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UNIT FUNDAMENTALS
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Ex 1 Temperature Effect on Fixed Bias
Ex 2 Temperature Effect on Voltage Divider
UNIT TEST
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UNIT OBJECTIVE

At the completion of this unit, you will be able to demonstrate the effect of a temperature increase on transistor bias by using typical transistor amplifier bias circuits.
Transistor bias refers to the dc operating conditions: the base, collector, and emitter dc voltages and currents.
Transistor bias depends on the dc voltage supply and on the values and configuration of the circuit resistors.
Transistor bias refers to the

a. ac operating conditions: the base, collector, and emitter ac voltages.

b. dc operating conditions: the base, collector, and emitter dc currents.
The Q-point of the load line is determined by the transistor bias.
Transistors are heat-sensitive devices.
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A change in transistor temperature can adversely affect the output signal quality.
If a circuit is not designed to overcome the effects of temperature change, the location of the Q-point can move toward the saturation or cut-off points causing signal distortion.
A transistor amplifier circuit with a base voltage divider and an emitter resistor fixes the bias voltage levels and, therefore, has good bias temperature stability.
The stability factor (S) is a measure of a transistor circuit's bias stability with changes in temperature.
A transistor amplifier circuit with good bias temperature stability has

a. a base voltage divider.
b. an emitter resistor.
c. Both of the above.
d. None of the above.
In order to complete the following exercises, you will need:

- F.A.C.E.T. base unit
- Power supply, 15 Vdc (2 required)
- Multimeter
- Clock
- TRANSISTOR AMPLIFIER CIRCUITS
- circuit board
Temperature Effect on Fixed Bias
When you have completed this exercise, you will be able to describe the effect of temperature on a fixed bias circuit by using a typical transistor circuit. You will verify your results with a multimeter, a clock, and calculations.
An increase in transistor temperature increases beta ($\beta$, the current gain) and *collector leakage current* ($I_{CBO}$) and decreases the base-emitter voltage difference.
A change in beta ($\beta$) has the greatest effect on the collector current in the fixed bias circuit.
If there is a large temperature increase, the collector current can reach the saturation point or a thermal runaway condition that could destroy the transistor.
An increase in transistor temperature increases

a. beta (β).

b. collector leakage current ($I_{CB0}$).

c. Both of the above.

d. None of the above.
The collector leakage current ($I_{CEO}$) is caused by the reverse bias voltage. $I_{CEO}$ increases with temperature.
$I_{CBO}$ is measured from the base to the collector with the emitter open.
The collector leakage current ($I_{CBO}$) is in the range of nanoamperes (nA), but it doubles with every 10° Celsius increase.
The collector leakage current \( (I_{CEO}) \) is 10 nA at 30\(^\circ\) Celsius. At 40\(^\circ\) Celsius, \( I_{CEO} \) would be about

a. 10 nA.
b. 20 nA.
c. 30 nA.
The stability factor (S), a measure of transistor temperature stability, is usually measured as the ratio of the change in collector current to the change in collector leakage current.

\[
S = \frac{\text{the change in } I_c}{\text{the change in } I_{CB0}}
\]
The stability factor (S) of a transistor circuit can range from a value as high as beta (20 to 500) to a value as low as 1.0.
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The lower the $S$ value, the more stable the transistor is against temperature change.
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The lower the S value, the more stable the transistor is against temperature change.

An S value less than 10 is considered good.
A transistor is more stable against temperature change when the transistor stability factor is

a. low.
b. high.
The fixed bias circuit, also referred to as the simple bias circuit, has poor temperature stability.
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The stability factor for the fixed bias circuit equals beta (β).
In a fixed bias circuit, a temperature increase causes a decrease in $V_{BE}$, which causes an increase in both the voltage drop across R3 and the base current.
The base current increase causes an increase in collector current.
The increase in beta and in collector leakage current compounds the collector current increase with base current.
In a fixed bias circuit, an increase in temperature causes a(n)

a. decrease in $V_{EE}$.
b. increase in the voltage drop across R3.
c. increase in the base current.
d. All of the above.
The fixed bias circuit is usually used only for transistor circuits that function as switches and that operate at cutoff (open) or saturation (closed).
The fixed bias circuit is best used for transistor circuits that function as

- switches.
- high gain amplifiers.
- high frequency amplifiers.
1. Locate the BIASESTABILIZATION circuit block.
1. Locate the BIAS STABILIZATION circuit block.

