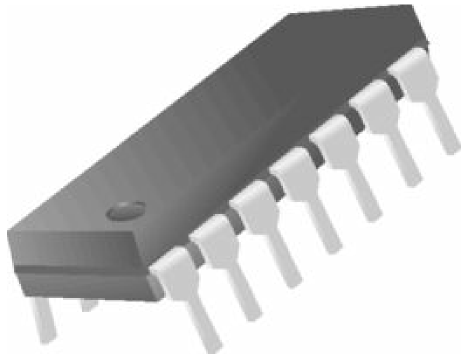
AS Systems & Control Study Notes
Part 8: Digital Integrated Circuits

Week 17: Learning Objectives

- Know the operating characteristics of logic families:
- TTL
- CMOS
- Understand the operation and applications of:
- Schmitt-Trigger



Logic IC properties

Logic ICs are simply integrated circuits designed to perform logic operations. As with all ICs they have different electrical characteristics. The operating characteristics of all ICs can be found on their datasheets published by the manufacturer. The following describes some of the basic terms:

Operating voltage: This is the supply voltage that the IC is designed to operate at. The supply voltage is identified on datasheets by the label "Vcc."

Power consumption: This is the amount of current the IC will draw from the power supply during normal operation, it is usually in terms of mA.

Input resistance: The inputs of all circuits have resistance, this means that the circuit connected to the input of and IC sees the IC as a resistor. If the input resistance is low then the IC will draw more current from the previous circuit connected to it, this limits its sensitivity. If the input resistance is low then the IC will draw less current from the circuit connected to it an is therefore more sensitive.

Logic levels: The two logic levels (high and low) are represented as two different voltages (one for high and one for low.) Different types of logic ICs have different voltage levels to represent these logic levels.

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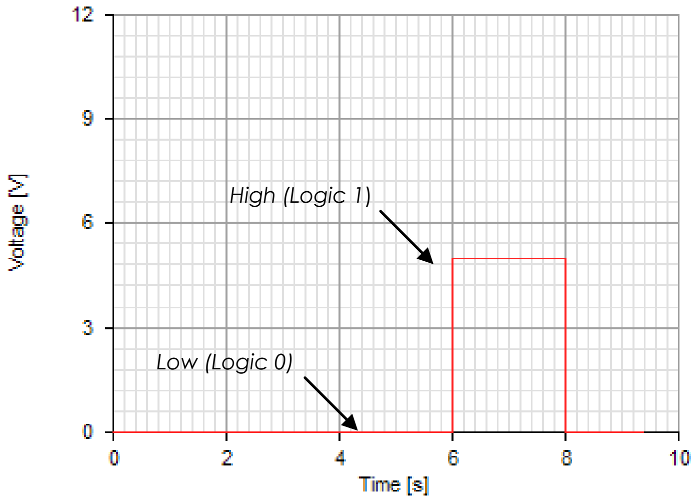
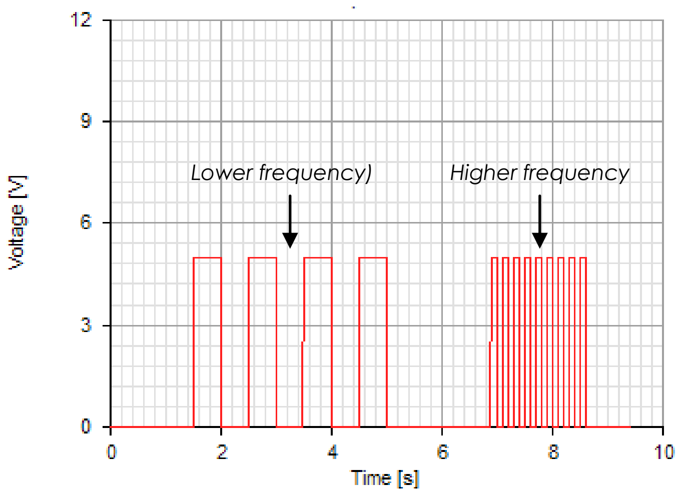


Digital signal with a high (logic 1) output voltage of 5V

Speed: In electronic systems it is often required that the output should be able to turn on and off very quickly. This is particularly true in microprocessor based systems where outputs may have to switch millions of times per second. There is a limit however to the speed a circuit can switch, different types of logic ICs have different maximum operating frequencies.



