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Application Note AN015

Creating Schmitt-Triggered Inputs on the Propeller P8X32A Microcontroller

Abstract: Schmitt-triggering diminishes or eliminates logic-level uncertainty from signals having slow rise/fall times and those burdened with superimposed noise. It achieves this using positive feedback to create a hysteresis band about the threshold of a logic input, which must be crossed in its entirety to effect a state change. With the addition of external resistors, along with programmed positive feedback, the P8X32A can enjoy the benefits of Schmitt-triggering on any of its inputs.

Introduction

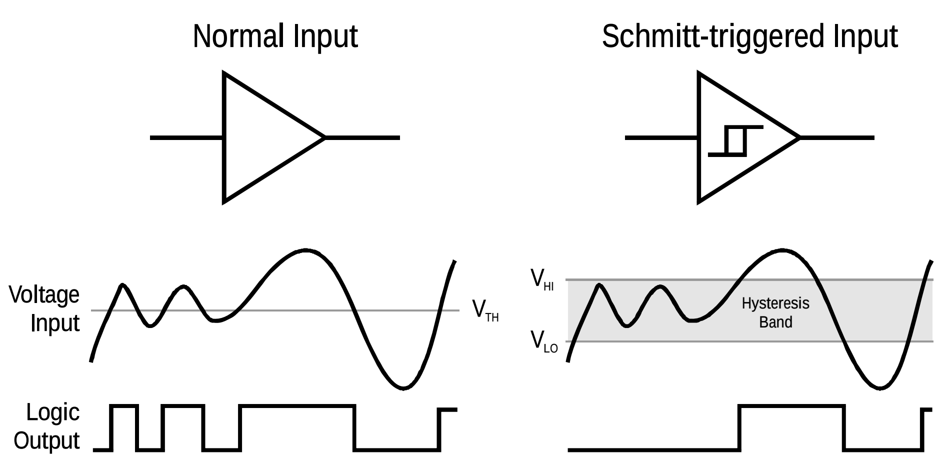
The Propeller P8X32A's digital input logic thresholds are fixed at approximately Vdd/2, without any hysteresis and without a way to configure them for Schmitt triggering. With the addition of a couple external resistors per input and by committing one separate pin for feedback, any number of Propeller inputs can gain Schmitt-triggering capability.

Schmitt Trigger Principle

The inputs of a Schmitt-triggered logic device exhibit hysteresis. This is to say that if a rising voltage on an input first registers as a logic "1" at some threshold V_{HI}, and if a falling voltage on the input first registers as a logic "0" at some threshold V_{LO}, the input displays hysteresis if $V_{HI} > V_{LO}$. The area between the two thresholds is known as the "hysteresis band."

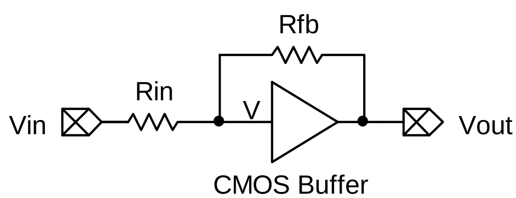
Hysteresis is a valuable digital input characteristic when presented with signals having slow rise or fall times or with signals carrying superimposed noise voltages. Without hysteresis, small variations in the input voltage near a gate's logic threshold, V_{TH}, can cause multiple logic transitions on its output. Adding hysteresis can reduce or eliminate this problem, as Figure 1 illustrates.

Figure 1: Hysteresis Band with Schmitt-triggered Input



The equivalent circuit for a Schmitt trigger consists of a normal logic buffer with a resistor in its input path and another resistor feeding back from its output, as shown in Figure 2.

Figure 2: Equivalent circuit for a Schmitt Trigger



In this schematic, the voltage V at the buffer's input satisfies the following equation:

$$\frac{V_{out} - V}{R_{fb}} = \frac{V - V_{in}}{R_{in}}$$ **Equation 1**

To compute the V_{HI} and V_{LO} thresholds, solve Equation 1 for Vin, substitute the buffer's threshold voltage, V_{TH}, for V, then compute for Vout = 0 and Vout = Vdd, respectively:

$$V_{in} = \frac{(R_{in} + R_{fb})V_{TH} - R_{in}V_{out}}{R_{fb}}$$ **Equation 2**

$$V_{HI} = \frac{(R_{in} + R_{fb})V_{TH}}{R_{fb}}$$ **Equation** 3**: output low**

