

DC Biasing - BJTs

By: Mujahidin

mujahidin@iddhien.com

iddhien@gmail.com

<http://iddhien.com>

1 Introduction

DC-Biasing
BJTs

Biasing refers to the DC voltages applied to the transistor to turn it on so that it can amplify the AC signal.

Use the following important basic relationship for a transistor :

$$V_{BE} = 0.7V$$

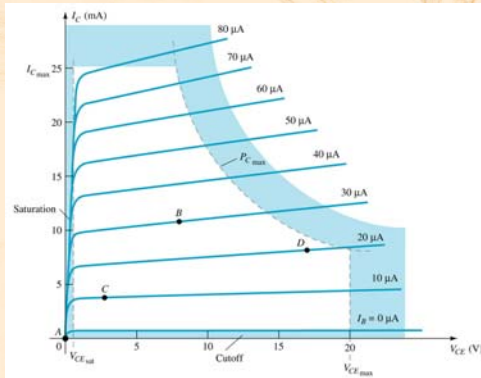
$$I_E = (\beta + 1)I_B \cong I_C$$

$$I_C = \beta I_B$$



2 Operating Point

DC-Biasing
BJTs



The DC input establishes an operating or quiescent point called the ***Q point***.

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2 Operating Point

DC-Biasing
BJTs

Biassing and the 3 States of Operation

- **Active or Linear Region Operation**
Base – Emitter junction is forward biased
Base – Collector junction is reverse biased
- **Cutoff Region Operation**
Base – Emitter junction is reverse biased
- **Saturation Region Operation**
Base – Emitter junction is forward biased
Base – Collector junction is forward biased

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DC-Biasing Circuit

DC-Biasing
BJTs

- Fixed-Bias Circuit
- Emitter-Stabilized Bias Circuit
- Collector-Emitter Loop
- Voltage Divider Bias Circuit
- DC Bias with Voltage Feedback
- Miscellaneous Bias Circuits

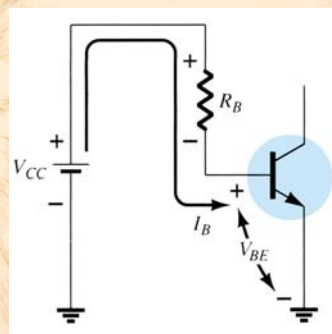
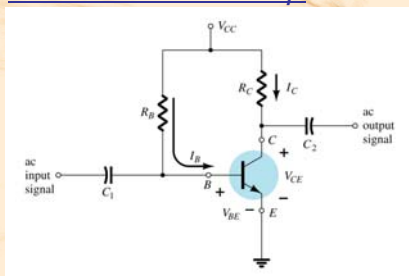
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3 Fixed-Bias Circuit

DC-Biasing
BJTs

Base-Emitter Loop



$$+V_{CC} - I_B R_B - V_{BE} = 0$$

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

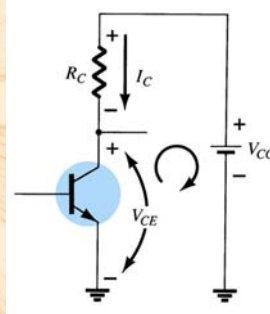
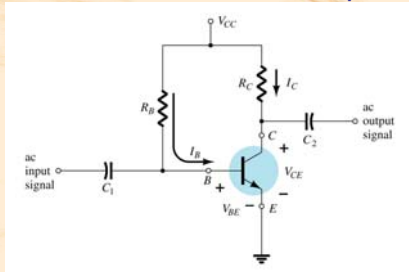
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3 Fixed-Bias Circuit

