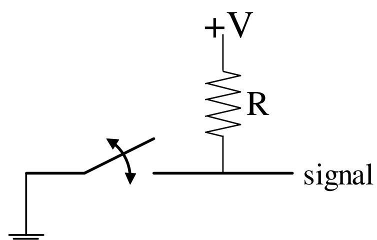
Lab 2 – Combinational Logic I ELE202 FALL2007

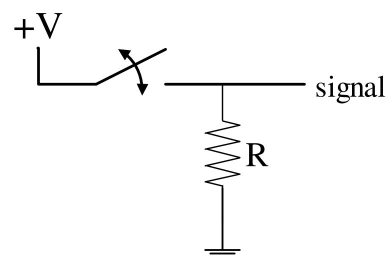
Objectives
- Learn to use real-world switches and LED indicators
- Build and test some combinational logic using standard CMOS ICs

Procedure

1. Input signals – to test logic circuits we will need to apply external input signals, each of which takes on the binary values "0" and "1" which are represented by a low (ground) or high (power supply) voltage, respectively. While you could connect inputs to the power and ground busses using wires, it is inconvenient to have to keep moving wires to change input values; switches are much simpler in that a simple change on the switch position can be used to generate the change of logic value.

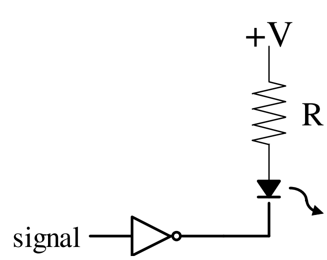
   How to implement input signals depends upon the type of switch; two standard configurations for a single pole, single throw switch (abbreviated SPST – like a household light switch or a doorbell button) are shown below. Each configuration consists of the switch, a resistor R, and wires for connecting to power (+V) and ground. (Note that I was a little sloppy on these diagrams; I didn't put dots on the point where the 3 lines meet, but do mean for them to be connected.) The purpose of the resistor is to either "pull-up" or "pull-down" the output voltage when the switch is open (i.e. the contacts within the switch do not touch). The idea of pull-up or pull-down is that no matter what position the switch is, the output signal is always connected to a constant logic value (it is not "floating" meaning that the value is undetermined). Pull-up and pull-down resistors set the initial logic value for the switch output (or the nominal value for a momentary push button such as a keyboard switch) while also limiting the current flow into/from the next part of the circuit. The exact value for the resistor R is not very important as long as it is not too large or too small; 1KΩ-100KΩ is fine.



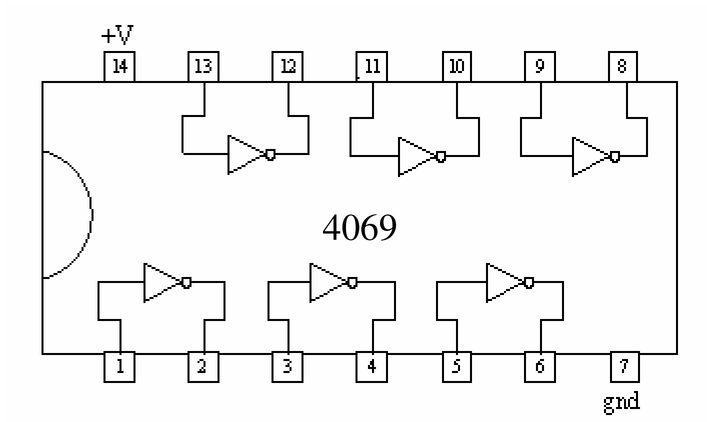


   SPST switches made to fit on the breadboard (so called DIP switches) are available with 4 or 8 switches in a single package since it is common to need multiple switches for multiple inputs. Locate such a package in your electronics kit (or the bins in the lab) and wire up three switches using separate resistors for each. Be sure that your result matches one of these diagrams precisely.

2. Output signals – to observe outputs of logic circuits we can measure a voltage using a voltmeter; however, a simpler method is to connect the output to an LED so that logic "1" will light the LED while logic "0" will not. The circuit, shown to the right, is a simple implementation of such an indicator light. The inverter acts as a buffer to isolate the LED from the rest of your circuit under test; this is particularly important as you build larger circuits since the current draw of an LED can make gates connected to the



same signal work incorrectly. The dropping resistor R, typically in the range 500-1000 Ω, acts to limit the LED current to at most 100 mA. This is very important so that you do not burn out the device. Be sure to always use dropping resistors with LEDs. Wire up a single logic level indicator; check to make sure it works. For the inverter you should use one of the 6 inverters on the 4069 IC (hex inverters) in your kit with pin specification shown below.



