

Engr354 - Introduction to "REAL" Logic Gates

Logic Families

The most commonly used logic circuits can be divided into two general categories. The first is Transistor-Transistor Logic (TTL) and the second is Complementary Metal Oxide Semiconductor Logic (CMOS). The names come from the type of transistors that are used and the circuit topology. TTL logic gates are constructed using bi-polar transistors (PNP and NPN types). CMOS logic gates are constructed using Metal Oxide Semiconductor (MOS) transistors (N-channel and P-channel types). We will first talk about TTL type gates.

There are many sub-types within the general categories of TTL and CMOS gates. Each subtype is noted for its particular combination of performance characteristics such as maximum speed of operation, input/output voltage levels, power consumption, delay time, etc. The sub-types can represent different stages in the advancement of performance.

Among the TTL type gates, one of the first families created in the 1970's was the 74xx series of gates. The xx here stands for 2 or 3 digits that identify a package containing one or more particular gates such as an AND, OR, NAND, etc. For example, a 7400 package contains four 2-input NAND gates. Although the number 7400 refers to the whole package, industry slang may call for "a 7400 gate" when referring to just one NAND gate. Other families are the 74Lxx (Low power TTL), 74Sxx (Schottky TTL), 74LSxx (Low power Schottky TTL), and 74ALSxx (Advanced low power Schottky TTL) families. Typically the same gate logic function can be purchased in all families.

Gate performance varies from family to family. The 74Lxx is the slowest family. The 74ALSxx is the fastest. For many years, the 74LSxx family was by far the most popular. More recently, CMOS logic gates have taken over as their combination of speed, low cost, and low power fits many design criteria. A popular CMOS logic series is the 74HCxx. It is given the 74 prefix because it is pin compatible with the 74xx series of logic parts. The HC stands for "high-speed CMOS".

Component Numbering

In the number 74LSxx listed above, the digits xx are numbers that define the logic function performed by a part. The LS just states that it is Low Power Schottky technology. The 74 indicates that this is a commercial grade part (0 to 70 degree Celsius operation) versus a military grade part (-55 to +125 degree Celsius operation) for which the prefix 54 is used.

In addition, there are prefix characters and suffix characters that may be printed on a part or may be required when you order a part. The precise definition of these is manufacturer dependent. Many companies sell logically equivalent and often electrically equivalent parts using the same basic number (i.e. 74LSxx).

The package style for the gates we will use is called a DIP or Dual-Inline-Package. There are two rows of pins spaced 0.3" apart with a 0.1" spacing between adjacent pins in a row. Most new designs, particularly for portable equipment, use smaller packages with closer pin spacing to reduce circuit board space. These packages are often "surface-mount" rather than DIP.

The Basic Gates

The integrated circuits supplied to you along with your logic board are as follows:

2	74HC00	Quad 2-Input NAND Gates
1	74HC02	Quad 2-Input NOR Gates
1	74HC04	Hex Inverting Gates
1	74HC10	Triple 3-Input NAND Gates
2	74HC74	Dual Positive Edge-triggered D Flip-Flops
1	74HC86	Quad 2-Input XOR Gates
1	74HC138	1-of-8 Decoder/Demultiplexer
2	74HC151	8-to-1 Multiplexer
1	74HC153	Dual 4-to-1 Multiplexer
1	74HC163	Fully Synchronous 4-bit Counter

The connection diagrams for these gates can be found in the data sheets posted to the class web page. Data sheets for additional logic parts can be found in an appropriate data book or on the web. Check the projects lab or the digital lab for reference books on TTL and CMOS logic circuits. Note that in addition to the inputs and outputs for each gate in a package there is a power and ground connection for each package. The power is typically labeled Vcc or Vdd for both TTL and CMOS logic families.

74HCxx Gate Electrical Characteristics

While there are many important electrical characteristics that must be considered and correctly chosen when doing a design for a product, there is a subset that will suffice to allow us to begin designing functional logic circuits. This subset includes the allowed input and output voltages for logic high and low, the gate input current for logic high and low, and the maximum output current in both logic states. These values can be summarized as follows for the 74HCxx family running with Vdd = 4.5 volts:

- Input voltage ranges
 - Maximum voltage for logic 0 = 1.35v
 - Minimum voltage for logic 1 = 3.15v
- Input currents (for each input pin)
 - Typical current for logic 0 or logic 1 = ± 0.1 nA
- Output currents (i.e. allowed current when output voltage is in legal range)
 - Maximum current for logic 0 = 4 milliamps flowing into a gate output terminal while retaining the output voltage below 0.33 volts.
 - Maximum current for logic 1 = 4 milliamps flowing out of a gate output terminal while retaining the output voltage above 3.84 volts.

Note: Current flows into the output of a 74HCxx gate when it is in a logic 0 state. Current flows out of a 74HCxx gate when it is in a logic 1 state.

- Output voltage
 - For logic 0, the output voltage will typically be around 0.15 volts but can be as much as 0.33 volts.
 - For logic 1, the output voltage will typically be about 4.5 volts with a small load and dropping if a load requires a logic 1 state.

How to Start Building Circuits

- Step 1 Develop a logic expression for the circuit to be implemented.
- Step 2 Draw a logic diagram of the gates and interconnections.
- Step 3 Label the logic diagram to show the signals coming into the logic and the signals going out of the logic using mnemonics of your choice.
- Step 4 Verify that the assertion levels that you have assumed for your logic match the assertion levels actually generated by the signal sources. Remember that the push buttons on your logic kits are toggle-on/toggle-off.
- Step 5 Using the package diagrams supplied, label the inputs and outputs of each gate with a pin number. **Also note the pins on each package that need to be connected to V_{dd} or ground.**
- Step 6 With the power disconnected, install the required parts in the breadboard. Make sure the pins are aligned with the holes before attempting to insert the part.
- Step 7 Connect ground on your breadboard to the ground pin on each integrated circuit used. Connect +3 volts to the power pin (V_{cc} or V_{dd}) of each integrated circuit.
- Step 8 Interconnect the logic gates using the pin numbers written on your logic diagram.
- Step 9 Connect the signal inputs and outputs.
- Step 10 Turn on the power and begin checking to see if the circuit works as desired.

Precautions

- Turn the power off while changing the wiring. This will reduce the chance of accidental damage that might occur if connections are temporarily made incorrectly.
- As you approach a table or desk where your logic board and parts are located, discharge the static electricity that has accumulated on you before touching the boards or the logic packages. While the 74HCxx chips are robust, thousands of volts of potential can be generated on your body and may overwhelm the protection circuits in a chip. The result: gate destruction. Also, there are CMOS parts on the I/O logic board which are also static sensitive. You can discharge yourself by touching a point of ground potential on your circuit or logic board.