DC-Biasing BJT's

Collector-Emitter Loop



$$I_C = \beta I_B$$

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

$$V_{CE} = V_C - V_E$$

Since $V_E = 0V$, then:

$$V_{CE} = V_C$$

$$V_{BE} = V_B - V_E$$

$$V_{BE} = V_B$$

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3 Fixed-Bias Circuit

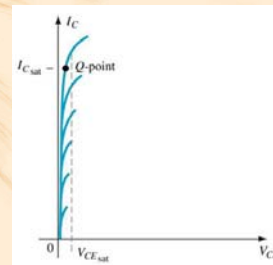
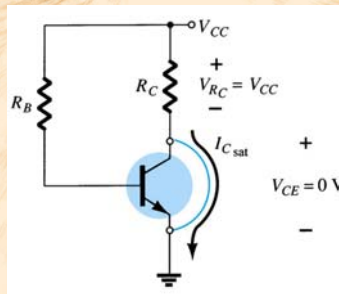
DC-Biasing BJT's

Transistor Saturation Level

When the transistor is operating in the Saturation Region, it is conducting at **maximum current** flow through the transistor.

$$I_{C_{sat}} = \frac{V_{CC}}{R_C}$$

$$V_{CE} \cong 0V$$



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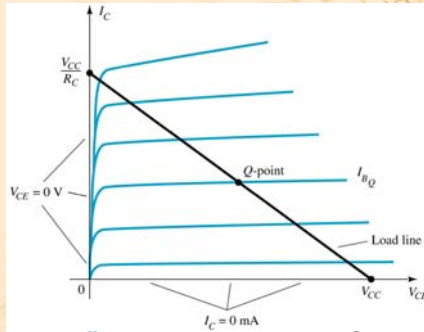
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3 Fixed-Bias Circuit

DC-Biasing
BJTs

Load-Line Analysis

The end points of the line are : I_{Csat} and V_{CE} cutoff



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

$$V_{CE} = V_{CC} \Big|_{I_C = 0 \text{ mA}}$$

$$I_C = \frac{V_{CC}}{R_C} \Big|_{V_{CE} = 0 \text{ V}}$$

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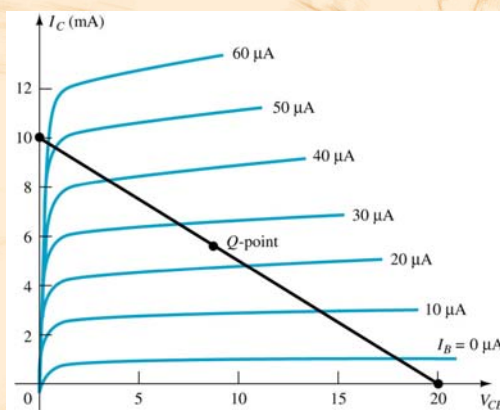
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3 Fixed-Bias Circuit

DC-Biasing
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Example Problem 4.3



Determine the required values of V_{CC} , R_C , and R_B for a fixed-bias configuration in the beside picture.

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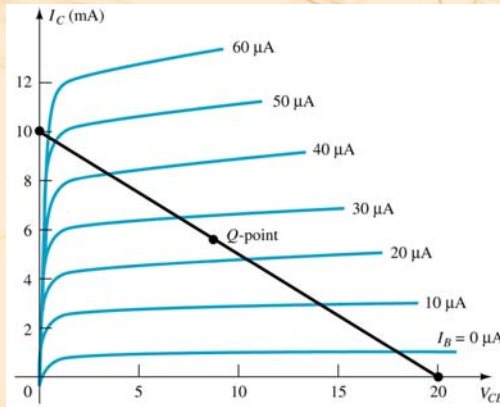
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3 Fixed-Bias Circuit

DC-Biasing
BJTs

Example Problem 4.3



$$V_{CE} = V_{CC} = 20V \text{ at } I_C = 0mA$$

$$I_C = \frac{V_{CC}}{R_C} \text{ at } V_{CE} = 0V$$

$$R_C = \frac{V_{CC}}{I_C} = \frac{20V}{10mA} = 2k\Omega$$

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

$$R_B = \frac{V_{CC} - V_{BE}}{I_B} = \frac{20V - 0.7V}{25\mu A} = 772k\Omega$$



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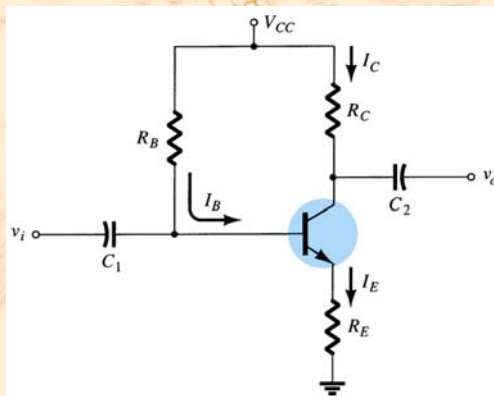
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4 Emitter-Stabilized Bias Circuit

DC-Biasing
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Adding a resistor to the emitter circuit stabilizes the bias circuit.



