DIGITAL LOGIC DESIGN I CS1026

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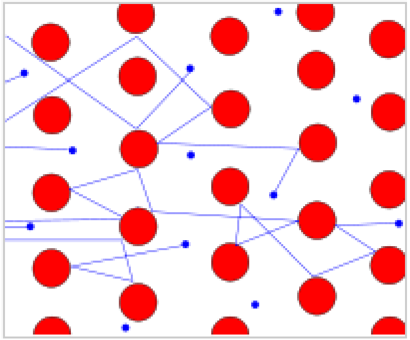
WHAT IS A CIRCUIT?



A circuit is a complete and closed path around which a circulating electric current can flow.

An electric current is a flow of electric charge. In electric circuits this charge is carried by moving electrons in a wire.

The Drude model treats electrons like pinballs bouncing among the ions that make up the structure of the material.

As the electrons bump their way through the material we must keep applying external energy to keep them moving.

The electrical current is provided by a Power Supply, a battery in our case where the Power, P is measured in Watts, W and is calculated as

- $P = V^2/R$
- $P = I^2*R$

Electrons are negatively charged and will be accelerated in the opposite direction to the electric field by the average electric field at their location. Thus, electrons are attracted to the positive end of a battery and repelled by the negative end.

RESISTIVITY

Electrical resistivity quantifies how strongly a given material opposes the flow of electric current.

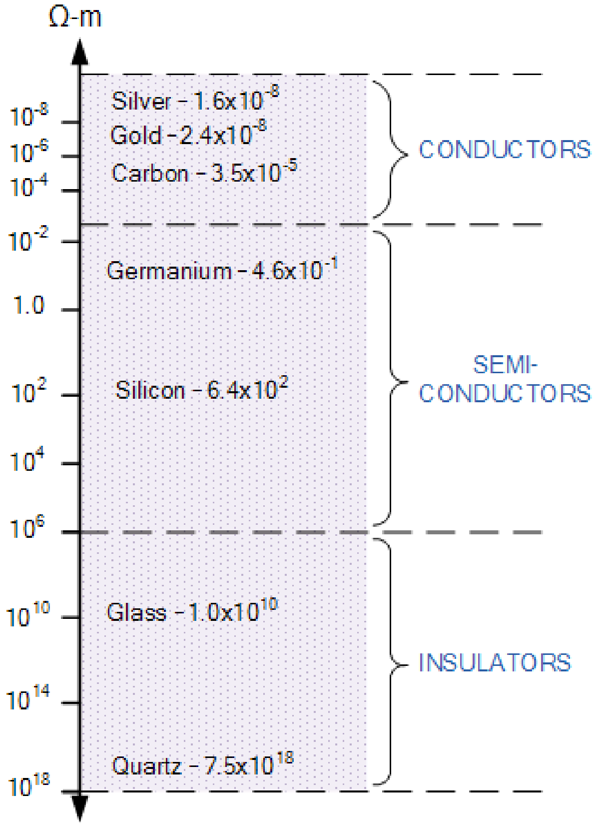
A low resistivity indicates a material that readily allows the movement of electric charge.

Resistivity is commonly represented by the Greek letter ρ (rho).

The SI unit of electrical resistivity is the ohm·metre (Ω·m).

Electrical conductivity is the reciprocal of electrical resistivity.

If a 1 m × 1 m × 1 m solid cube of material has sheet contacts on two opposite faces, and the resistance between these contacts is 1 Ω, then the resistivity of the material is 1 Ω·m.



RESISTIVITY

Many resistors and conductors have a uniform cross section with a uniform flow of electric current, and are made of one material.

The electrical resistivity, ρ is defined as:

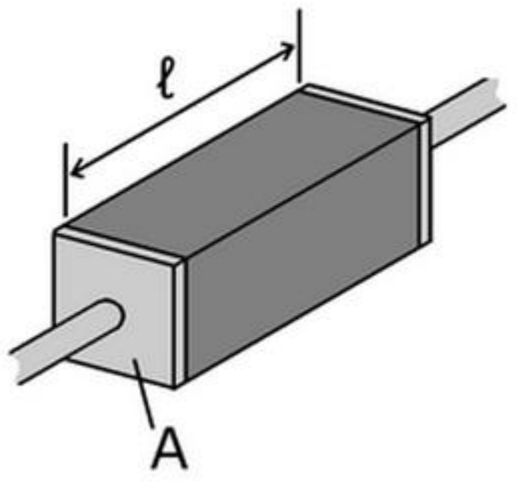
$$\rho = R\frac{A}{\ell}$$

where

R is the electrical resistance of a uniform specimen of the material

ℓ is the length of the piece of material

A is the cross-sectional area of the specimen



RESISTIVITY & RESISTANCE

Thus resistivity is an intrinsic property of a material unlike resistance.

In a hydraulic analogy, passing current through a high-resistivity material is like pushing water through a pipe full of sand.

Passing current through a low-resistivity material is like pushing water through an empty pipe.

If the pipes are the same size and shape, the pipe full of sand has higher resistance to flow.

Resistance, however, is not solely determined by the presence or absence of sand. It also depends on the length and width of the pipe: short or wide pipes have lower resistance than narrow or long pipes.

All copper wires, irrespective of their shape and size, have approximately the same resistivity, but a long, thin copper wire has a much larger resistance than a thick, short copper wire.

