Lab 8. Bipolar Junction Transistor as a Switch

You are required to study the biasing of a bipolar junction transistor (BJT) using DC-bias analysis. Your objective is to examine the circuit using simulation, the operation of the transistor as a switch.

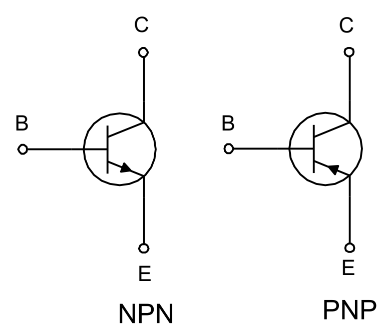
Required Tools and Technology

Software: NI Multisim Live — Access online http://multisim.com
View Help http://multisim.com/help/

1. Background Information

Transistors are known as a three terminals semiconductor device. 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 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



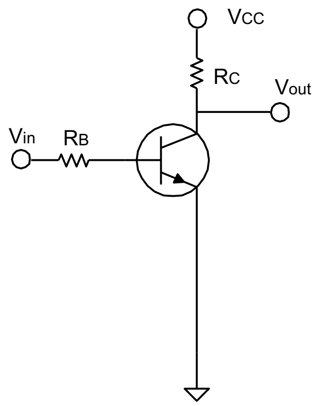
configuration depends mainly on the type of application for example, a current source or voltage amplifier with high input impedance. In the following sections you will practice a simple approach to establish the operating point of the BJT by looking at the V-I characteristics or maximum rating of the device used in the design. Also, you will explore the different types of transistor circuit configurations and amplifier classes.

1.1. DC Bias and Operating Point

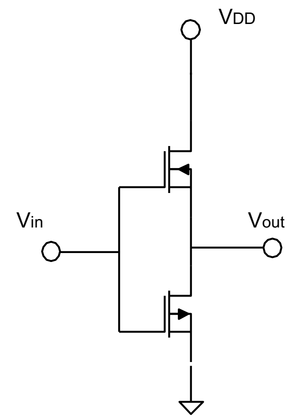
The DC bias is used to establish a starting point in the V-I characteristic of any active device such as BJTs and MOSFETs. The bias is made possible by using DC power source, and a number of resistive elements. Therefore, the simple electronic circuit will be consisting of the three-terminal device surrounded by a resistive circuit and all attached to a single or double DC power supply. The location of the operating point in a BJT (Q) depends on the following values I_C, V_{CE}, I_B, and can be written as $Q = f\ (I_C, V_{CE}, I_B)$. The temperature variation will cause a change in the DC current gain β, and in the collector reverse saturation current I_{CO}. Consequently, this thermal drift will increment the current I_C 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 R_E is used to stabilize the bias by providing a DC negative feedback in the input circuit. Adding a bypass capacitor C_E across R_E can eliminate the effect of R_E at signal frequencies. One quick choice of R_1, and R_2 can be achieved using the ratio 1/3 for example if you choose $R_1 = 12k$, then $R_2 = 4k$, 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 Q point at the middle of the V-I characteristics simply choose $V_{CE} = \frac{V_{CC}}{2}$, and $I_C = \frac{I_{C\,saturation}}{2} = \frac{V_{CC}}{2*(R_C + R_E)}$, obviously these initial choices are subject to change till the desired response of the circuits is obtained. The value of V_{CE} is used to check if the operating point has gone into the saturation or the cut-off region. If $V_{CE} = 0$ this, will be an indication that the transistor is operating in the saturation region. If $V_{CE} = V_{CC}$ this, will be an indication that the transistor is operating in the cutoff region.

1.2. Transistors as A switch

The initial location of the operating point Q within the V-I characteristics of the transistors is chosen according to the type of applications. Some voltage amplifier require that the Q point to be in the middle of the V-I characteristic (active region) so that when a signal applied to the amplifier the Q 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 Q 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 Q point to swing between the cutoff and the saturation. This means that the transistor initial Q 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 Q is needed in some applications such as switching circuits.