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4 Emitter-Stabilized Bias Circuit

DC-Biasing
BJTs

Base Emitter Loop

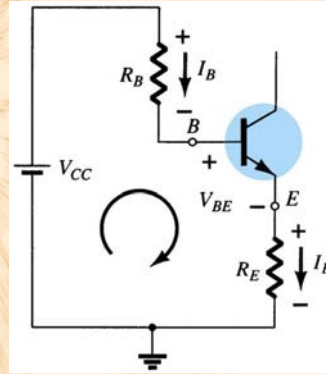
Applying Kirchoffs voltage law:

$$+V_{CC} - I_B R_B - V_{BE} - I_E R_E = 0$$

$$I_E = (\beta + 1)I_B$$

$$V_{CC} - I_B R_B - V_{BE} - (\beta + 1)I_B R_E = 0$$

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



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4 Emitter-Stabilized Bias Circuit

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Collector-Emitter Loop

Applying Kirchoffs voltage law:

$$+I_E R_E + V_{CE} + I_C R_C - V_{CC} = 0$$

Knowing that $I_E \cong I_C$ and solving for V_{CE}

$$V_{CE} = V_{CC} - I_C (R_C + R_E)$$

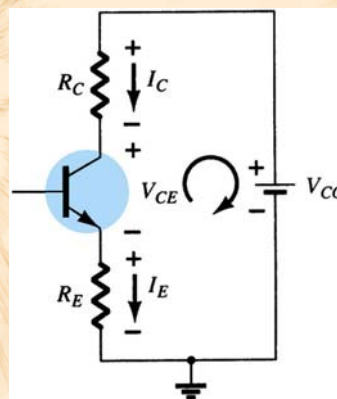
$$V_E = I_E R_E$$

$$V_C = V_{CE} + V_E$$

$$V_C = V_{CC} - I_C R_C$$

$$V_B = V_{CC} - I_B R_B$$

$$V_B = V_{BE} + V_E$$



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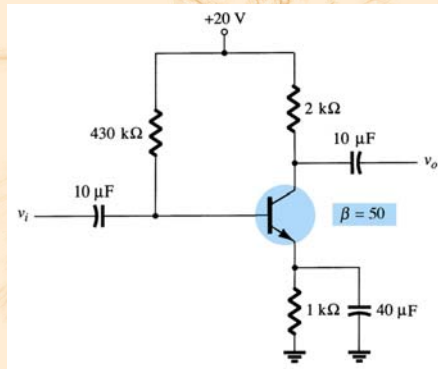


4 Emitter-Stabilized Bias Circuit

DC-Biasing
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For the emitter bias network, determine:

- (a). I_B
- (b). I_C
- (c). V_{CE}
- (d). V_C
- (e). V_B
- (f). V_{BC}



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4 Emitter-Stabilized Bias Circuit

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BJTs

Improved Bias Stability

Adding R_E to the Emitter improves the stability of a transistor.

Stability refers to a bias circuit in which the currents and voltages will remain fairly constant for a wide range of temperatures and transistor Beta's (β).

The temperature surrounding the transistor circuit is not always constant; the Beta (β) of a transistor is not a fixed value.