RESISTANCE

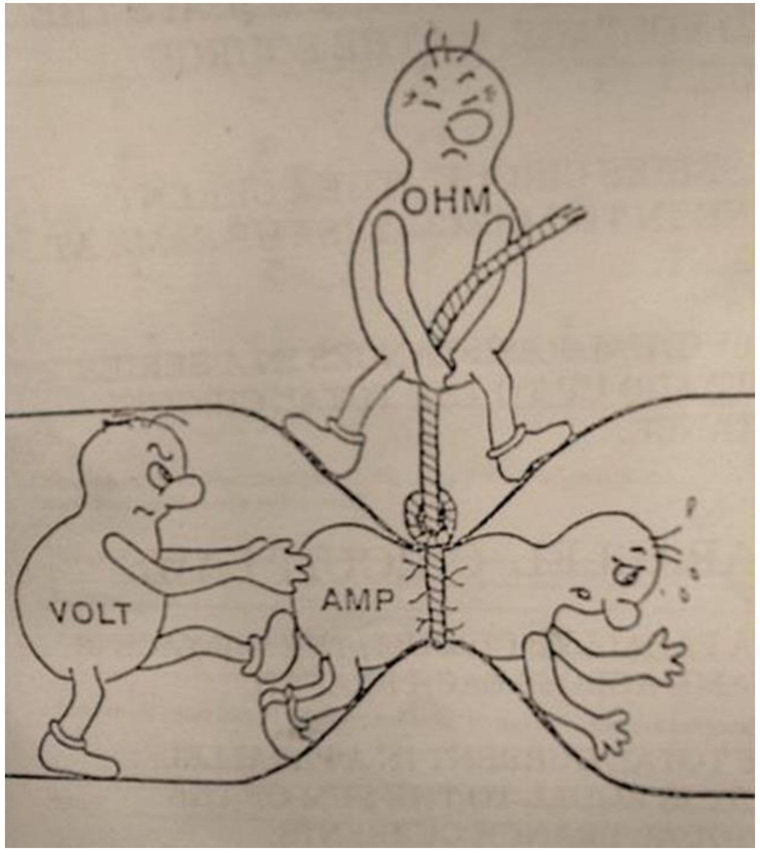
Resistance, R, is the capacity of a material to impede the flow of current (electric charge).

It is defined in term of current, I (measured in Amperes), and Voltage, V (measured in Volts)

It is measured in Ohms, Ω

Ohms Law states that the direct current flowing in a conductor is directly proportional to the potential difference between its ends

- $V = I * R$



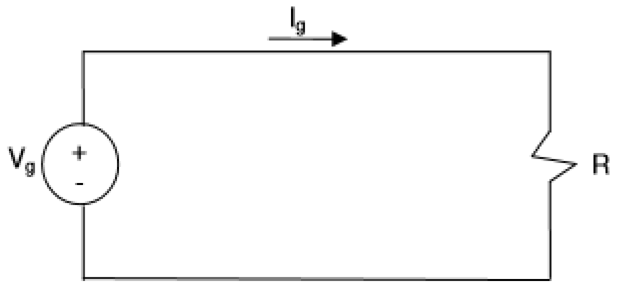
RESISTORS

A resistor is a passive two-terminal electrical component that implements electrical resistance as a circuit element.

The flow of current through a resistor will convert electrical energy to thermal energy. In some applications, this property is desirable (e.g. heater, toaster, oven) and in other applications it is undesirable (e.g. transmission line, digital devices)

EXAMPLE

Find the value of the resistance ,R, and the power consumed by the resistor if Vg = 1 kV and Ig = 5 mA.



Answer

R= Vg/Ig = 1000/0.005 = 200 kΩ

Pr = Ig^2 * R = $(.005)^2$*(200,000)= 5 W

SHORT CIRCUITS

A short circuit is an electrical circuit that allows a current to travel along an unintended path, often where essentially no (or a very low) electrical resistance is encountered.

A common type of short circuit occurs when the positive and negative terminals of a battery are connected with a low-resistance conductor, like a wire.

With low resistance in the connection, a high current exists, causing the cell to deliver a large amount of energy in a short time.

A large current through a battery can cause the rapid buildup of heat, potentially resulting in an explosion or the release of hydrogen gas and electrolyte (an acid or a base), which can burn tissue, cause blindness or even death.

Overloaded wires can also overheat, sometimes causing damage to the wire's insulation, or a fire.

A fuse is a type of low resistance resistor that acts as a sacrificial device to provide overcurrent protection in either the load or source circuit.

Its essential component is a metal wire or strip that melts when too much current flows through it, interrupting the circuit that it connects.

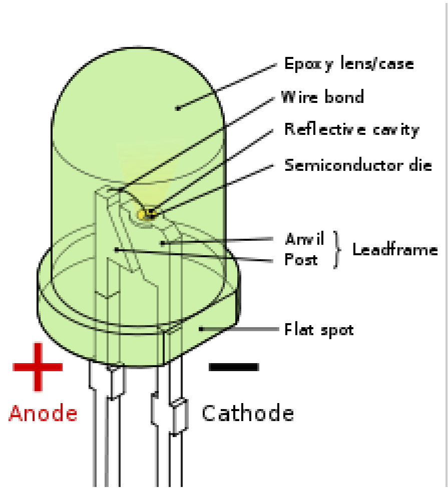
A circuit breaker is an automatically operated electrical switch designed to protect an electrical circuit from damage caused by overload or short circuit.

