

### Lab 7: Bipolar Junction Transistors

**Object:** To explore the operation of the bipolar junction transistor and measure its current gain parameter,  $\beta$ .

**Apparatus:** TDS2004B Digital Oscilloscope, 10X Attenuating Probes, Simpson 260 VOM Meter, Fluke 73 DMM, Circuit Chassis, 2N2218 Transistor, Various Resistors, and Cables.

**Introduction:** Today we take up the most important electronic invention of the 20<sup>th</sup> century – the transistor – an *active* device which might be viewed as two silicon diodes arranged back-to-back.

#### Exercises:

1. Prepare for this experiment by obtaining a 2N2218 transistor, a medium-power device intended for general purpose switching and amplifier applications. By referring to the *bottom-view pinout* of the 2N2218 shown in Fig. 1, identify the emitter (E), the base (B) and collector (C) leads, and infer the directions of the BC and BE pn-junctions using the Fluke multimeter set in diode mode. From your results, draw into your notebook the correct “two-diode” schematic for the 2N2218. Is it an NPN or PNP type? Which pin is in electrical contact with the transistor case?

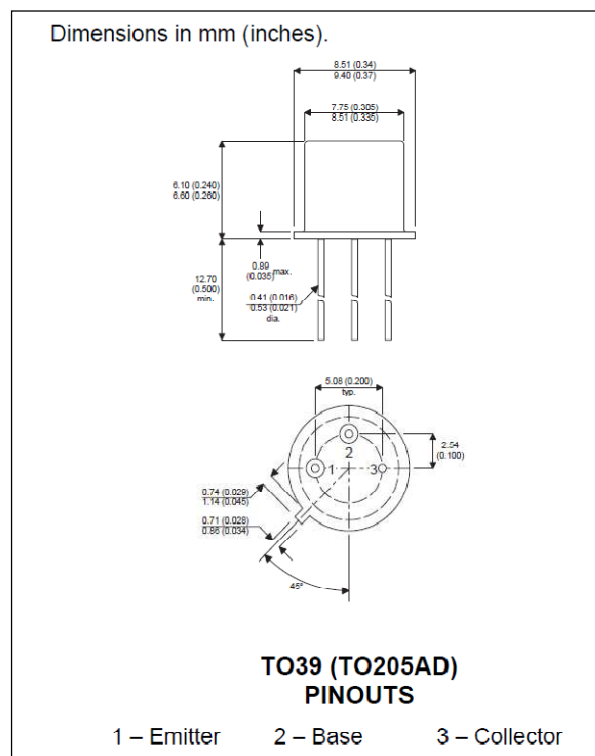


Fig. 1: Pin-out diagram for the 2N2218 bipolar junction transistor.

2. In this experiment you will make use of the DC voltages available from the power supply mounted on your circuit chassis. Plug in the chassis power cord and turn on the power switch. Use the Fluke meter to measure the voltage values and record these values in your notebook. Now turn off and unplug the chassis power supply while you assemble the transistor circuit.
3. The circuit shown in Fig. 2 is designed to permit you to observe current amplification capabilities of a transistor and measure the parameter,  $\beta$ . You will use the analog Simpson 260 VOM meter (“volts-ohms-milliamps”) as a milliammeter in this circuit. Note that current must actually flow through the meter and the red meter lead must be connected to the + input and the black lead must be connected to the – (common) input. You will use the digital oscilloscope with the 10X attenuating probes as a high input impedance DC voltmeter to monitor the base-to-emitter voltage  $V_{BE}$  and the collector-to-emitter voltage  $V_{CE}$ . Use the 10k potentiometer mounted in your chassis as a variable resistor. Recall that the resistance between the center terminal (the sliding contact) and either end terminal can be varied with the knob position. Measure and record the resistance values for each resistor you will use in this circuit. The base resistor  $R_B$  will be changed out in this experiment. It will take on values of 20K, 47K, 120K, 200K, and 470K. Arrange your wiring so that it can be changed easily. Wire up the circuit shown in Fig. 2 using one of the 3-pin transistor sockets on your chassis. Have your instructor check your circuit before proceeding.

