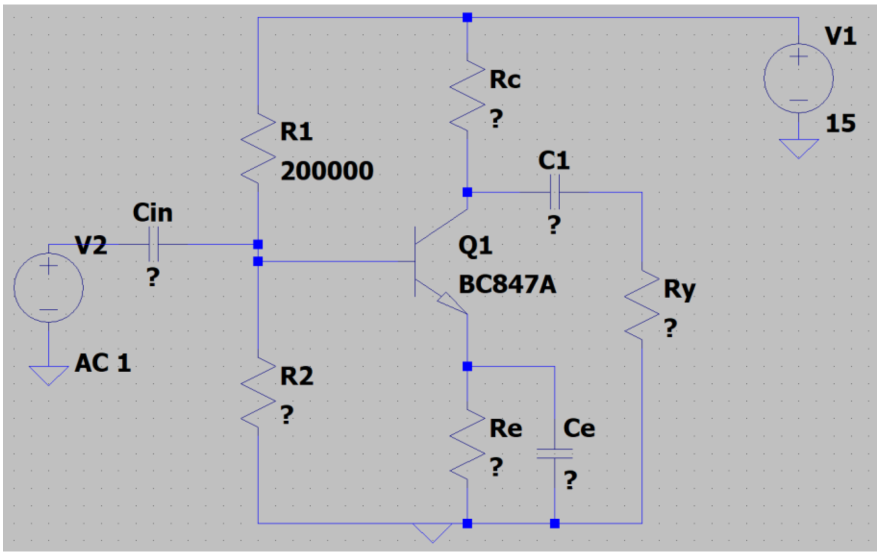
1. Experiment Purpose & Foreknowledge

-Calculations:



Derive the equations necessary for the calculation of quiescent (Q) point voltage and current values of the circuit in above. Calculate the values of resistors so that it satisfies the specifications given below:

Peak to peak unclipped 5V voltage difference should be obtained across the load (R_Y =5.3 kΩ)

Value of collector current of Q point: I_{CQ} =0.9 mA, $R_E + r_e$ = 1kΩ, C_{in} = 80 nF,

Calculate the small signal gain of the amplifier.

Calculate the values of the capacitors in the circuit so that pulse drop will be %5 caused by the effect of each capacitor. Assume you applied a pulse wave to the input whose pulse-width is 10 µs.

Transistor parameters: V_{BE} = 0.66 V, h_{fe}=180, V_{CEsat}=0.09 V.

- Purpose:

- Obtain the DC quiescent point of the circuit using the given resistor values and specifications.
- Sketch the frequency-gain curve of the circuit and determine the cut-off frequencies using the capacitor values calculated.
- Observe the pulse-response of the circuit (pulse droop and rise time) using the calculated capacitor values. (Choose proper values for amplitude and frequency of the input signal)

- Foreknowledge:

The gain is defined as the ratio of quantity measured at the output to quantity measured at the input. There are three types of gain which are: voltage gain, current gain and power gain. The gain, input impedance and output impedance are important to determine the behaviour of a circuit. A two-port amplifier is presented in Figure 1.

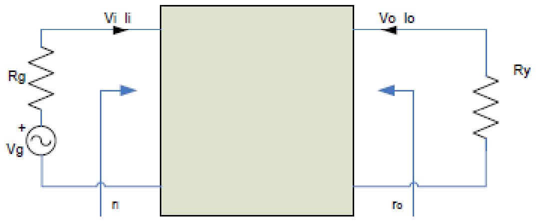


Figure 1 Two-Port Amplifier Block

The highest gain of an amplifier can be obtained in the absence of signal-loss at the input and output of the amplifier. This condition is satisfied for a voltage amplifier in the case of input resistance is infinite and the output resistance is zero.

The curve plotted for the change in gain of the amplifier versus frequency is called gain-frequency curve (Figure 2).

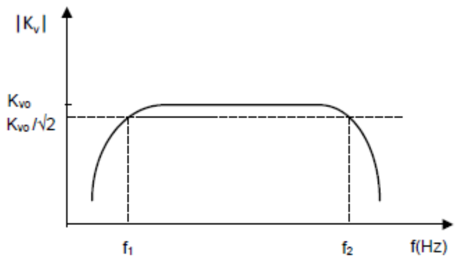


Figure 2 Gain Frequency curve of an amplifier

If high gain is desired, multiple stages of single-transistor circuits are connected in cascade form. In this case, the previous stage's DC conditions shouldn't affect the next stage's operating conditions. In addition, the signal source connected to the input and the load connected to the output shouldn't change the operating conditions of the amplifier. Therefore, coupling capacitors can be used to insulate the circuit from DC components for low-frequency applications.