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4 Emitter-Stabilized Bias Circuit

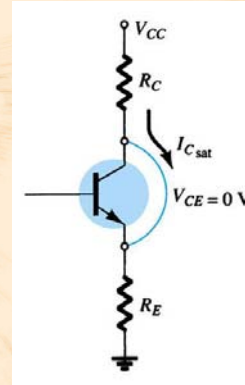
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BJTs

Saturation Level

Apply a short circuit between the collector-emitter terminals and calculate the resulting collector current :

$$I_{CSAT} = \frac{V_{CC}}{R_C + R_E}$$

The addition of the emitter resistor reduces the collector saturation level below that obtained with a fixed bias configuration using the same collector resistor



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4 Emitter-Stabilized Bias Circuit

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BJTs

Load Line Analysis

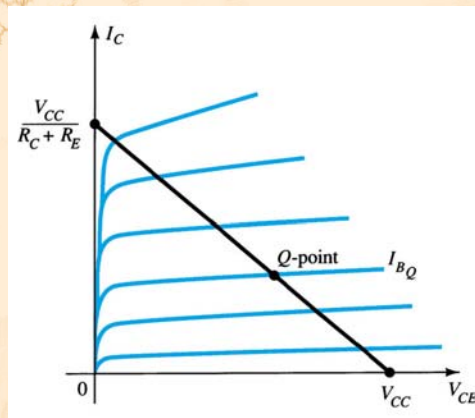
The load line end points can be calculated:

V_{CE} Cutoff

$$V_{CE} = V_{CC} \quad / \quad I_C = 0mA$$

I_C Sat

$$I_C = \frac{V_{CC}}{R_C + R_E} \quad / \quad V_{CE} = 0V$$



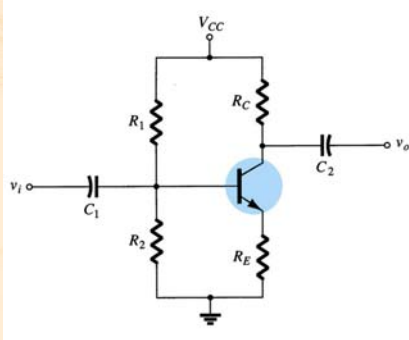
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5 Voltage Devider Bias

DC-Biasing
BJTs



This is a very stable bias circuit. The currents and voltages are almost independent of variations in β .



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5 Voltage Devider Bias

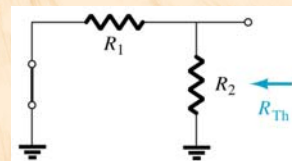
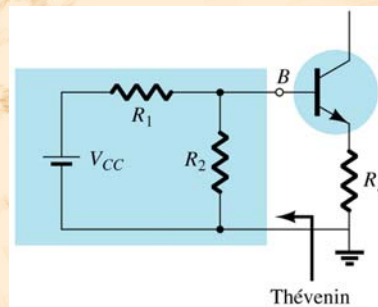
DC-Biasing
BJTs

Exact Analysis

The input side of the Voltage Devider bias circuit can be redrawn as shown in side figure. The thevenin equivalent network for the network to the left of the base terminal can then be found in the following manner:

R_{TH} : The voltage source is replaced by a short circuit equivalent

$$R_{TH} = R_1 \parallel R_2$$



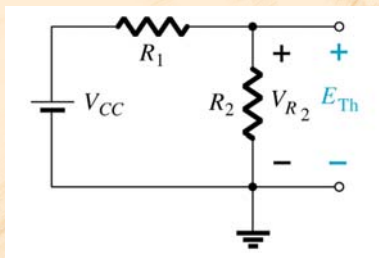
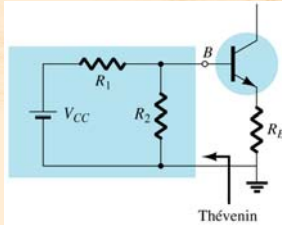
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5 Voltage Devider Bias

DC-Biasing
BJTs



E_{TH} : The voltage source V_{CC} is returned to the network and the open circuit thevenin voltage determine as follows :

$$E_{TH} = V_{R_2} = \frac{R_2 V_{CC}}{R_1 + R_2}$$

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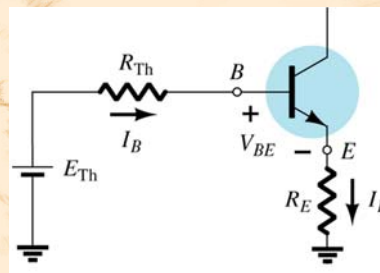
5 Voltage Devider Bias

