Understanding Schmitt Triggers

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Most CMOS, BiCMOS and TTL devices require fairly fast edges on the high and low transitions on their inputs. If the edges are too slow they can cause excessive current, oscillation and even damage the device. Slow edges are sometimes hard to avoid at power up or when using push button or manual type switches with the large capacitors needed for filtering. Heavily loaded outputs can also cause input rise and fall time to be out of spec for the next part down the line.

On a normal (non-Schmitt trigger) input the part will switch at the same point on the rising edge and falling edge. With a slow rising edge the part will switch at the threshold. When the switch occurs it will require current from Vcc. When current is forced from V_{CC}, the V_{CC} level can drop causing the threshold to shift. When the threshold shifts it will cross the input again causing the part to switch again. This can go on and on causing oscillation which can cause excessive current. The same thing can happen if there is noise on the input. The noise can cross the threshold multiple times and cause oscillation or multiple clocking.

The solution to these problems is to use a Schmitt trigger type device to translate the slow or noisy edges into something faster that will meet the input rise and fall specs of the following device. A true Schmitt trigger input will not have rise and fall time limitations.

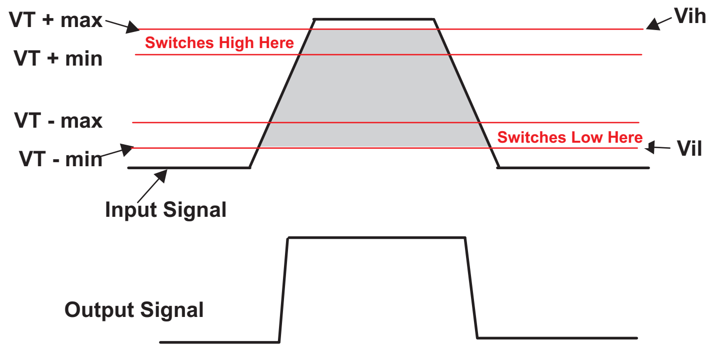
There are parts that have Schmitt trigger action. This means that they will have a small amount of hysteresis that will help with noise rejection but will still have an input rise and fall time limit. These will usually not have any VT specs in the datasheet and will have rise and fall time limitations specified for the inputs in the recommended operating conditions.

The true Schmitt trigger input has the switching threshold adjusted where the part will switch 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 specs.

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

The important thing to remember here is that **(Vt+ max) = Vih and (VT– min) = Vil**.

In the specs you will see multiple limits related to the Schmitt trigger inputs. All of the limits are important for different reasons. On the input rising edge the part will be guaranteed to switch between (Vt+ min) and (Vt+ max). On the falling edge the part will be guaranteed to switch between (Vt– max) and (Vt– min). The part is guaranteed not to 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. We specify this hysteresis will be at least the min and no more than the max (^Vt) spec.



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

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

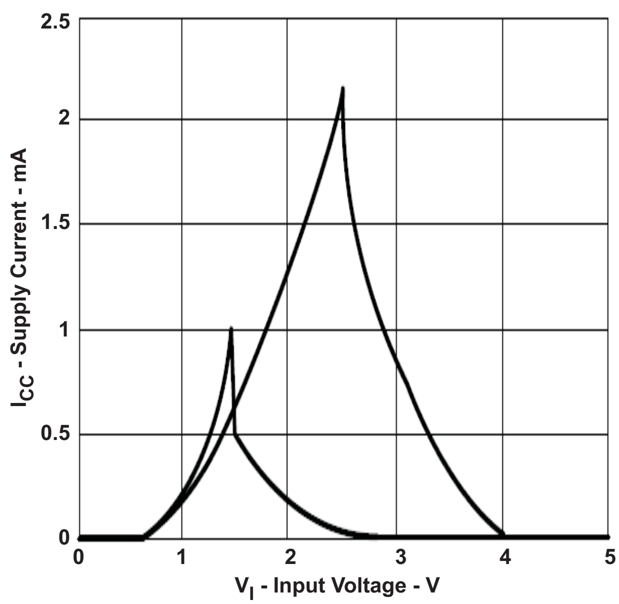


Figure 1. Supply Current as a Function of Input Voltage

Schmitt triggers should be used anytime you need to translate a sine wave into a square wave as shown in this oscillator application. Or they should be used where a slow or noisy input needs to be sped up or cleaned up as in the switch de-bouncer circuit.

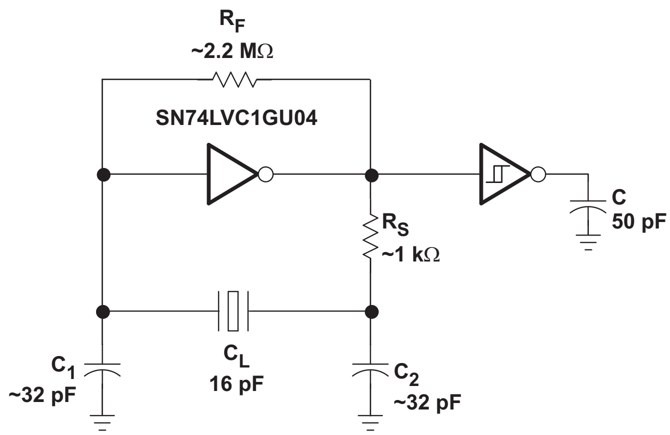


Figure 2. Oscillator Application Using Schmitt Trigger Inverter

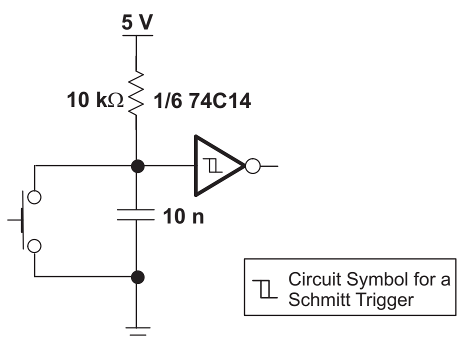
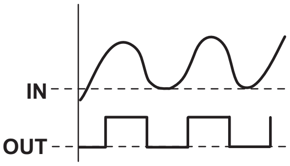


Figure 3. Switch De-bouncer Using Schmitt Trigger Inverter

Conclusion

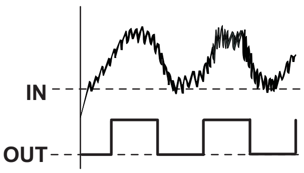
Schmitt triggers should be used any time you need to

1. Change a sine wave into a square wave.



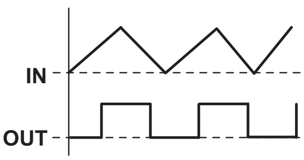
(a)

2. Have noisy signals that need to be cleaned up



(a)

3. Have slow edges that need to be converted to fast edges.



(a)

We specify the part will switch on the rising edge between (VT+ min) and (VT+ max).

We specify the part will switch on the falling edge between (VT– max) and (VT– min).

Between (VT+ min) and (VT– max) we assure the part will not switch. This can be used for noise rejection. These 2 limits can overlap.

We assure there will be a minimum amount of hysteresis. This is specified as delta VT min.

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 all 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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