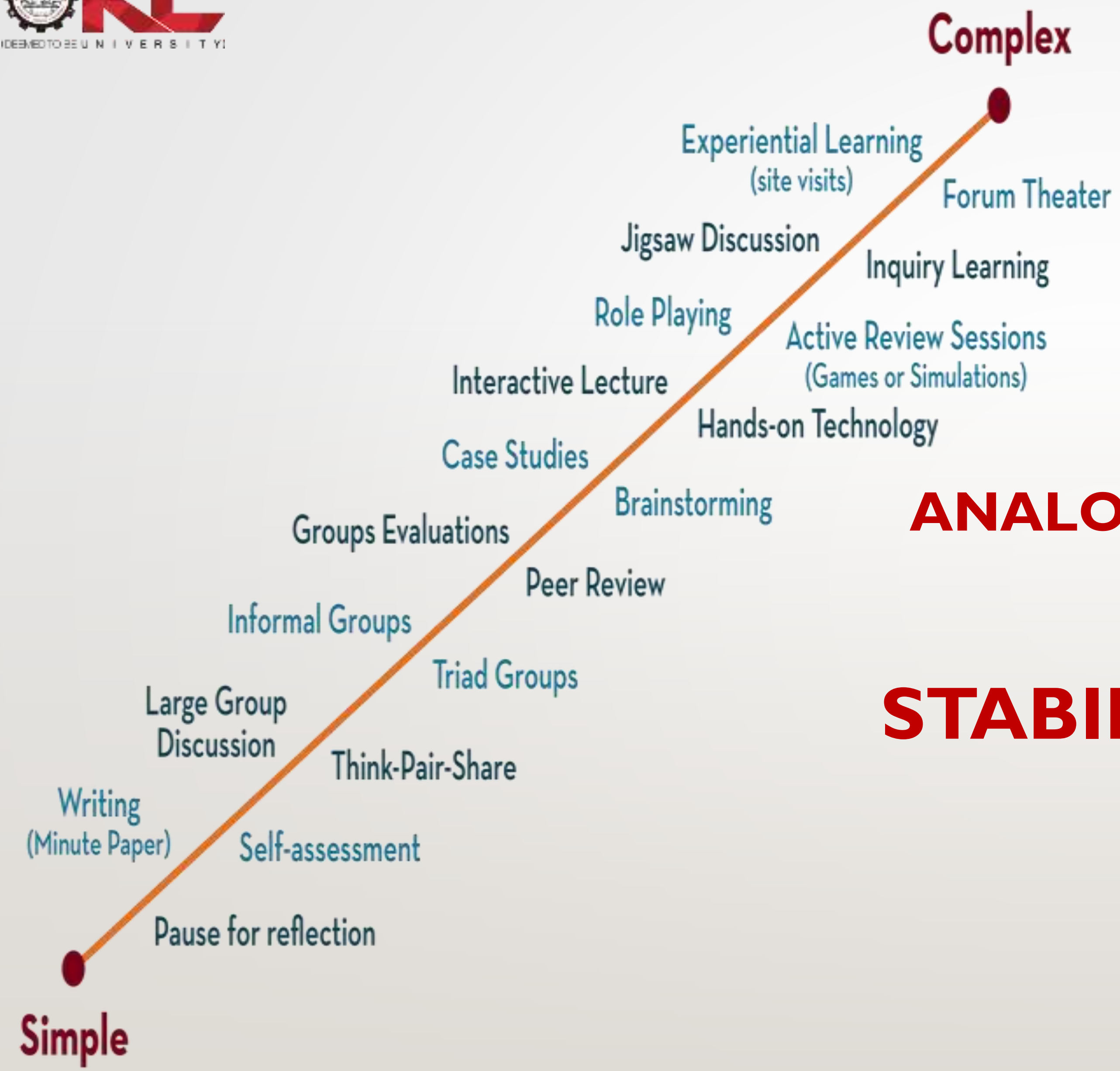


AY-2025-2026
ODD SEM

Department of ECE

ANALOG ELECTRONIC CIRCUIT DESIGN
23EC2104

Topic:

STABILITY FACTOR OF BJT BIAS

Session - 06

SESSION CONTENT

- Stability Factor
- Stability Factor for Fixed Bias
- Stability Factor for Collector Feedback Bias
- Stability Factor for Voltage Divider Bias

AIM OF THE SESSION

To compare stability of various biasing circuits for BJT

INSTRUCTIONAL OBJECTIVES

This Session is designed to:

1. Demonstrate stability factor
2. Compare stability of various biasing circuits

LEARNING OUTCOMES

At the end of this session, you should be able to:

1. Derive stability factor for BJT
2. Select biasing circuit based on stability factor

REVISIT BIASING OF BJT

➢Biasing refers to the application of D.C. voltages to setup the operating point in such a way that output signal is undistorted throughout the whole operation.