2. Turn potentiometer R3 fully counterclockwise (CCW) for maximum resistance.
   Connect the fixed bias circuit shown. Use resistor R1.
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2. Turn potentiometer R3 fully counterclockwise (CCW) for maximum resistance. Connect the fixed bias circuit shown. Use resistor R1.

3. Adjust the positive variable dc power supply so that $V_A$ equals 6.0 Vdc.
4. Adjust potentiometer R3 for 0.20 Vdc across R5 in the collector circuit.

NOTE: If R3 cannot be adjusted for 0.20 Vdc across R5, disconnect R1 and connect R2 to the circuit. Adjust R3 for 0.20 Vdc across R5. The flexibility in using R1 or R2 is due to the large variation in Q1 beta.
5. Adjusting potentiometer R3 for 0.20 Vdc across R5 sets the collector current ($I_c$).
Calculate the collector current.

$I_c = \underline{\text{______}} \text{ mA}$
6. You will observe the change in base-emitter voltage ($V_{BE}$) and collector current ($I_C$) due to an increase in transistor Q1 temperature after the transistor is heated for 2 minutes.

On your circuit board, the HEATER is the resistor that is physically on top of transistor Q1.
7. Measure the base-emitter voltage ($V_{BE(\text{cold})}$).

$$V_{BE(\text{cold})} = \text{Vdc}$$
8. Connect the transistor HEATER to the circuit by using a two-post connector, and make note of the time.

After the HEATER is connected for 2 minutes, measure $V_{BB{\text{(hot)}}}$.

$V_{BB{\text{(hot)}}} = \underline{\text{ }} \text{ Vdc}$
9. Disconnect the HEATER from the circuit.
\[ V_{BE(\text{cold})} = 0.644 \text{ Vdc} \]
\[ V_{BE(\text{hot})} = 0.606 \text{ Vdc} \]

10. Does \( V_{BE} \) decrease or increase when the transistor Q1 temperature increases?

a. increase
b. decrease
$V_{BE\text{(cold)}} = 0.644\ \text{Vdc}$

$V_{BE\text{(hot)}} = 0.606\ \text{Vdc}$

11. What is the change in $V_{BE}$ after the transistor is heated for 2 minutes?

The change in $V_{BE} =$ $\phantom{0}$ Vdc
12. Wait at least 10 minutes for transistor Q1 to cool.

Then, if necessary, readjust R3 for 0.20 Vdc across R5.
12. Wait at least 10 minutes for transistor Q1 to cool.

Then, if necessary, readjust R3 for 0.20 Vdc across R5.

13. Enter the voltage across R5

\( V_{R5\text{(cold)}} \).

\[ V_{R5\text{(cold)}} = \boxed{\text{Vdc}} \]
14. Calculate the collector current \( I_{C(cold)} \).

\[ I_{C(cold)} = \text{[value]} \text{mA} \]
15. Connect the transistor HEATER to the circuit, and make note of the time.

After the HEATER is connected for 2 minutes, measure the voltage across R5 \( (V_{R5(\text{not})}) \).

\[
V_{R5(\text{not})} = \text{Vdc}
\]
16. Disconnect the HEATER from the circuit.
$V_{R0\text{(hot)}} = 0.224 \text{ Vdc}$

17. What is the collector current ($I_{C\text{(hot)}}$) after the transistor is heated for 2 minutes?

$I_c =$ ______ mA
\[ I_{C(\text{hot})} = 2.24 \text{ mA} \]
\[ I_{C(\text{cold})} = 2 \text{ mA} \]

18. Does \( I_c \) decrease or increase when the transistor Q1 temperature increases?

a. decrease  
b. increase
19. What is the change in $I_c$ after the transistor is heated for 2 minutes?

the change in $I_c = \boxed{\text{mA}}$
$I_{C(\text{hot})} = 2.24 \text{ mA}$

$\quad I_{C(\text{cold})} = 2 \text{ mA}$

20. What is the percentage (%) of change in collector current ($I_C$) after transistor Q1 is heated for 2 minutes in a fixed bias circuit?

\[
\text{\% change} = \frac{I_{C(\text{hot})} - I_{C(\text{cold})}}{I_{C(\text{cold})}} \times 100
\]
• Transistors are temperature sensitive.
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- A change in beta ($\beta$) due to a change in temperature has the most significant effect on collector current in a fixed bias circuit.
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- A change in beta ($\beta$) due to a change in temperature has the most significant effect on collector current in a fixed bias circuit.

- The base-emitter voltage ($V_{BE}$) decreases with a transistor temperature increase.
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- A change in beta ($\beta$) due to a change in temperature has the most significant effect on collector current in a fixed bias circuit.