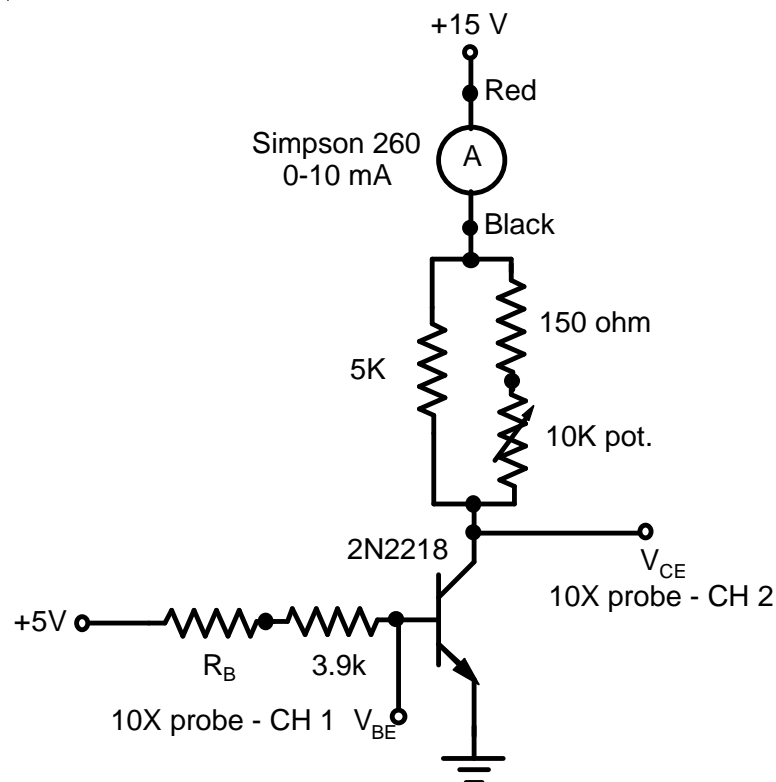


Fig. 2: Circuit for observing current amplification of the bipolar junction transistor.

4. The resistor network on the collector permits you to vary  $V_{CE}$  for a (relatively) fixed base current. Start with a 47K resistance for  $R_B$ . Use 10X attenuating probes to connect the base (CH 1) and the collector (CH 2) to the oscilloscope. Remember to set the probe attenuation on the channel 1 and 2 menus appropriately. Use AUTO trigger mode since you will be monitoring DC voltages. Set the potentiometer knob to a point in the middle of its range. Plug in the chassis and turn on the power supply.
  - Is the base-to-emitter voltage roughly consistent with that of a forward-biased diode?
  - From the measured value of the base-to-emitter voltage determine the base current. Your Fluke meter indicates the collector current. Is the transistor amplifying the input base current? By how much?
  - Vary the potentiometer knob position and note the range of collector-to-emitter voltages. Does the collector current remain relatively constant as you vary the collector-to-emitter voltage? We say that the “looking into the collector” the transistor looks like a current sink. It sinks the same current independent of the voltage.
  - For each of about ten collector-to-emitter voltages, measure the base voltage (from which you can determine the base current) and the collector current. Do you see signs that the transistor is saturating at the lowest collector-to-emitter voltages?
  - Generate a graph of  $I_C$  vs.  $V_{CE}$ .
5. Now make a careful measurement of the transistor current amplification parameter,  $\beta$ . To do so you will swap out the base resistor and measure the resulting base current and collector current. Use the five resistor values indicated in part 3 above. Do the best you can to make all of these measurements at the same collector-to-emitter voltage (by adjusting the potentiometer for each case). Make a graph of  $I_C$  vs.  $I_B$ . Determine  $\beta$  and its uncertainty from a least squares fit. Compare your value with the value obtained by other lab teams. You should find that there is substantial variation in the value of  $\beta$  for the same transistor type. In the amplifier circuit that you will construct in the next experiment, the design is such that the circuit performance does not rely on a precise value of this parameter.