For the components needed for DC signals but not necessary for AC signals, by-pass capacitors can be used. Both of coupling and by-pass capacitors affect the frequency response of the circuit.

Common-emitter amplifier:

In these circuits, base is the input terminal, collector is the output terminal and emitter is common for input and output. Since the input resistance of the common-emitter amplifier is higher than the common-base amplifier's, it is more suitable to be used for cascade connection.

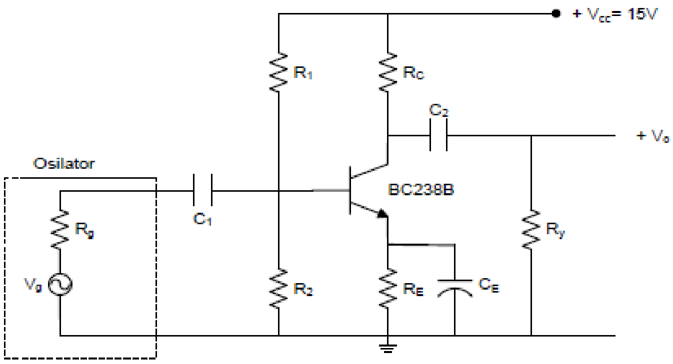


Figure 3 Common Emitter Amplifier

By DC analysis, assuming $I_B << I_C$, the equations below can be written:

$$V_{CC} = V_{CEQ} + I_{CQ}(R_E + R_C) \tag{1.1}$$

$$R_{DC} = R_E + R_C \tag{1.2}$$

$$R_{AC} = \frac{R_C R_Y}{R_C + R_Y} \tag{1.3}$$

If the line corresponds to Equation 1.1 is plotted (DC load line) , I_B will be the intersection point of this line and characteristic curves of the amplifier. DC load line intersects the horizontal axis at the V_{CC}/R_{DC} point and its slope is $-1/R_{DC}$. The other line, which is called AC load line, intersects the characteristic curves at the same point (I_B) and its slope is $-1/R_{AC}$. Since R_{AC} is not equal to R_{DC} , their intersection points with the axes will be different. (Figure-3.5)

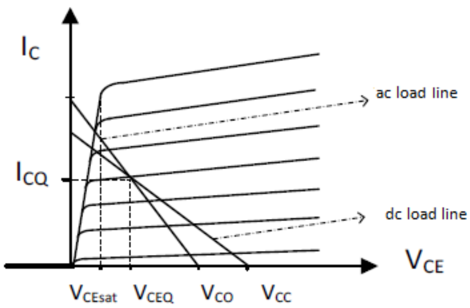


Figure 4 Load Line

Using slope of AC load line, equation for V_{CO} can be derived (Equation-1.4). If Equation-1.1 is substituted in Equation-1.4, we get Equation-1.5.

$$V_{CO} = V_{CEQ} + R_{AC}.I_{CQ} \tag{1.4}$$

$$V_{CO} = V_{CC} - (R_{DC} - R_{AC}).I_{CQ} \tag{1.5}$$

If a time-varying signal is applied as input to the circuit, the value of collector current will change hence the voltage difference between collector-emitter will also change. The amount of variation is limited by V_{CEsat} and V_{CO} as seen in equations below:

$$V_p = V_{CO} - V_{CEQ} = R_{AC}.I_{CQ} \qquad V_n = V_{CEQ} - V_{CEsat} \tag{1.6}$$

As a result of proper choice of the values for quiescent point, the amount of clipping for positive and negative alternance will be equal, so the symmetric clipping condition can be written as below:

$$V_{CEQ} - V_{CEsat} = V_{CO} - V_{CEQ} = R_{AC}.I_{CQ} \tag{1.7}$$

$$I_{CQ} = \frac{V_{CC}-V_{CEsat}}{R_{DC}+R_{AC}} \tag{1.8}$$

Amplifying the input signal without distorting its shape is called as linear amplfication. In other words, the output of a linear amplifier is always proportional to its input. Since this condition cannot always be satisfied, output signal will differ from the input signal although the circuit is linear. The causes of these distortions are the internal parasitic capacitances of the circuit, the coupling capacitors and the by-pass capacitors. High valued capacitors cause distortion for the signals in low frequency range, but low valued capacitors and parasitic capacitances affect the circuit in high frequency range.

Pulse response:

Ideally, if a square wave is applied as input to an amplifier, a square-wave is expected at the output. But, because of the parallel capacities seen in equivalent circuit of the amplifier, the output signal cannot change at the same time with the input signal. Since the coupling and by-pass capacitors are considered as short-circuit for quick-changes of the signal, the equivalent circuit shown in Figure-3.6(a) can be used to analyze the behaviour of the circuit for such signals.