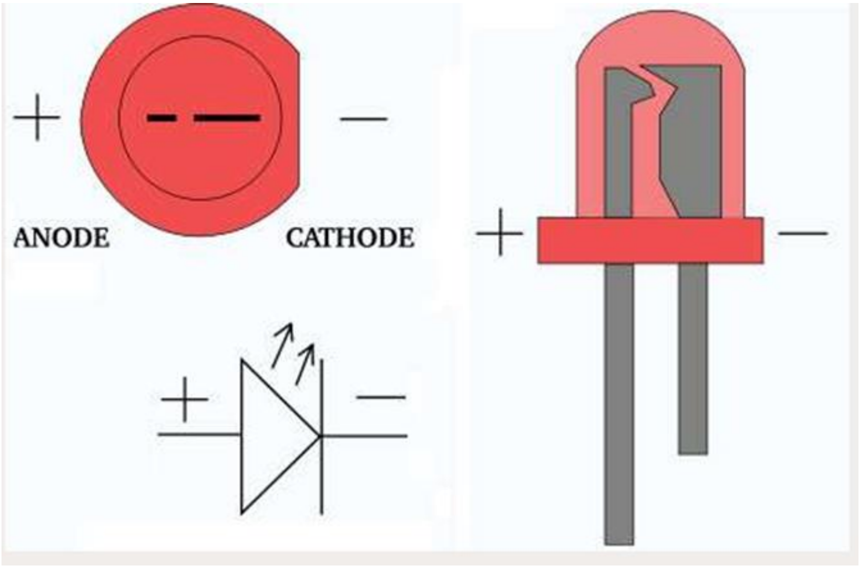
LIGHT EMITTING DIODE

When a light-emitting diode is switched on, electrons are able to recombine with holes within the device, releasing energy in the form of photons.

Notice that the leads of the device are two different lengths. This is to indicate that one "leg" of the device is the anode, and the other is the cathode. On an LED device the longer leg is always the anode, and the shorter leg is the cathode. Current always flows from the anode to the cathode.

In a simple circuit, the anode of the LED is connected to the positive voltage supply, and the cathode is connected to ground, or the negative voltage supply.





BEFORE YOU START WIRING…

Familiarise yourself with the position of circuit breakers and read the safety posters in each laboratory.

When building circuits, keep the power off.

Do not touch bare wires or parts on the breadboard.

Do not lean against metal surfaces when working, such as radiators.

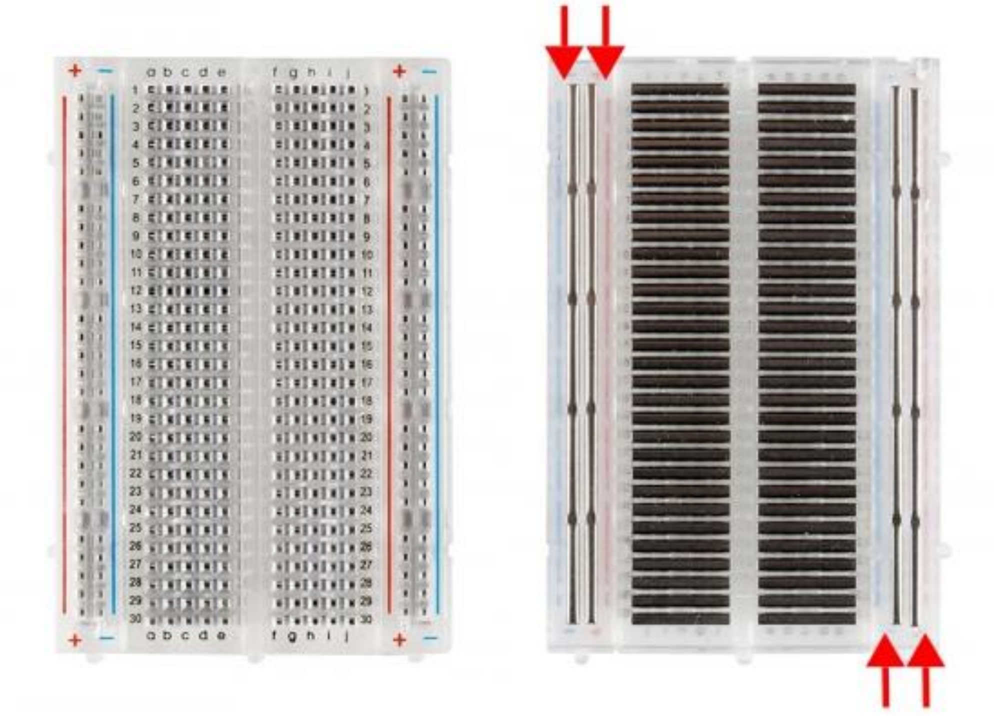
Be careful with sharp objects.

You should inspect laboratory equipment for visible damage before using it. If there is a problem with a piece of equipment report it to the technician or lecturer. DO NOT return faulty equipment to a storage area.

Never strip insulation from a wire with your teeth or a knife, always use an appropriate wire stripping tool.

Shield wire with your hands when cutting it with a pliers to prevent bits of wire flying about the bench.

A breadboard is a construction base for prototyping of electronics. Originally it was literally a bread board, a polished piece of wood used for slicing bread. In the 1970s the solderless breadboard (AKA plugboard, a terminal array board) became available and nowadays the term "breadboard" is commonly used to refer to these



A medium-size breadboard with the adhesive back removed to expose the power rails.

