The Nuts and Volts of BASIC Stamps
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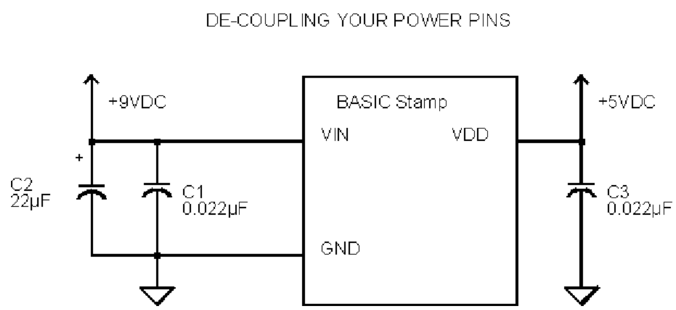
Protecting Your Stamp From The Cold, Cruel World

I've spent the last few months working on a design that is going to be located in a very inhospitable environment. I've had to deal with widely varying temperatures, a noisy power bus, high current loads, and a slew of other factors which don't look upon electronics in a friendly manner.

All of this work started me thinking about some of the things that I take for granted. There are a few tried and true circuits that I regularly use for protecting my microcontroller designs. I thought it might be nice to cover a few of these concepts, as well as some techniques for powering your BASIC Stamp designs. These are circuits and/or techniques that have helped me to ensure successful electronic designs. I'm no analog guru — nor do I pretend to be one — but the concepts that I'm laying out here can help you to avoid many of the pitfalls that the real-world often presents.

It is also helpful to keep in mind that no matter how well thought out your PBASIC program is, a noise spike can still scramble the brains of your BASIC Stamp. This can lead to unpredictable behavior, or a complete system failure of your BASIC Stamp design.

Figure 53.1: Typical De-Coupling Capacitors



De-coupling Capacitors

It is good practice to isolate your local circuit (which can be an IC or group of ICs) from your supply impedance. This is termed "de-coupling," and is routinely accomplished with capacitors.

Each IC in your circuit could benefit from de-coupling capacitors, but it is essential to use de-coupling capacitors on any high-speed logic chips that you may be using (the BASIC Stamp). The fast rising and falling edges of your logic level signals as they switch states require additional current pulses from your power supply. Small ceramic capacitors can supply these currents, when kept in close proximity to your ICs. Placing the de-coupling capacitor within a half inch of your IC will typically do the trick. In most cases, the actual value of the de-coupling capacitor can vary. A good rule of thumb is to use a value between 0.1uF and 0.01uF.

For circuits that are driving large loads, it may be necessary to use low frequency de-coupling capacitors. A 10-47 uF electrolytic or tantalum capacitor can often reduce voltage ripple caused by switching frequencies in the kHz range. All schematics that I have seen of the various BASIC Stamps have shown a 22uF capacitor on the output of the on-board linear regulator, so some protection of this type may already be in place.

I have found that placing a 0.022uF de-coupling capacitor as close to each IC as possible reduces noise on the power bus significantly. I also ensure that at least one 22uF capacitor is included in each design, and that a few 2.2uF ceramic capacitors are located next to any IC that may be driving additional circuitry.

I think the best philosophy regarding de-coupling capacitors is that they are cheap, so use them with great vigor, and sprinkle them throughout your design.

Power Supplies

Electronics these days tend to end up in just about any place you can imagine. Cheap power supplies, car batteries, or noise caused by switching inductive loads (like turning on motors or lamps) can create enormous problems for logic level parts such as the BASIC Stamp.

Filtering your incoming power supply can be done several ways. A resistor in series with the Stamp VIN pin, as well as a low-frequency de-coupling capacitor, can act as a low-pass filter which will smooth out noise spikes. Pre-regulating your supply, such as with a zener diode, can help reduce the damaging characteristics of an inductive spike on your input voltage.

