DESIGNING SOLID STATE DC SWITCHES – A QUICK REFERENCE

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A common problem that most of the electronics hobbyist & amateurs face with is interface of DC low system (usually, logic devices like microcontrollers) with an external high voltage system (AC/DC) for switching control purposes. Also, students of field other than electronics find it difficult to understand the concept of solid state switching and end up with a mess in the output interface sections of their projects.

The following article-cum-tutorial describes the concept of designing solid state DC switches using bipolar transistors (PNP & NPN) in a layman's language. The flow of article will start from the relevant basics of a transistor and will pass through the selection guidelines, design concept and end in typical applications. The article can be used as a quick reference while designing such interfaces.

As a project designer, a person is concerned with the design aspect of a solid state switch; given the input & output parameters. A typical application can be of switching control of a DC 12V relay through a 5V microcontroller logic port pin as shown in figure 1. The switch remains on as long as control signal is present (i.e. the relay remains energized as long as control signal is available).

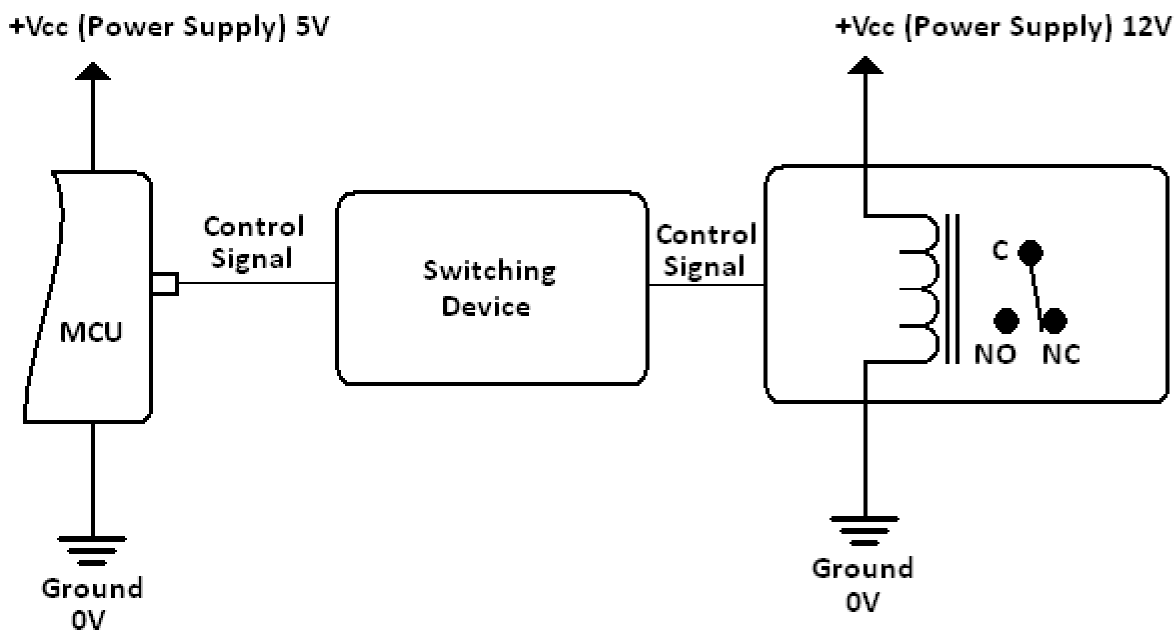

Figure 1.: A typical application of DC solid state switch

The transistor works as a switch in saturation mode. The notation of transistor is shown in figure 2. The terminal with the arrow is always an emitter and the direction of arrow shows the direction of flow of current. Hence, for an NPN transistor, current flow is from collector to emitter whereas it is reverse for a PNP transistor. The base of the transistor is used to trigger the transistor into saturation mode and hence it works as a switching device.

