1. Determine Q values (I_B, I_C, and V_out) for the BJT common-emitter amplifier. 
   Note: BJT made of silicon (use $V_{FB} = 0.6V$), $\beta_{spec} = 100$ and $V_{bb} = 1.5V$

$$V_{in}(t) = 100\sin(\omega t) \text{ milli-Volts}$$

2. Determine AC gain.

3. What is the purpose of the coupling capacitor C1?
Objective
Investigate the characteristics and output limitations of a BJT Common-Emitter Amplifier.

Workbench Equipment
- Digital Oscilloscope, Agilent 54621A
- Function Generator, Agilent 33120A
- Digital Multimeter, Agilent 34401A
- DC Power Supply, Agilent E3640A
- Dual-tracking DC Power Supply, TPS-4000

Check-out Equipment, 20-111 window
- Large Breadboard
- Scope Probe (10:1), 2
- Banana to grabber 2 pair, 2red / 2black
- BNC to grabber lead
- Banana to Banana lead, 2

Background
BJT as an amplifier
A transistor can be used as a switch or as an amplifier. This experiment demonstrates a BJT used as an amplifier. Experiment #6 will demonstrate a BJT used as a switch.

There are two types of BJTs, npn and pnp. The npn is the most common BJT and will be used in this experiment. BJTs have three leads; emitter, base and collector. The fabrication and circuit symbol for a npn BJT is shown in Figure 3-1.

When operated as an amplifier, the base emitter junction (pn junction) is forward-biased and the base collector junction is reversed biased since \( V_{CE} \) is made at least three to four times \( V_{BE} \). Therefore, the BJT operates in its active region as shown in Figure 3-2. Current gain (\( \beta \)) is approximately constant and optimum (ideally equal to \( \beta_{spec} \)) in the active region. As experiment #6 will discuss, when a BJT is used as a switch operates in either the cut-off region (switch “off”) or saturation region (switch “on”). The cut-off region is the area of the
Ic v. V_{CE} plot where both base and collector current are small. The saturation region is the area of the Ic v. V_{CE} plot where the curves are sloped, not flat, and $\beta$ is not optimum.

BJT Common-Emitter Amplifier Analysis
Find the Q (quiescent) values. The Q values are Ib, Ic and V_{out} due to DC sources only. For the following analysis refer to Figure 3-3.

KVL around loop Ib yields: 
$$I_b = \frac{V_{bb} - 0.6}{R_1 + (\beta_{spec} + 1)R_e}$$  \hspace{1cm} (3-1)

Where 0.6V is the forward-bias voltage drop across base-emitter junction (BJT made of Silicon).

Since the BJT operates in the active region: 
$$I_c = \beta_{spec}I_b$$  \hspace{1cm} (3-2)

Nodal analysis: 
$$V_{out} = 15 - I_cR_C$$  \hspace{1cm} (3-3)
Where 15V is the Vcc source value.

Include AC signal to be amplified, $V_{in}$, in analysis: $V_{in} = A\sin(\omega t)$ Volts

First, coupling capacitor, C1, allows an AC signal through the base loop without affecting the DC base current. A coupling capacitor ideally acts like a short to AC and an open to DC.
The AC signal produces sinusoidal variation around Q values:

Note: Denominator of $I_{bac}$ does not have $R_1$ term, this assumes all ac current flows through path C1, Q1 base – emitter and $R_e$.

\[
I_b = Q_{value} + I_{bac} = \frac{(V_{bb} - 0.6)}{R_1 + (\beta_{spec} + 1)R_e} + \frac{A \sin(\omega t)}{(\beta_{spec} + 1)R_e} \tag{3-4}
\]

Still $I_C = \beta_{spec}I_b$, therefore:

\[
I_C = \beta_{spec} \left[ \frac{(V_{bb} - 0.6)}{R_1 + (\beta_{spec} + 1)R_e} + \frac{A \sin(\omega t)}{(\beta_{spec} + 1)R_e} \right] \tag{3-5}
\]

Still $V_{out} = 15 - I_C R_C$, therefore:

\[
V_{out} = 15 - R_C \beta_{spec} \left[ \frac{(V_{bb} - 0.6)}{R_1 + (\beta_{spec} + 1)R_e} + \frac{A \sin(\omega t)}{(\beta_{spec} + 1)R_e} \right] \tag{3-6}
\]

AC gain is the ratio of sinusoidal amplitudes of $V_{out}$ and $V_{in}$.

\[
AC_{gain} = \frac{V_{outpeak}}{V_{inpeak}} \tag{3-7}
\]

For a BJT common-emitter amplifier, $V_{out}$ is limited by $V_{CC}$ and electrical ground, 0V. The amplified output signal $V_{out}$ will distort if any portion of its waveform contacts either limit.

**Procedure:**

- Set Agilent E3640A DC power source to 1.5 VDC and a current limit of 0.5 Amps. This source will be used as $V_{bb}$.
- Set TPS 4000 DC power source to 15 VDC. Use a voltmeter to verify. Do not rely on the power supply analog meter. This source will be used as $V_{cc}$.
- Use bench function generator (FG) for $V_{in}$. Put FG in ‘Hi Z’ mode. Set the FG to a sinusoidal signal of 100 milli-Vpp at a frequency of 1KHz.
- Build circuit Figure 3-3 (without sources connected). Be certain to connect the transistor correctly, consult Figure 3-4 below, if unsure consult instructor.

**Fig. 3-4** BJT Leads

- Connect sources in the following order; $V_{bb}$, $V_{cc}$, $V_{in}$.
- Observe on scope both $V_{out}$ (collector of transistor) and $V_{in}$ (signal from FG).
Note: You may need to increase the amplitude of $V_{in}$ several hundred mVpp in order for Autoscale to “grab” signal. If so, after Autoscale “grabs” signal, set amplitude back to 100 mVpp and manually adjust voltage / division settings to optimally display waveforms on scope screen.

- Use Quick Measure to display volts peak to peak of both $V_{out}$ and $V_{in}$. Also use Quick Measure to display average value of $V_{out}$ (this is the Q value of $V_0$). Capture an image of this display and record AC gain.

  o Note: Quick Measure will include amplitude noise spikes. If signals are excessively noisy, the bandwidth limit option under the channel menu can be used to reduce noise. Also, cursors can be used to measure amplitude instead of Quick Measure.

\[
\text{AC gain} = ______
\]

- Decrease $V_{bb}$ (in 0.01 Volt increments) until the average value of $V_{out} = 14.75$ Volts.
- The positive peaks of $V_{out}$ should be noticeably distorted. Use Quick Measure to display volts peak to peak of both $V_{out}$ and $V_{in}$. Also use Quick Measure to display average value of $V_{out}$. Capture an image of this display and record AC gain.

\[
\text{AC gain} = ______
\]

- Increase $V_{bb}$ (in 0.01 Volt increments) until the average value of $V_{out} = 1.75$ Volts.
- The negative peaks of $V_{out}$ should be noticeably distorted. Repeat step before previous step.

\[
\text{AC gain} = ______
\]

- Turn off power to circuit. Physically remove $R_c$ and $R_e$ from circuit and measure their resistance with an ohmmeter.

\[
R_C = \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{0} \phantom{}