The zener diode will act as a "rough" regulator acting to keep the voltage on your VIN pin at the zener's rated voltage. The zener can clamp positive going voltage spikes, and reduce the effects of negative going voltage spikes. Figure 53.2 shows an input clamping circuit that can be used to protect your BASIC Stamp. Figure 53.3 is a simulation of the zener clamping circuit and how it handles both positive and negative voltage spikes of 9us duration.

Power dissipation in your clamping circuit can be a problem if you select a zener diode that is rated at a voltage below your input voltage (as I did in my simulation). Your series resistor is then dissipating power based on the difference between your input voltage and the voltage that your zener diode is regulating at.

What usually works best is to select a low value series resistance (or none if your circuit is drawing a significant amount of current) and a zener diode whose voltage rating is slightly higher than the power supply you are using. For instance, if you were powering the BASIC Stamp with a 12VDC supply, you might select a 10-ohm series resistor, and a 13V zener diode. The goal here is to protect the BASIC Stamp from voltage spikes that might damage its on-board regulator.

Figure 53.2: Zener clamp on your power input supply

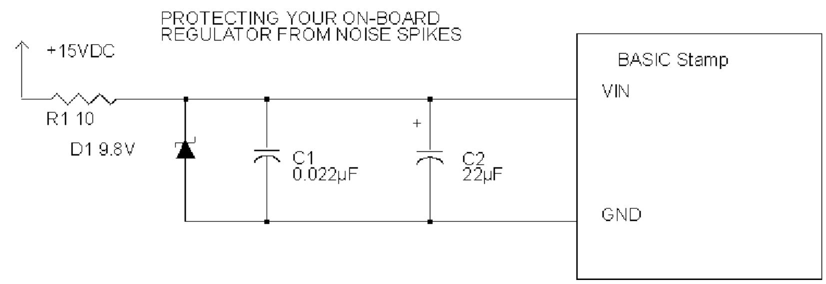


Figure 53.3: Simulation of input clamp

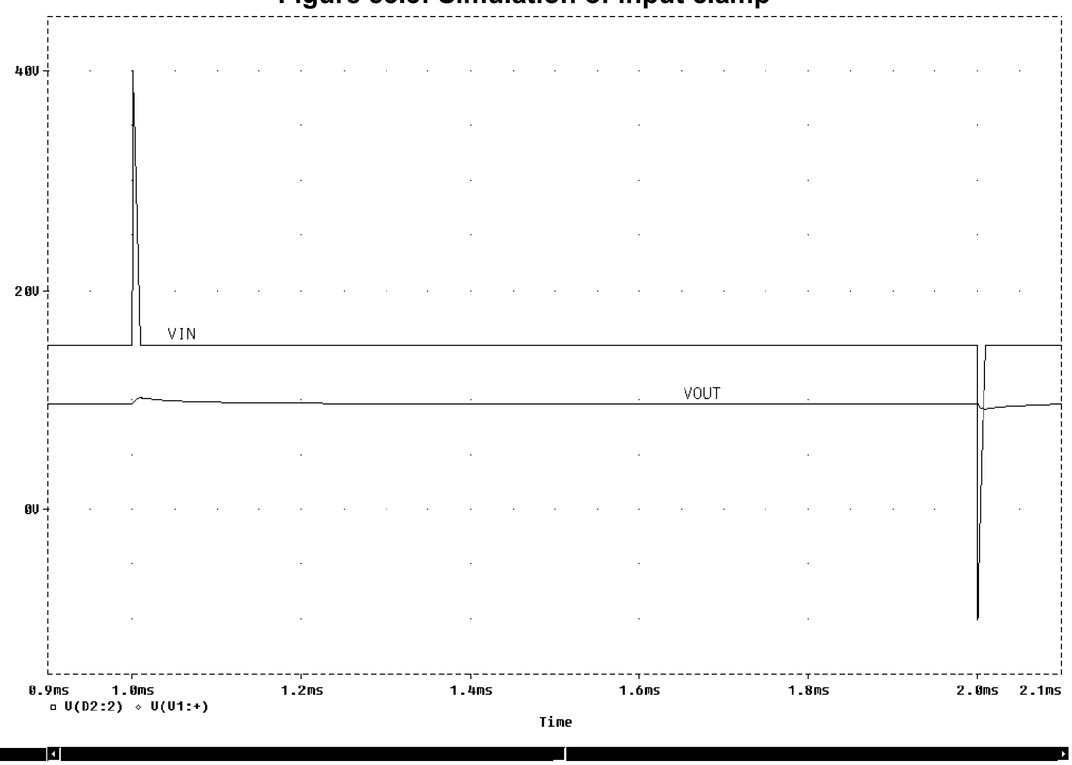
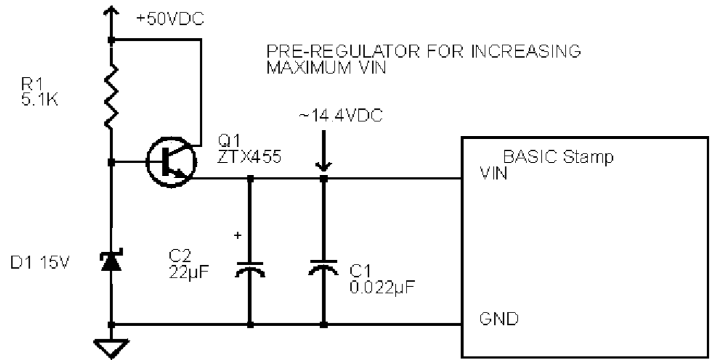


