The Nuts and Volts of BASIC Stamps

Parallax, Inc.
www.**parallaxinc**.com

Nuts and Volts
www.**nutsvolts**.com

Column #6, August 1995 by Scott Edwards:

Silicon Steroids for the Stamp Help Your Projects Heft Big Loads – Using Switching Transistors

ONE of the outstanding characteristics of the PIC microcontroller used in the BASIC Stamp is its ability to directly drive loads like LEDs through its input/output pins. The Stamp can source (conduct to +5) up to 20 mA and sink (conduct to ground) up to 25 mA. Total current sourced or sunk by all eight pins should not exceed 40 or 50 mA, respectively.

Now I'll grant that 25 mA doesn't sound like a lot of current. But shop around. Other microcontrollers make a big deal out of having a few "high-current" pins capable of sourcing 2 mA and sinking 10.

OK, so the Stamp is a muscle-bound brute by microcontroller standards. It still gets sand kicked in its face by applications that need to drive motors, incandescent bulbs, relays, solenoids, etc. In today's column we're going to pump up the Stamp to new levels of power. Let's start with the basic transistor switch. To keep matters simple, we will limit our discussion to current-sink capability—switching current to ground.

The tools for the job are simple and easy to obtain; a resistor and an NPN transistor. Figure 6.1 shows the capabilities of a common 2N2222, a high-gain transistor, and a low-power Darlington transistor.

**Figure 6.1: Simple one-transistor switch boosts the
Stamp's current-switching capability**
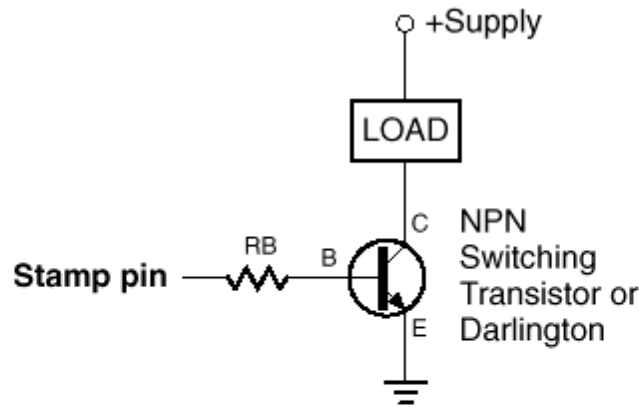
Transistor	RB	Base Current	Load Current	Max +Supply	C–E Voltage Drop	Remarks
2N2222	390Ω	11 mA	100 mA	30 V	0.5 V	Common
ZTX689B	390Ω	11 mA	2 A	12 V	0.5 V	High-gain
ZTX605	3.3k	1 mA	1 A	100 V	1.5 V	Darlington

In Figure 6.1, you can think of the collector (C) and emitter (E) of the transistor as forming a switch to ground. Current at the base turns the switch on. If Stamp pin 0 were connected to this circuit, the instruction High 0 would turn on current to the load; Low 0 would turn it off.

Transistors switches are good, but not perfect. See the column in Figure 6.1 that says C-E Voltage Drop? The voltage across the load will be that much smaller than the supply voltage. For example, if you're driving a flashlight bulb with a 2N2222 transistor and a 6-volt supply, the bulb will actually see only 5.5 volts. The other half volt will be lost, "dropped," across the transistor.

The voltage drop, multiplied by the current drawn by the load, gives you the power in watts wasted by the switching transistor. Where does the wasted power go? It produces heat, sometimes lots of it. For example, the Zetex ZTX689B can conduct as much as 2 amperes of current with a 0.5-volt drop, losing 1 watt to waste heat in the process. When you consider that a small soldering iron has a 15-watt heating element, you can imagine how hot that little transistor can get. Larger switching transistors have metal tabs on their cases for attachment to heat sinks. The large surface area and other properties of the heat sink help spread and dissipate all that waste heat. (A 15-watt soldering iron is very hot; an electric blanket with the same wattage is barely warm.)

All three transistors in the Figure 6.1 are compatible with Stamp output capabilities, but the third--the Darlington transistor—looks especially good from the Stamp's point of view. It requires only 1 mA to drive a 1-ampere load.But whoa, the C-E voltage drop is terrible at 1.5 volts. Can't we get a Darlington with better C-E specs?

In a word, no. Darlingtons consist of two NPN transistor in the same case wired in a way that multiplies their overall gain (ratio of current in to current controlled). In the process, the Darlington adds one base-to-emitter junction worth of voltage drop, approximately 0.7 volts, to the C-E drop.

Despite this drawback, Darlingtons are so handy for interfacing logic to loads that IC manufacturers offer arrays of seven or eight Darlington switches, complete with appropriate base resistors and protective diodes, in neat IC packages. Figure 6.2 shows two such units, the ULN2003 and ULN2803. These interface directly to a Stamp pin to drive loads of up to 500 mA per output.