DC-Biasing
BJTs

$$E_{TH} - I_B R_{TH} - V_{BE} - I_E R_E = 0$$

Substituting $I_E = (\beta + 1) I_B$

$$I_B = \frac{E_{TH} - V_{BE}}{R_{TH} + (\beta + 1) R_E}$$



For the collector emitter loop:

$$V_{CE} = V_{CC} - I_C (R_C + R_E)$$

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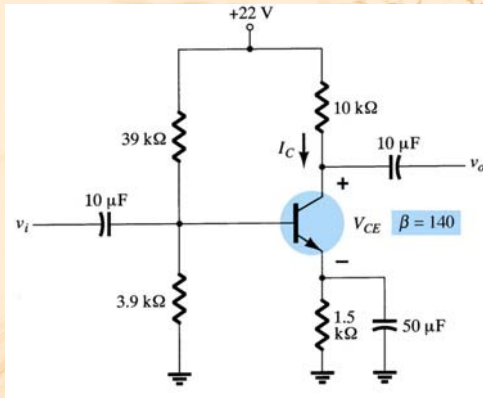


5 Voltage Devider Bias

DC-Biasing
BJTs

Example

Determine the dc bias voltage V_{CE} and the current I_C for the voltage divider configuration



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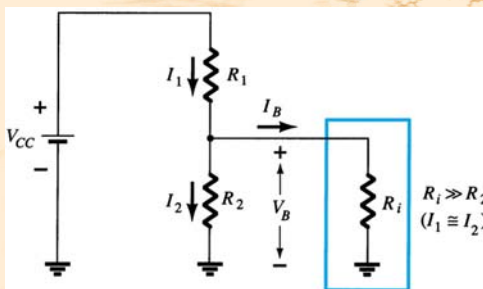
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5 Voltage Devider Bias

DC-Biasing
BJTs

Approximate Analysis

The input section of voltage divider bias can be represented by the network below.



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

$$V_E = V_B - V_{BE}$$

$$I_E = \frac{V_E}{R_E}$$

Collector Emitter Voltage:

$$I_{CQ} \cong I_E \rightarrow V_{CE} = V_{CC} - I_C R_C - I_E R_E$$

$$V_{CEQ} = V_{CC} - I_C (R_C + R_E)$$

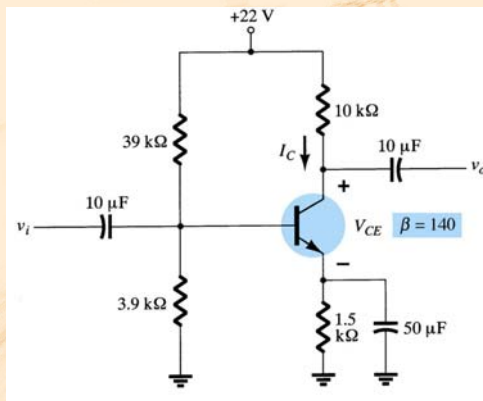
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5 Voltage Divider Bias

DC-Biasing
BJTs

Repeat the exact analysis of voltage divider bias analysis if β is reduce to 70, and compare solutions for I_{CQ} and V_{CEQ}



Tabulating The result

β	$I_{CQ}(mA)$	$V_{CEQ}(V)$
140	0.85	12.22
70	0.83	12.46

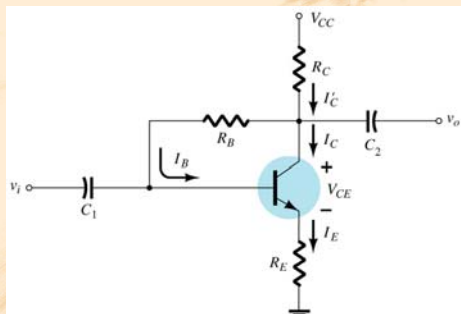
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6 DC Bias With Voltage Feedback

DC-Biasing
BJTs

Another way to improve the stability of a bias circuit is to add a feedback path from collector to base. In this bias circuit the Q-point is only slightly dependent on the transistor Beta β .