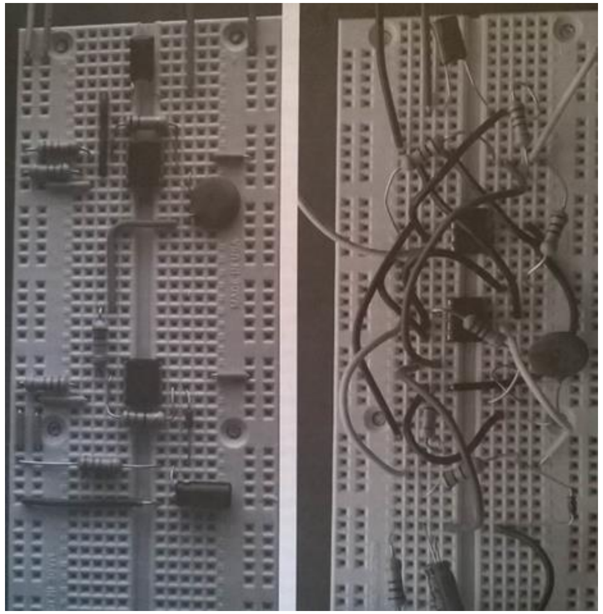
USING BREADBOARDS

To make connections to a board, use pieces of insulated solid (not stranded) wire of an appropriate diameter the insulation of which has been removed on both ends, exposing about 12 mm (or about 0.5 inches) of bare wire. Several different lengths of such wires may be appropriate for a given circuit.

To insert a connecting wire, make sure its bare ends are straight and push each end vertically all the way into a hole using long-nosed pliers. Electronic components such as resistors, capacitors, or integrated circuits can be plugged directly into a breadboard. Resistors with a large power rating may have leads that are too thick, which can damage the connections in the board.

IT IS VERY IMPORTANT TO GET INTO THE HABIT OF WIRING A CIRCUIT NEATLY RIGHT FROM THE BEGINNING. A neatly built circuit is less likely to contain mistakes and is easier to debug.

GOOD & BAD WIRING!



TIPS

HAVE CIRCUIT FUNCTIONS GROUPED TOGETHER. TRY AND LAYOUT THE CIRCUIT SO IT MATCHES THE SCHEMATIC. THIS WILL MAKE THE CIRCUIT EASIER TO DEBUG.

SIGNAL FLOW SHOULD BE LEFT TO RIGHT, FROM INPUT TO OUTPUT.

Try and use red for power and back for ground wires. If unavailable, use a light colour for power and a dark for ground. Positive supplies at top, ground at bottom. If dual supplies are used, have positive on top, negative at bottom and ground in the middle. Make sure all ground lines are joined and that all instruments are grounded to the common ground.

Keep the power off while you are building or modifying your circuit. Mark all completed connections on your diagram as you go.

Use short connections. Long wires are messy and cause interference.

Cut each wire exactly to size. Keep wires close to the board's surface.

Try to connect components such as resistors or capacitors directly - without extra wires connected to them.

Plug in chips so that they straddle the troughs on the proto board.

Do not pass wires over components or over other wires.

MORE TIPS

Be sure that bare wires or component terminals cannot become accidentally shorted together if something is moved. In particular, have the power and ground leads well separated and unable to touch each other.

Do not use more wires than necessary.

Before plugging ICs (integrated circuits) into a board, be sure that their pins are straight – straighten if necessary with long-nosed pliers.

Make sure you are "discharged" before handling ICs by touching the metal case of a properly grounded instrument.

Use resistors with a sufficiently high power rating (1/4 W resistors are fine in almost all circuits in this lab) and capacitors with a sufficiently high voltage rating.

Unplug ICs very carefully, to avoid bending the pins.

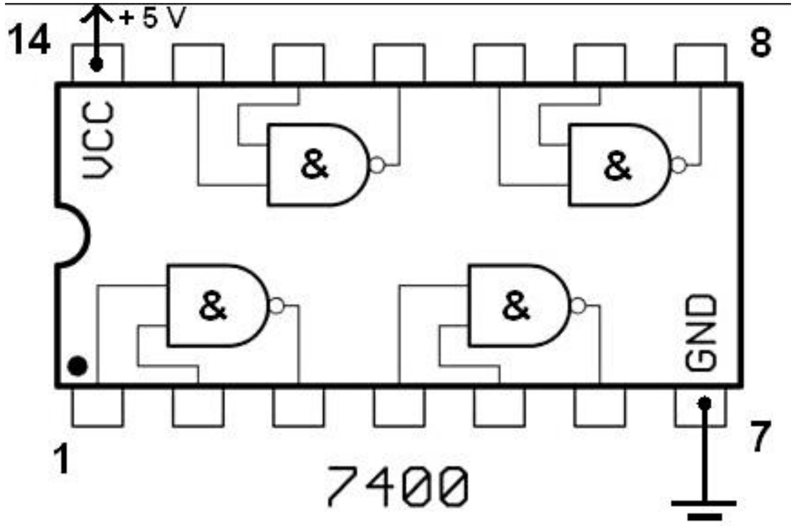
When finished wiring a circuit, inspect all connections to make sure you have made no mistakes. Only when you are happy with the result should you turn on the circuit.

