Electronics Lab Basics

Preliminaries

0. In Physics 200 you constructed simple circuits with resistors (R), capacitors (C, a.k.a. condensers), and inductors (L, a.k.a. chokes or coils) according to a *schematic circuit diagram*. You used common electrical instruments like digital multimeters (DMMs), digital oscilloscopes ('scopes' or DSO), power supplies (a.k.a. battery eliminators) and function generators (a.k.a. signal generators) to measure the behavior of those circuits. Please refresh your understanding of these devices by reading
`www.physics.csbsju.edu/217/electric_measurement.pdf`
as there will not be time to review these devices in class or lab. Do note the homework problems assigned from that review. For many of you its been a while since you've done electronics, so I expect questions. . . please feel free to ask them!

1. The aim of these electronics labs is to build and understand lots of circuits. Much of the lab report formalism you've followed in other physics labs will be discarded here so you spend the maximum amount of time building circuits. For example, there will be almost zero concern about measurement errors.

2. The 'lab manual' for a lab will consist of an enumerated list of actions, and your lab report will mostly consist of a corresponding numbered list reporting the results of those actions (perhaps just the phrase 'it worked' or a numerical measurement). However, note some additional required components of your report:

   (a) Lab title, date, your name. Note: while you will work individually in lab, I hope you will be discussing/helping your neighbors with the lab.

   (b) A parts list of chips actually used recording the actual chip numbers. Commonly a TTL quad NAND gate would be a 74XX00 where, for example, XX=LS for low power Schottky chip or XX=ALS for advanced low power Schottky chip. See HH 12.1.1–2 for how these 'equivalent' chips differ. Military chips often have more confusing labels. For example a "/00104" (7400 equivalent) carried the following label: `C00 JM38510/ 00104BCB 8337C` Note: it will be graded as incorrect to record every character on a label (as above); just record the pertinent identifying number!

   This parts list serves two purposes: (A) it allows you to return each chip to its proper bin and (B) it requires you to look at each chip as you pull it from the bin and confirm that it is the chip you need. (Not uncommonly students will mis-return their chips screwing up the next student's project.)

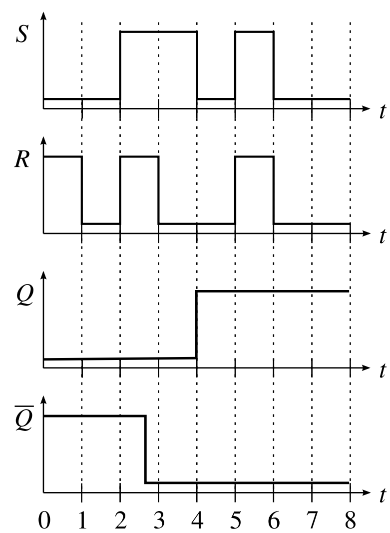
   At the start of the lab you will not know which chips you select, so leave a full blank page to record the chips used *as you use them*.

   (c) Every time you make a measurement with a DMM you must include a schematic diagram (or diagram fragment) that shows exactly where the red and black leads of the DMM were placed. Every recorded DMM measurement should record every digit displayed by the DMM. (If you drop digits the grader must assume that they were not displayed and hence you used the wrong DMM range; this will result in a reduced grade.)

(d) Every time you record a scope trace you must include horizontal and vertical scale settings (and the size of a DIV on your sketch—this is one place where quad ruled notebook paper helps!), the location of ground (zero volts), and the signal frequency. All of these numbers are on the scope display. In addition report the type of Coupling being used on the displayed channel. Feel free to report "same settings as previous" if that is the case.