3. Basic CMOS gate package – to assemble combinational logic circuits we will need both AND and OR gates with different numbers of inputs. The relevant CMOS ICs that we have available (either in your kit or the lab bins) include:

4071 Quad 2-input OR	4073 Triple 3-input AND
4081 Quad 2-input AND	4075 Triple 3-input OR

   The connections for these devices, and other gates, (the "pin-outs") are shown below. Typically, one can find this information using the databooks in the lab or on-line. You might notice that many similar gate packages have the same pin-outs. From this list of gates, select one 2-input gate and one 3-input gate (which ones is up to you). Fully test each gate by experimentally verifying its truth table; use the switch inputs and logic indicator you built in the first two parts of this lab. Record the truth table on the summary report form.
4. Simple 3-input combinational circuit – you are to assemble and test a logic circuit to implement a 3-input truth table; your specific truth table depends upon which lab section you are in. The options, in table form, appear below. Note that you can either use minterms or maxterms (i.e. brute force) to implement this circuit in SOP or POS forms, or you can use algebraic operations to simplify your circuit, the choice is up to you. On the report form, give an algebraic expression for your Boolean function and sketch your implementation of it using gate symbols.
   a. Test your circuit using switches and the indicator light assembled above. Make sure that all 8 combinations of inputs produce the required output.
   b. Using the 555 timer and 4520 binary counter setup from lab 0 (running at the faster speed), use the counter as the inputs to your combinational circuit (specifically, use pins 6, 5, and 4 as inputs **A**, **B**, and **C**, respectively, so that **C** changes most quickly). Verify the resulting digital waveform from your circuit (e.g. the truth table's output column) on one trace of an oscilloscope; put the signal from pin 4 (**C**) on the other trace. Demonstrate the result to your instructor. Sketch the resulting waveforms (both the output and **C**) on your summary report form.

A	B	C		Monday	Wednesday	Thursday	Friday
				value of Y			
0	0	0		1	0	0	0
0	0	1		1	1	1	1
0	1	0		0	1	0	0
0	1	1		0	0	1	0
1	0	0		1	1	0	1
1	0	1		0	1	1	0
1	1	0		0	0	1	1
1	1	1		1	0	0	1

Troubleshooting

Here are some simple ideas on what to check BEFORE you ask the TA or instructor for help:

1. Check that you've wired the switches correctly so that switching positions generates both logic signals.
2. Check that you have power and ground connected on each device.
3. Check that the ICs and LEDs are oriented properly (i.e. where is pin 1 on the IC? Which wire on the LED is the anode?)
4. Be sure that additional inputs to the ICs are set to the correct values (e.g. pins 2 and 7 on the 14520 must be set to specific values for the counter to operate).
5. Identify parts of the circuit that do work so as to isolate the problem.