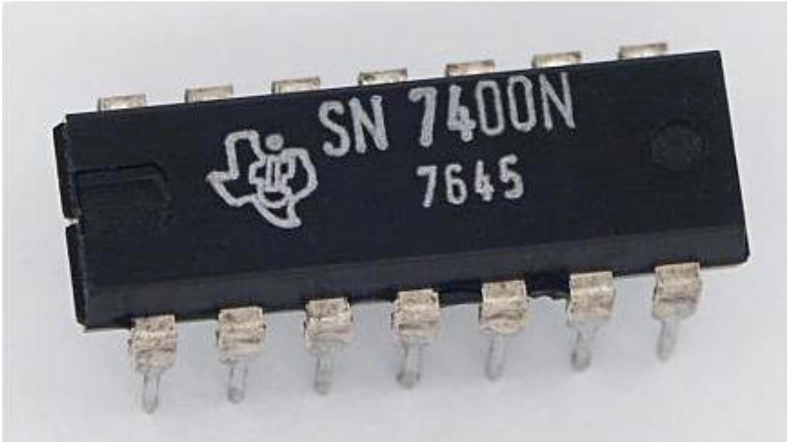
MY FIRST CIRCUIT

First, connect an LED and resistor between ground and 5V and check it lights

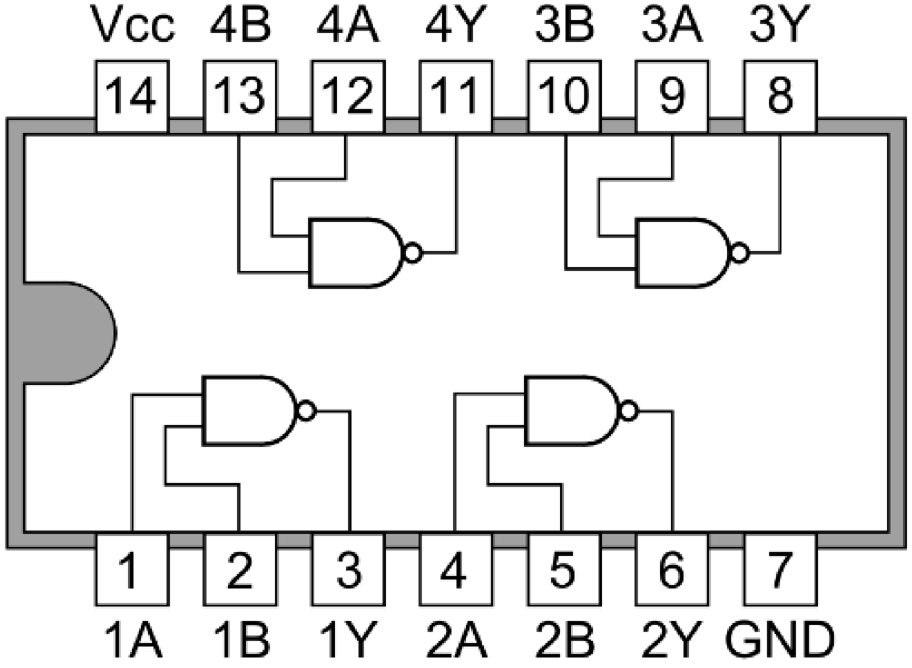
Next, hard wire the 7400 NAND inputs and confirm it works

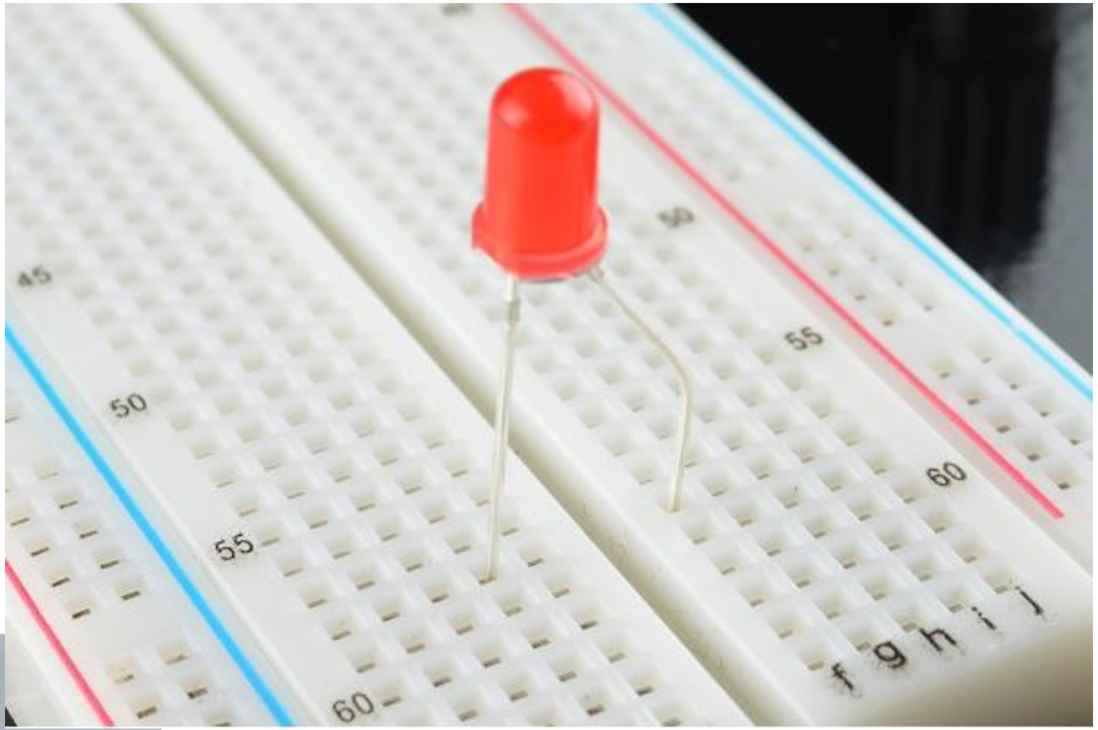
Finally, add the switches and pull down resistors and confirm the truth table

