Application Brief
Understanding Schmitt Triggers

TEXAS INSTRUMENTS

Most CMOS, BiCMOS and TTL devices require fast edges on the high and low transitions of their inputs. If the edges are too slow, they can cause excessive current, oscillation, or may damage the device.

Slow or Noisy Edges

Slow edges are sometimes hard to avoid at power-up or when using push-button or manual switches with the large capacitors needed for filtering. Heavily loaded outputs can also cause input rise and fall time to be out of specification for the next part down the line. On a normal (non-Schmitt trigger) input, the part switches at the same point on the rising edge and falling edge. With a slow rising edge the part at the threshold. When the switch occurs, it requires current from V_{CC}.

When current is forced from VCC, the VCC level can drop and cause the threshold to shift. When the threshold shifts it crosses the input again causing the part to switch again. This pattern can continue causing oscillation, which can cause excessive current. This pattern can also happen if noise is on the input. The noise can cross the threshold multiple times and cause oscillation or multiple clocking.

Hysteresis

The design to these problems is to use a Schmitt trigger device to translate the slow or noisy edges into something faster that meets the input rise and fall specifications of the following device. A true Schmitt trigger does not have rise and fall time limitations.

Parts with Schmitt trigger action have a small amount of hysteresis that helps with noise rejection but still have an input rise and fall time-limit. These parts usually do not have VT specifications in the data sheet and have rise and fall time limitations specified for the inputs in the recommended operating conditions.

The true Schmitt trigger input has the switching threshold adjusted where the part switches at a higher point (Vt+) on the rising edge and at a lower point (Vt–) on the falling edge. The difference in these switching points is called Hysteresis (^Vt). Here is an example of Schmitt trigger specifications:

Table 1. Example of Schmitt Trigger Specifications

PARAMETER	V_{CC}	MIN	MAX	UNIT
V_{T+} (Positive-going input threshold voltage)	1.65V	0.76	1.13	V
	2.3V	1.08	1.56	
	3V	1.48	1.92	
	4.5V	2.19	2.74	
	5.5V	2.65	3.33	
V_{T-} (Negative-going input threshold voltage)	1.65V	0.35	0.59	V
	2.3V	0.56	0.88	
	3V	0.89	1.2	
	4.5V	1.51	1.97	
	4.5V	1.88	2.4	
ΔV_T Hysteresis ($V_{T+} - V_{T-}$)	1.65V	0.36	0.64	V
	2.3V	0.45	0.78	
	3V	0.51	0.83	
	4.5V	0.58	0.93	
	5.5V	0.69	1.04	

It is important to remember (Vt+ max) = Vih and (VT– min) = Vil. In the specs, multiple limits are related to the Schmitt trigger inputs. All of the limits are important for different reasons. On the input rising edge, the part switches between (Vt+ min) and (Vt+ max). On the falling edge, the part switches between (Vt– max) and (Vt– min). The part does not switch between (Vt– max) and (Vt+ min). This is important for noise rejection.

The hysteresis is the delta between where the part switches on the rising edge and where it switches on the falling edge. The hysteresis is at least the minimum and no more than the maximum (^Vt) specification.
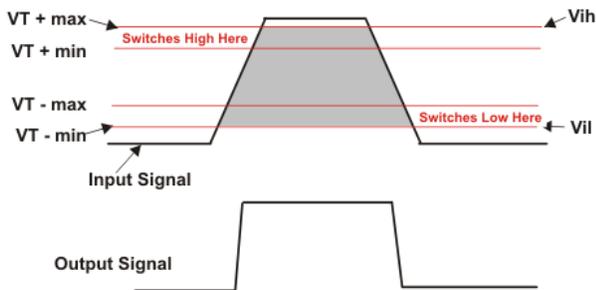
Figure 1. Hysteresis Switch Time

In Figure 1, the input levels Vih and Vil must be greater than (VT+ max) and less than (VT– min) to ensure the part switches. The switching points on the above plot are separated to give a clearer visual picture. In reality, the (VT+ min) and (VT– max) may overlap.

Input Voltage

One common misconception is that the current consumption is less when switching a slow signal into a Schmitt trigger. This misconception is partly true because the Schmitt trigger prevents oscillation which can draw a lot of current; however, the I_{CC} current may still be higher due to the amount of time the input is not at the rail. This is Delta I_{CC}. Delta I_{CC} is where the inputs are not at the rails and upper or lower drive transistors are partially on. The plot below shows I_{CC} across the input voltage sweep.
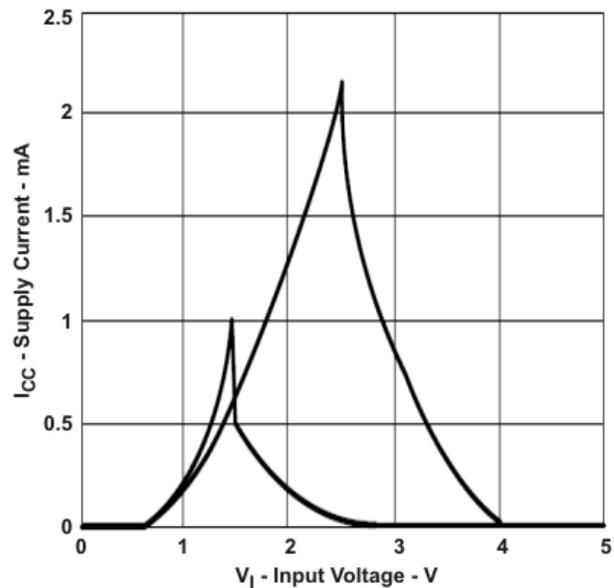