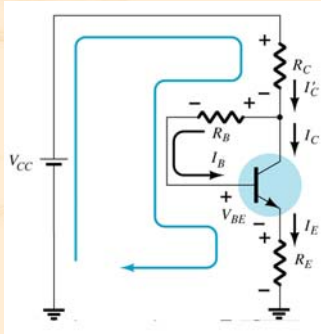
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6 DC Bias With Voltage Feedback

DC-Biasing
BJTs

Base Emitter Loop



$$V_{CC} - I_{C'}R_C - I_B R_B - V_{BE} - I_E R_E = 0$$

Note: $I_{C'} = I_C + I_B$
but usually $I_B \ll I_C$ -- so $I_{C'} \cong I_C$

Knowing $I_C = \beta I_B$ and $I_E \cong I_C$
then:

$$V_{CC} - \beta I_B R_C - I_B R_B - V_{BE} - \beta I_B R_E = 0$$

Simplifying and solving for I_B :

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

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6 DC Bias With Voltage Feedback

DC-Biasing
BJTs

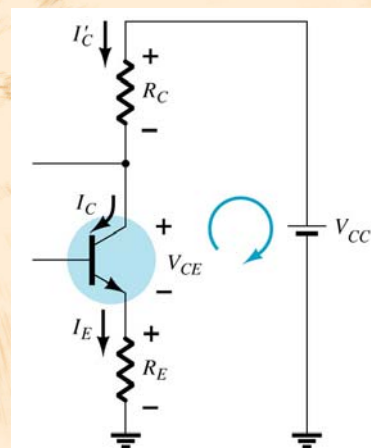
Collector - Emitter Loop

$$I_E R_E + V_{CE} + I_C R_C - V_{CC} = 0$$

Since $I_{C'} \cong I_C$ and $I_C = \beta I_B$

$$\rightarrow I_C (R_C + R_E) + V_{CE} - V_{CC} = 0$$

$$V_{CE} = V_{CC} - I_C (R_C + R_E)$$



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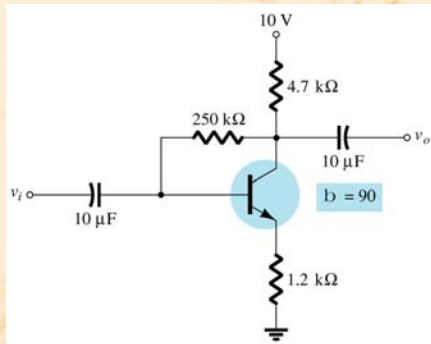


6 DC Bias With Voltage Feedback

DC-Biasing
BJTs

Example 4.11 → (187)

Determine the quiescent levels of I_{CQ} and V_{CEQ} for the network below.



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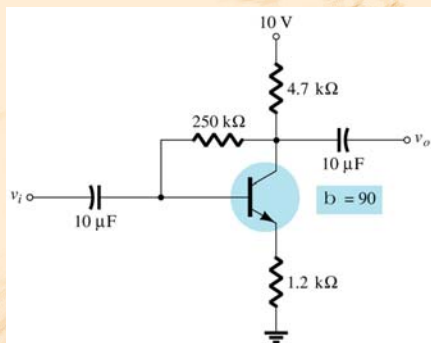
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6 DC Bias With Voltage Feedback

DC-Biasing
BJTs

Example 4.12 → (188)

Repeat the exmple 4.11 using the beta of 135 (50% more than example 4.11)



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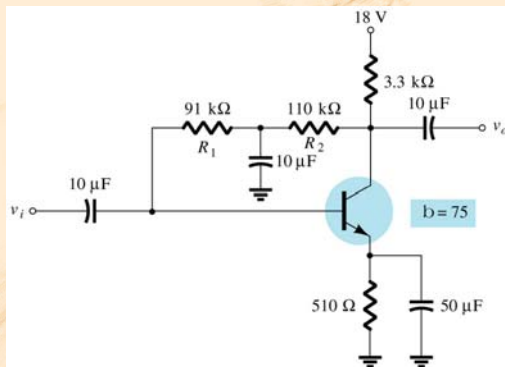
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6 DC Bias With Voltage Feedback

DC-Biasing
BJTs

Example 4.13 → (188)

Determine the dc level of I_B and V_C for the network of figure below.