Additional Information
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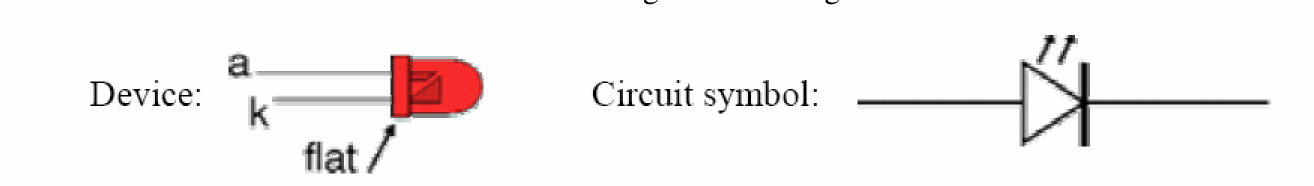
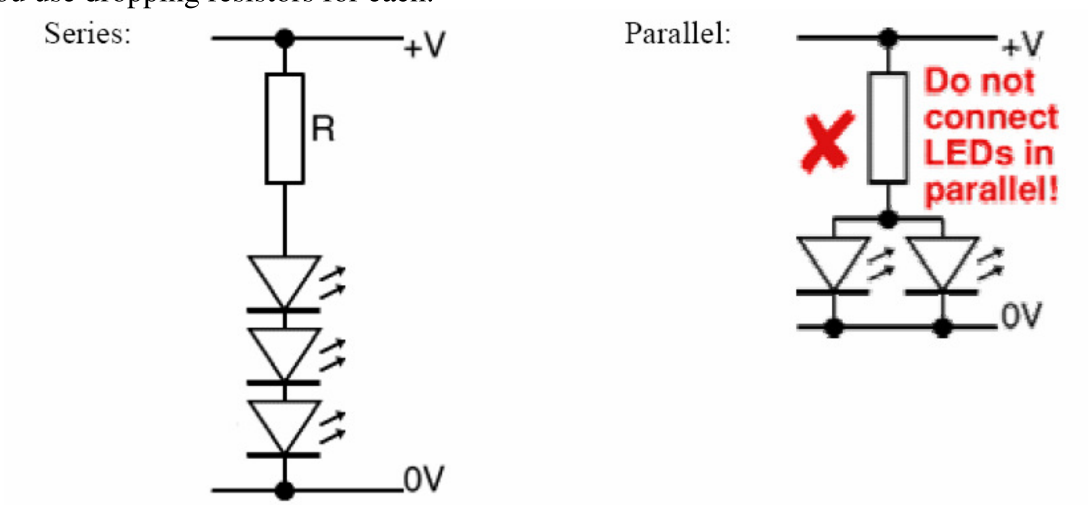
More Information on LEDs:
An LED is an electronic component that emits colored light when a DC current passes through it. As shown below, the anode (a) and cathode (k) are indicated by different length leads or a flat spot on the LED case. Current flows when the anode is at a higher DC voltage than the cathode.



LEDs come in a variety of colors (red and green are common). Remember, LEDs can be destroyed by excessive current, so always use a series resistor!

Note that it is fine to put LEDs in *series* as shown below; the result is a set of lights that work simultaneously. Putting them in *parallel* often doesn't work well (yielding unequal illumination) unless you use dropping resistors for each.

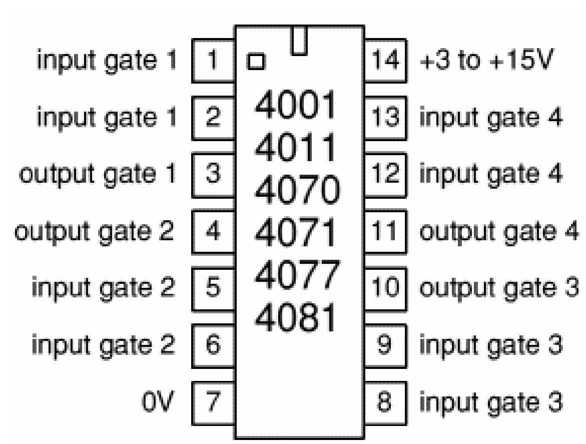


More Information on CMOS ICs:
CMOS is a terrific technology for implementing logic functions for ELE202 lab. It is designed to work with a power supply of between 3 and 18 volts DC (so 9 volt battery breadboards should work fine as long as the batteries are not dead – note that lots of LEDs with small dropping resistors will shorten battery life). There are a number of things to note:

1. Always connect all inputs to a device to something – even if it's just power ('1') or ground ('0'); otherwise your circuit may not work properly. Note that this does not apply to unused gates on a particular IC package. Just make sure that all inputs for those gates that you do use are connected.
2. Outputs are not always able to directly drive both an LED and other gate inputs; hence, use the isolated LED indicator circuit described in part 2 above for indicators.
3. CMOS is not a very fast logic family. Typical gate propagation delays are 30 nsec. Fortunately, this will be fast enough for all of our ELE202 exercises!

There are many ICs in the 4000 series of CMOS. Many of the gate ICs have identical pinouts (shown below), the way in which the gates' inputs and outputs are connected to the pins of the IC. Additional information on the ICs can be found in databooks or on-line.

