



Transistor Configuration

Objectives



- To review BJT biasing circuit.
- To study BJT amplifier circuit
- To understand the BJT configuration.
- To analyse single-stage BJT amplifier circuits.
- To study the differential amplifier.
- To design amplifier circuits.

Transistor Biasing Circuits

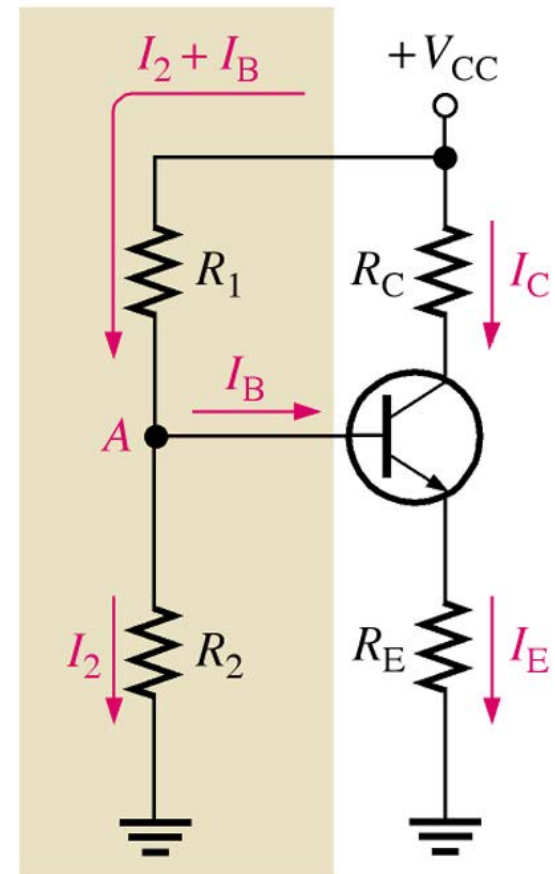


- Voltage Divider Bias
- Emitter Bias
- Base Bias
- Emitter-feedback Bias
- Collector-feedback Bias

Voltage Divider Bias



Voltage-divider bias is the most widely used type of bias circuit. Only **one** power supply is needed and voltage-divider bias is more stable (β independent) than other bias types. For this reason it will be the primary focus for study.

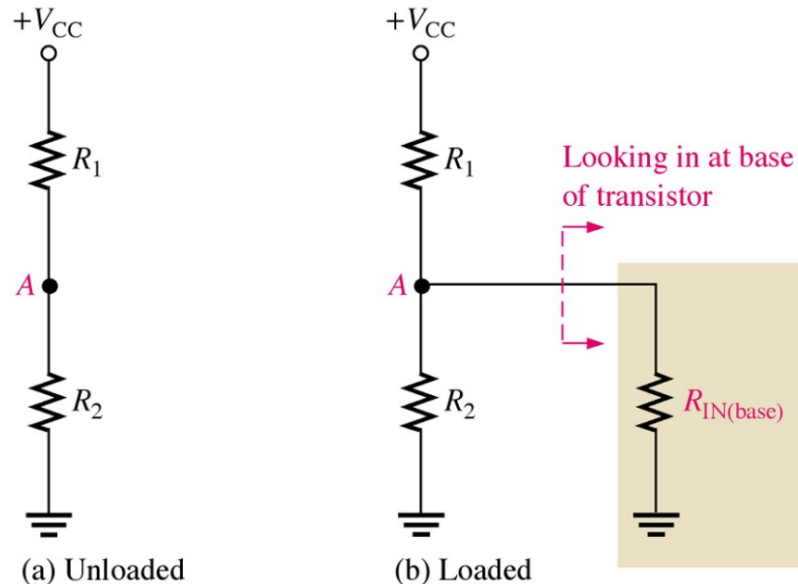




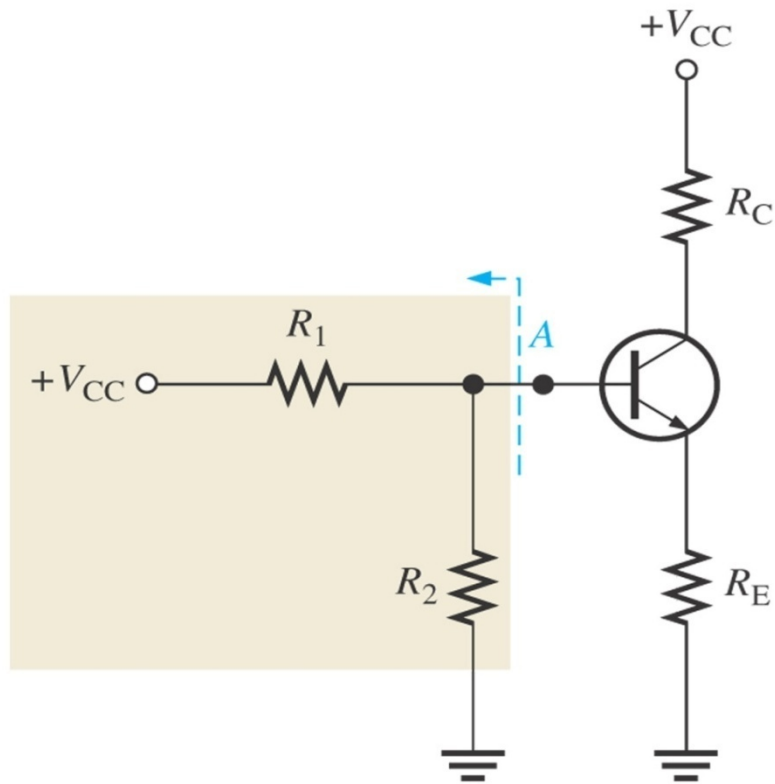
In the case where base to ground resistance(input resistance) is low enough to consider, we can determine it by the simplified equation