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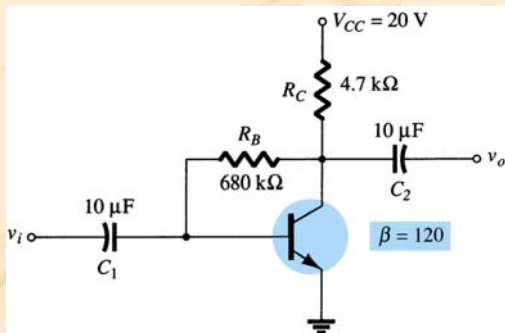
7 Miscellaneous Bias Configuration

DC-Biasing
BJTs

Example 4.14 → (190)

For the network of figure below:

- Determine the I_{CQ} and V_{CEQ}
- Find the V_B , V_C , V_E , and V_{BC}



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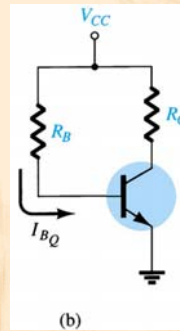
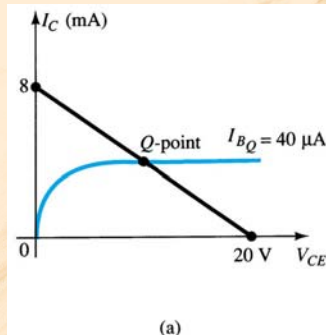
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8 Design Operations

DC-Biasing
BJTs

Example 4.19 → (196)

Given the Device characteristic of the figure (a), and then determine the V_{CC} , R_B , and R_C for the fixed bias configuration of figure (b)



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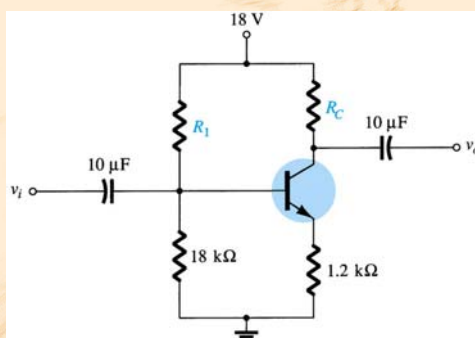
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8 Design Operations

DC-Biasing
BJTs

Example 4.20 → (197)

Given the $I_{CQ} = 2 \text{ mA}$, and $V_{CEQ} = 10 \text{ V}$, determine the R_1 and R_C for the network below.



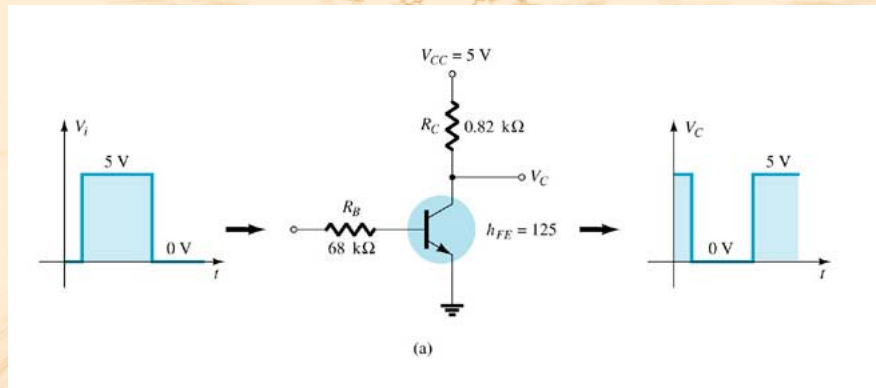
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9 Transistor Switching Network

DC-Biasing
BJTs

Transistors with only the DC source applied can be used as electronic switches.



