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COMMON EMITTER AMPLIFIER

TITLE: Common Emitter Transistor Amplifier

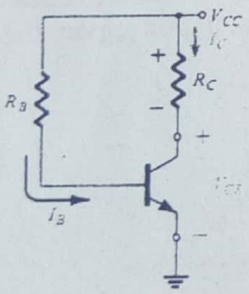
OBJECTIVE: 1. To understand the concept of DC load line and AC load line
2. To understand the operation of Common Emitter Amplifier
3. To understand the effect of DC blocking capacitors

PART1: THEORY AND PRACTICAL CONSIDERATIONS

Importance of the DC-load line:

The DC load line is a graph that represents all the possible combinations of I_C and V_{CE} for a given amplifier. Regardless of the behavior of the transistor, the collector current (I_C) and collector emitter voltage (V_{CE}) should always lie on the DC load line. It depends only on V_{CC}, R_C and R_E. ***A transistor should satisfy the DC-load line and the output characteristic curve at the same time. The point which satisfies both the curves is the operating point of the transistor.***

*Note: When a biased transistor does not have an **ac input**, it will have **specific dc values** of I_C and V_{CE}. These values correspond to a specific point on the **dc load line** known as the **Q-point**.*



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

$$I_C = \frac{-V_{CE}}{R_C} + \frac{V_{CC}}{R_C}$$

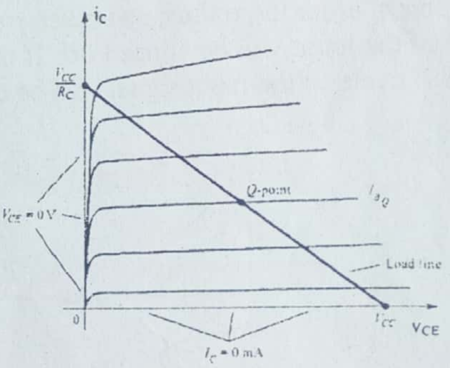
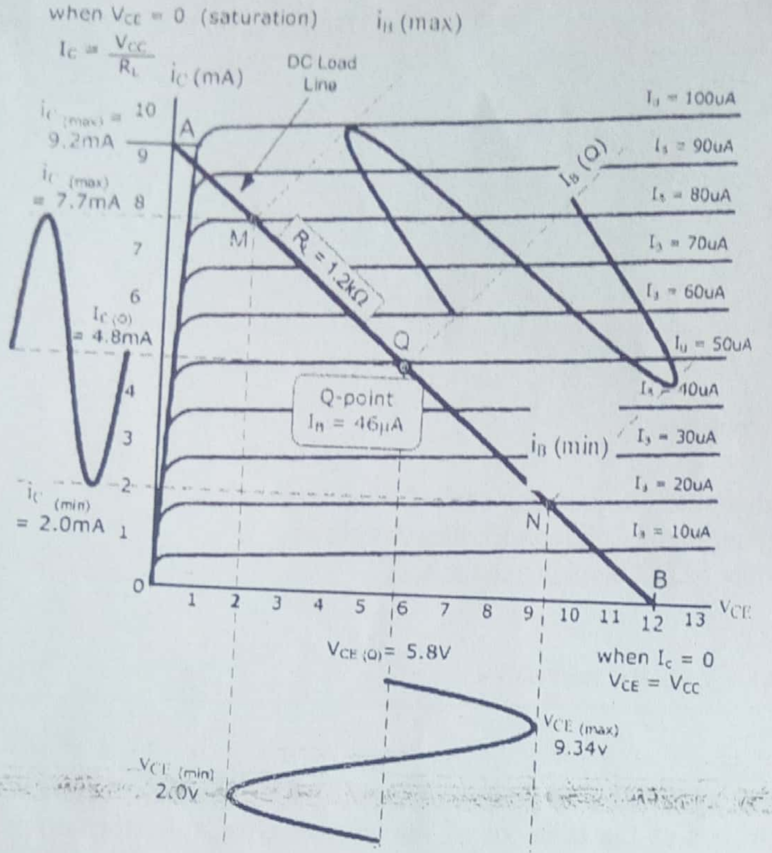


Figure 1. DC Load line of a fixed biased transistor

Applying an ac input to a biased transistor:

When an ac signal is applied to the base of a transistor, i_C and v_{CE} will both vary around their Q-point values. When the Q-point is centered, i_C and v_{CE} can both make the maximum possible transitions above and below their initial dc values.