➢Also once selected properly, the Q point should not shift because of change of I_C due to

(i) β variation due to replacement of the transistor of same type
(ii) Temperature variation

Stabilization

➢The process of making operating point independent of temperature changes or variation in transistor parameters is known as stabilization.

➢ Stabilization of operating point is necessary due to
❖ Temperature dependence of I_C
❖ Individual variations
❖ Thermal runaway

STABILIZATION

Temperature dependence of I_C & Thermal runaway

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

- **I_{CBO} is strong function of temperature. A rise of 10°C doubles the I_{CBO} and I_C will increase (β+1) times of I_{CBO}**
- **The flow of I_C produce heat within the transistor and raises the transistor temperature further and therefore, further increase in I_{CBO}**
- **This effect is cumulative and in few seconds, the I_C may become large enough to burn out the transistor.**
- **The self destruction of an unstablized transistor is known as thermal runaway.**

Stability Factor

- **The rate of change collector current I_C with respect to the collector leakage current I_{CBO} is called stability factor, denoted by S.**

$$S = \left(\frac{dI_C}{dI_{CBO}}\right)$$

Lower the value of S, better is the stability of the transistor.

STABILITY FACTOR

$$I_C = \beta I_B + (\beta + 1) I_{CBO} \qquad \textbf{(1)}$$

Differentiating equation (1) w.r.t I_C

$$1 = \left(\frac{dI_B}{dI_C}\right) + (\quad +1)\frac{dI_{CBO}}{dI_C}$$

$$1 = \left(\frac{dI_B}{dI_C}\right) + \frac{(\beta + 1)}{S}$$

$$S = \frac{(\beta + 1)}{1 - \left(\frac{dI_B}{dI_C}\right)}$$

➢**The rate of change collector current I_C with respect to the collector leakage current I_{CBO} at constant β and I_B is called stability factor, denoted by S.**

Different biasing schemes

(i) Fixed bias (base resistor biasing)
(ii) Collector Feedback bias
(iii) Voltage divider bias

STABILITY FACTOR FOR FIXED BIAS

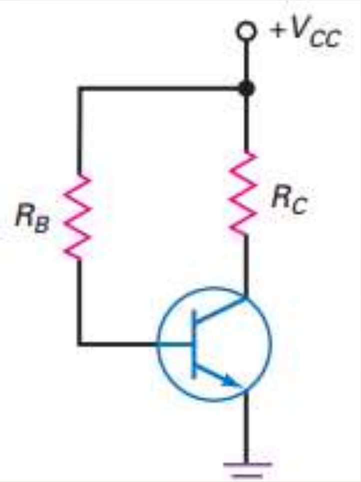


Fig. 6.1. Fixed Bias

Using KVL in the base-emitter loop

$V_{CC} - I_B R_B - V_{BE} = 0$; $I_B = (V_{CC} - V_{BE})/R_B$

$I_C = \beta I_B = \beta(V_{CC} - V_{BE})/R_B$

Using KVL in the collector-emitter loop

$V_{CC} - I_C R_C - V_{CE} = 0$; $V_{CE} = V_{CC} - I_C R_C$

$Q(V_{CE}, I_C)$ is set

STABILITY FACTOR FOR FIXED BIAS

Advantages:

- **Operating point can be shifted easily anywhere in the active region by merely changing the base resistor (R_B).**
- **A very small number of components are required.**

Disadvantages:

- **Poor stabilization**
- **High stability factor($S=\beta+1$ because I_B is constant so $dI_B/dI_C = 0$), hence prone to thermal runaway**

Usage:

- **Due to the above inherent drawbacks, fixed bias is rarely used in linear circuits (i.e., those circuits which use the transistor as a current source). Instead, it is often used in circuits where transistor is used as a switch.**

How the Q point is affected by changes in V_{BE} and I_{CBO} in fixed bias?