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9 Transistor Switching Network

DC-Biasing
BJTs

The transistor will switch between saturation and cutoff regions.

$$I_{csat} = \frac{V_{CC}}{R_C}$$

You must ensure that: $I_B > \frac{I_{csat}}{\beta_{dc}}$

Also consider the resistance across the transistor at saturation:

$$R_{sat} = \frac{V_{CESat}}{I_{csat}}$$

The resistance across the transistor in cutoff is theoretically infinite, but it is calculated:

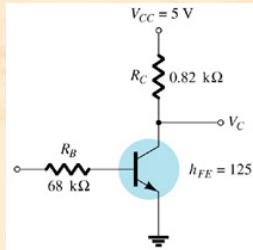
$$R_{cutoff} = \frac{V_{CC}}{I_{CEO}}$$

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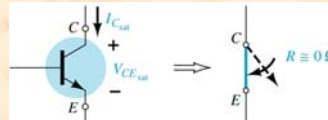
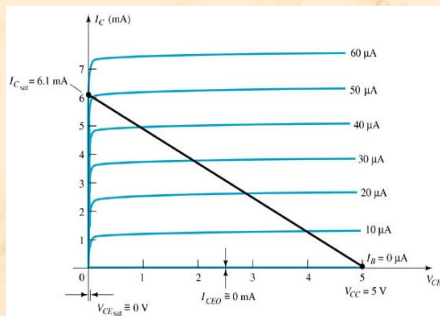
9 Transistor Switching Network

DC-Biasing
BJTs

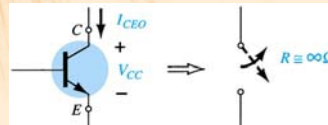


$$I_B = \frac{V_i - 0.7V}{R_B} = \frac{5V - 0.7V}{68k\Omega} = 63\mu A$$

$$I_{Csat} = \frac{V_{CC}}{R_C} = \frac{5V}{0.82k\Omega} \cong 6.1mA$$



Saturation conditions and the resulting terminal resistance



Cutoff conditions and the resulting terminal resistance.

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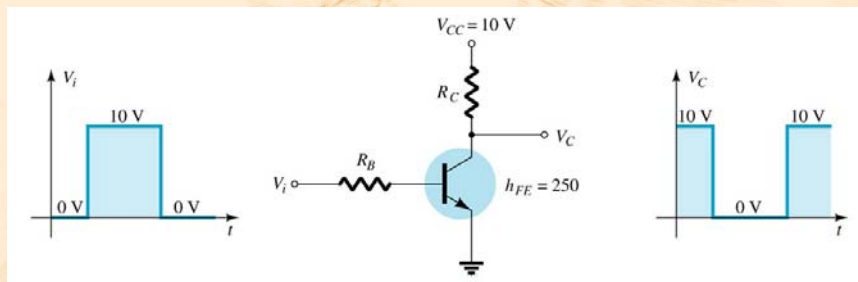
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9 Transistor Switching Network

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BJTs

Example 4.24 → (204)

Determine the R_B and R_C for the transistor inverter of the figure below, if $I_{Csat} = 10mA$



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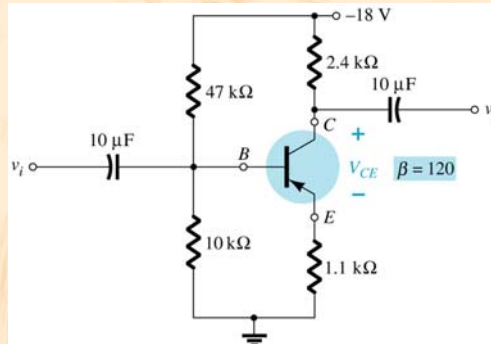
10 PNP Transistors

DC-Biasing
BJTs

The analysis for PNP bias transistor circuits is the same as that for NPN transistor circuits. The only difference is that the currents are flowing in the opposite direction.

Example 4.27 → (209)

Determine the VCE for the voltage-divider bias configuration of the figure below



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11 Practical Application

DC-Biasing
BJTs

1. Relay Driver
2. Transistor Switch
3. Constant Current Source
4. Logic Gates
5. Current Mirror
6. Voltage Level Indicator



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