$$R_{IN(base)} = \beta_{DC} R_E$$

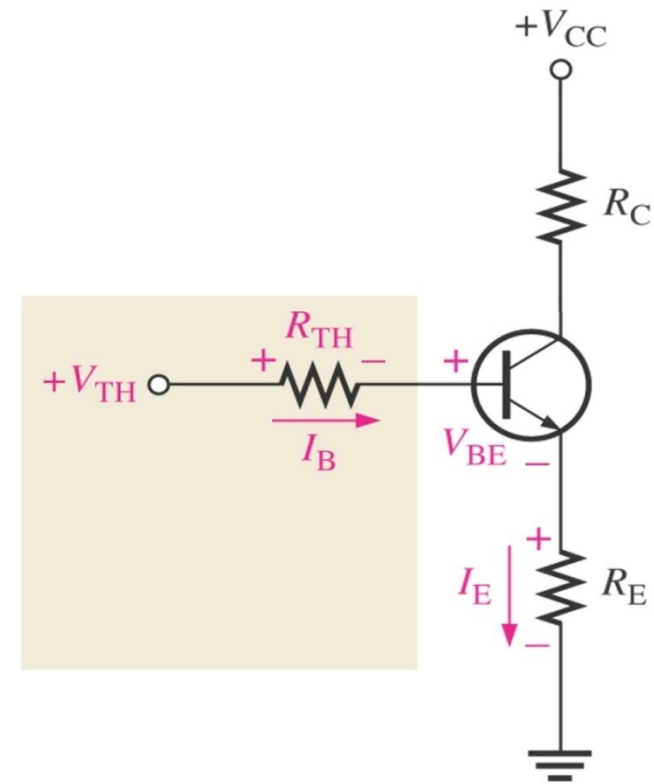
We can view the voltage at point A of the circuit in two ways, with or without the input resistance(point A to ground) considered.



Thevinizing the bias circuit



(a)



(b)

Stiff voltage divider



Stiff voltage divider: (No loading effect)

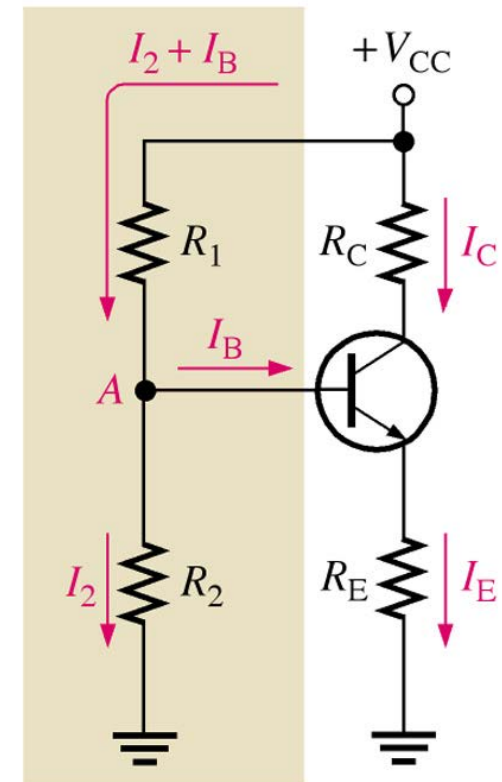
1. I_B is much smaller than I_2
2. $R_{IN(BASE)} = \beta_{DC} R_E > 10R_2$

$$V_B = (R_2 / (R_1 + R_2)) V_{CC}$$

$$I_E \approx I_C$$

Non-Stiff voltage divider: (with loading effect)

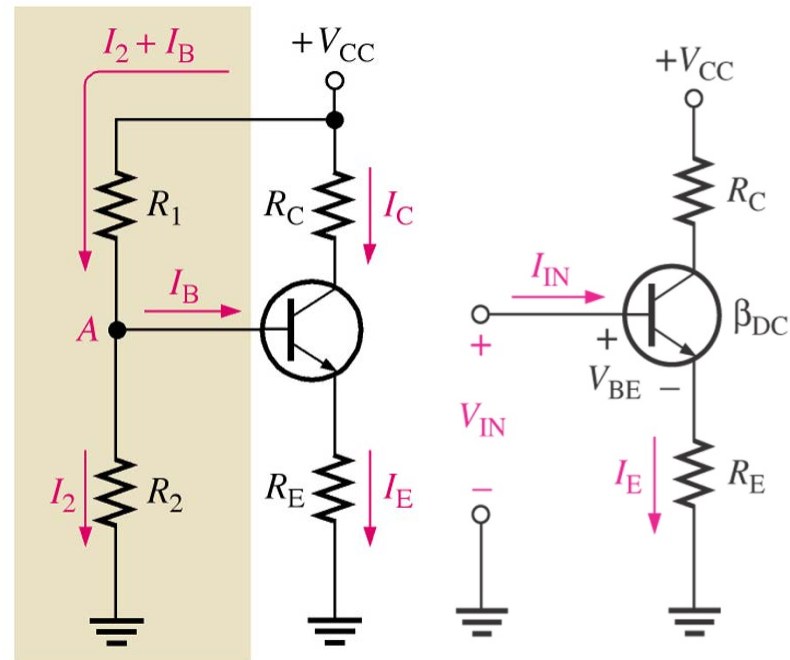
$$V_B = \left(\frac{R_2 \parallel \beta_{DC} R_E}{R_1 + (R_2 \parallel \beta_{DC} R_E)} \right) V_{CC}$$





We now take the known base voltage and subtract V_{BE} to find out what is dropped across R_E . Knowing the voltage across R_E we can apply Ohm's law to determine the current in the collector-emitter side of the circuit. Remember the current in the base-emitter circuit is much smaller, so much in fact we can for all practical purposes we say that I_E approximately equals I_C .

