Experiment 3

Bipolar Junction and Field-Effect Transistors (Simulation)

1. OBJECTIVES

- To study the biasing of a BJT using DC-Bias analysis.

- To examine using simulation, the performance of a Common Emitter single stage amplifier.

- To study through the simulation, the operation of the transistors as a switch.

- To analyze various rectifier circuits with capacitor using PSPICE software and analyze ripple factor.

2. THEORY

Transistors are known as a three terminals semiconductor devices. There are two main types: bipolar junction transistors (BJT) and Field-effect transistors (FET). The BJT is made of either germanium or silicon. Each of these materials is "doped" to give the n-type (in which electrons are the majority carriers) and p-type (holes are the majority carriers). The BJT device is made as follows: a thin region of n-type material is sandwiched between two regions of p-type material to make a pnp transistor. The same method is used to make a npn transistor. The boundaries between the n and p regions in a BJT are called junctions and the corresponding user terminal names for the npn regions are the Collector, the Base, and the Emitter. BJTs are current controlled devices. In silicon BJT, the forward bias on the base-emitter junction must exceed 0.7 V to activate the device and to allow the majority carriers (current) to flow across the junction with little resistance. In germanium transistors the forward bias must exceed 0.3 V. Figure 1(a) shows the BJT symbol for npn and pnp-type. The second type of the three terminal semiconductor devices is the field-effect transistors FET. Metal-Oxide semiconductor Field-Effect Transistor (MOSFET) is the most popular kind of the field-effect transistors. It is characterized as a voltage controlled device. The source and drain of a MOSFET are formed by diffusing impurities into a substrate of one type (n-type or p-type) to make regions of opposite type. The gate consists of a layer of aluminum evaporated on to a very thin layer of silicon dioxide, which insulates it from the substrate. The main advantages of the MOSFET over the BJT are: easy to manufacture, small size, high input impedance, and less power consumption. MSOFET is considered the basic building cell in most of the VLSI applications, such as, digital logic, memories, microprocessors, microcontrollers, buffer amplifiers, and analog switches. However the BJT maintains its position in the applications that require high power and high frequencies. Figure 1(b) shows the MOSFET symbol for N-channel, and P-channel MOSFET transistors (depletion type).

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| Figure 1(a) | Figure 1(b) |

The DC bias, and circuits configurations are the two main issues that concern the first time circuit designer. The DC bias establishes the static operating point for the device, while the decision of using a certain configuration depends mainly on the type of application for example, a current source or voltage amplifier with high input impedance. In the following sections you will practice a simple approach to establish the operating point of the BJT by looking at the V-I characteristics or maximum rating of the device used in the design. Also you will explore the different types of transistor circuit configurations and amplifier classes.

a) DC Bias and Operating Point

The DC bias is used to establish a starting point in the V-I characteristic of any active device such as BJTs and MOSFETs. The bias is made possible by using DC power source, and a number of resistive elements. Therefore, the simple electronic circuit will be consisting of the three terminal device surrounded by a resistive circuit and all attached to a single or double DC power supply. The location of the operating point in a BJT () depends on the following values , ,, and can be written as (, ,). The temperature variation will cause a change in the DC current gain, and in the collector reverse saturation current . Consequently this thermal drift will increment the current  and change the location of the operating point. If the thermal drift continues, the device could be driven into the saturation region without applying any input signal. A number of biasing schemes have been used in designing BJT circuits to avoid such instability. The self-bias CE with single power supply is shown in figure 2. The resistor  is used to stabilize the bias by providing a DC negative feedback in the input circuit. Adding a bypass capacitor across  can eliminate the effect of  at signal frequencies. One quick choice of , and  can be achieved using the ratio 1/3 for example if you choose , then , and all related values can be computed. The operating point location can be chosen the same way for example if you want to locate the  point at the middle of the V-I characteristics simply choose, and , obviously these initial choices are subject to change till the desired response of the circuits is obtained. The value of  is used to check if the operating point has gone into the saturation or the cut-off region. If  this, will be an indication that the transistor is operating in the saturation region. If  this, will be an indication that the transistor is operating in the cutoff region. In the MOSFET circuits, biasing technique that stabilize or controls the deviations in the  point is similar to those used in BJT circuits see figure 2.