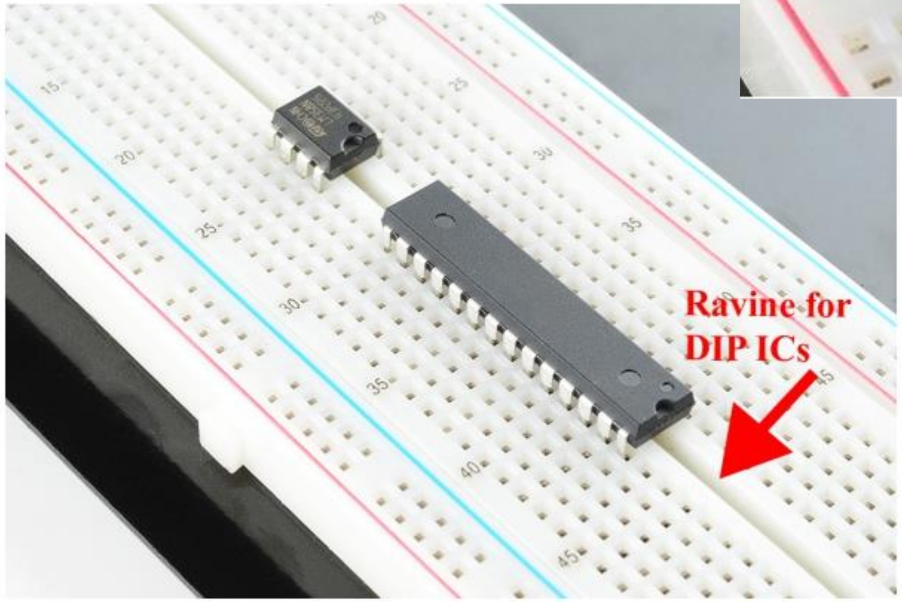




7400 Quad 2-input NAND Gates






Ravine for
DIP ICs

CONNECT AN LED

You can often connect LEDs to give a visual indication of a 1 (LED lighted) or a 0 (LED dark).

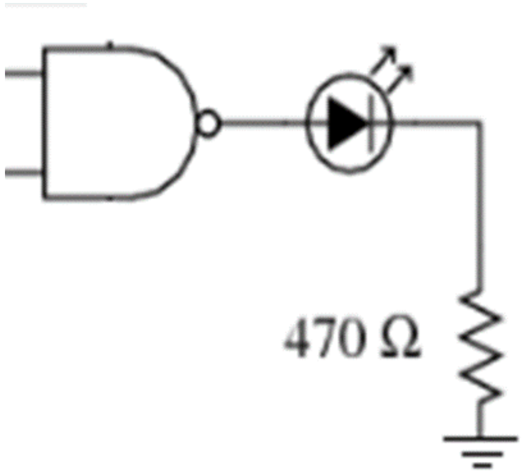
If you connect LED indicators to your circuit remember that an LED is not the same in both directions, and you have to get the correct end connected to the resistor. The other end of each LED is connected to ground (or just "grounded").

Here's the circuit to show the output of a NAND gate

When the output of the gate is a 1, the output voltage will be five (5) volts. Current will flow through the series combination of the resistor and the LED, so the LED will light. When the output of the gate is a 0, the output voltage will be zero (0) volts and the LED will not be lit.

Thus, the LED lights up when the output is a 1, and doesn't light when the output is a 0.

You can use this indication scheme to show the status for any signal. It doesn't have to be the output of a gate.



LEDs have two properties that you care about:

1. forward voltage drop - how much voltage has to go across the led to light up
2. maximum current - how much current the LED can handle.

The forward voltage drop varies depending on the chemicals/materials used inside the LED but typically, they're

Red	30mA	1.7V
Bright red	30mA	2.0V
Yellow	30mA	2.1V
Green	25mA	2.2V
Blue	30mA	3.3V

If the LED doesn't get this much voltage, it may not light up. The maximum current is exactly that, the maximum the LED can tolerate. If you give it more current than the value the datasheet says the LED can handle, the LED may destroy itself or it may become so bright the color changes (for example red becomes orange).

Even though a datasheet may say the LED supports up to - for example - 20 mA, it doesn't mean you should configure the circuit to give it 20mA. 20 mA for that LED may be super bright.

You might find 10mA is easier on the eyes and bright enough for your needs.

Voltage = Current x Resistance

Voltage is the voltage you supply to the circuit, from which you take out the forward voltage of the LED.
Current is how much current you want to allow through the LED in Amperes : 1A = 1000 mA so 10 mA = 0.01A , 100mA = 0.1A etc

So if your input voltage is 5v and you want to use a LED with a forward voltage of 2.2v at a maximum of 10 mA, then your formula becomes :

5v - 2.2v = 0.01 x R

so R becomes (5-2.2) / 0.01 = 280 ohms.

This 280 ohms is not a standard value, so you can use 270 ohms or 300 ohms, which are easy to find. A lower resistor value means a bit more current is allowed through led, a higher value means less current is allowed.

Because resistors dissipate heat energy as the electric currents through them overcome the "friction" of their resistance, resistors are also rated in terms of how much heat energy they can dissipate without overheating and sustaining damage.

This power rating is specified in the physical unit of "watts."