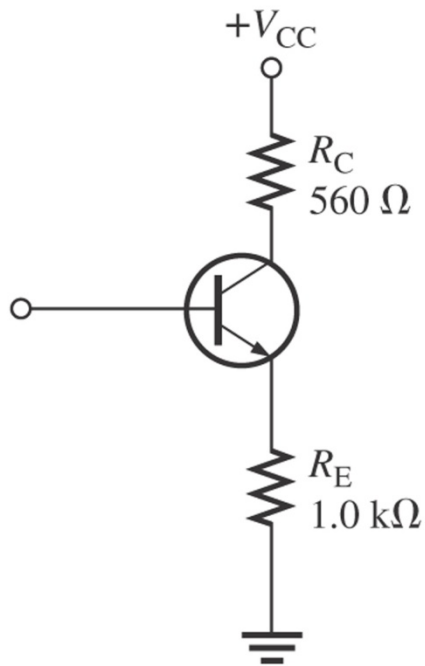
$$I_E \approx I_C$$



Example



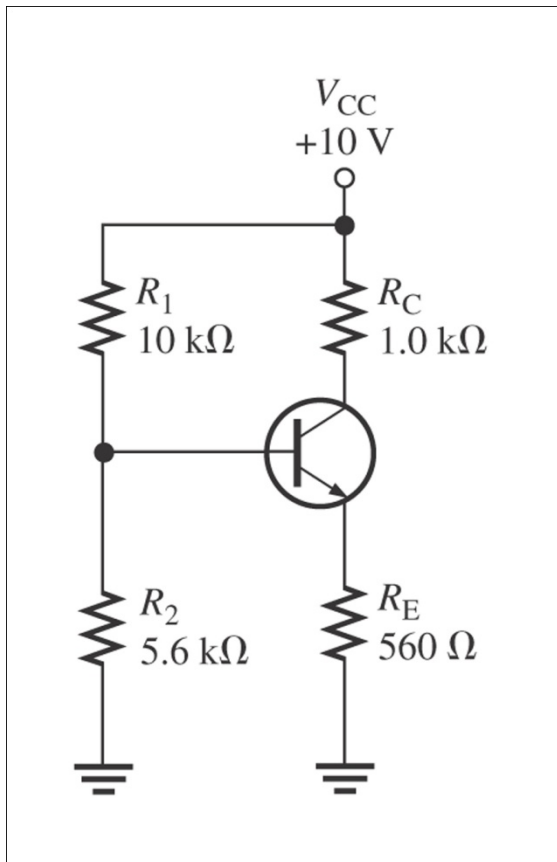
- Determine the dc input resistance looking at the base of the transistor if $\beta_{DC} = 125$.



Example



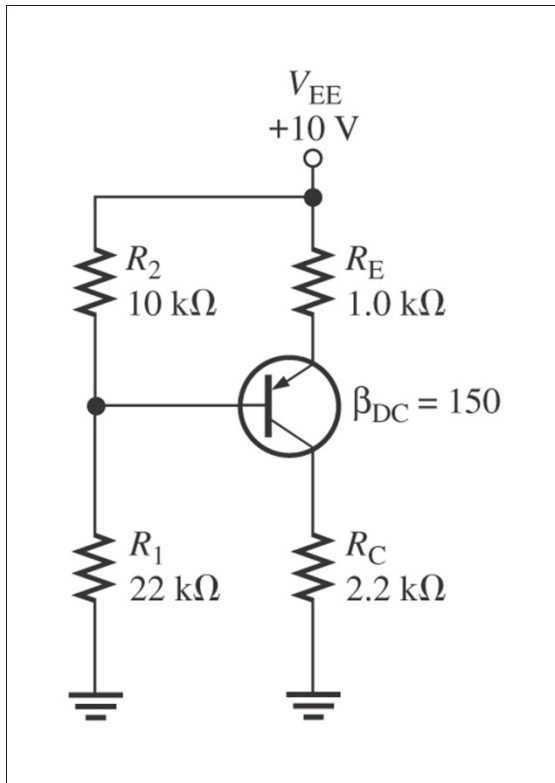
- Determine V_{CE} and I_C in the stiff voltage divider biased transistor circuit if $\beta_{DC} = 100$.



Example



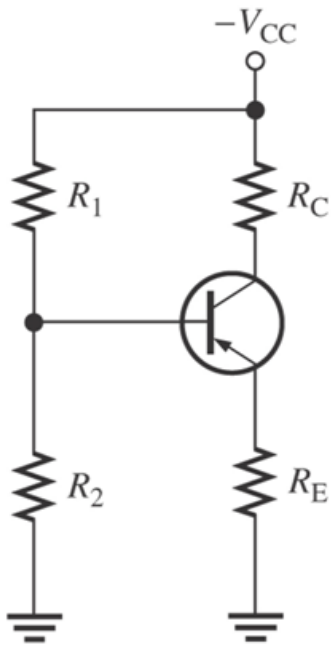
- Find I_C and V_{EC} for the pnp transistor circuit as given.



Example



- Find I_C and V_{CE} for the pnp transistor circuit as given. Assume $R_1=68\text{ k}\Omega$, $R_2=47\text{ k}\Omega$, $R_C=1.8\text{ k}\Omega$, $R_E=2.2\text{ k}\Omega$, $V_{CC}=-6\text{ V}$ and $\beta_{DC}=75$.





Emitter Bias

This type of circuit is independent of β making it as **stable** as the voltage-divider type. **The drawback is that it requires two power supplies.**

Two key equations for analysis of this type of bias circuit are shown below. With these two currents known we can apply Ohm's law and Kirchhoff's law to solve for the voltages.

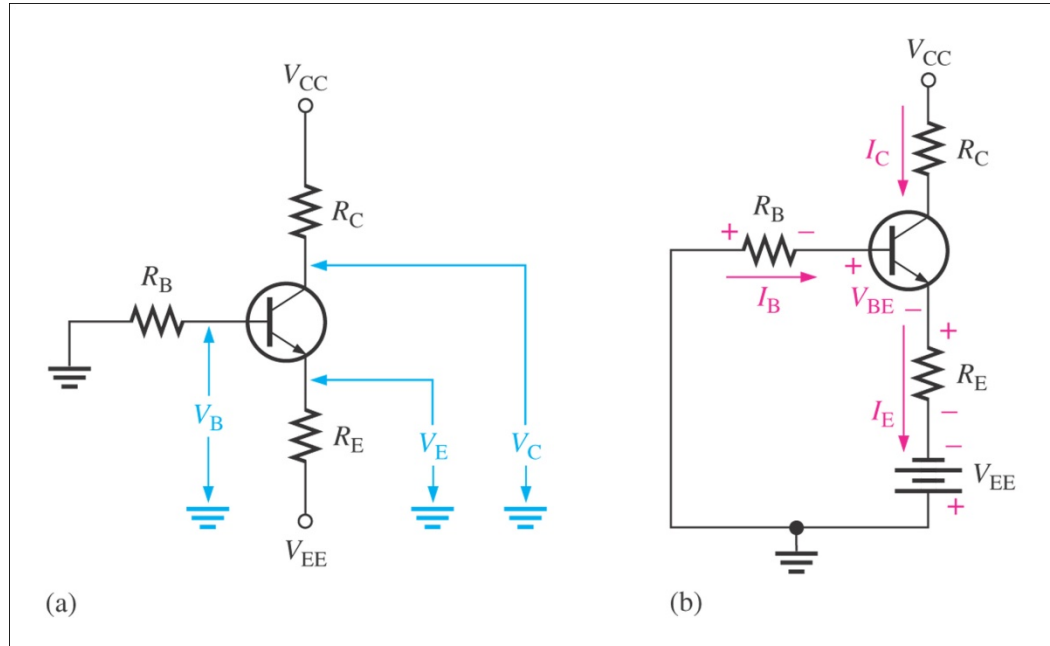
Approximation calculation:

$$V_E = V_B - V_{BE} \approx -1 \text{ V}$$

$$V_E = I_E R_E + V_{EE}$$

$$I_C \approx I_E = (-V_{EE} - 1) / R_E$$

↑
independent of β



Precise calculation:

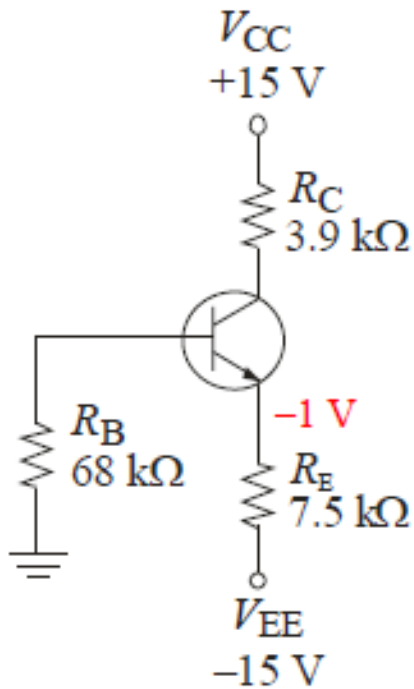
$$I_B \approx I_E / \beta$$

$$I_C \approx I_E \approx (-V_{EE} - V_{BE}) / (R_E + R_B / \beta_{DC})$$

Example



- Assuming that $V_E = -1 \text{ V}$, what is I_E ?



Base Bias



This type of circuit is very unstable since its β changes with temperature and collector current. Base biasing circuits are rarely used in linear circuits and mainly limited to **switching applications**.

KVL around base and collector circuits;

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

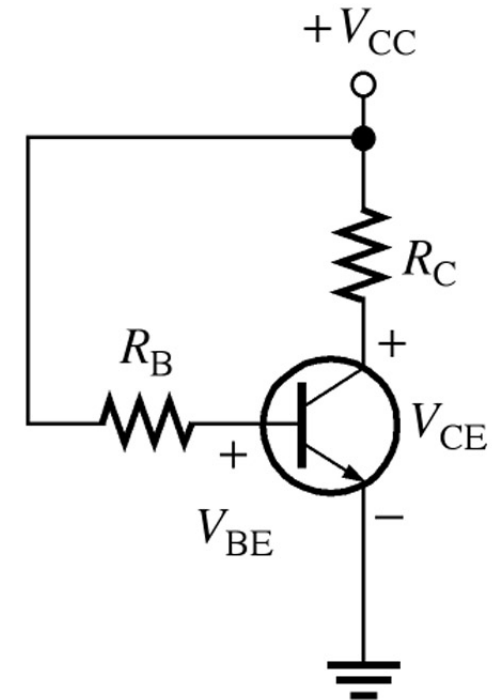
$$I_B = (V_{CC} - V_{BE}) / R_B$$

$$I_C = \beta_{DC} I_B$$

$$I_C = \beta_{DC} (V_{CC} - V_{BE}) / R_B$$

↑
dependent of β

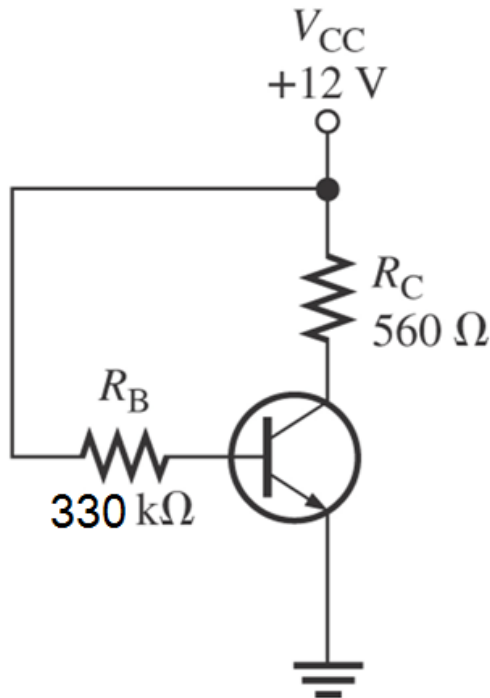
$$V_{CE} = V_{CC} - I_C R_C$$



Example



- Determine how much Q-point (I_C and V_{CE}) for the given circuit will change over temperature range where β_{DC} increases from 100 to 200.



