

BREADBOARDING BASICS

In order to get a circuit to function, we need to connect all of the components together and hook them up to the power supply. There are a number of different ways to connect electronic components together to build circuits. For the most part, you will be building your circuits in this lab on a white plastic rectangle with a lot of little holes in it called *solderless breadboard*, which we usually just call *breadboard* or sometimes *protoboard*. The breadboard gives us a way to hook up a circuit quickly without having to spend a lot of time building a printed circuit board (PCB) and soldering all of the components together, only to find out that the circuit was not designed correctly in the first place. On the breadboard, we can test a new circuit design and easily fix or optimize the design. Once we have built a circuit that works well, we can then construct a more permanent version of the circuit on a PCB or some other substrate.

Figure 1a shows a top view of a typical breadboard. Running along the left and right edges of the breadboard are four long columns of holes, called busses; we usually use these to distribute power and ground to all of the components in the circuit. We plug the components into the central area on the breadboard; the gap in the middle is just wide enough for a DIP package to straddle it. In the middle of the breadboard, the five holes on the left of the gap (often labeled abcde at the top and bottom of the breadboard, as shown in Fig. 1a) in each row are shorted together. Likewise, the five holes on the right of the gap (often labeled fghij at the top and bottom of the breadboard, as shown in Fig. 1a) in each row are shorted together. Figure 1b shows how the holes in the top of the breadboard are connected internally with metal traces.

When you insert a bare wire or a component lead into a hole in the top of the breadboard, the wire goes between a pair of spring-loaded clips that both grip the wire mechanically and make a solid electrical connection between the wire and the metal inside the breadboard. In general, you should use #20 gauge, #22 gauge, or #24 gauge solid-core hook-up wire to make your connections on the breadboard. If you use wires of higher gauge (i.e., smaller diameter), the spring clips may not hold them tightly enough. If you use wires of lower gauge (i.e., larger diameters), you may overextend the internal spring clips, which can ruin the use of that hole in future designs. Some larger components, such as large electrolytic capacitors have relatively thick leads, so insert them into the breadboard carefully. To make a connection, strip one end of a piece of hook-up wire (you should strip away about 1 cm of the insulation) and insert the bare end into a hole in the breadboard. Measure the length of wire that you need to make the connection plus about 1 cm for inserting the other end into the other hole. You should try to keep the wires flat to the breadboard and as short as possible. Remove the wire and strip the other end of it. Finally, insert both ends of the wire into the breadboard. Here are a few general guidelines for wiring breadboards:

- Cut your wires to the right length. It's hard enough to debug a complicated circuit on a breadboard without having to cut through a morass of long loops of wire with

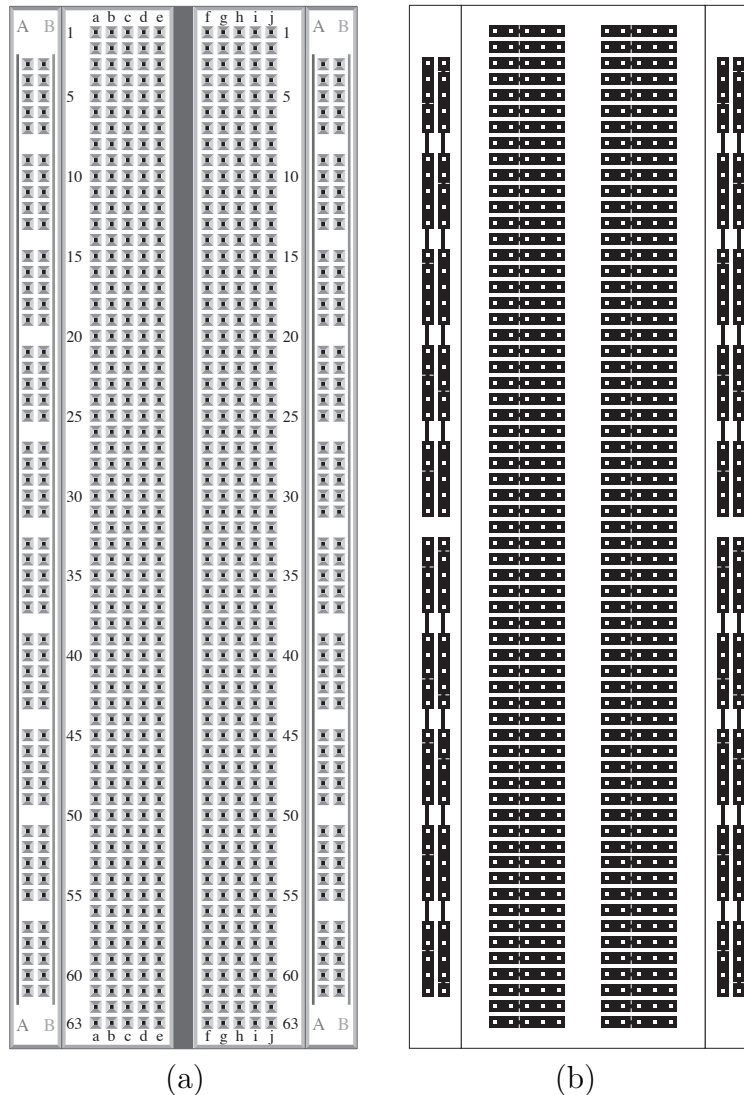


Figure 1: Solderless breadboard (a) top view and (b) cutaway view showing how the holes in the top of the breadboard are connected internally with metal connections.

a machete. If you keep your breadboard neat, it will be easier for you (or your lab instructor) to trace connections in your circuit and debug it.