- The base-emitter voltage ($V_{BE}$) decreases with a transistor temperature increase.

- The fixed bias circuit has very poor temperature stability; the collector current changes significantly with temperature change.
Transistors are temperature sensitive.

A change in beta ($\beta$) due to a change in temperature has the most significant effect on collector current in a fixed bias circuit.

The base-emitter voltage ($V_{BE}$) decreases with a transistor temperature increase.

The fixed bias circuit has very poor temperature stability; the collector current changes significantly with temperature change.

The fixed bias circuit is used mainly for transistor switch circuits that operate at either the saturation point (on) or the cutoff point (off).
1. Transistors are
   a. not very sensitive to changes in temperature.
   b. heat sensitive.
   c. reliable when operated above 75°C Celsius.
   d. pressure sensitive.
2. Transistor bias refers to the
   a. dc operating conditions.
   b. ac operating conditions.
   c. temperature stability.
   d. dc voltage supply.
3. The transistor base-emitter voltage ($V_{BE}$)

a. increases with an increase in temperature.
b. is not affected by temperature change.
c. decreases with an increase in temperature.
d. has no effect on collector current.
4. In a fixed bias circuit, an increase in transistor operating temperature moves the Q-point

a. toward the cutoff point.
b. insignificantly.
c. to a new dc load line.
d. toward the saturation point.
5. A transistor circuit with a stability factor of 200

a. is not affected by a temperature change.
b. has very poor temperature stability.
c. is usually used in audio amplifier circuits.
d. is usually not affected by a change in beta (β) due to a temperature change.
Temperature Effect on Voltage Divider
When you have completed this exercise, you will be able to describe the temperature effects on a voltage divider bias circuit by using a typical transistor circuit. You will verify your results with a multimeter, a clock, and calculations.
This transistor circuit has a voltage divider circuit with an emitter resistor for bias stability.
The collector current is almost independent of beta (\(\beta\)); consequently, as \(\beta\) changes with temperature, the effect on the circuit bias is minimal.
In this transistor circuit, beta (β) changes with temperature. The effect on the circuit bias is

a. maximum.
b. minimal.
c. nonexistent.
The junction of the voltage divider resistors (R1 and R4) connects to the transistor base terminal.
The junction of the voltage divider resistors (R1 and R4) connects to the transistor base terminal.
Use the voltage divider equation to calculate base voltage.

\[ V_B = V_A \times \frac{R_2}{R_1 + R_2} \]
Use the voltage divider equation to calculate base voltage.

\[ V_B = V_A \times \frac{R2}{R1 + R2} \]

The combination of a firm base voltage and feedback from the emitter resistor gives this circuit good temperature stability.
Under normal transistor operating conditions, the base voltage

a. is essentially constant.
b. varies widely to compensate for temperature.
As the collector and emitter currents increase due to a temperature rise, the emitter voltage increases.
As the collector and emitter currents increase due to a temperature rise, the emitter voltage increases.

An increase in the emitter voltage temporarily opposes and slightly increases the base voltage.
A slight increase in the base voltage decreases the base current, which counteracts the increase in collector and emitter currents.
As the emitter voltage increases due to a temperature rise, the base voltage

a. increases to a new value.
b. increases momentarily, then returns to normal.
c. decreases momentarily, then returns to normal.
The effect of the emitter voltage increase on the base voltage is called **feedback**.
The effect of the emitter voltage increase on the base voltage is called **feedback**.

The feedback suppresses the base current increase (input) and limits the collector current increase (output).
The larger the emitter resistor, the better the bias stability.

But an emitter circuit with a large emitter resistor has a smaller voltage gain and a Q-point closer to the saturation point, which limits the ac signal operating range.
The larger the emitter resistor,
a. the smaller the voltage gain.
b. the closer the Q-point to the saturation point.
c. the better the bias stability.
d. All of the above.
The stability factor \( S \) of this voltage divider bias circuit is approximately equal to the ratio of \( R_4 \) to \( R_7 \).

\[
S = \frac{1000}{390} = 2.56
\]
The new stability factor of this voltage divider bias circuit approximately equals the ratio of the new values of R4 to R7.

Calculate S.

\[ S = \]
A good bias circuit has a stability factor of 10 or less.
A good bias circuit has a stability factor of 10 or less.

From the S value you calculated, is this voltage divider bias circuit temperature stable?

a. yes
b. no
1. Locate the BIAS STABILIZATION circuit block.
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2. Turn the potentiometer R3 knob fully clockwise (zero resistance).