Emitter-feedback bias



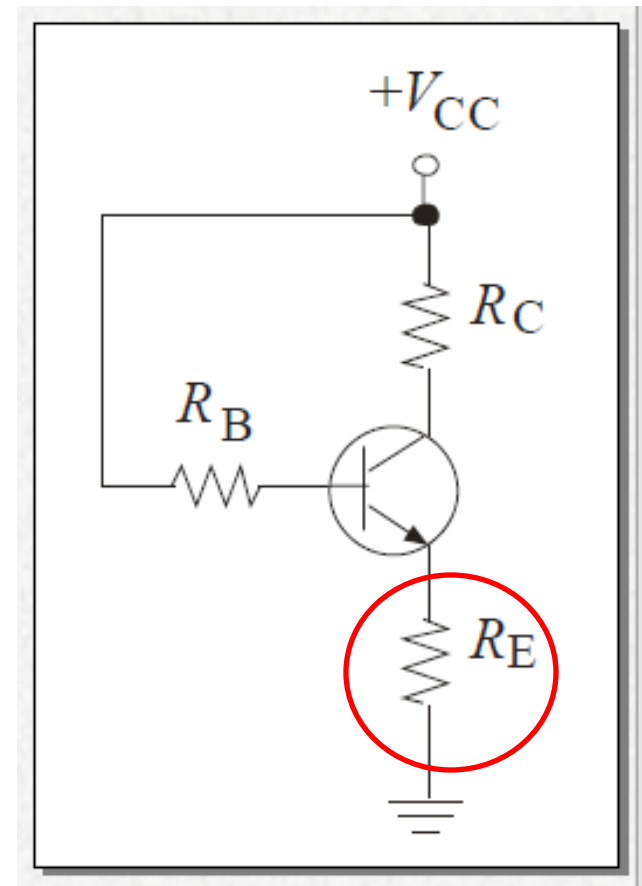
R_E changes base bias into emitter-feedback bias, which is **more predictable**. This is a form of **negative feedback**.

KVL around base circuit;

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

$$I_E / \beta_{DC} = I_B$$

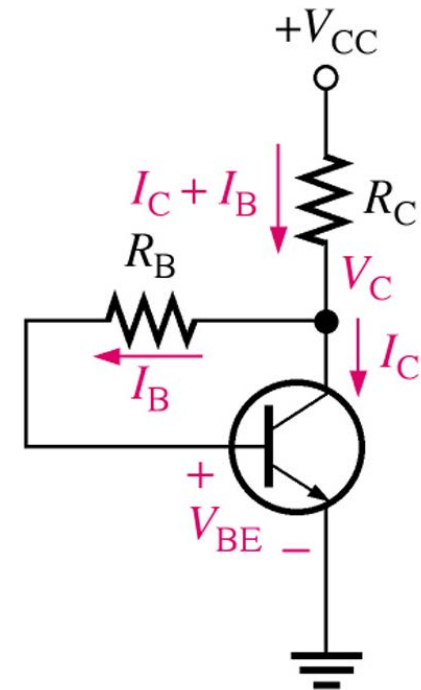
$$I_E = \frac{V_{CC} - V_{BE}}{R_E + \frac{R_E}{\beta_{DC}}}$$



Collector-feedback bias



Collector-feedback bias is kept stable with negative **feedback**, although it is not as stable as voltage-divider or emitter bias. With increases of I_C , less voltage is applied to the base. With less I_B , I_C comes down as well. The two key formulas are shown below.



$$I_B = (V_C - V_{BE}) / R_B$$

$$I_C = (V_{CC} - V_{BE}) / (R_C + R_B / \beta_{DC})$$

Review Summary(1)



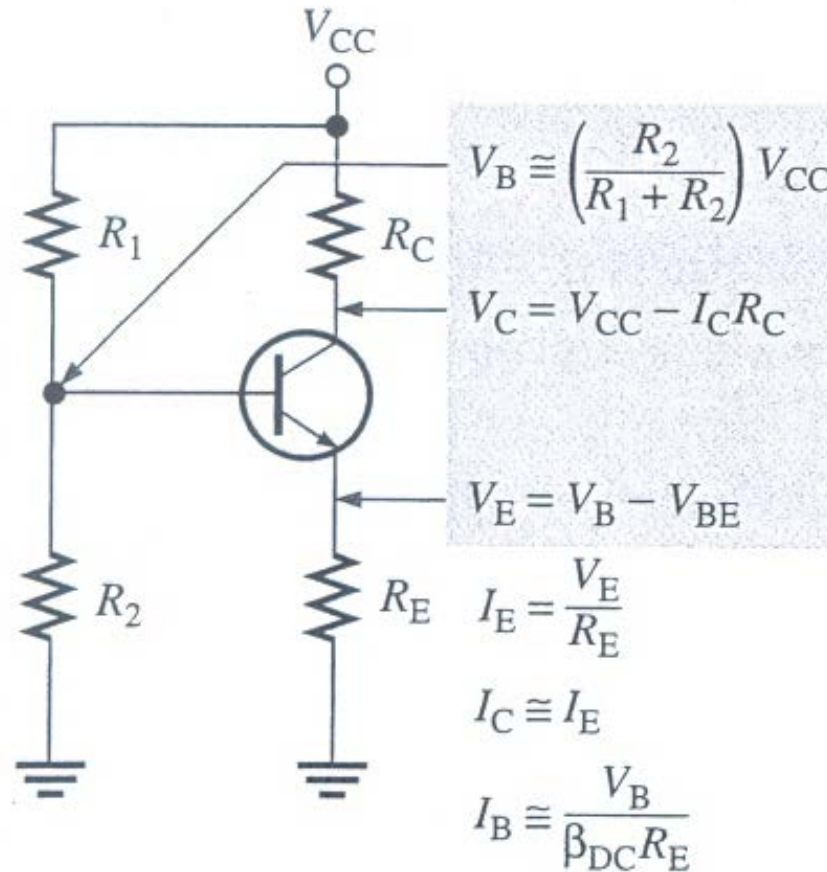
- The purpose of biasing is to establish a stable operating point (Q-point).
- The Q-point is the best point for operation of a transistor for a given collector current.
- The dc load line helps to establish the Q-point for a given collector current.
- The linear region of a transistor is the region of operation within saturation and cutoff.