Figure 53.4: Rough Zener-NPN Pre-Regulator



Power dissipation can often be a problem with the BASIC Stamp on-board linear regulator. The power dissipated by a linear regulator can be characterized by (Vin-Vout)*Isupply. The higher the input voltage, the less current required to overheat a linear regulator. With a 30VDC input voltage, a five-volt regulator will have to dissipate one watt of power, as heat, when supplying just 40mA. Placing another, higher value linear regulator between the input voltage and the Stamp's VIN pin can allow both regulators to share the power dissipation requirements.

As your input voltage gets higher, this becomes more difficult since many linear regulators are rated for 30-35VDC maximum input voltage. A transistor and zener diode pre-regulator can sometimes allow you to get the job done. Many transistors can handle large voltage drops from their collector to emitter (denoted in the data sheet as Vce), but heatsinking will still be required, and may be extensive. Figure 53.4 shows an example of a zener diode-NPN voltage regulator.

Protecting Your Input Pins

The BASIC Stamp is based on a Microchip PIC microcontroller. These microcontrollers have internal protective diodes that shunt signals higher than about 5.6V to the +5VDC bus, and signals lower than -0.6V to the ground bus. There can be some interesting unintended consequences regarding these protective diodes.

One of the more interesting is that the BASIC Stamp can be powered off of one of its I/O pins. For example, if the BASIC Stamp was not powered, but a +5.7VDC signal was present on one of its I/O pins, the protective diode would be forward biased (turned on), and about 5VDC would then be present at the Stamp's +5VDC bus, and could power the BASIC Stamp.

Furthermore, positive voltage spikes present on your I/O pins can be translated directly to your BASIC Stamp +5VDC output (or negative going spikes to your ground bus). This can create problems which are hard to diagnose. Imagine turning on a relay with your BASIC Stamp, and watching your temperature sensor go up in smoke. There is no apparent connection between the two devices, yet they are only separated by diodes internal to the microcontroller which the BASIC Stamp is based on.

Protecting your input pins can be done in a manner similar to the zener diode clamp used on the power supply. Yet, in this case, the series resistor can be much larger and can be a more active instrument in attenuating voltage spikes. The input impedance for a BASIC Stamp pin set as an input is about 1 megohms (very rough estimate). The input impedance can be estimated from the leakage current that is typical of an input pin (about 1uA maximum).