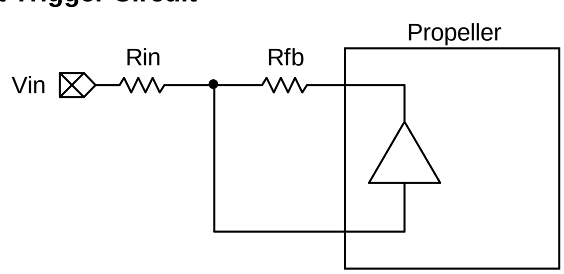
$$V_{LO} = \frac{(R_{in} + R_{fb})V_{TH} - R_{in}V_{dd}}{R_{fb}}$$ **Equation** 4**: output high**

For example, for Vdd = 3.3 V, V_{TH} = 1.5 V, R_{in} = 510 Ω, and R_{fb} = 5.1 kΩ, the hysteresis band would extend from V_{LO} = 1.32 V to V_{HI} = 1.65 V. Also note from the above equations that the width of the hysteresis band, V_{HI} - V_{LO} = R_{in}Vdd / R_{fb}, depends only upon the ratio of the two resistor values and the value of Vdd.

Propeller Hardware Implementation

Figure 3 shows the Propeller equivalent of Figure 2.

Figure 3: Propeller Schmitt Trigger Circuit



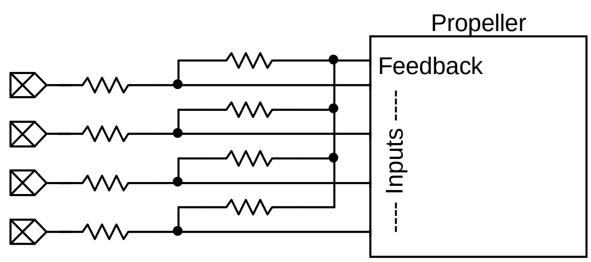
In this schematic, two Propeller pins provide the Schmitt-triggering function: one for the input; the other for the feedback output. The internal "buffer" does not exist as an actual circuit but, rather, as a software function. Moreover, this buffering does not even need to be continuous but can take place only when it's necessary to read the input pin. It works like this:

1. Apply the input previously read from the input pin to the feedback pin.
2. Read the input pin.
3. Save the reading from step 2 for the next iteration of step 1.

The input (high or low) read in step 2 will effectively be Schmitt-triggered.

Because the feedback does not have to be continuous, a single feedback pin can operate in conjunction with any number of input pins, as long as those pins do not need to be read simultaneously, as Figure 4 illustrates.

Figure 4: Multiple Inputs with a Single Feedback Pin



Applying the previous reading for each input pin, in succession, to the feedback pin and then reading that input pin results in a reading of the pins' Schmitt-triggered states.

Propeller Software Implementation

The Spin implementation of Schmitt triggering is quite simple, consisting of two lines:

```
outa[FB_PIN] := pin_state
pin_state := ina[INP_PIN]
```

In this code snippet, **pin_state** is a variable that keeps track of the latest state (0 or 1) read from the pin denoted by INP_PIN. The pin number of the feedback pin is FB_PIN.

In Propeller Assembly language (PASM), it is import not to read the input state too soon after setting the feedback pin. This is due to the low-pass filter created by the feedback resistor and the Propeller pin's input capacitance. The next example illustrates Schmitt triggering in PASM.

```
'Initial setup:

              or        dira,fb_mask            'Make the feedback pin an output.

'Pin reading:

              test      pin_state,#1 wc         'Set carry from pin_state bit 0.
              muxc      outa,fb_mask            'Copy carry to feedback pin.
              nop                               'Wait for things to settle...
```

```
              nop
              nop
              mov       pin_state,ina          'Read the pins.
              shr       pin_state,#INP_PIN     'Shift input pin's state to bit 0.

'Variables:

fb_mask       long      1 << FB_PIN            'Bit mask for feedback pin.
pin_state     long      0                      'Current value of pin.
```

In the example above, **pin_state**, INP_PIN, and FB_PIN have the same meanings as before.

Resources

Download the example Spin code zip archive: www.parallaxsemiconductor.com/an015.

Revision History

Version 1.0: original document.