Review Summary (2)



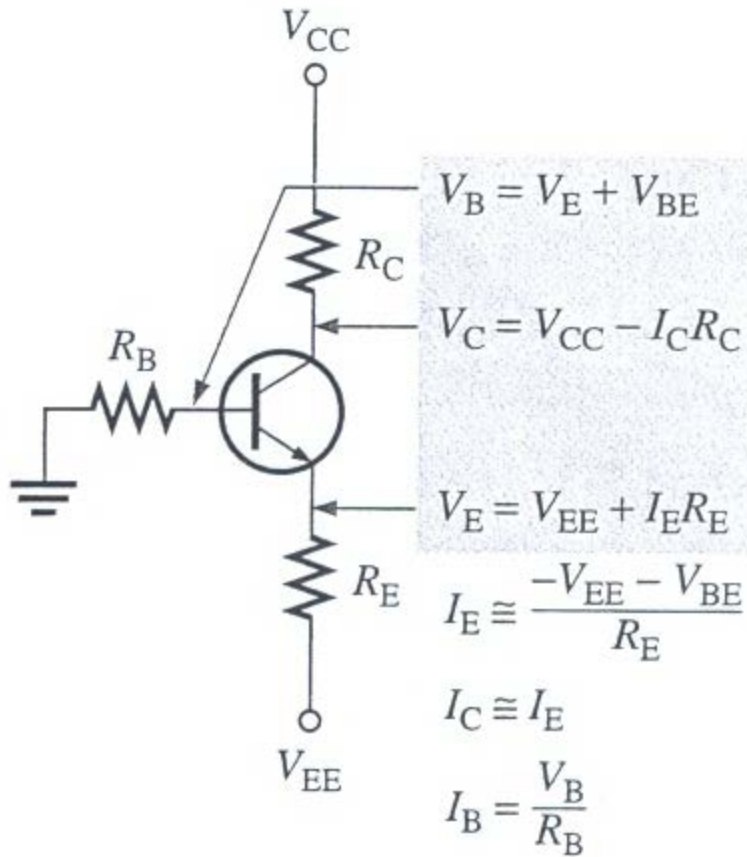
- Voltage-divider bias is most widely used because it is stable and uses only one voltage supply.
- Base bias is very unstable because it is β dependent.
- Emitter bias is stable but require two voltage supplies.
- Collector-feedback is relatively stable when compared to base bias, but not as stable as voltage-divider bias.

Summary of Bias Circuits(1)

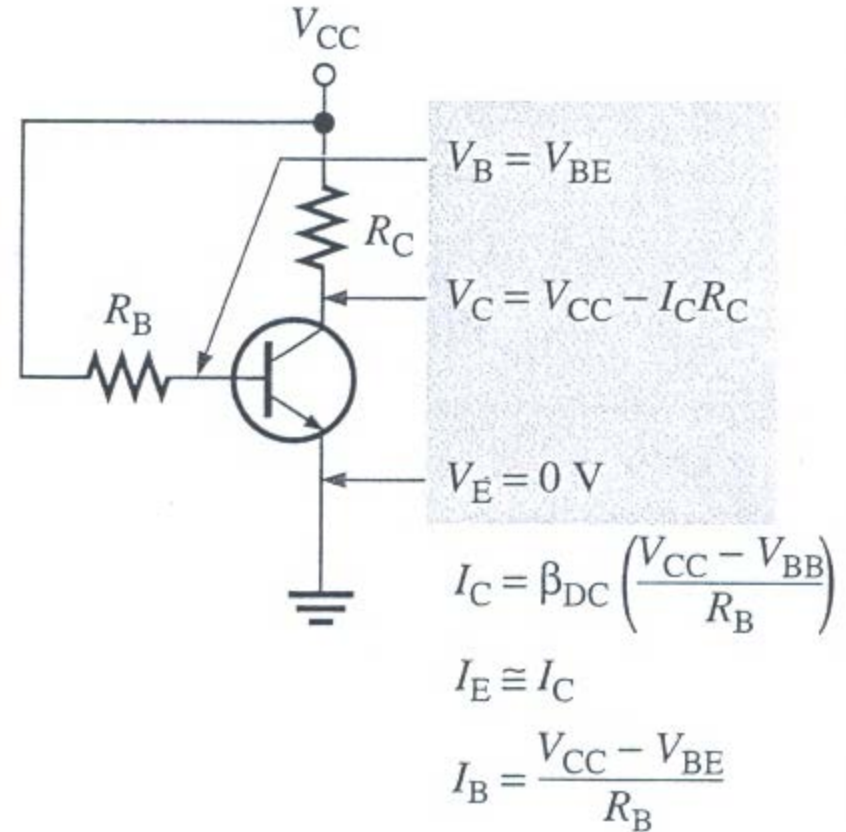


Voltage Divider

Summary of Bias Circuits(2)