Figure 2

b) Single -Stage Amplifier configurations

Three different amplifier circuit configurations can be obtained by selecting one of the transistor terminals as a common between input circuit and output circuit. In the BJT circuits, figure 3 shows these configurations, which are known as Common Base (CB), Common Emitter (CE), and Common Collector (CC). These amplifier circuit configurations lead to significant changes in the amplifier characteristics. The most noticeable changes in CC (emitter follower) configurations are: the input resistance becomes very high and the gain is close to the unity. These specific characteristics are translated into a useful application known as buffer amplifier. Therefore amplifier configurations are employed to widen the scope of the amplifier circuit applications.

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| FIG 3 |

 **c) Transistors As A switch**

****The initial location of the operating point  within the V-I characteristics of the transistors is chosen according to the type of applications. Some voltage amplifier require that the  point to be in the middle of the V-I characteristic (active region) so that when a signal applied to the amplifier the  point would swing evenly with the positive and the negative portions. This type of amplifier application is called class AB amplifier. In another type of amplifier the initial location of the  point is in the cutoff region. In this case the amplifier will be off when no signal is applied to its input and on when the signal of the right polarity is applied. This type of amplifier is classified as a class B amplifier and one example is push-pull power amplifier. The push-pull amplifier uses the full span of the V-I characteristics to amplify the positive or the negative half of the input signal. Another application requires the  point to swing between the cutoff and the saturation. This means that the transistor initial  point is in the cutoff region. A positive input signal will drive the transistor to the saturation region. This extreme swing of the operating point  is needed in some applications such as switching circuits. Figure 4 shows the digital logic inverter using the BJT and the MOSFET operating in Cutoff-Saturation mode. The truth table for both circuits is shown below. Figure 4

3. SIMULATION PROCEDURE

3.1 COMMON-EMITTER BJT AMPLIFIER

1. Make the schematics as shown in Fig. 5. Select the npn transistor Q2N2222 from the EVAL library.



V11

Vout

Vin2

Vin1

Fig.5

1. Set the signal source as follows: VOFF=0, VAMPL=0.5, FREQ=5K and AC=1. This is VSIN in the SOURCE library.
2. Do bias-point analysis (Analysis Type: Bias Point) to get the Quiescent point (IC, VCE).
3. Create a new simulation profile “Time Domain”.
4. Set the Simulation Settings as follows: Analysis Type to “Time Domain (Transient), and Run to Time 1.0m. Make “Maximum Step size=1u”. Run the simulation.
5. On the graph window, use the cursor to measure the peak voltage at the points Vout, Vin1 and Vin2.
6. Calculate the input resistance and the gain of the CE Amplifier. For input resistance, you need the voltage V1 and the current going into the capacitor C3. For current use the feature “ADD TRACE” in the output window.
7. The resistors R4 and R5 have been put to bias the BJT.
8. Create a new Simulation Profile “Frequency Domain”.
9. Set the Simulation Settings as follows: Analysis Type to AC Sweep/Noise, Start Frequency =10, End Frequency 1000k and Points/Decade 11.
10. From the PSPICE menu, select **Markers Advanced** ** dB Magnitude of Voltage** and place it at the output VOUT.
11. Run the simulation.
12. User Cursor to determine the upper 3dB point, the lower 3dB point, Gain, and BW.

3.3 TRANSISTORS AS A SWITCH

1. Make the schematic as shown in Fig. 6. Select the npn transistor Q2N2222 from the EVAL library. The source V2 is VPULSE in the Source library.



Fig. 6

1. Conduct a time domain analysis (Run to Time = 200 ms). Verify that the BJE is working as an electronic switch.

**4. Questions**

1. Is the circuit inFig6,acting as a switch? If yes, then how?
2. Why do we care about the bandwidth of an amplifier?
3. What is the use of R7 and the capacitor C2 in the circuit in Fig. 5?