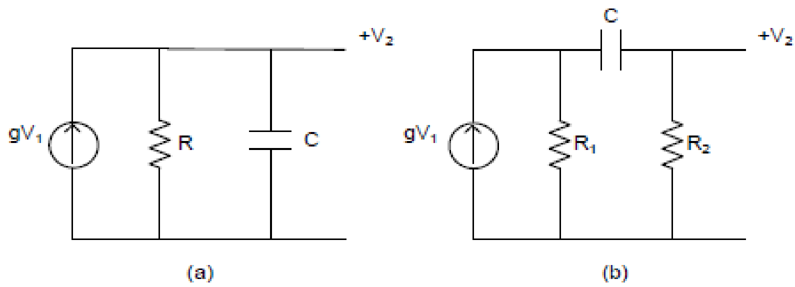


Figure 5 High and Low Frrequency Equivalents

If a pulse wave is applied to the input of the circuit given in Figure-3.6(a), the equation for the output can be written as:

$$V_2(t) = K_o.V.(1 - e^{-t/\tau})$$

Here, τ is time-constant, V is the amplitude of pulse-signal and K_o is voltage gain of the amplifier. The time required for the response to rise from 10% to 90% of maximum value of $V_2(t)$ is called as rise time (t_r). Rise time of the output can be calculated using the equation below.

$$t_{r=}2{,}2.\tau = 2{,}2.R.C$$

For the circuits in cascade form, rise time can be calculated using rise time of each stage as given in the equation below:

$$t_r \cong 1{,}1.\sqrt{t_{r1}^2 + t_{r2}^2 + \cdots + t_{rn}^2}$$

As a result, the output signal of an amplifier whose input signal is a pulse-signal, rises during rise time and reaches to a value higher than its value at rest. If a capacitor is used for coupling in this circuit, the output signal can't keep its new value and decreases until it reaches to the value at rest. This behaviour can be analyzed using the circuit given in Figure-3.6(b).

If a pulse wave is applied to the input of the circuit given in Figure-3.6(b), the equation for the output can be written as:

$$V_2(t) = K_o.V.(e^{-t/\tau})$$

$$V_2(t) = K_o.V.(1 - e^{-t/\tau})$$

Here, τ is time-constant, V is the amplitude of pulse-signal and K_o is voltage gain of the amplifier. The time required for the response to rise from 10% to 90% of maximum value of $V_2(t)$ is called as rise time (t_r). Rise time of the output can be calculated using the equation below.

$$t_{r=}2{,}2.\tau = 2{,}2.R.C$$

For the circuits in cascade form, rise time can be calculated using rise time of each stage as given in the equation below:

$$t_r \cong 1{,}1.\sqrt{t_{r1}^2 + t_{r2}^2 + \cdots + t_{rn}^2}$$

Here, V is the amplitude of pulse-signal , K_o is voltage gain of the amplifier and τ is time-constant:

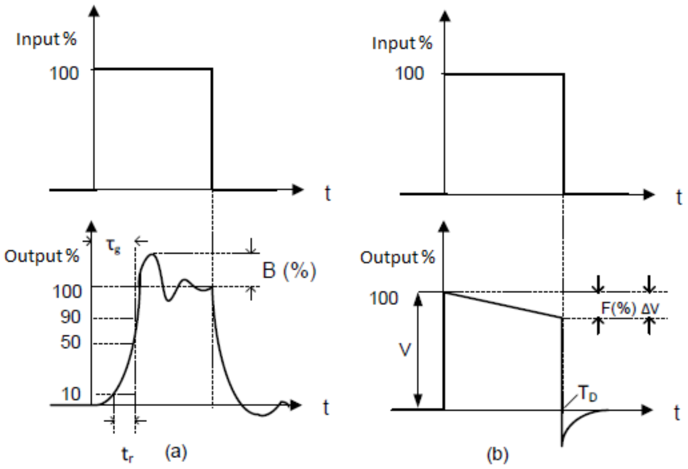
$$\tau = (R_1 + R_2).C$$

The change of the signal corresponds to this equation is shown in Figure-3.7(b). As it can be proven from the equation, at the time t= τ, amplitude of the output signal is 1/e of its value at the begining. This decrement is called as pulse droop and it can be calculated using the equation given below:

$$F = \frac{T_D}{\tau}$$

Not only coupling capacitors, but also by-pass capacitors cause pulse droop and its value can be calculated using equation below:

$$F = \frac{T_D}{C_E r_e}$$



2. Measurements

a) Calculation of the resistor values and simulation of bias point.

b) AC analysis and gain – frequency plot

c) Transient analysis and observation of pulse droop.

3. Experiment Board

4. Experiment Procedure

5. Experiment Report

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