- Cut off just enough insulation to make a good connection. If you cut off too much insulation, you might have bare wire sticking up out of the hole. Two such pieces of exposed bare wire could make contact and short something out. If you don't strip away enough insulation, then you may not be able to insert the wire in far enough to make good contact with the spring clips.
- Try to keep your wires flat to the breadboard, and try not to make wires loop over other wires or over ICs or other components. If you strap your chips into the breadboard with a bunch of wires, then you have to rip all of the wires out in the event that you

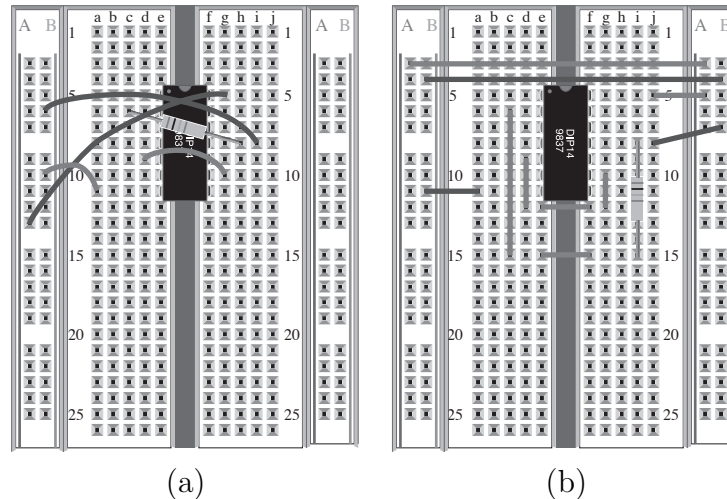


Figure 2: Two alternative ways to wire the same circuit on a breadboard. (a) A messy version of the circuit with long wires that loop over each other and over the IC. (b) A neat version with short wires that don't cross each other and don't loop over the chip. You should always try and make your circuits look like that shown in part b rather than the one shown in part a. Neat circuits are much easier to follow, to debug, and to fix than are messy ones.

need to remove the chip.

- Try to color-code connections of the same type, such as power and ground connections, using wires of different insulation colors. This practice makes it easier to follow connections in your circuit.

Figure 2 shows two different breadboarded versions of the same circuit connections. The version shown in Fig. 2a is messy with long wires looping over each other and over the IC. Moreover, the resistor in the circuit of Fig. 2a crosses over top of the IC. In this case, if we had to remove the IC and replace it with another one, we would have to rip out almost all of the wires. The connections in this circuit are also hard to trace, because wires cross each other all over the place. Imagine what the breadboard would look like with a lot of other ICs and many more wires! On the other hand, the version of the circuit shown in Fig. 2b is connected together with a series of short wires that are flat to the breadboard. Note that none of the wires cross each other and that the IC is not strapped into place by the wires and the resistor. In this case, it is easy to replace the IC or the resistor without disturbing any of the other connections. Note how the resistor connects from one side of the chip to the other by making a series of 90° turns along unoccupied sections of the breadboard. You should always try to make your circuit look more like the one shown in Fig. 2b! It may take longer to be neat about your wiring, but, in the long run, the investment will pay off as time saved in debugging.

When you insert or remove an IC from your breadboard, you should be very careful, because the pins on the sides of the DIP package are made from thin metal that bends very easily. Many an IC has been ruined during one of these two processes. To insert a chip into the breadboard, place the chip down on the breadboard at the location at which you want

to insert it. Make sure that the pins are aligned with the holes in the breadboard. Apply an even and gentle pressure on the top of the chip until it goes into place. For large chips, it is especially important to apply even pressure to both ends of the chip simultaneously. If you don't, it's very easy to smash half the pins against the bottom of the chip. To remove a chip, you need to pull it out straight up, pulling evenly on both the top and the bottom at once. There are special tools called *IC pullers* that look like a funny pair of tweezers that grab the top and bottom of an IC at the same time, so that you can pull out the chip uniformly. If you don't happen to have an IC puller handy, you can remove a chip by carefully prying up the top by a little bit and then the bottom and then alternate until the chip comes free from the holes in the breadboard. If you pull up on just one side until the pins come out of the holes, you will wind up bending half of the pins at the end of the chip opposite that on which you pulled. Sometimes the pins can be bent back, but more often than not, the chip is ruined.