   Connect the voltage divider bias circuit shown.
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2. Turn the potentiometer R3 knob fully clockwise (zero resistance).
   Connect the voltage divider bias circuit shown.

3. Adjust the positive variable dc power supply to 6.0 Vdc.
4. Measure the voltage ($V_{R5(cold)}$) across resistor R5 in the collector circuit.

$V_{R5(cold)} = \quad V_{dc}$
4. Measure the voltage ($V_{R5(\text{cold})}$) across resistor R5 in the collector circuit.

$$V_{R5(\text{cold})} = 0.19 \text{ Vdc}$$

5. Leave the multimeter connected across R5.
\[ V_{R5(\text{cold})} = 0.19 \text{ Vdc} \]

6. Calculate the collector current \((I_C(\text{cold}))\).

\[ I_C(\text{cold}) = \boxed{ \text{mA} } \]
In the following steps, you will measure the change in collector current due to an increase in transistor Q1 temperature after a 2 minute period.
7. Connect the transistor HEATER to the circuit, and make note of the time.
7. Connect the transistor HEATER to the circuit, and make note of the time.

Measure the voltage across R5 ($V_{R5\text{(hot)}}$) after the HEATER is connected for 2 minutes.

$V_{R5\text{(hot)}} = $ \[\text{Vdc}\]
8. Disconnect the HEATER from the circuit.
9. What is the collector current \((I_{C_{\text{hot}}})\) after 2 minutes?

\[ I_{C_{\text{hot}}} = \boxed{\text{mA}} \]
\[ I_{C(cold)} = 1.9 \text{ mA} \]
\[ I_{C(heat)} = 2 \text{ mA} \]

10. Does \( I_C \) decrease or increase when the transistor Q1 temperature increases?

a. increase  
b. decrease
11. What is the percentage (%) of change in collector current after transistor Q1 is heated for 2 minutes in a fixed bias circuit?

% change = ?

I_{C(cold)} = 1.9 \text{ mA}
I_{C(heat)} = 2 \text{ mA}
12. Is the percentage of increase in the voltage divider's collector current less than, equal to, or more than the percentage of change in collector current of the fixed bias circuit, calculated previously?

% change (voltage divider circuit) = 5.26%
% change (fixed bias circuit) = 12.0%

a. less than
b. equal to
c. more than
- The voltage divider bias circuit has the lowest increase in collector current with an increase in temperature because the collector current is almost independent of beta.
- The voltage divider bias circuit has the lowest increase in collector current with an increase in temperature because the collector current is almost independent of beta.

- The voltage divider circuit with an emitter feedback resistor tries to maintain a constant base voltage ($V_B$).
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- The voltage divider circuit with an emitter feedback resistor tries to maintain a constant base voltage ($V_B$).

- The stability factor ($S$) of a voltage divider circuit is about equal to the ratio of the base resistor to the emitter resistor.
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- The stability factor ($S$) of a voltage divider circuit is about equal to the ratio of the base resistor to the emitter resistor.

- A bias circuit with a stability factor less than 10 is very stable.
The voltage divider bias circuit has the lowest increase in collector current with an increase in temperature because the collector current is almost independent of beta.

The voltage divider circuit with an emitter feedback resistor tries to maintain a constant base voltage ($V_B$).

The stability factor ($S$) of a voltage divider circuit is about equal to the ratio of the base resistor to the emitter resistor.

A bias circuit with a stability factor less than 10 is very stable.

Because of the emitter resistor, any increase in emitter current causes the emitter voltage to increase. This increase feeds back and decreases the base current.
1. An ideal common emitter transistor bias circuit with a low stability factor has:
   a. a collector resistor larger than the emitter resistor.
   b. base and collector resistors.
   c. a voltage divider circuit and an emitter resistor.
   d. two dc power supplies.
2. A good stability factor is
   a. less than 10.
   b. over 50.
   c. equal to \( \beta \).
   d. None of the above.
3. A voltage divider circuit has an emitter resistor. As the emitter voltage increases with temperature, the base

   a. current increases.
   b. to ground voltage decreases.
   c. current decreases.
   d. current remains the same.
4. The voltage divider circuit with an emitter resistor has good temperature stability because the collector current change due to temperature change

a. depends on the dc supply voltage.

b. depends on $\beta$.

c. equals the emitter current.

d. is almost independent of $\beta$. 
5. The purpose of the voltage divider circuit with an emitter resistor is to

a. set the collector current.
b. fix $\beta$ for the transistor.
c. maintain an essentially constant Q-point.
d. maintain a constant $V_{BE}$. 