Figure 2. Supply Current as a Function of Input Voltage

Sine Waves

Use Schmitt triggers to translate a sine wave into a square wave as shown in this oscillator application. Also, use Schmitt triggers to speed up a slow or noisy input, or clean up an input, as in the switch de-bouncer circuit.
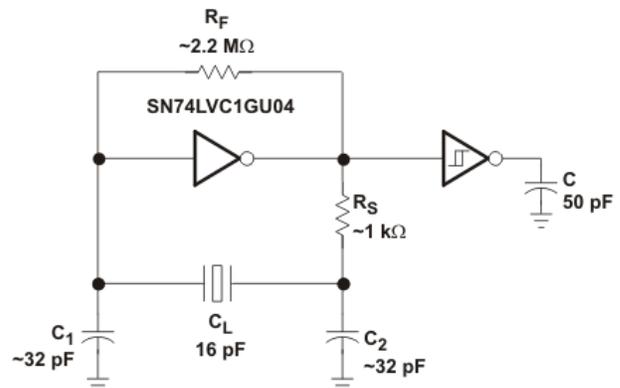

**Figure 3. Oscillator Application Using Schmitt Trigger Inverter**
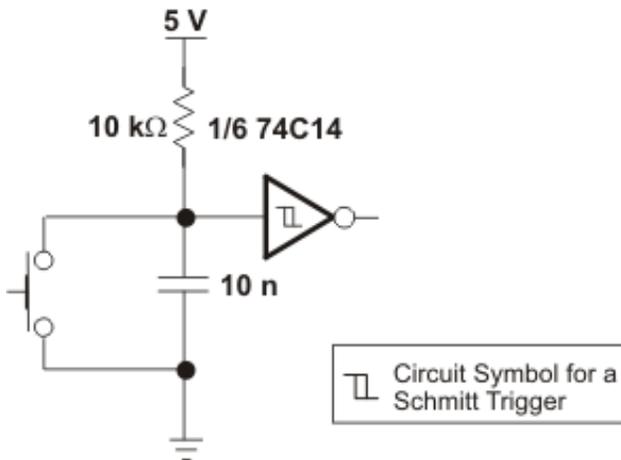
Figure 4. Switch De-bouncer Using Schmitt Trigger Inverter

Conclusion

Schmitt triggers can be used to change a sine wave into a square wave, clean up noisy signals, and convert slow edges to fast edges.
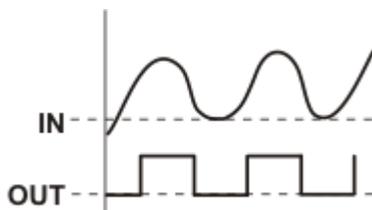

Figure 5. Sine Wave to Square Wave
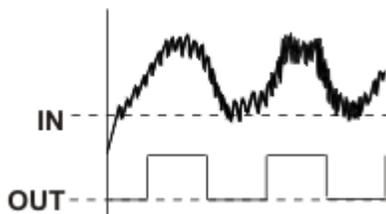
Figure 6. Clean Noisy Signals
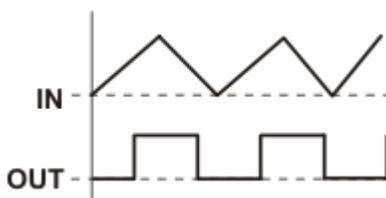
Figure 7. Convert Slow Edges

We specify the part switches on the rising edge between (VT+ min) and (VT+ max). We specify the part switches on the falling edge between (VT– max) and (VT– min).

Between (VT+ min) and (VT– max), we specify the part does not switch. This specification can be used for noise rejection. These two limits can overlap.

We specify a minimum amount of hysteresis as delta VT minimum.

- Vih = (VT+ max)
- Vil = (VT– min)

Texas Instrument Schmitt trigger functions are available in most all technology families from the 30 year old 74xx family to the latest AUP1T family. These two Schmitt-trigger functions are available in most families:

- 14 for inverting Schmitt trigger
- 17 for non-inverting Schmitt trigger

Texas Instrument also has a complete line of little logic products with Schmitt trigger inputs.

Configurations

SN74LVC1G57, SN74LVC1G58, SN74LVC1G97, SN74LVC1G98, SN74LVC1G99 SN74AUP1G57, SN74AUP1G58, SN74AUP1G97, SN74AUP1G98, SN74AUP1G99

Low to High Translators

SN74AUP1T02, SN74AUP1T04, SN74AUP1T08, SN74AUP1T14, SN74AUP1T157, SN74AUP1T158, SN74AUP1T17, SN74AUP1T32, SN74AUP1T86

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