Any series resistors should be selected so as not to form a voltage divider with the input impedance of a BASIC Stamp pin configured as an input. This is especially important if your input signals are already attenuated by external devices such as op-amps which do not have rail-to-rail outputs (like the LM741).

A series resistor of about 1k ohms, in conjunction with a zener diode rated for 5.1-5.6V, and a capacitor can effectively protect input pins from voltage spikes, and reduce noise that might affect your BASIC Stamp's program flow. The series resistor forms a low-pass filter with the capacitor in this circuit. If you are measuring pulses or frequencies with a particular Stamp pin, be sure to select component values so that your signals are not attenuated out of existence by the protective circuit. You can calculate the frequency threshold of a low-pass filter with the equation …

$$f = 1/(6.28*R*C)$$

When measuring short pulses, keep in mind that the rise time of your pulse will be limited by the low-pass RC filter described above. The time it takes for a signal to rise from 10% of its maximum voltage to 90% of its maximum voltage through an RC filter can be approximated by 2.2*R*C. This is also considered the rise-time of the signal in question. For the circuit in Figure 53.5, this rise-time is roughly 48us. This is the time it takes for a five-volt pulse to rise from 0.5V (10% of 5V) to 4.5V (90% of 5V).

Figure 53.5: Protective circuit for input pins

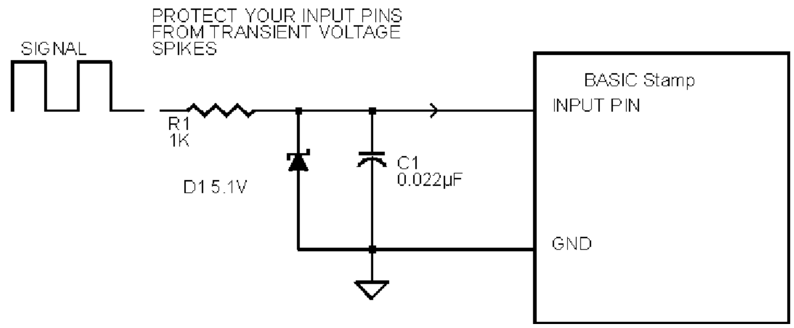


Figure 53.6: Rough Zener-NPN Pre-Regulator

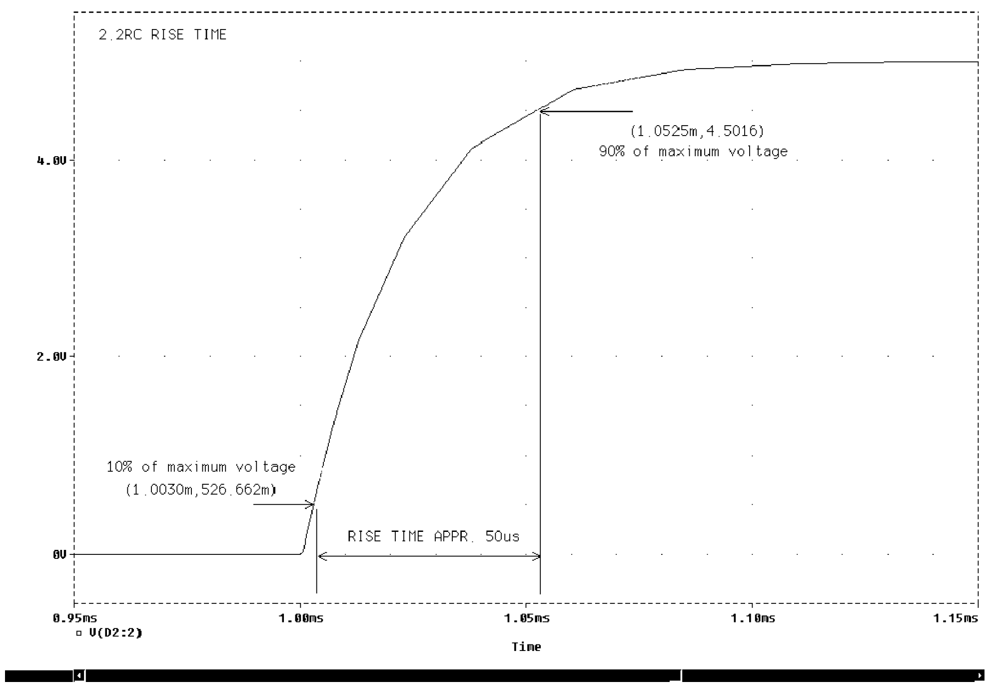
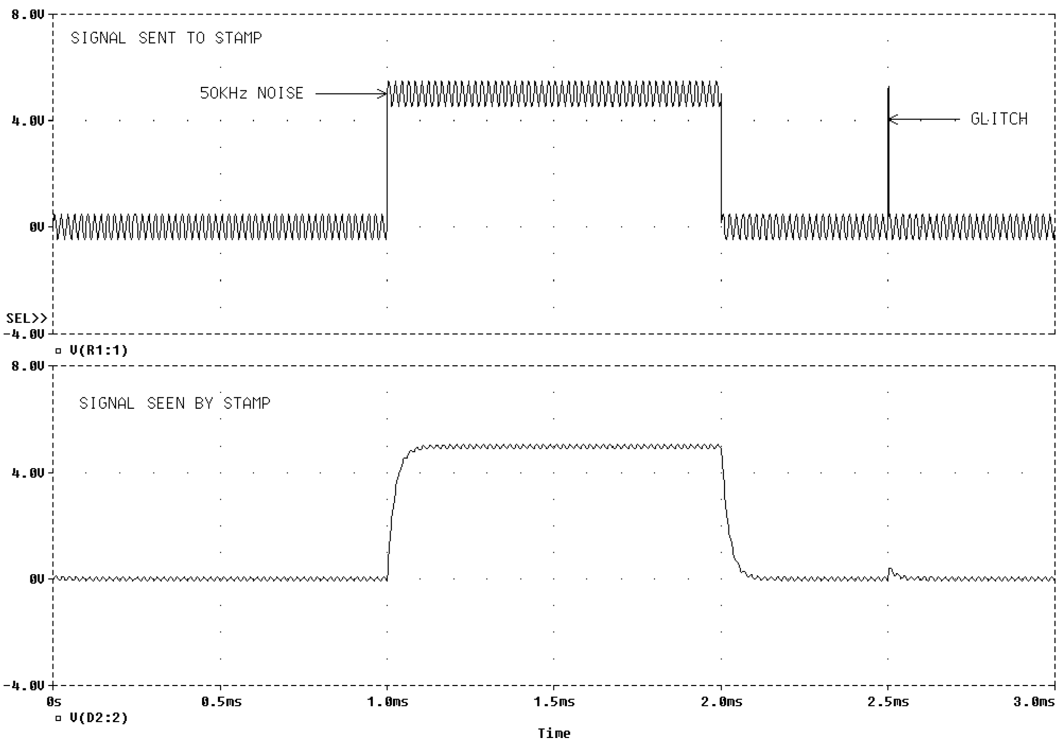


Figure 53.7: Effects of Protective Measures on Input Pins

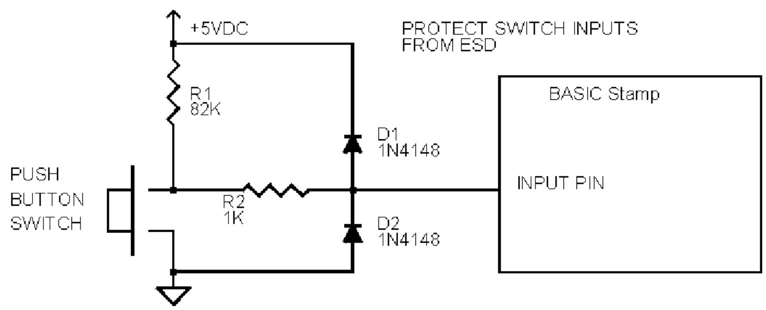


This means that if you are intent on measuring short pulses, you should consider the effects of filtering on the BASIC Stamp's ability to make the measurement in question. Figure 53.6 provides a graphical representation of the rise time for the filter circuit in Figure 53.5.