$$I_B = (V_{CC}-V_{BE})/R_B \qquad I_C = \beta I_B$$

STABILITY FACTOR FOR COLLECTOR FEEDBACK BIAS

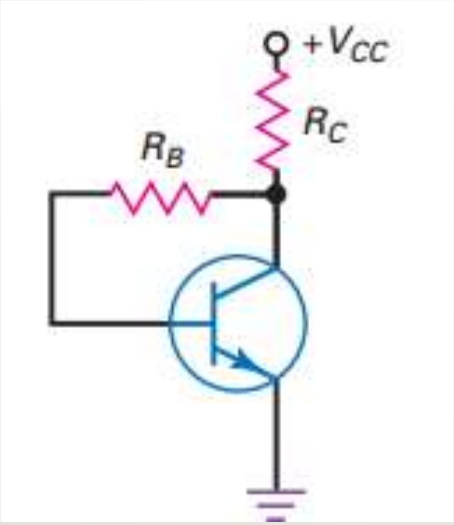


Fig. 5.2. Collector Feedback Bias

$V_{CC} = (I_C+I_B)R_C + V_{CE}$ **(1)**

$V_{CE} = I_B R_B + V_{BE}$ **(2)**

Since, $I_C = \beta I_B$ so from equation (1) & (2)

$$I_B = \frac{V_{CC} - V_{BE}}{R_B + (1+\beta)R_C}$$

Q(V_{CE},I_C) is set

STABILITY FACTOR FOR COLLECTOR FEEDBACK BIAS

Advantages:

➢Better stabilization compared to fixed bias

Disadvantages:

➢This circuit provides negative feedback which reduces the gain of the amplifier.

Usage:

➢The feedback also decreases the input impedance of the amplifier as seen from the base, which can be advantageous. Due to the gain reduction from feedback, this biasing form is used only when the trade-off for stability is warranted.

How the bias stability is improved in collector base bias?

If I_C becomes larger than design value, it causes an increase voltage drop across R_C hence smaller value of V_{CE} which in turn causes I_B to be smaller than its design value. Since $I_C = \beta I_B$ thus I_C will also tend to be reduced towards its original value.

For bais Stabilization : $R_B \ll \beta R_C$

$$I_C = \beta \left[\frac{V_{CC} - V_{BE}}{R_B + (1+\beta) R_C} \right]$$

If $R_B \ll \beta R_C$

$$I_C = \frac{V_{CC} - V_{BE}}{R_C}$$

STABILITY FACTOR FOR VOLTAGE DIVIDER BIAS

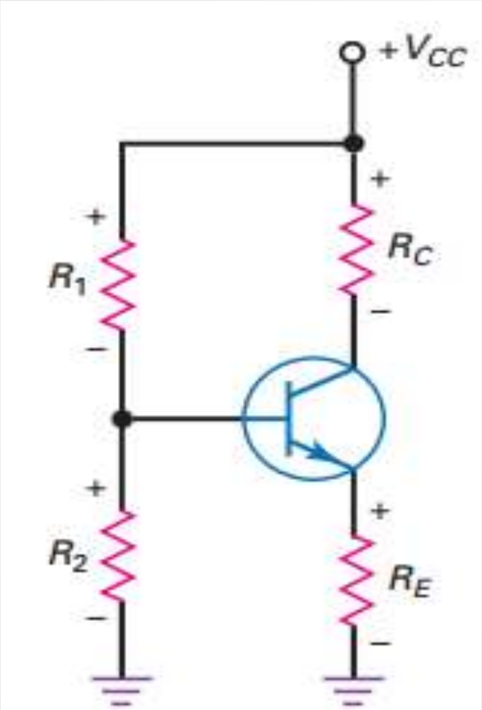


Fig. 6.3.Voltage divider bias for BJT

$$V_{Th} = I_B R_{Th} - V_{BE} - (I_B + I_C) R_E$$

$$0 = R_{Th}\left(\frac{dI_B}{dI_C}\right) + \left(1 + \frac{dI_B}{dI_C}\right) R_E$$