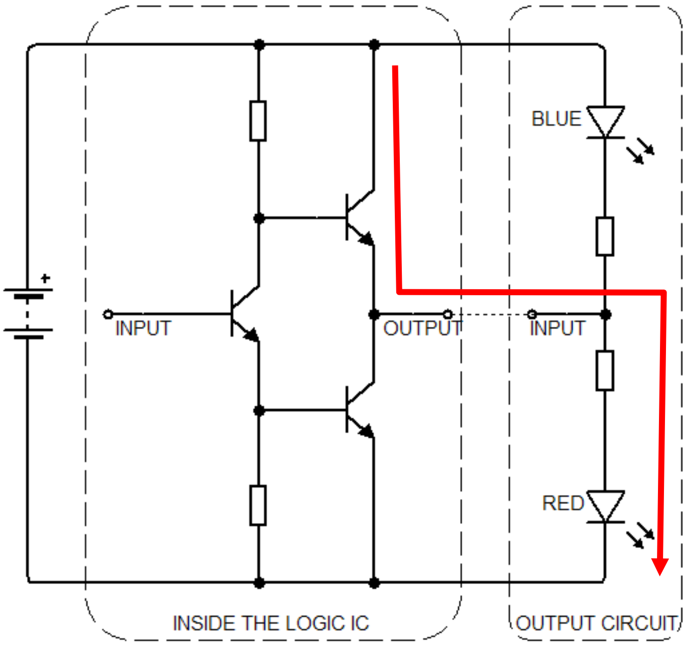
Digital signal pulses

Maximum output current: The output pins of a logic IC can supply a limited amount of current to the device connected to it. In general it is advantageous for the IC to be able to supply a higher current.

There are two types of output current. When the output voltage is high then current will flow out of the IC in to the load connected to it, this is known as the "sourcing" current. When the output voltage is low then current will though the load and back into the IC, in other words the current is flowing in the opposite direction. In this case the IC is said to be "sinking" current. It is common for the sinking current to be much higher than the sourcing current.

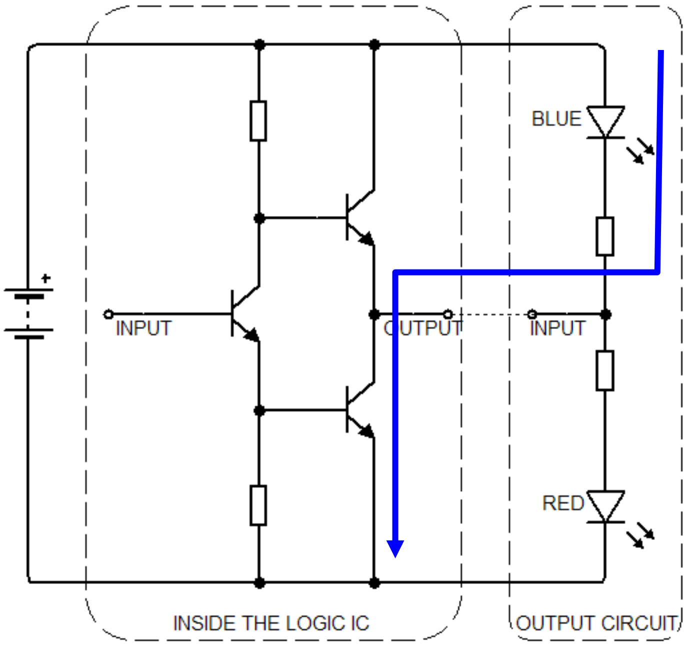
The following circuits show the output section of a logic gate driving two LEDs.