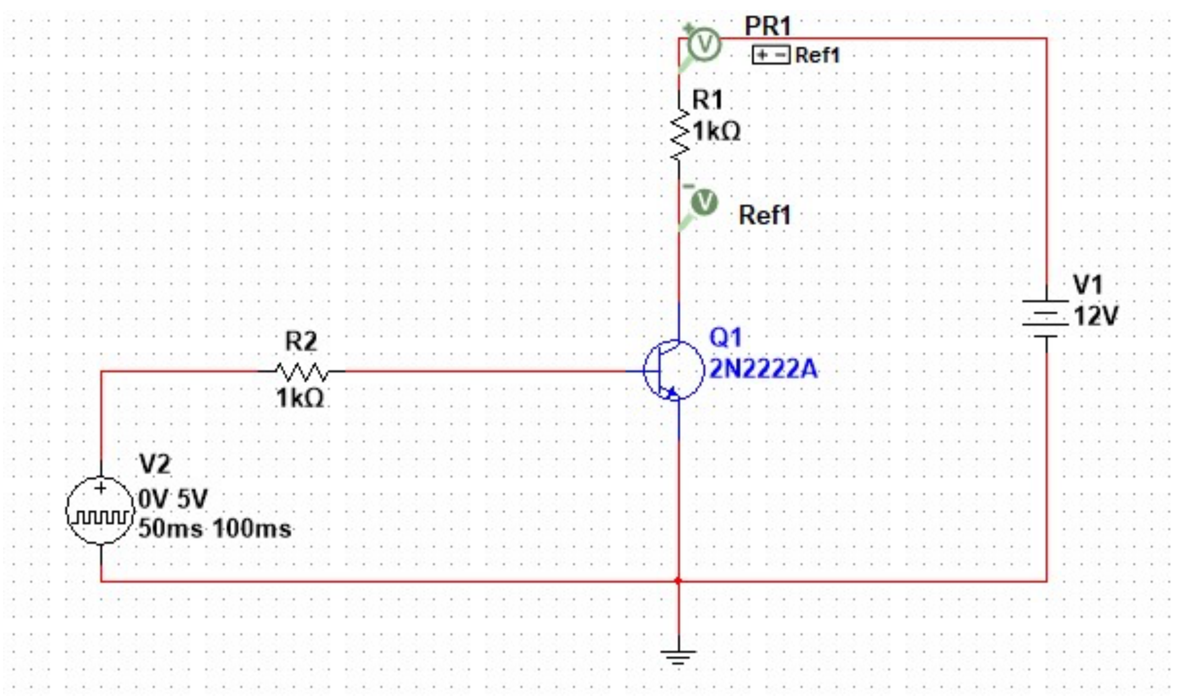
Input	BJT output	MOSFET Output
0 or ground	Vcc	Vdd
High or Vin	0 or ground	0 or ground

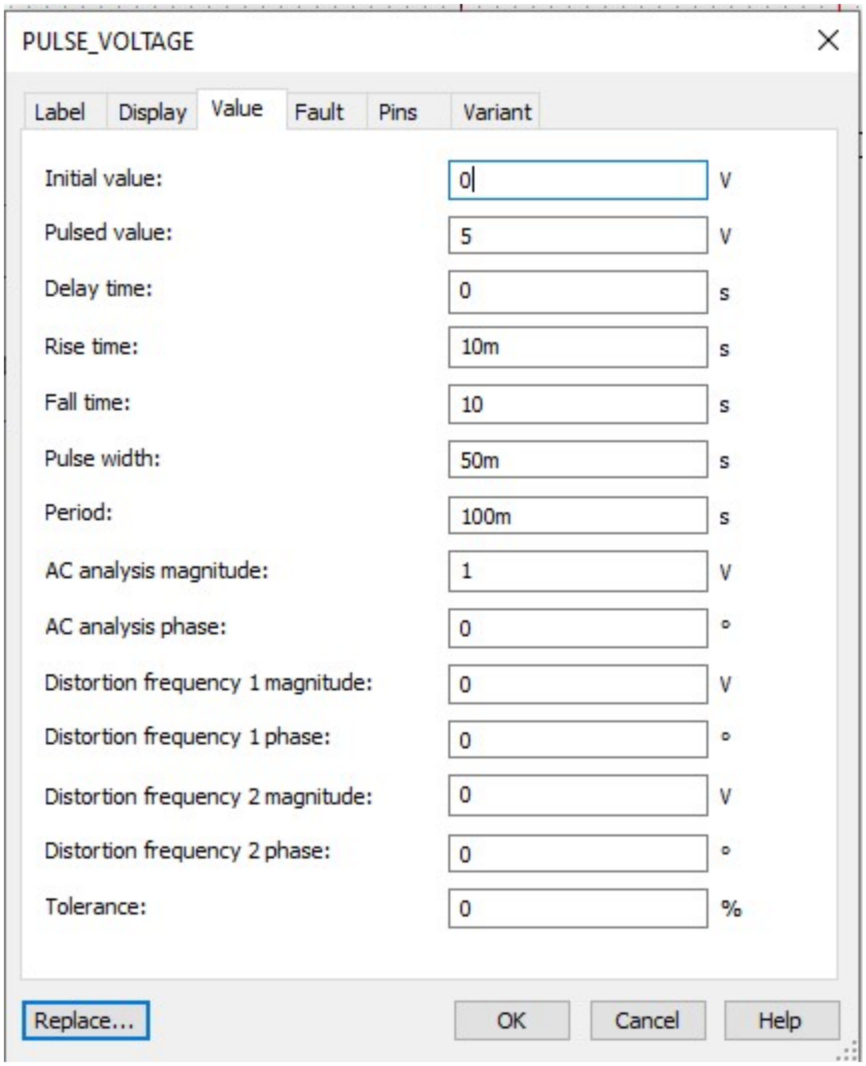


2. Exercise

2.1. Transistor as a Switch Simulation

1. Make the schematic as shown in below. Select the npn transistor Q2N2222 from the EVAL library. The source V2 is PULSE_VOLTAGE in the Source library, configure it to the settings below.
2.





3. Conduct a time domain analysis (Transient) with a stop time of 0.002s. Verify that the BJT is working as an electronic switch.

3. Questions

1. Is the circuit in Fig 6, acting as a switch? If yes, then how?
2. If you consider the signal to base (V2) is input, what is the Vc? Compare the maximum value of V2 and Vc.
3. Why do we care about the bandwidth of an amplifier?