Figure 6.2: Handy power switches on-a-chip: the ULN 2x03 ICs.
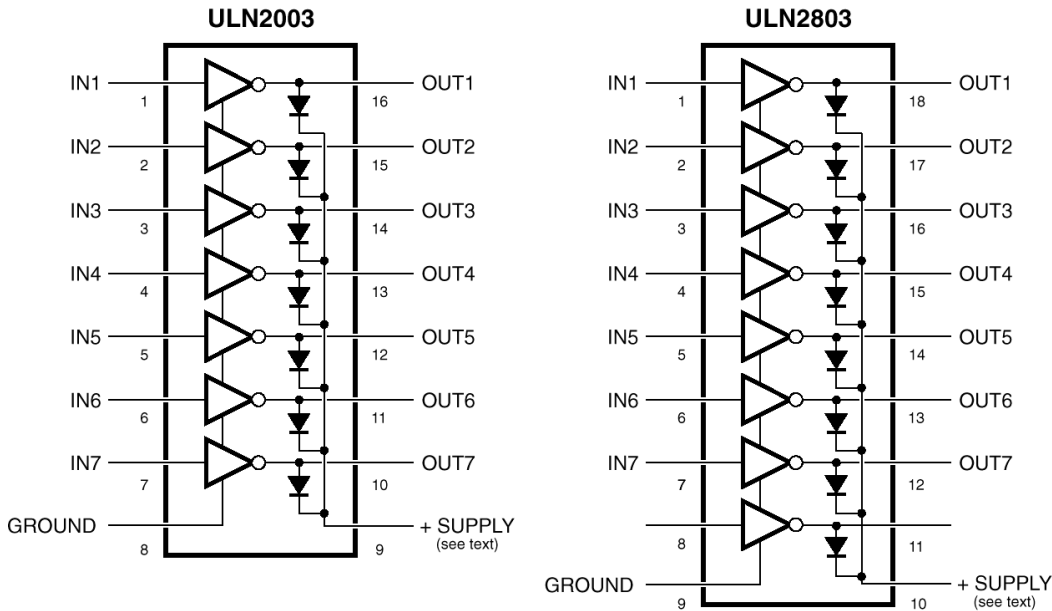
The input pins of the ULN2x03s can connect directly to Stamp I/O pins. They're equivalent to connecting the pin to the left of RB in Figure 6.1. The output pins of the ULN2x03s are equivalent to the collector (C) connection of the transistor switch in Figure 6.1. They provide a switched ground connection for the load.

The ULN2x03s also feature something not shown in Figure 6.1, a series of diodes connected to their outputs. When the devices are used to power inductive loads like relays and motors, these diodes should be connected to the positive supply that powers the load. When one of the ULN2x03 switches cuts power to the inductive load, the load's magnetic field collapses, generating a nasty negative power spike. The diodes short out this spike, preventing it from damaging the transistor switch.

If you construct your own switches with discrete transistors, you'd do well to copy this protective feature. Just add a common rectifier diode like a 1N4002 with its banded end (cathode; the negative connection when the diode is conducting) to the + connection of the relay or motor. The diode won't interfere with the normal operation of the motor or relay, but it'll snub those spikes!

A real-world example

Francis Rogers of Sun City West, Arizona wrote me to describe an application he'd like to build with the Stamp. He has a PC with barcode software that can read membership cards for his S.C.W. Metals Club. The barcode software generates a code through the PC serial port when it's presented with a valid card. Mr. Rogers would like the Stamp to read this code and energize a relay to unlatch a door.

This fits perfectly with the theme of this month's column. Figure 6.3 is the schematic. I've made some assumptions about Mr. Rogers' barcode software: that it can be set to output at 2400 baud, and that all valid cards output some common code for the Stamp to recognize.

Thanks to the serial-input (Serin) command's built-in "qualifier" feature, the entire program takes just a few lines of Stamp code:

```
loop:
  low 7                     ' Pin 7 low to latch door
                            ' (relay open)
  serin 0,N2400,("OK")      ' Watch serial input
                            ' until "OK" rec'd.
  high 7                    ' Pin 7 high to unlatch door
                            ' (relay closed).
  pause 5000                ' Wait 5 seconds.
goto loop                   ' Latch door and resume
                            ' watching serial input.
```

Of course, Mr. Rogers will have to substitute the actual password for "OK" in the program above.

That's it for this month. Next time, we'll look at a nifty IC that lets the Stamp transmit and receive DTMF tones (telephone touch tones). In addition to obvious telephone applications, DTMF can be used as a form of low-speed, high-reliability data transfer. Stay tuned!

Figure 6.3: When the Stamp receives the proper code from the PC bar-code reader, it activates a relay to unlock the door

PC running barcode software,
serial output: 2400 baud, N81

Stamp

1N4002

+12V

pin0   pin7

Relay

com port data out
(DB25 = pin 2
DB9 = pin 3)

22k

390

com port signal ground
(DB25 = pin 7
DB9 = pin 5)

2N2222

Barcode ID reader