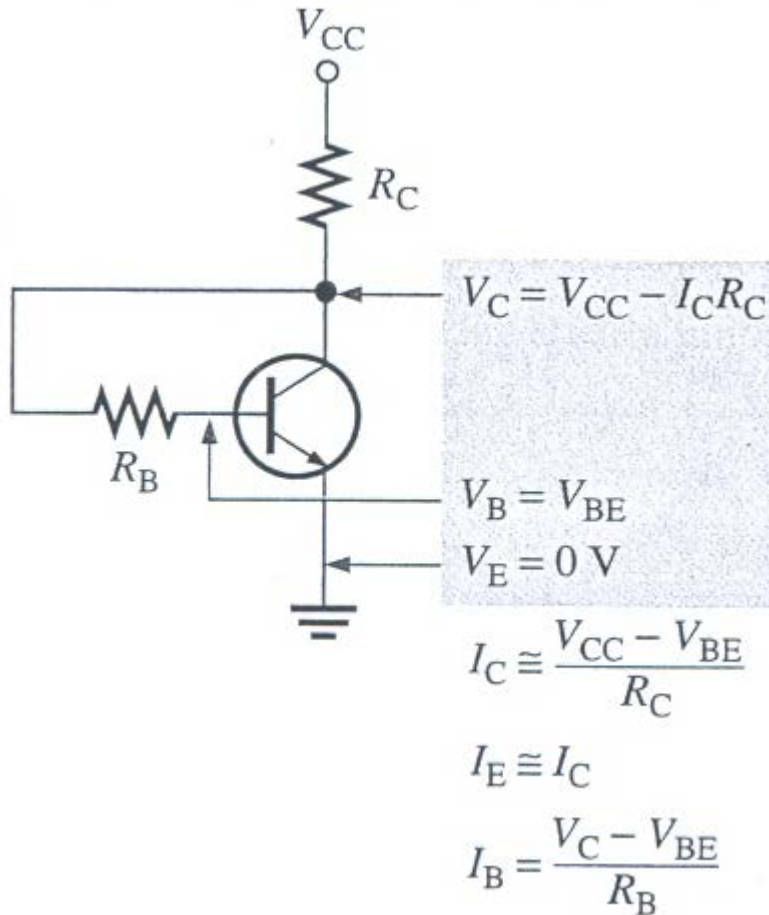


Emitter Bias

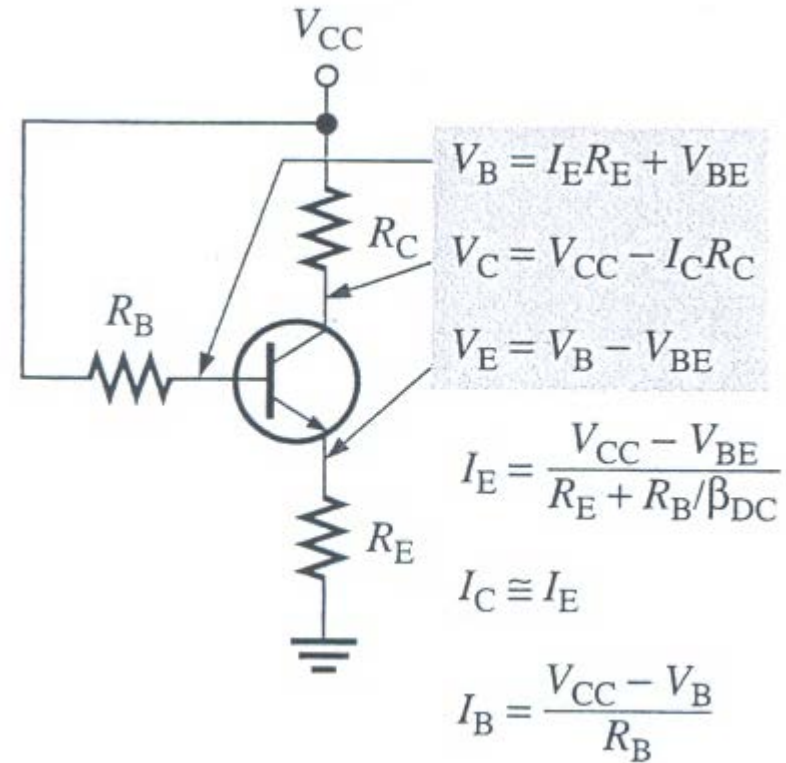


Base Bias

Summary of Bias Circuits(3)



Collector-feedback Bias

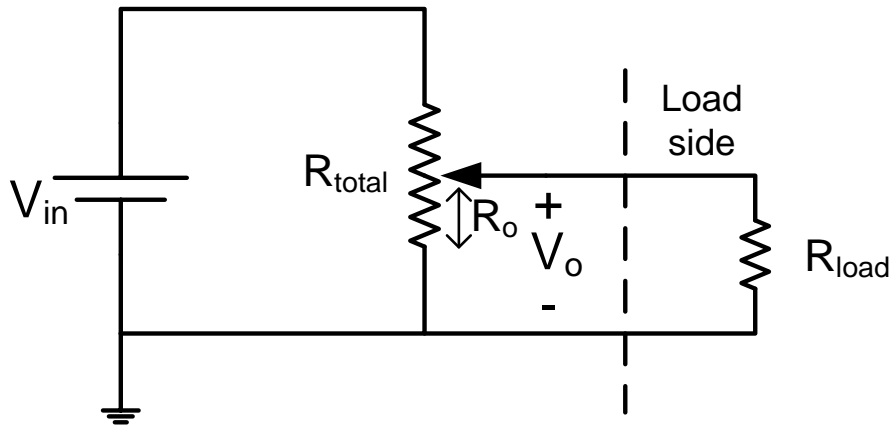


Emitter-feedback Bias

Supplement



Loading Effect



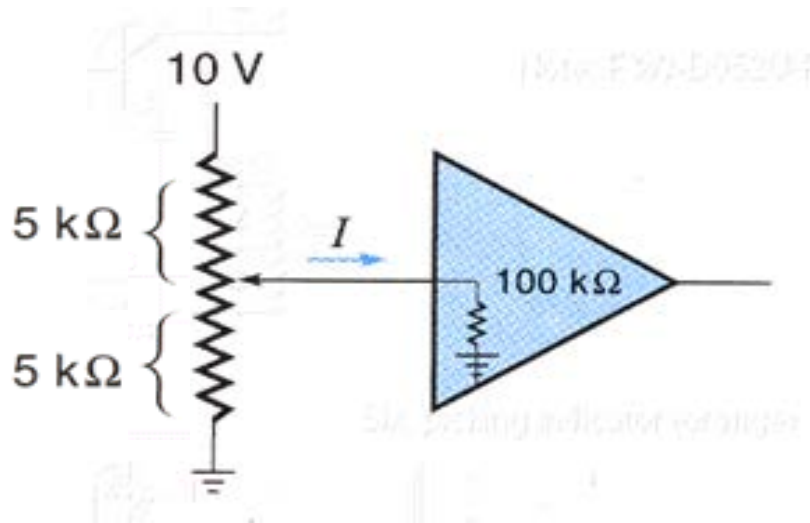
- The load resistance connected to the potentiometer introduces the error to the output voltage

- [Unloaded] Without R_{load} ,
$$V_o = \frac{R_o}{R_{total}} V_{in}$$
- [Load] With R_{load} ,
$$V_o = \frac{R_o // R_{load}}{(R_{total} - R_o) + R_o // R_{load}} V_{in}$$
- Loading Error:
$$V_o[unloaded] - V_o[load]$$