You might also be interested in knowing how big a resistor you need to use.
The power dissipated in a resistor by limiting the current is determined with the formula
P = I x I x R

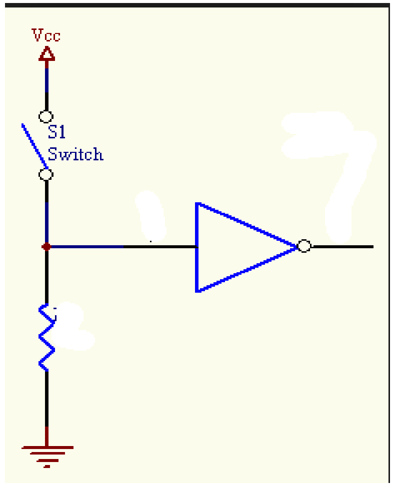
So if we go with the example above where we go with a 270 ohm resistor and 10mA goes through it, then the power will be 0.01 x 0.01 x 270 = 0.027 watts , which means a 0.125w resistor (1/8w) is more than enough for this.

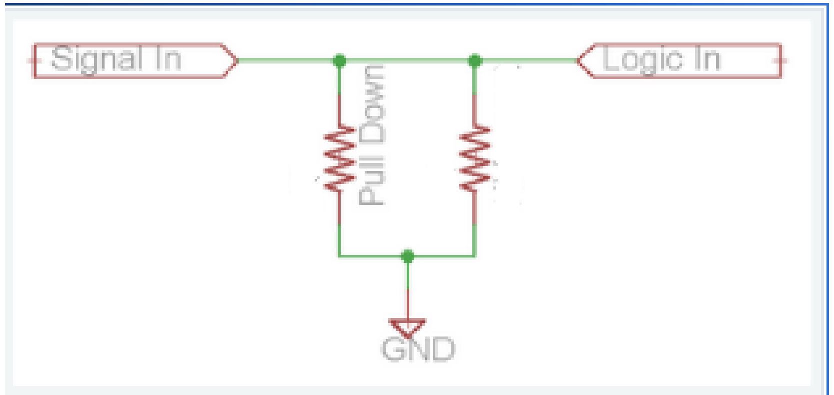
Pull Resistors

In TTL (Transistor Transistor Logic) circuits, pull resistors are resistors used to assign a default value to a TTL signal

A pull resistor works because you can basically model most logic inputs as a really big resistor if the input is valid. One terminal of the resistor is your input node, this is what is sampled by your logic device. The other terminal goes to ground. This is standard on most TTL devices. When you put a pull resistor on it you're creating one of two potential circuits. With a pull-down you have a parallel resistance.

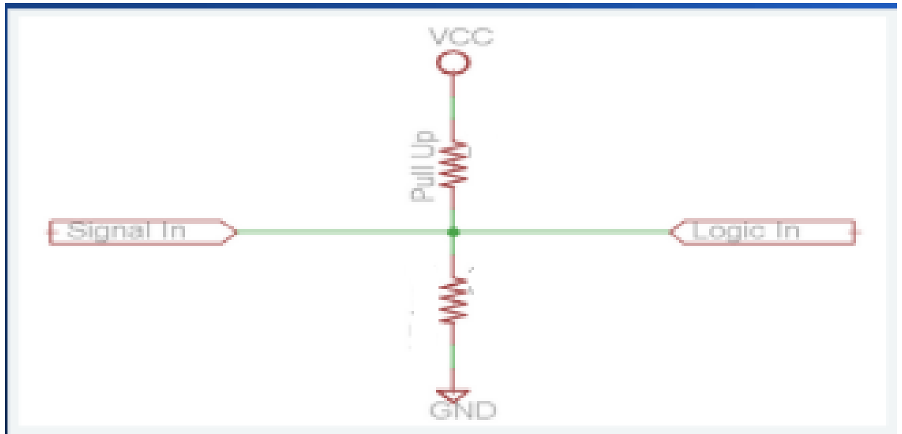
A rule of thumb is to use a resistor that is at least 10 times smaller than the value of the input pin resistance. In bipolar logic families which operate at 5V, the typical pull resistor value is 1-5 kΩ.