(e) As required, make clear and legible schematic circuit diagrams. Note that a 'schematic diagram' is not a picture of the physical circuit. The physical IC may put functionally related inputs/outputs at seemly random positions on the package; your diagram should show logically related inputs/outputs together. Note: a 'pin-out' displays the location of inputs/outputs on the package; generally pinouts are included in the lab manual and there is no reason to reproduce them in your report (unless it helps *YOU* figure out your circuit). HH Appendix B describe how to make schematic diagrams (but much of it is more relevant to analog electronics). In particular there is no reason to show power (+5 V) and ground connections in digital schematics (but these are hugely important in analog electronics). Note: generally there is no need to reproduce in your lab report a schematic diagram found in the lab manual.

(f) A timing diagram or stacked oscilloscope trace is often required to show how voltages change at various places in the circuit at the same time. See example right. Use the quadrille rules to *carefully* line up timing events and make sure to label axes and scales.

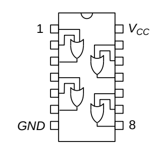


(g) Note: past physics lab reports have requested sections like: Purpose, Theory, Discussion, Conclusion; they are not needed for these electronics lab reports. I do welcome a Lab Critique to help improve the lab, but it is not required.

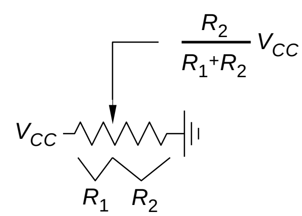
3. You will be building your circuits on a 'protoboard'. At the center of your protoboard you will find an array of interconnected holes on a 0.1 inch grid. The protoboard is designed to accept dual in-line package ('DIP') ICs and allow connection to the DIP pins using the adjacent horizontal row of holes. Use of a protoboard (a.k.a. breadboard) is explained the the following youtube videos:

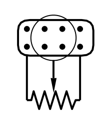
   - `http://www.youtube.com/watch?v=oiqNaSPTI7w`
   - `http://www.youtube.com/watch?v=Mq9XMNsoAd8`

   which you are required to view before coming to the first lab. Additionally your protoboard includes power supplies, a function generator, potentiometers (a.k.a. *pot*), logic indicators (LEDs), BNC connectors, debounced pushbuttons, switches, and speaker. For this class you are required to adopt two consistent practices: (A) color code your wires using red = +5 V (power, V_{CC}), black = 0 V (ground), and other colors for signal wires; and (B) always place chips with pin 1 up (and to the left). Please note that our color code is *not* that used for (120 V, 60 Hz) household wiring; there black is power and white is ground.

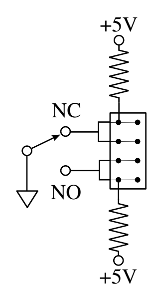


   The pot or potentiometer is the most common item on the protoboard to be destroyed by students. A pot consists of a sweeper arm (denoted by the arrow) that touches a resistive slab at an adjustable location, dividing the resistive slab into two 'resistors'. If the ends of the pot are connected to power and ground (see right), the sweeper samples the voltage in between the ends; the voltage divider equation could be applied to give the sweeper voltage, but in practice neither R_1 or R_2 is known exactly (although they could perhaps be estimated based on how far the pot had been turned). Pots are labeled with the total slab resistance $R_1 + R_2$. On the protoboard, the sweeper is connected to the central four holes. To destroy a pot, all you need do is connect power and ground between the sweeper and an end, and then rotate the knob for small resistance between them; a huge current will flow, burning off the delicate sweeper end. Never draw appreciable current from a sweeper!

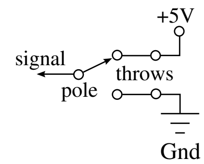




   The other item commonly destroyed by students is the debounced pushbutton pictured to the right. It has two positions: normally closed (NC) and normally open (NO). The common side of the button is connected to ground as denoted by the inverted triangle. In order to get an actual logic high output voltage (rather than an unconnection, i.e., an open) the other side of the switch needs to be connected to +5 V, but you must make this connection through a 'pull-up' resistor ($\sim$ 3 kΩ). A direct connection to +5 V will result (when the switch is connected) in a huge current flow through the pushbutton destroying it. To access the signal generated by the pushbutton, use one of the six remaining junction points (3 for NC, 3 for NO). The picture shows the pushbutton set up to use both sides — if you only need a one type, just connect the appropriate side through a resistor to 5 volts.