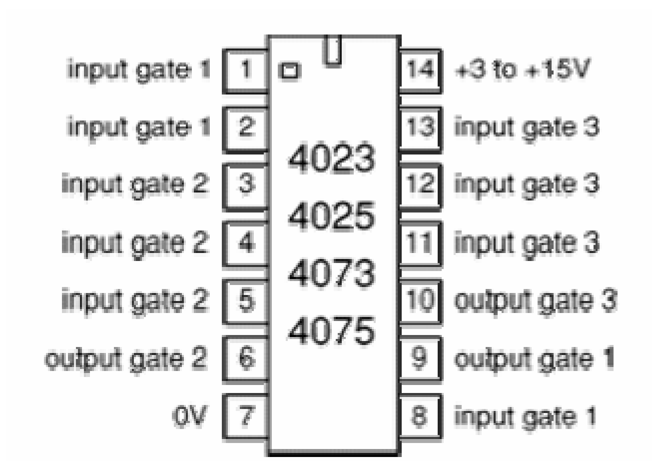
Quad 2-input gates
4001 quad 2-input NOR
4011 quad 2-input NAND
4070 quad 2-input EX-OR
4071 quad 2-input OR
4077 quad 2-input EX-NOR
4081 quad 2-input AND



Triple 3-input gates

4023 triple 3-input NAND
4025 triple 3-input NOR
4073 triple 3-input AND
4075 triple 3-input OR

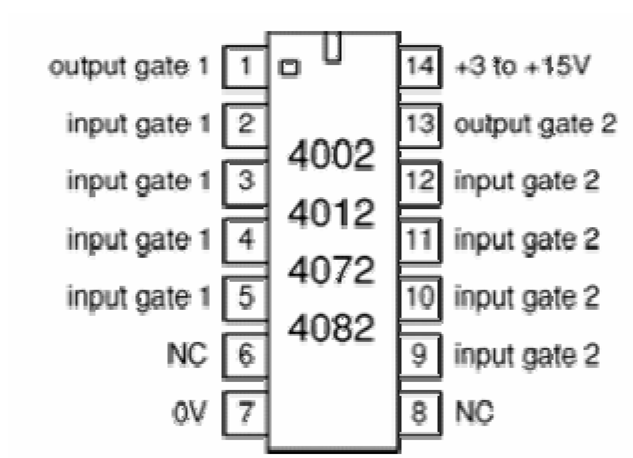
Notice how gate 1 is spread across the two ends of the package.



Dual 4-input gates

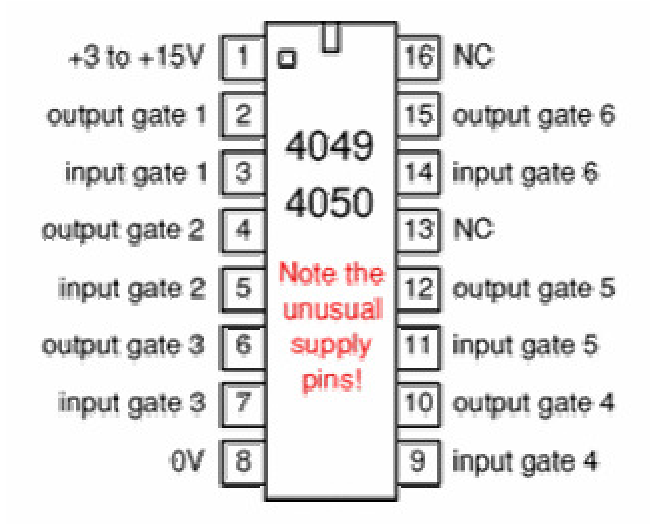
4002 dual 4-input NOR
4012 dual 4-input NAND
4072 dual 4-input OR
4082 dual 4-input AND

NC = No Connection (a pin that is not used).



Inverters and buffers

4049 hex NOT (inverting buffer)
4050 hex non-inverting buffer



Inputs: These ICs are unusual because their gate inputs can withstand up to +15V even if the power supply is a lower voltage.

Outputs: These ICs are unusual because they are capable of driving 74 series TTL gate inputs directly. To do this they must have a +5V supply (TTL supply voltage). The gate output is sufficient to drive two standard TTL inputs or four LS TTL inputs.

NC = No Connection (a pin that is not used).
Note the unusual arrangement of the power supply pins for these ICs!

ELE202 Summary Report Form
Lab 2 – Combinational Logic I

Lab day (circle one): Mon Tue Wed Thur

____
NAME

Gate verification:

2 input gate
Gate type: ___________

Truth table:

Input A	Input B	Output

3 input gate:
Gate type: ___________

Truth table:

Input A	Input B	Input C	Output

Algebraic expression for circuit:

Circuit sketch:

Demonstration:

Portion	Observed by	Date
Scope waveforms		

Waveform sketches (output and **C**):

Score: /8 pts.