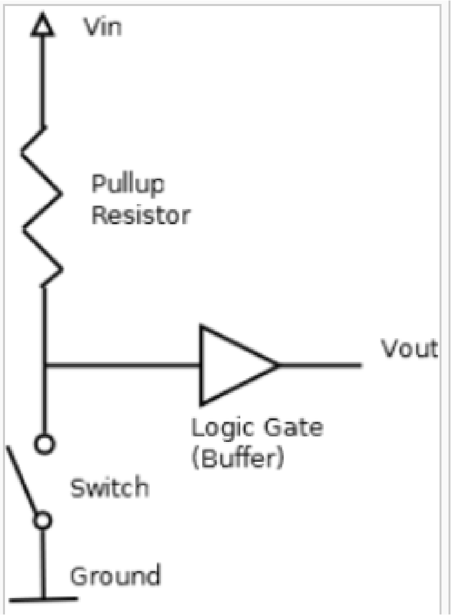


Pull Down Resistor Diagram

With a pull-up resistor you've got a voltage divider



Pull Up Resistor Diagram



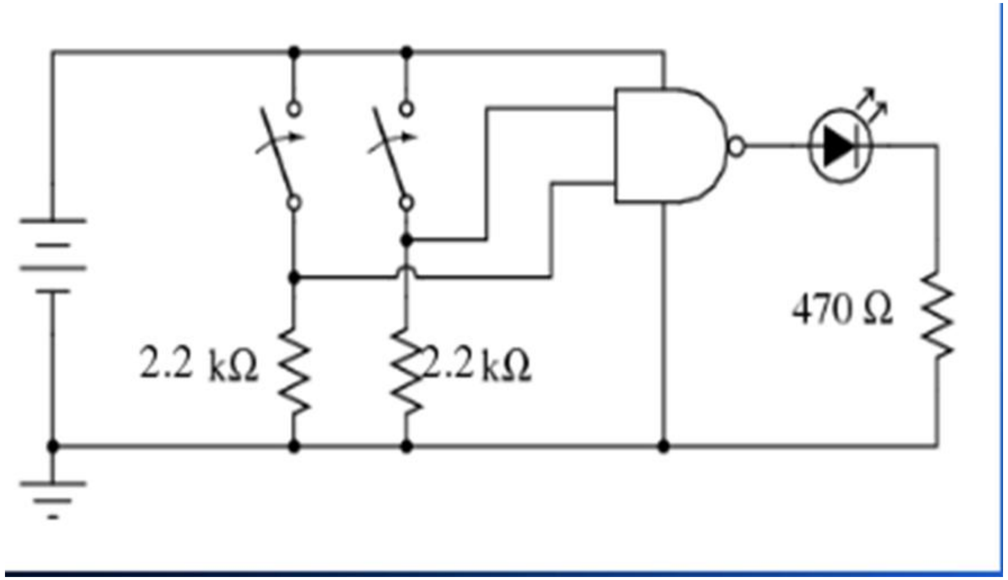
The appropriate value for the pull-up resistor is limited by two factors. The first factor is power dissipation. If the resistance value is too low, a high current will flow through the pull-up resistor, heating the device and using up an unnecessary amount of power when the switch is closed.
This condition is called a strong pull-up and is avoided when low power consumption is a requirement.
The second factor is the pin voltage when the switch is open. If the pull-up resistance value is too high, combined with a large leakage current of the input pin, the input voltage can become insufficient when the switch is open.

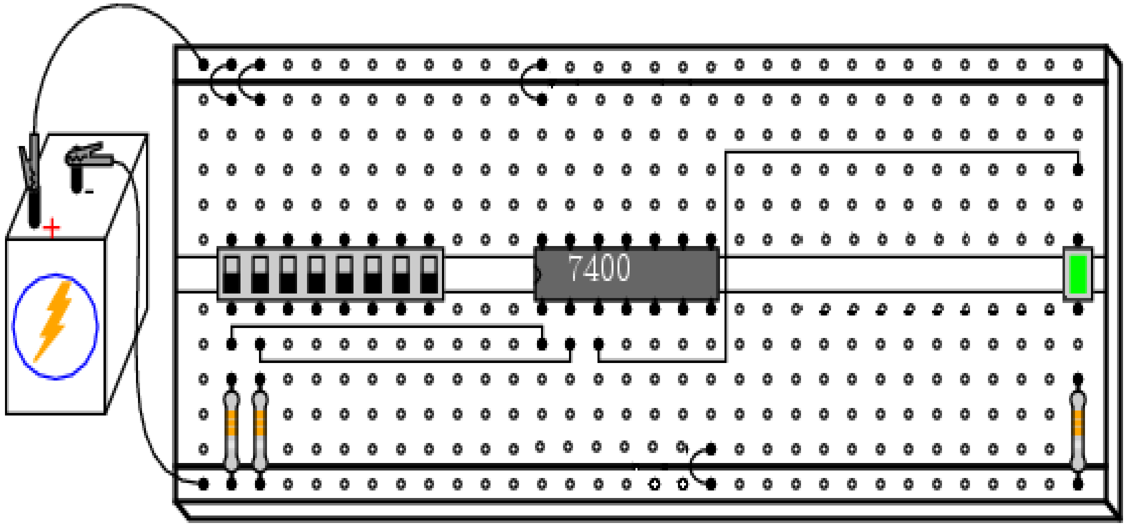
FINAL CIRCUIT

The two 2.2 kΩ resistors are placed in the circuit to avoid floating input conditions on the used gate.

With a switch closed, the respective input will be directly connected to Vcc and therefore be "high."

With a switch open, the 2.2 kΩ "pulldown" resistor provides a resistive connection to ground, ensuring a secure "low" state at the gate's input terminal. This way, the input will not be susceptible to stray static voltages.

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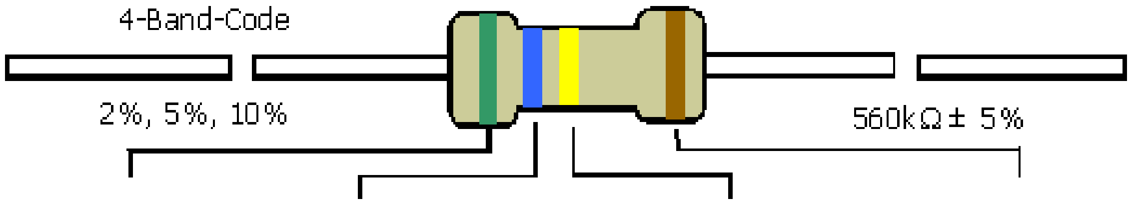
Resistor Color Code Guide



COLOR	1st BAND	2nd BAND	3rd BAND	MULTIPLIER	TOLERANCE	
Black	0	0	0	1Ω		
Brown	1	1	1	10Ω	± 1%	(F)
Red	2	2	2	100Ω	± 2%	(G)
Orange	3	3	3	1KΩ		
Yellow	4	4	4	10KΩ		
Green	5	5	5	100KΩ	±0.5%	(D)
Blue	6	6	6	1MΩ	±0.25%	(C)
Violet	7	7	7	10MΩ	±0.10%	(B)
Grey	8	8	8		±0.05%	
White	9	9	9			
Gold				0.1	± 5%	(J)
Silver				0.01	± 10%	(K)