A home-made 'side-board' switch bank will be used to provide digital inputs throughout the labs. Each sideboard contains 8 single pole double throw (SPDT) switches. The typical use is to connect one throw to +5 V, the other throw to ground, and take your signal from the pole. Therefore, when you plug the sideboard into the protoboard, make sure that the pole pins go into horizontal signal holes, not the vertical power/ground 'bus' holes. Note: some switches in a bank may be bad. If you suspect a bad switch, connect the output to an LED on the protoboard to verify its operation.



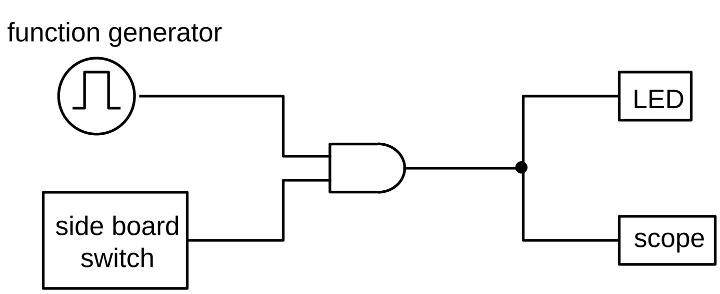
4. Over the course of the lab you will need to make or steal many short connecting wires. Store then in your provided box. DO NOT hide ICs and other components in your box: at the end of each lab return components to the proper storage container. The grader will take off points for each non-wire component found hiding in your box.

5. **Advice:** Retain this (and future) lab descriptions as the attached chip pin-outs will aid you in your digital design project (Lab 6).

Lab 0

0. The aim for this zeroth lab is to become familiar with the protoboard we will be using to build circuits. I assume you have, as requested, reviewed the youtube videos that outline how a protoboard allows solderless connection of simple discrete components and DIP ICs. Your instructor will describe several additional features of the protoboard we will be using in lab and show you where the various components can be found in the lab room. You will build a simple gate circuit and use the function generator (WaveTek 180) and scope (Tektronix 1002B) to test the circuit. Finally you will, using paper and pencil, show in detail how two circuits could be constructed using standard TTL chips on your protoboard.

1. Build the following gate circuit using a quad-AND IC. The traditional number of a quad-AND TTL IC is 7408; grab two differently-labeled quad-AND ICs. As required carefully record each chip's number. This circuit allows a a side board switch to control the transmission of a digital signal (in this case a signal produced by the function generator). Demonstrate your working circuit to your instructor.