Exercise

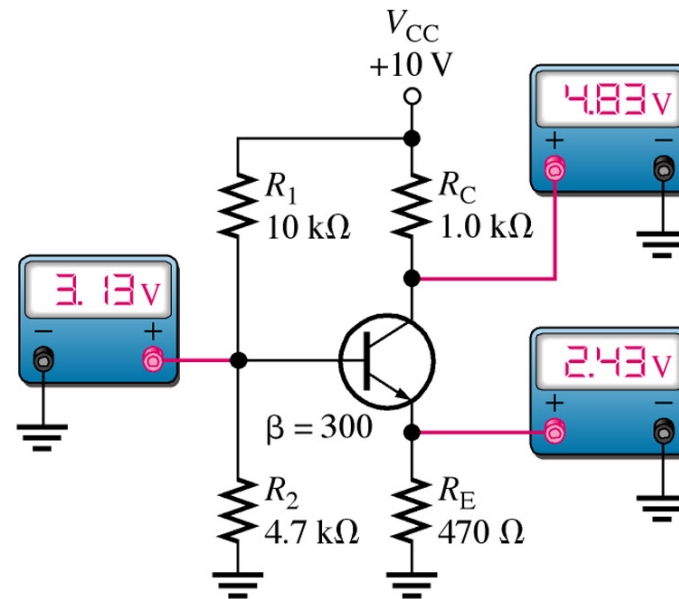
- From a given circuit, the output voltage from the potentiometer is used to drive the load with $100\text{k}\Omega$ resistance. As a result, the loading error is applied at the output of the pot. What is the value of loading error in volts??? Explain the method to overcome this problem??



Troubleshooting



Shown is a typical voltage divider circuit with correct voltage readings. Knowing these voltages is a requirement before logical troubleshooting can be applied. We will discuss some of the faults and symptoms.





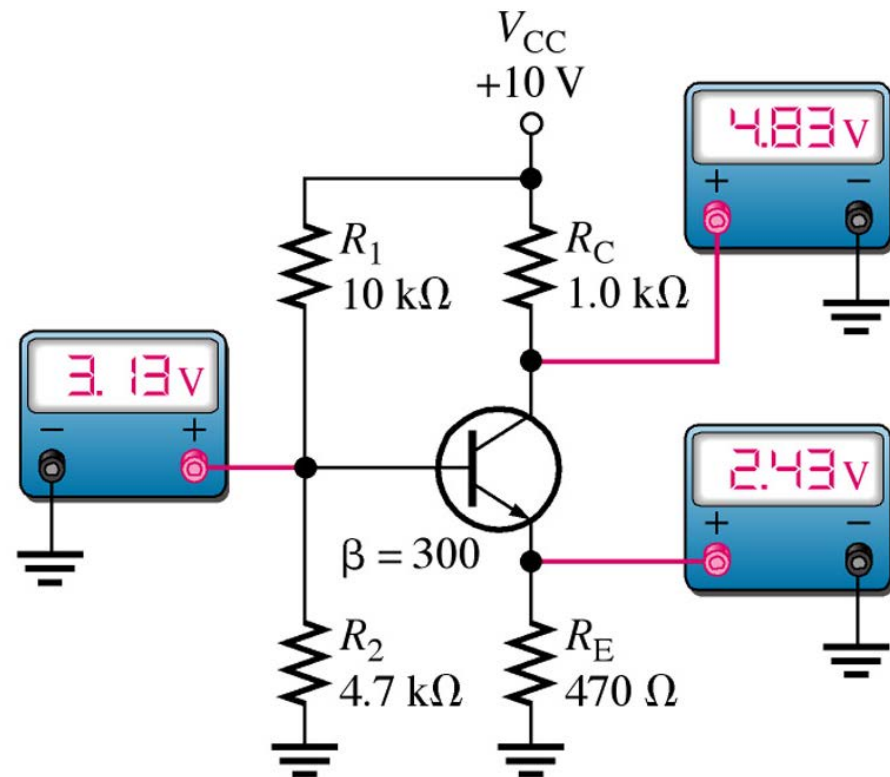
R1 Open

With no bias the transistor is in cutoff.

Base voltage goes down to 0 V.

Collector voltage goes up to 10 V (V_{CC}).

Emitter voltage goes down to 0 V.





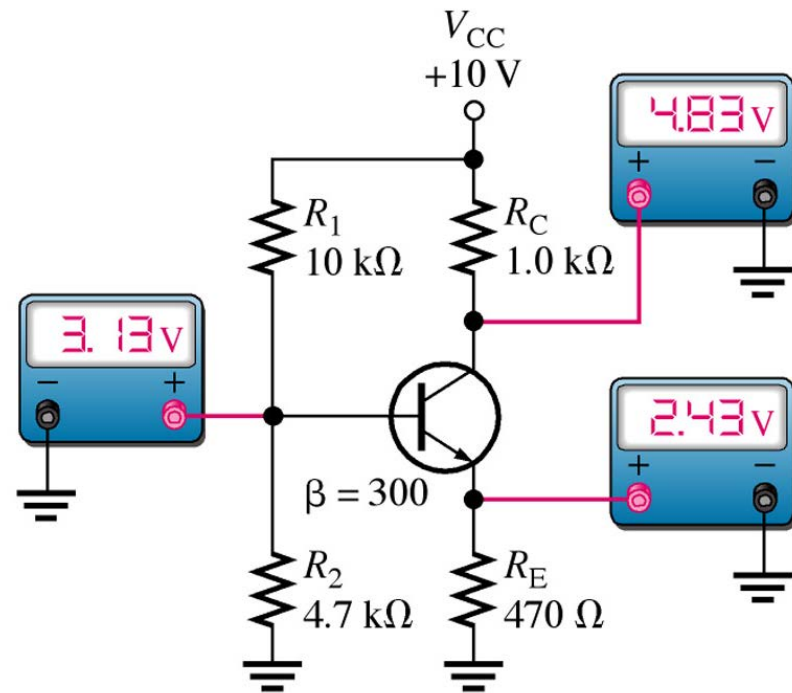
Resistor R_E Open:

Transistor is in cutoff.

Base reading voltage will stay approximately the same.

Collector voltage goes up to 10 V (V_{CC}).

Emitter voltage will be approximately the base voltage + .7 V.





Base Open Internally:

Transistor is in cutoff.

Base voltage stays approximately the same.

Collector voltage goes up to 10 V (V_{CC}).

Emitter voltage goes down to 0 V.

