ECE112 - An Introduction to Electrical Engineering

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Using the BJT as a Saturated Switch

Consider the circuit below. The objective of the circuit is to control the motor with a switch. The motor draws 100mA. The switch is not able to switch 100mA but is able to switch at least 10mA.We will use the transistor to act as a power on-off switch for the motor. Its ability to act as a current amplifier will allow it to do this. When the transistor is saturated it will establish a low effective resistance to ground for the lower terminal of the motor

Figure 1: Go figure.

To properly design this circuit, we consult the datasheet for the 2N4401. On page three of the datasheet we find the plot of $V_{ce(sat)}$ versus collector current. This curve shows the relationship between the collector current and the voltage between collector and emitter when the transistor is saturated and the beta is 10. It is important to note that these are *typical* curves and that some parts may exhibit better or worse curves. However, most parts will behave very closely to these curves in most cases.

Figure 2: Go figure.

For our circuit, since are attempting to pass 100mA through the transistor and have the voltage from collector to emitter very small (like a real switch would), we can pick a point on the curve that indicates that at a saturation voltage of 0.1V will be achieved at a I_c of 100mA. With a β of 10, I_b would be (100mA/10) or 10mA.

To determine the value of R1 required to limit the base current to 10mA, we can write the KVL loop through the base emitter junction when the switch is closed.

$$-10 + R1(10mA) + 0.7 = 0$$

$$R1 = 9.3/0.010$$

$$R1 = \underline{930\ ohms}$$

Since we are using typical curves and since 930 ohms is not a standard value of resistor, we would be prudent to use a 860 ohm resistor to ensure sufficient base current is available to keep the transistor in saturation.

With R1 at 860 ohms, when the switch is closed, the transistor will saturate and establish a 0.1 volt potential between collector and emitter. Thus 9.9 volts will be available to the motor instead of the full 10 volts. This is quite good and still represents only a 1% loss in available voltage to the motor. In addition, with the switch only handling a little over 10mA, its life will be greatly extended.