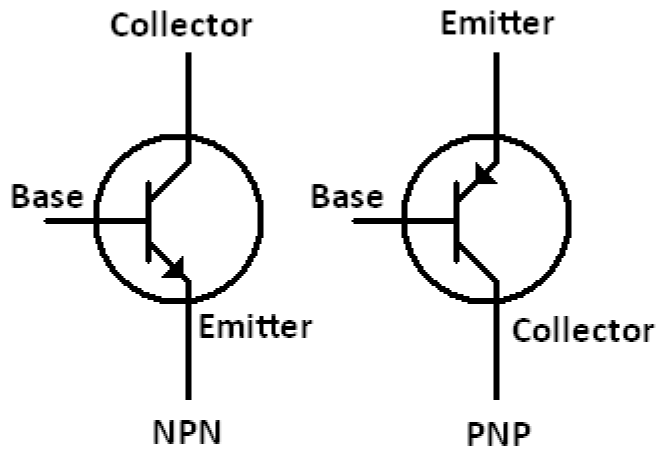

Figure 2.: Transistor Notations

The salient design concepts are:

1. The switching can either be done by a NPN or PNP transistor. For switching ground (0V), a NPN transistor is used whereas for switching Vcc (+5V, +12V, +24V, etc), PNP transistor is used.
2. For switching on a NPN transistor, a positive voltage has to be applied at its base (i.e., NPN transistor is an active HIGH device). Whereas, for switching on a PNP transistor, zero voltage (ground) has to be applied at its base (i.e., PNP transistor is an active LOW device).
3. Hence, while using a NPN transistor, its emitter has to be connected to ground and collector to the load. The other terminal of the load is connected to V_{cc} (power supply). Whereas, while using a PNP transistor, its emitter has to be connected to V_{cc} (power supply) and collector to the load. The other terminal of load will be grounded. Hence, the load current I_L will flow through collector & emitter.

Since the base is used for triggering the transistor into the operation, the base current I_B is of extremely low value. Injection of high current into the base can damage the transistor permanently. To limit I_B, a base current limiting resistor R_B is kept at base.

The schematic is shown in figure 3.

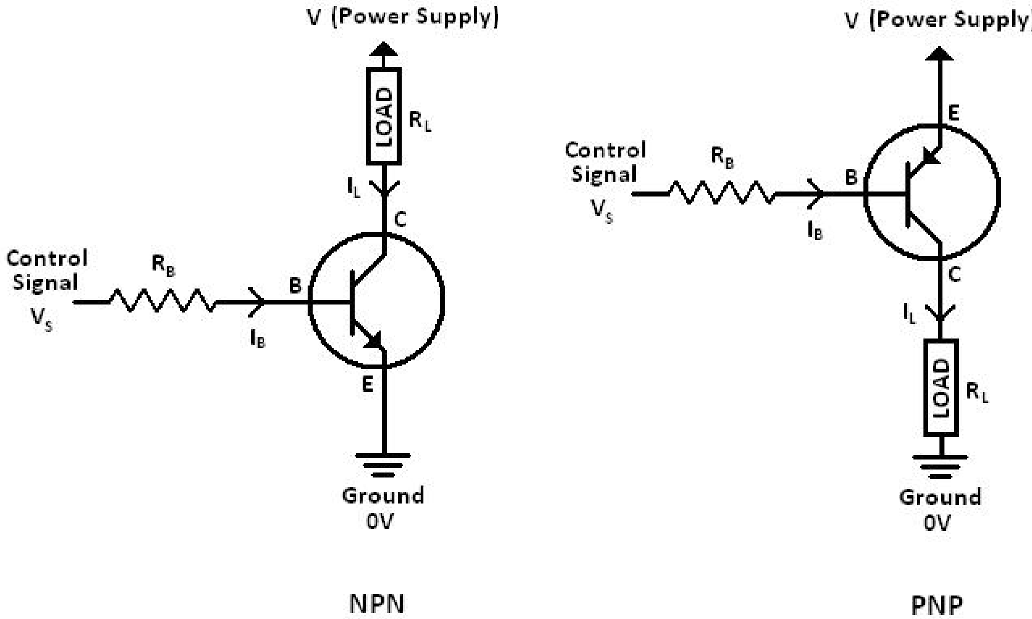

Figure 3.: Schematic

Since PNP transistor is an active LOW device, there are chances of spurious switching instances due to noise signals. Hence, NPN transistor is mostly used for switching purposes.