$$\frac{dI_B}{dI_C} = -\frac{R_E}{R_{Th} + R_E}$$

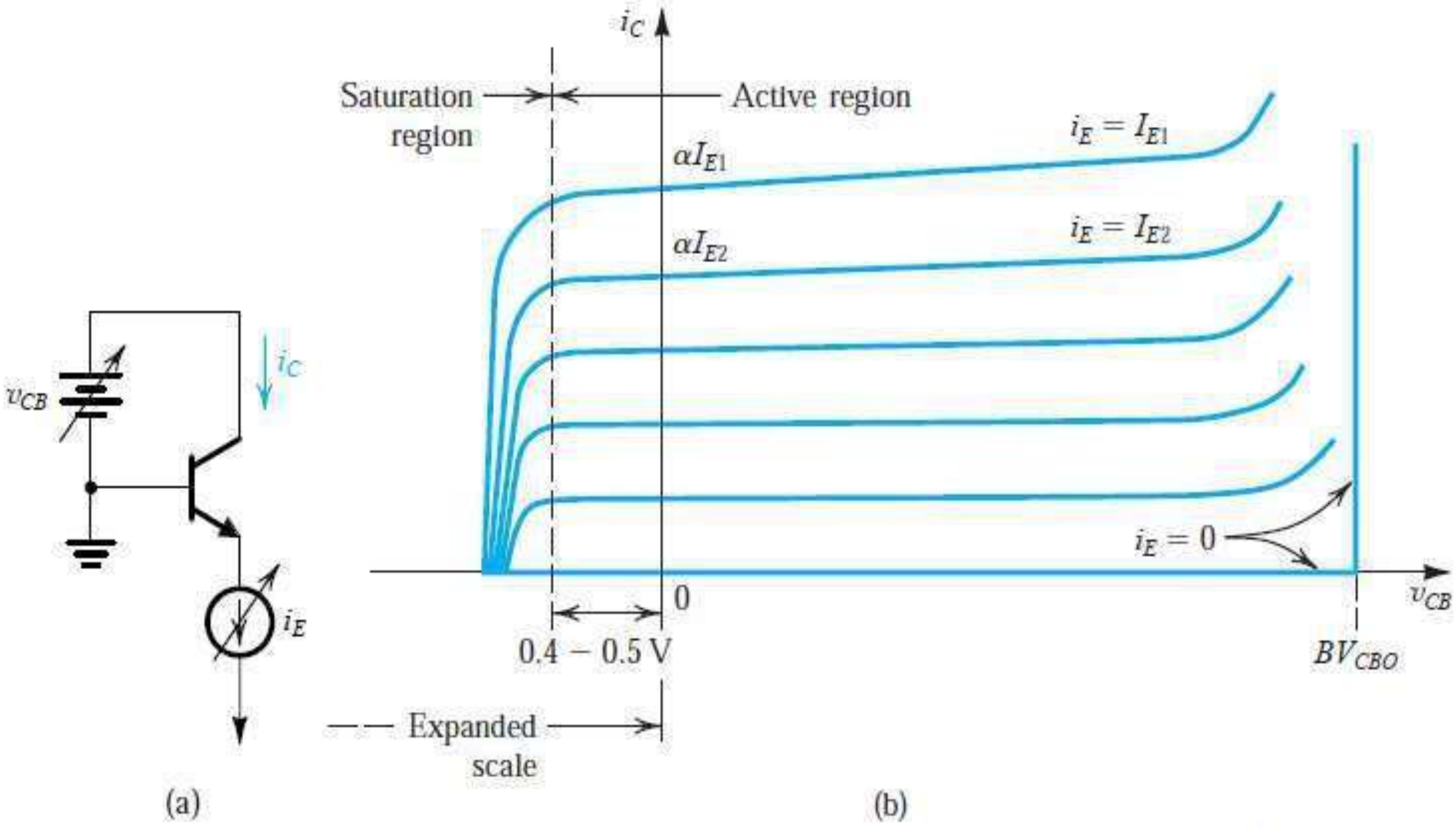
$$S = (\beta + 1)\frac{(R_{Th} + R_E)}{R_E(\beta + 1) + R_{Th}}$$

$$S = (\beta + 1)\frac{\left(1 + \frac{R_{Th}}{R_E}\right)}{(\beta + 1) + \frac{R_{Th}}{R_E}}$$

➢For stability, S should be small which can be achieved by making R_{Th}/R_E small. For very small R_{Th}/R_E ; S = 1 (ideal case)