When the output is high the logic IC's output will **source** current causing the red LED to light:



A logic circuit sourcing current

When the output is low the logic IC's output will **sink** current from the power supply, though the blue LED and back into the output pin on the IC. Therefore the blue LED will light.



A logic circuit sinking current

Logic Families

The two main types of logic ICs are:

- TTL (ICs in the 74LSxxx series)
- CMOS (ICs in the 40xx series)

TTL logic ICs are constructed from bipolar transistors and CMOS logic ICs are constructed from MOSFETs. These two types have their own relative merits, the choice of logic family depends on the application. The table compares the two types:

Properties	TTL Logic	CMOS Logic
Operating Voltage (Vcc)	5V +/- 0.25V	3Vto 15V
Power Consumption	Medium	Low
Input Resistance	Medium	High
Logic Levels:		
Low	0V to 0.7V	0V to 30% of Vcc
High	2.5V to 5V	70% to 100% of Vcc
Max. output current:		
Sourcing	1.6mA	4mA *(If Vcc=5V)*
Sinking	16mA	4mA *(If Vcc=5V)*
Speed	Fast	Slow

Logic voltage levels

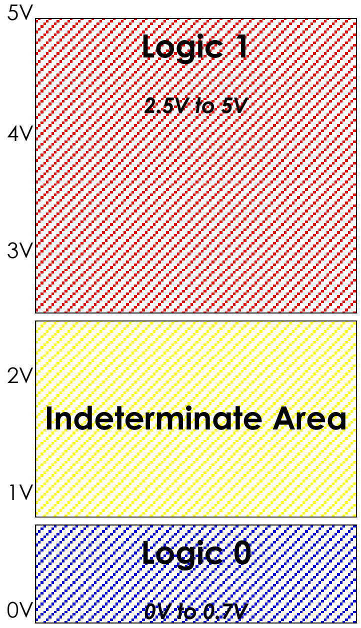
The table on the previous page shows how the two different logic families (TTL and CMOS) use different voltages to represent the two logic levels (high and low.)

The charts below show the voltages used to represent the two logic states for both TTL and CMOS devices:

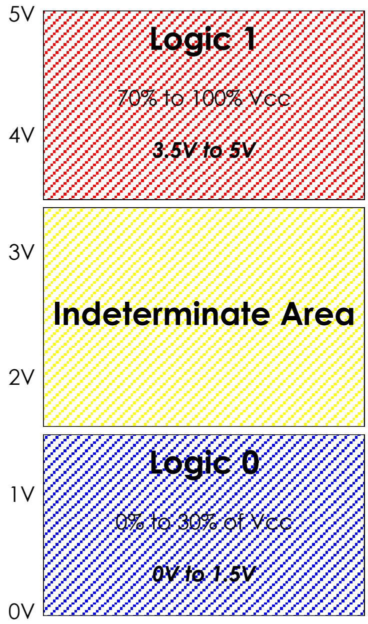
TTL levels are set at specific voltage, this is because the supply voltage (Vcc) must be close to 5V.

CMOS ICs can be powered from a voltage of between 3V and 15V. Therefore the logic voltage levels are set as a percentage of the supply voltage.

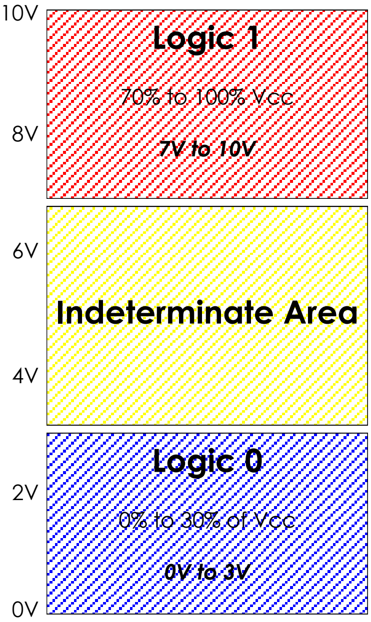
TTL Logic Levels



CMOS Logic levels (Vcc = 5V)