Figure 53.7 shows the input signal versus the signal as seen by the BASIC Stamp after the signal passes through the protective circuitry in Figure 53.5. The incoming signal has a 50kHz 0.5V peak-to-peak noise signal, a logic level pulse, and a 1us glitch. As you can see, the protective circuit filters out most of the noise and prevents the glitch from reaching the BASIC Stamp. The glitch is too short and, due to the rise time of the RC filter, it never reaches a logic high level which could be measured by the BASIC Stamp.

One killer of electronic components is electrostatic discharge (ESD). If you don't believe me, try walking across your carpet with just socks on — be sure to shuffle your feet — and then touch your finger to your favorite BASIC Stamp project. Of course, if you do this, you'll be shelling out some bucks for a new BASIC Stamp, and probably a handful of other replacement components. On second thought, just take my word for it.

Figure 53.8: ESD protection on switches



But you can see from being shocked by your friends, neighbors, and loved ones that we humans have quite a capacity (or is it potential?) for carrying potential (or is it capacity?). Anyway, we can all carry a healthy enough charge to zap a BASIC Stamp into next week. This can be particularly common in designs with keypads.

Figure 53.8 shows a commonly used method of protecting I/O pins on microcontrollers from ESD when interfacing to switches or buttons. The pull-up resistor (82k ohm) is required to ensure that pressing the switch does not short your power supply to ground. The switching diodes allow transient voltages to open a path to either ground or the +5VDC bus, depending on the polarity of the voltage spike. The 1k ohm series resistor acts to limit the current during transient voltage spikes and protects the diodes which limit the voltage on the microcontroller input pins.

The diodes which are internal to the Stamp I/O pins (that I had mentioned earlier in the article) can be used in place of the external switching diodes, but should probably not be considered as robust a form of protection.

Conclusion

I think two general rules apply to protecting your BASIC Stamp designs: Rule 1: If any connection interfaces to the outside world, PROTECT IT. Rule 2: If you can think of something bad that somebody could do to your design, assume it WILL HAPPEN.

When you are planning a BASIC Stamp design, always take time to look at where each connection is going. And try to figure out what odd things may happen to it. If you have a keypad or LCD display, can somebody spill liquid on it? If you have a relay that you are controlling, what happens if it can't close or open? If you are using switching transistors, can they overheat? If a part blows up, will it blow up open or shorted?

Spending ample time figuring out both how to protect your electronics, as well as what to protect them from, can be surprisingly beneficial. There are certainly cases where protection is not much of a concern. Most chip-to-chip connections are short and don't require much in the way of filtering or protective circuitry.

There are also situations that cry out for protective measures. For example, you may have a small robot using an IR detector for wall sensing. It’s a good idea to mount IR detectors of this nature at a point where they are unobstructed by objects on the robot itself. This may be at a distance from your BASIC Stamp. Any wires or ribbon cables connecting these two devices will act as antennae and can conduct noise generated by your motors, battery chargers, or any other "noise generators." These kinds of connections are good candidates for protective circuitry.

After a while, protecting your circuits becomes second nature, and you start making trade-offs such as cost versus the level of protection you may receive from a specific circuit addition. I always try to add all of the protective circuitry that I can think of and, after the design is up and running, I whittle away the things that may be overkill.
In the end, good engineering is about one-third experience, one-third forethought, and one-third time in (or sometimes out) of lab testing. I think there is another ± one-third or so wrapped up in test equipment, time of day, amount of beer you had the night before, and a few other important factors. Of course, the most indisputable measure of good engineering is design survivability. So protect your Stamps, and give them good safe homes!