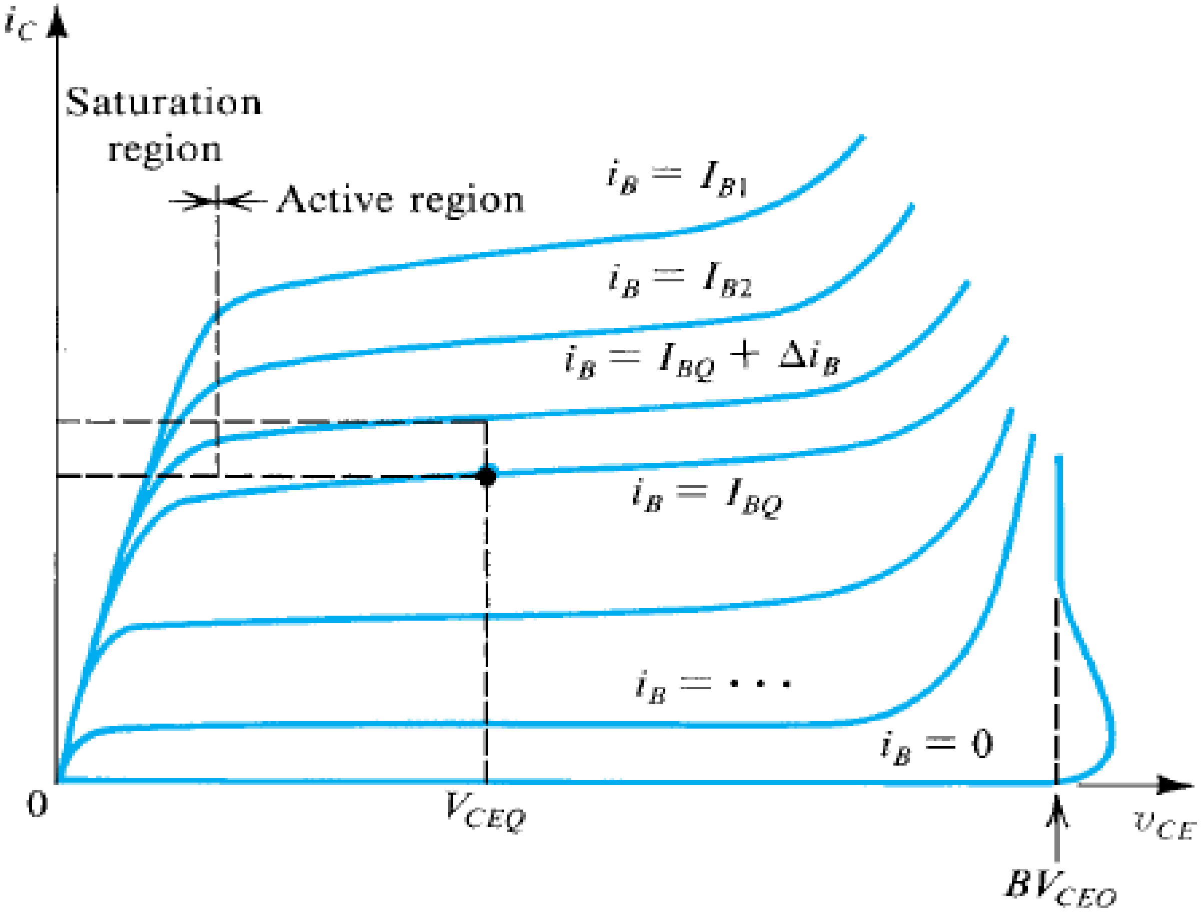
➢For very small R_{Th}/R_E : $R_2 \downarrow \longrightarrow R_{Th}$ current drawan by R_2 will be large. $R_E \uparrow \longrightarrow$ Large V_{cc} required. Hence comproise is made in selection.