CMOS Logic levels (Vcc = 10V)



Advantages of CMOS ICs

- The inputs of CMOS have a high input resistance and are therefore more sensitive than TTL.
- CMOS ICs can operate on a power supply ranging from 3V to 15V whereas TTL ICs are limited to 5V.
- CMOS ICs consume much less power than TTL ICs.
- CMOS ICs are more resilient to fluctuations in power supply voltage because the logic voltages are represented as a percentage of the supply voltage.

Disadvantages of CMOS ICs

- CMOS ICs are sensitive to electrostatic discharge (ESD.) This means that they can be damaged by static electricity that can build up on the human body. They must therefore be handled with care and stored in electrostatic dissipative packaging.
- Older CMOS ICs can operate at a lower speed than TTL. Modern CMOS devices however do not suffer from this effect.

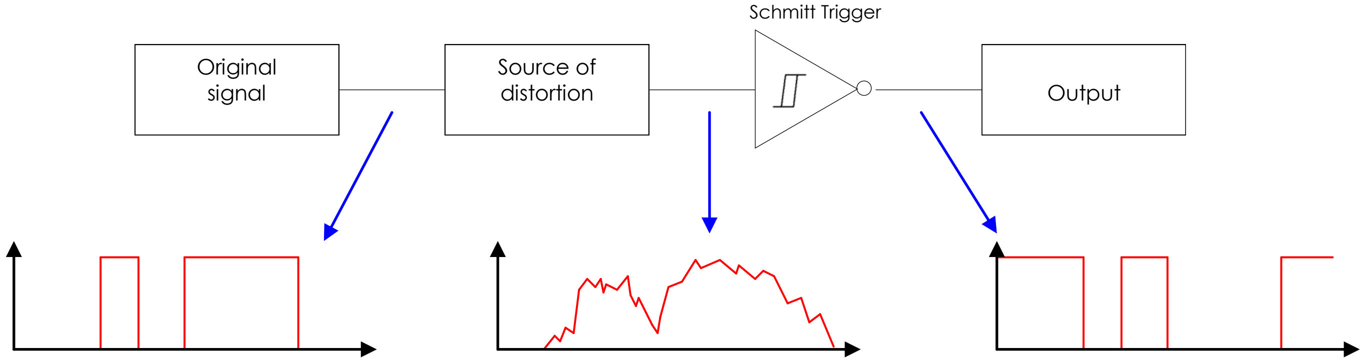
ESD Warning sign

Schmitt Triggers

Sometimes a digital signal may become distorted during its passage through circuits or conductors. This can cause the proceeding logic circuits to misinterpret the logic state as voltages can encroach into the indeterminate region of the logic level.

A Schmitt Trigger is used to tidy up the digital signal to ensure that the logic states are interpreted correctly. A Schmitt trigger is a type of signal conditioner.

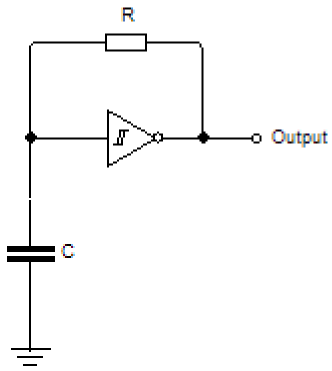
The diagrams below show how a distorted signal can be tidied up by the Schmitt trigger to produce a reformed signal:



Original digital signal *Distorted digital signal* *Recovered digital signal*

Simple astable multivibrator

A Schmitt trigger can be used to make a simple astable multivibrator using only a few components. Although the output frequency cannot be accurately controlled it can be used for basic functions where this is not important.



Schmitt trigger based Astable

$$F \approx \frac{1}{R \times C}$$