The value of R_B can be computed by following procedure:

$$R_B = \frac{Switching\ Voltage\ (V_S)}{Base\ Current\ (I_B)}$$

The *switching voltage* is the voltage of control signal. In the typical application considered in figure 1, it comes from a microcontroller and is usually 5V.

The HFE or the amplification factor of a transistor is the ratio of *load current (I_L)* and the *base current (I_B)*.

$$HFE = \frac{I_L}{I_B}$$

The HFE of the transistor is usually mentioned in its datasheet. It can be alternatively found out by a HFE port available on most of the hobbyist multimeters as shown in figure 4. Note that the HFE of transistor may be different even if the transistors are of same part number.

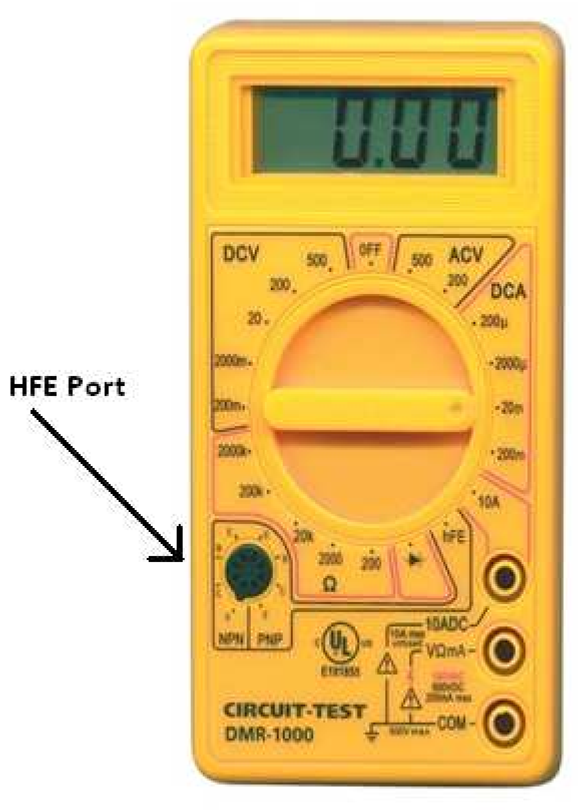

Figure 4.: HFE port on multimeter

The expression of R_B, now becomes,

$$R_B = \frac{V_s * HFE}{I_L}$$

Considering the possibility of 125% overload in the load current,

$$R_B = \frac{V_s * HFE}{1.25\, I_L}$$

The load current can be found out by,

$$I_L = \frac{Supply\ Voltage\ (V)}{Load\ Resistance\ (R_L)}$$

The *supply voltage (V)* is the voltage which is used to power up the load. This is different from the controller's supply voltage of 5V. In the application considered in figure 1, the load is a relay of 12V. Hence *V = 12V* for that case. The load resistance R_L can be found out by measuring the resistance between the two leads of the load (example, relay coil) by ohmmeter / multimeter. The final expression of R_B is,

$$R_B = \frac{V_S * HFE * R_L}{1.25 * V}$$

Taking example of figure 1,

V_S = 5V,
HFE = 200 (found out from multimeter),
R_L = 200Ω,
V = 12V

The R_B comes to a value of 13.3kΩ with the above values. Hence, it can be chosen to a nearest possible standard value of available resistors.

For PNP switching device the expression for R_B remains the same, except that the triggering now takes place with 0V instead of 5V (active low).

Applications: The DC switch explained, can be used in numerous applications like switching high voltage device with a low voltage device, switching a high – current consuming device with a limited current sourcing capacity device like microcontroller, switching relays from computer parallel/serial port, circuits involving source isolation with common ground, et al.

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