Transistor Breakdown and Temperature Effects



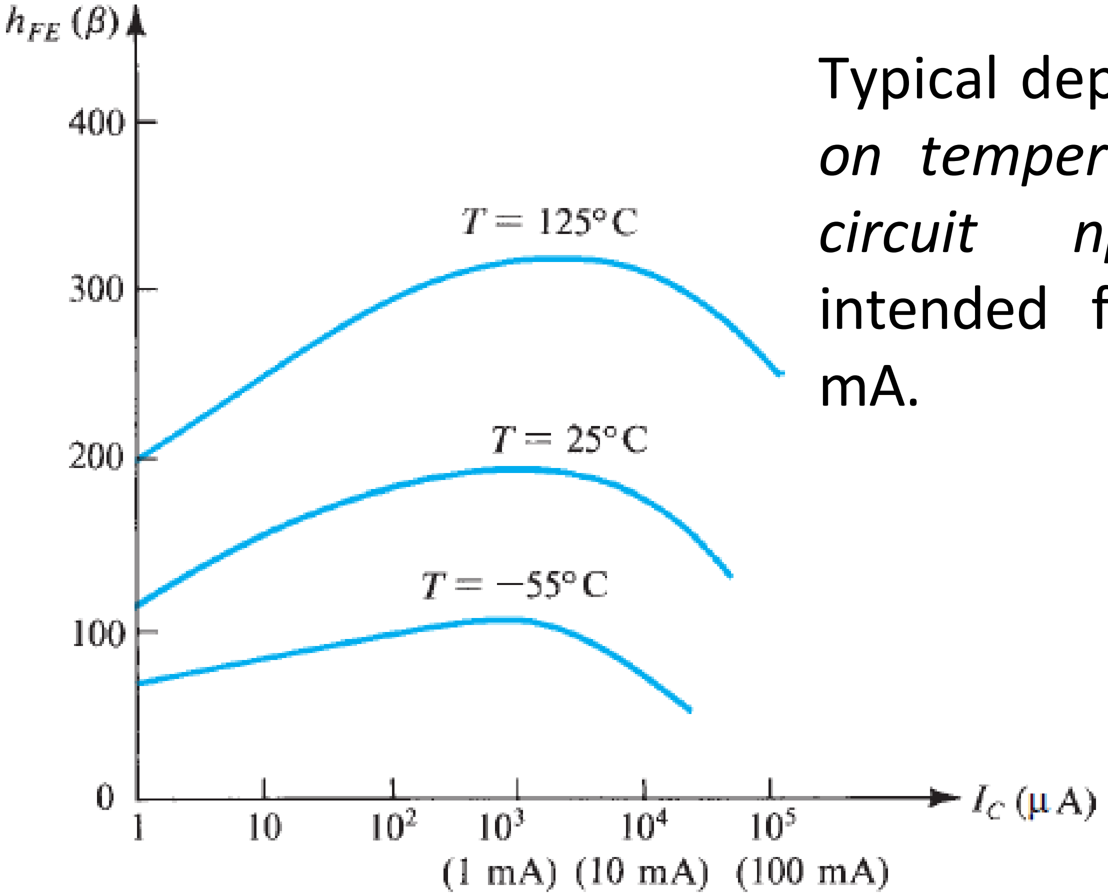
The BJT common-base characteristics including the transistor breakdown region.

Transistor Breakdown and Temperature Effects



The BJT common-emitter characteristics including the breakdown region.

Transistor Breakdown and Temperature Effects



Typical dependence of β on *IC and on temperature in an integrated-circuit npn silcon transistor* intended for operation around 1 mA.

Example Problems

6.1. Compare the stability factors for fixed bias, collector feedback bias and voltage divider bias for BJT

Solution:

S= 1+ β for fixed bias.

S = 1 could be achieved with collector feed back bias at the cost of reducing R_B which draw more base current which causes less battery life for V_{CC}

S=1 could be achieved with voltage divide bias at increase input current or increase supply voltage.

SELF-ASSESSMENT QUESTIONS

1. Which Bias more thermally stable?

(a) Emitter Bias
(b) Base Bias
(c) Collector feedback Bias
(d) Voltage divider bias

2. Which of the following bias is less effected by temperature variation?

(a) Voltage divider bias
(b) Collector feedback bias

SELF-ASSESSMENT QUESTIONS

3. Which of the following is ideal stability factor for BJT?

(a) 1
(b) 1+β
(c) zero
(d) β

4. Which of the following is the smallest realizable stability factor?

(a) 1
(b) 1+β
(c) zero
(d) β

ANSWERS

1. D
2. A
3. C
4. A

TERMINAL QUESTIONS

1. Obtain the expression for stability factor of BJT with respect to reverse saturation current.
2. Obtain the stability factor for Fixed bias of BJT.
3. Obtain the stability factor for Collector feedback bias of BJT.
4. Obtain the stability factor for voltage divider bias of BJT.
5. Compare stability of fixed bias and voltage divider bias.

REFERENCES FOR FURTHER LEARNING OF THE SESSION

Reference Book:

1. Robert L. Boylestad and Louis Nashelsky - “Electronic Devices and Circuit Theory”

THANK YOU

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