$V_{CC} = 12V$
$R_C = 1.2k$

Therefore, the DC load line is given by,

$$I_C = \frac{-V_{CE}}{1200} + \frac{12}{1200}$$

Figure 2. Example curve of a DC load Line for a fixed biased transistor

Reason to use Q point at the center of the load line:

The operating point (Q-Point) of a transistor is normally placed at the center of the active region in order to produce an undistorted amplified output. If the transistor is in cut-off, the negative half cycle of the input will be clipped off. If the transistor's Q-Point is placed in the saturation region, the positive half cycle of the input signal will be clipped off.

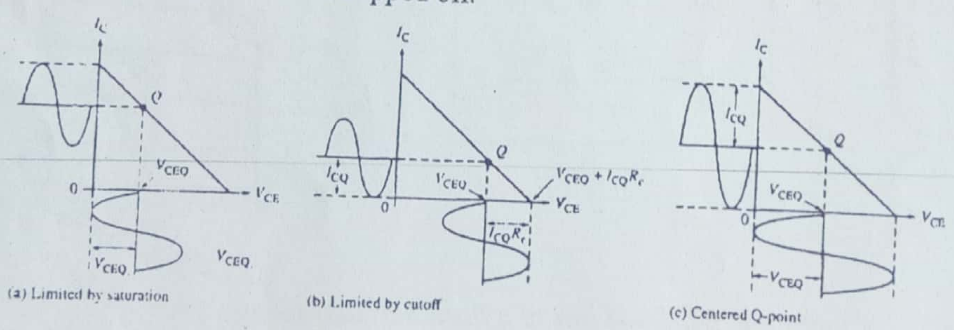


Figure 3. Effect on the maximum output swing caused by various placements of the Q-point

Important factors to consider when biasing a transistor:

- The Q-point should be placed at the center of the active region
- Q-point should be insensitive to variations in transistor parameters (for example, it should not shift if transistor is replaced by another transistor of the same type), temperature variations, supply voltage variations and etc.

e.g. The β of a transistor varies with temperature.

The AC-equivalent Circuit of an Amplifier:

This is also known as the *small signal equivalent circuit* of an amplifier. Here, it is assumed that the non-linear characteristics of the amplifier can be considered linear since the signals are small. ***Note that the ac-equivalent circuit of the whole amplifier and the small signal model of the transistor are two different concepts. After we find the ac equivalent circuit of the amplifier we can use a suitable model for the transistor which will account for the small signal behavior inside the transistor.*** Also note that there is more than one method to model the small signal behavior of a transistor(e.g. h-parameter model, hybrid-π mode). Depending on the application a suitable model is selected to model the transistor.

How to obtain the AC-equivalent circuit of the amplifier:

- Short circuit the capacitors
- Replace independent voltage sources with their internal resistances (short circuit ideal voltage sources)
- Replace independent current sources with their internal resistances (open circuit ideal current sources)

Explanation:

As an example, consider the $+V_{CC}$ terminal of the voltage source of Figure 4(a). The voltage at this terminal is held constant at $+V_{CC}$, and there is no time variation of this voltage since it is an independent parameter. Consequently, we can set this terminal to be an 'AC ground' in the small signal circuit.