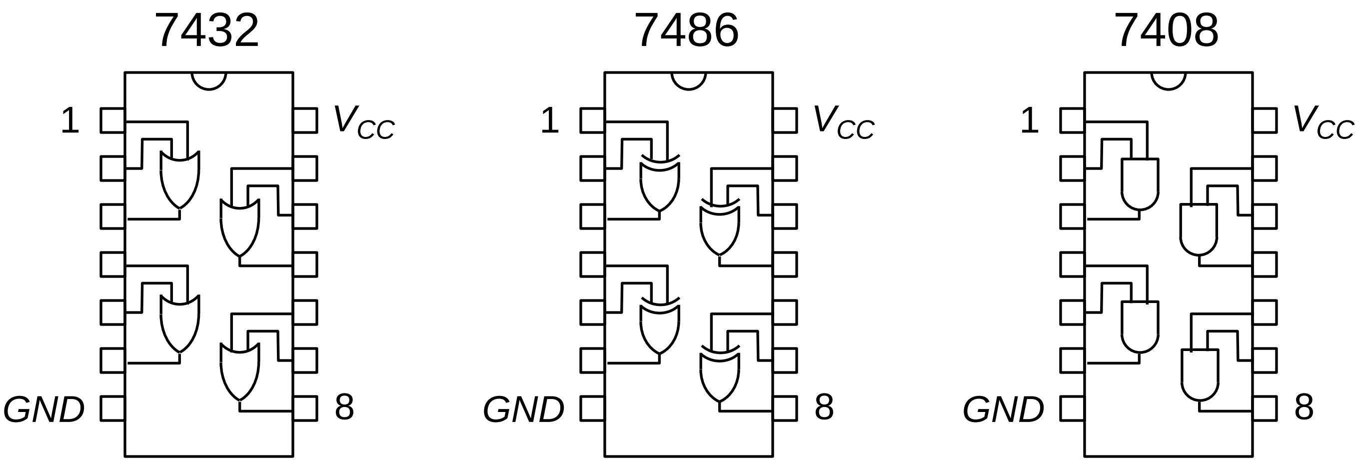
2. The last page of this document shows the 'pin-out' of three TTL chips ('32=quad-OR, '86=quad-XOR '08=quad-AND), circuit diagrams for two simple circuits, and a representation of the face of your protoboard. The first circuit is called a half-adder; it takes two 1-bit numbers (D_1 & D_2) and finds the resulting carry+sum (i.e., $D_1 + D_2 = \text{carry} + \Sigma$) as in the truth table:

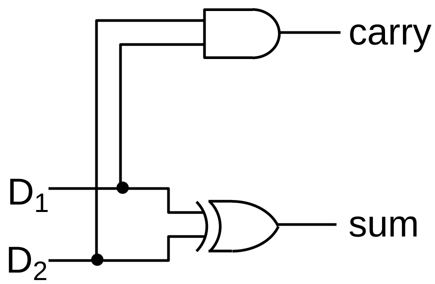
D_1	D_2	carry	Σ
0	0	0	0
1	0	0	1
0	1	0	1
1	1	1	0

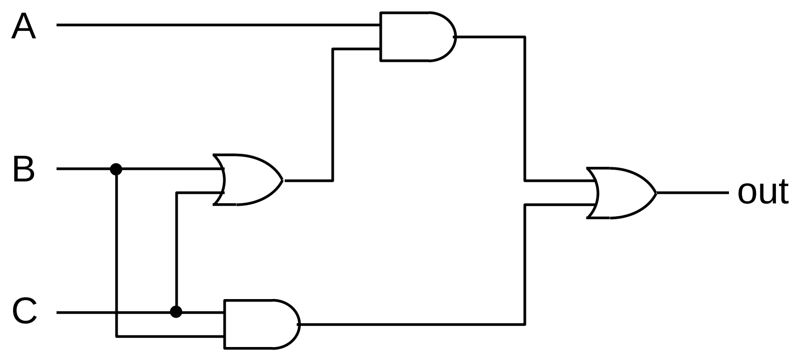
The second circuit provides a 'majority-rule' function for three voters: A, B, C with the truth table:

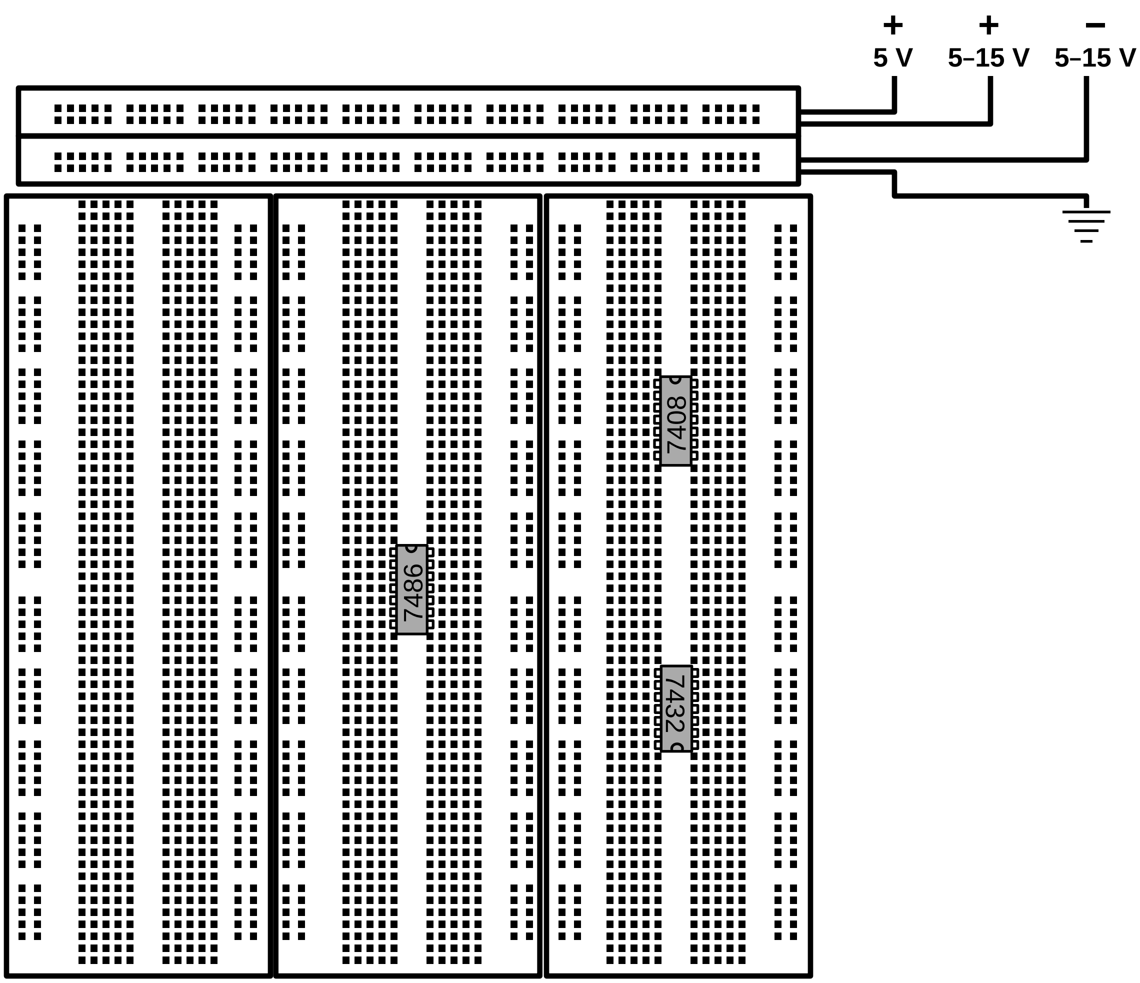
A	B	C	out
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	1
1	0	0	0
1	0	1	1
1	1	0	1
1	1	1	1

Using the provided diagram of the face of your protoboard, draw in every wire required to make these two circuits. Use colored pens to match our color coded wires: red for +5V (a.k.a. power or V_{CC}), black for ground, green (or other color) for the signal wires for the half-adder, and purple (or another distinct color) for the signal wires for the majority rule circuit. For each input (D_1, D_2, A, B, C) label the row of holes that contains that input. Similarly for each output (carry, sum, out): label the row of holes that contains that output. Attach the resulting picture to your lab notebook. Note: circuit pictures as above are rarely a required part of your lab notebook; we are much more interested in the logical schematic circuit diagram. Circuit pictures like this quickly become too complex to understand (but occasionally they can help YOU wire up and debug the circuit).


7432
7486
7408
1
VCC
GND
8


carry
sum
D1
D2


A
B
C
out


+
5 V
+
5–15 V
–
5–15 V
7408
7486
7432