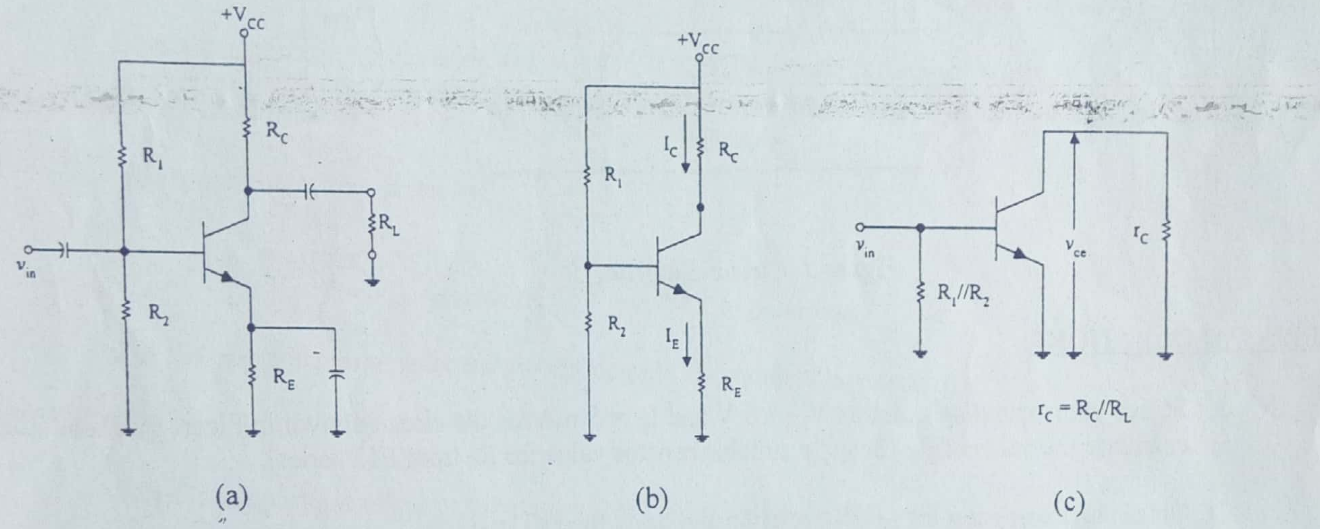


Figure 4. (a) A Voltage Divider Biasing Circuit
(b) DC equivalent Circuit
(c) AC equivalent Circuit

The concept of AC-Load Line:

The *AC-Load line* is used to find the maximum possible output voltage ($Vo_{p\text{-}p}$) swing for a given amplifier circuit. *It intersects the dc load line at the quiescent point.*
The ac load line of a given amplifier will not follow the curve of the dc load line. This is due to the fact that DC-Load of an amplifier is different from the AC-Load.

APPARATUS: List the apparatus you used

TRANSISTOR DATA: BC109-NPN general purpose transistor
Please read the transistor datasheet for specifications

CIRCUIT DIAGRAM:

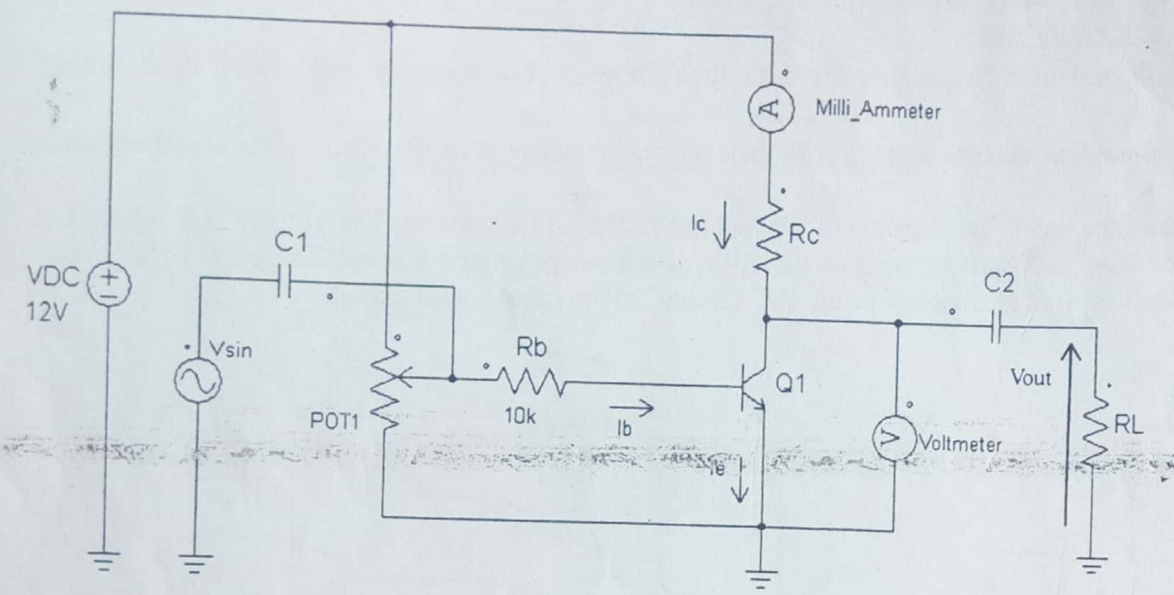


Figure 5. Circuit Diagram

PRE- CALCULATIONS:

1. Select your operating point as V_{CE}= 6 V and I_C = 5 mA for the circuit shown in Figure 5. Then calculate the value of R_C (Select a suitable resistor value for R_C from E12 series).
2. Obtain an expression for I_C-V_{CE} relation and draw the DC load line.
3. Draw the AC equivalent circuit for the amplifier circuit with the load connected as shown in Figure 5.(no need to draw the small signal model of the transistor)
4. Obtain an expression for i_c - v_{ce} relation for the amplifier (small signal relation). Then draw the AC load line (you should draw DC and AC load lines on the same graph). Also indicate the gradients of the two load lines. *Note: the AC load line should pass through the Q-Point.*

PROCEDURE:

1. Connect the circuit as shown in Figure 5 **omitting the load resistance R_L**. (Do not switch on the power supply until an instructor checks the circuit.)
2. Set V_{CE} to 6 V by adjusting POT1.
3. Apply a sinusoidal input signal (1 kHz) and increase the amplitude of the input signal until you get the maximum undistorted output voltage swing. Observe the variation of the output.
4. Observe the input and the output signals (**with and without C_2**) and sketch them on a same time scale. Then calculate the *Small Signal No-Load Voltage Gain* of the amplifier.

5. Connect the load resistor (R_L=10 kΩ).Observe the input/output. If the output is distorted, adjust the input signal's amplitude to get the maximum undistorted output voltage swing. Then calculate the *Loaded Small Signal Voltage Gain* of the amplifier.

6. Move the operating point upwards until V_{CE} = 2 V by adjusting the POT1. Using the voltmeter reading and milli-ammeter reading locate the operating point on the DC load line. For the same input sinusoidal signal as used in step 3, observe and sketch the output voltage signal (**with C_2 and without R_L**). Is there a change in output signal when compared with what you saw under step 4? If there is any change explain the reason for that.

7. Now move the operating point until V_{CE} = 10 V and repeat the same procedure used in step 6.

RESULTS:

1. Using the AC equivalent circuit of the amplifier and using the h-parameter model for the transistor, calculate the theoretical small signal voltage gain of the amplifier and compare with the observed results (for both loaded and no-load conditions). *You may need to refer to the datasheet of the transistor.*

2. Select the operating point such that V_{CE} = 6 V. Calculate the value of β_{dc} (h_{FE}) at the Q- point.
   Note: for parts 2 and 3 you need to refer to your observations in Static Characteristics of a Transistor lab session to get the information about the output characteristics of the BJT.

3. The h-parameters are given by,

$$\beta(h_{fe}) = \left(\frac{\Delta I_C}{\Delta I_B}\right)_{V_{CE}=constant}, \quad h_{ie} = \left(\frac{\Delta V_{BE}}{\Delta I_B}\right)_{V_{CE}=constant}$$

   For the operating point selected above compute the value of h-parameters.

DISCUSSION:

1. What is the purpose of using capacitors at the input and the output?
   Should you change the capacitance value when your input signal's frequency ranges changes?
   Hint: find out about the impedance imposed by a capacitor to ac signals
2. What is the difference between small signal amplifiers and large signal amplifiers? What are their applications?
   Note: You may come across terms like power amplifiers and voltage amplifiers. Find out whether they refer to the same amplifier types mentioned above.
3. What is the effect of adding an emitter resistance (with a capacitor parallel to the resistor) to the circuit? What would happen if you remove the parallel capacitor?
4. What is the effect of adding a load resistance (with a capacitor in series to the resistor) to the circuit? What would happen if you remove the series capacitor?
5. What is the advantage of common emitter configuration when compared with common collector and common base configurations? Explain the reasons.
   Hint: Find out about the requirements of a basic amplifier. Then find out which configuration offers the best solution.

eferences:

1. Integrated Electronics-Analog and Digital Circuits and Systems
   By Jacob Millman and C. Halkias
2. Microelectronic Circuits-Sedra/Smith
3. Electronic Devices and Circuits-David. A. Bell
4. Electronic Devices and Circuit Theory- Robert Boylestad and Louis Nashelsky