AP207/208 Laboratory Electronics

The Art Of Breadboarding Electronics

ALEX FARINAS

In the next two quarters of AP207/208 lab we will be building everything from voltage dividers to self-contained microcontrollers. The one common component in all of these circuits will be the breadboard that they are built on. This handout is meant as a brief introduction to good breadboarding practice in general and to the specific proto-board that you will be using in our lab.

The Horowitz and Hayes lab manual discusses good breadboarding practice on pages 24 and 25. The two points mentioned in the lab manual are sound connections and logical layouts. Good connections to the breadboard, particularly to probes, will prevent accidental shorts and confusing results due to poor or intermittent electrical contact. One common problem is probing IC leads directly. IC pins are very close together, making it very easy to slip and short adjacent pins. This could damage the part, the proto-board or both, since power supplies and ground are very often next to each other on ICs. Using IC test clips or wires running to a clear area of the board will prevent these mishaps. Another good technique is to mount all components flush with the proto-board surface. Flush-mounted components don't stick up out of the board and are therefore less easily knocked out of place, so trim the leads when necessary. Logical layouts will prevent a lot of frustration when building active circuits as you will be able to tell at a glance if the circuit is connected properly. Many active circuits are damaged by improper application of power supplies to the chip, which should be easy to detect when using a color coding scheme. Keeping the power off when laying out the circuit, and turning signals on last and off first will similarly prevent damage to the active components.

The following is a summary of good breadboarding practice:

- Always make sound electrical and mechanical connections:
  - Use BNC and Banana jacks for off-board connections,
  - Clip scope probes to resistor leads or short wires plugged into the node of interest.
  - Make all components lie flat (trim the leads if necessary), avoid a cable jungle.
- Try to build a logical circuit:
  - Use intuitive directions for signal flow,
  - Place the power supplies in a convenient and logical arrangement,
  - Use a color code to help keep track of complex wiring.
- Turn the power off when you don't need it:
  - Turn power off while laying the circuit out,
  - Turn power on before signals,
  - Turn signals off before power.

An example of good breadboarding practices is shown in Figure 1. Notice that the circuit is laid out neatly, with plenty of space between components and clearly defined power busses. All resistors, capacitors and wires have been trimmed to lie flat on the board. Well laid out circuits like this allow the designer to easily interchange components and perform tests.

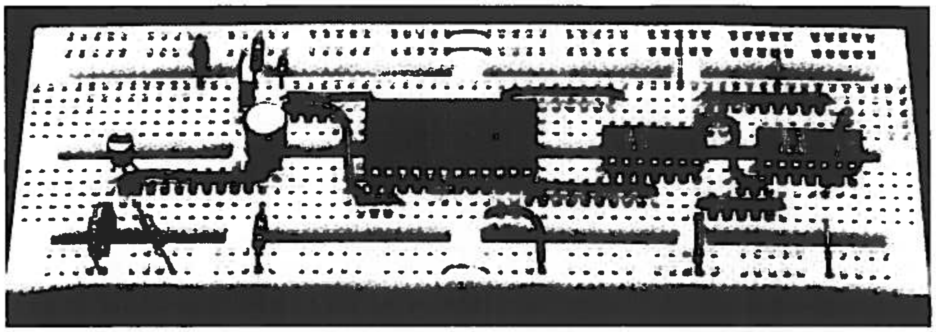

Figure 1. Good breadboard layout (© Copyright 1982 Reston Publishing Company, Inc.)

In the lab you will be using the Global Specialties PB-503 Analog/Digital proto-board, pictured in Figure 2. This section describes some of the features (some very confusing) of the proto-board as well as ways to avoid damaging it. For more detailed specifications ask the TA for a copy of the proto-board instruction manual. The first thing to notice about the board is the large central region. This area contains three universal breadboarding sockets (like the one seen in Figure 1). These sockets are made up of many rows of five holes. All of these five holes are connected internally and are used to make connections between components. In general, rows laid end to end (as in the power strip on the very top) are also connected together. Some notable exceptions to this rule are the two strips facing each other across the deep groove in the center of the three sockets and the strips facing each other across the mounting screws. These strips make excellent power supply busses (leftmost -15 V, left center ground, right center +5 V, rightmost +15 V?) but need to be shunted across the screws (once again, see Figure 1). The strips on top are connected to voltage supplies (two adjusted with knobs above the strip) as well as to the four banana plugs in the upper-right-hand corner of the board. One precautionary note, the holes in the board are meant to accommodate 22AWG solid wire, trying to insert larger leads damages the board (if it won't go in, don't force it).

Outside the central square of sockets lie various specialized modules, indicated by boxes. The box below the banana plugs contains the logic indicators. These LEDs are actively driven by internal circuits which will be damaged if large voltages are applied. These indicators should not be necessary until the digital portion of the course. Below the logic indicators lies the speaker. The speaker has an 8 Ω impedance (at audio frequencies, it's a DC short!) and a power rating of 1/4 W. Applying more than 1/4 W of power to the speaker will quickly destroy it. This amount of power at high frequencies (~1 kHz) will sound quite loud. The size of the speaker makes it very inefficient at radiating low frequency (~50 Hz) waves and therefore the same 1/4 W may not be audible at these frequencies. The connections to this device are as implied by the figure, four pins are provided for each connection to the speaker.

The lower right-hand and left-hand corners house BNC connectors for out-of-board connections (the banana plugs are connected to the power supplies and therefore cannot be used for this purpose). One thing to note here is that the shell connection is connected to ground, although you might think from the figure that it is floating. Moving towards the center one sees the two switch boxes. The SPDT switches are the simplest devices on the board, they connect as shown. The (8) dip switches will connect the respective plug to ground or +5 V, depending on the position of the SPDT switch next to it. This device will also be useful in building digital circuits. In the middle of the bottom row are the two potentiometers. These devices are notorious for their lack of reliability, it is always a good idea to test them before using them. Be careful when turning the knob all the way to either side as this may short the wiper (the center pin) to that pin. It is in general a good practice to add a small resistor in series with the potentiometer so that this does not happen, this will also lead to more predictable results. Note that large currents flowing through the wiper can weld it to the internal resistor, leading to failure or improper operation. Always suspect the potentiometer!

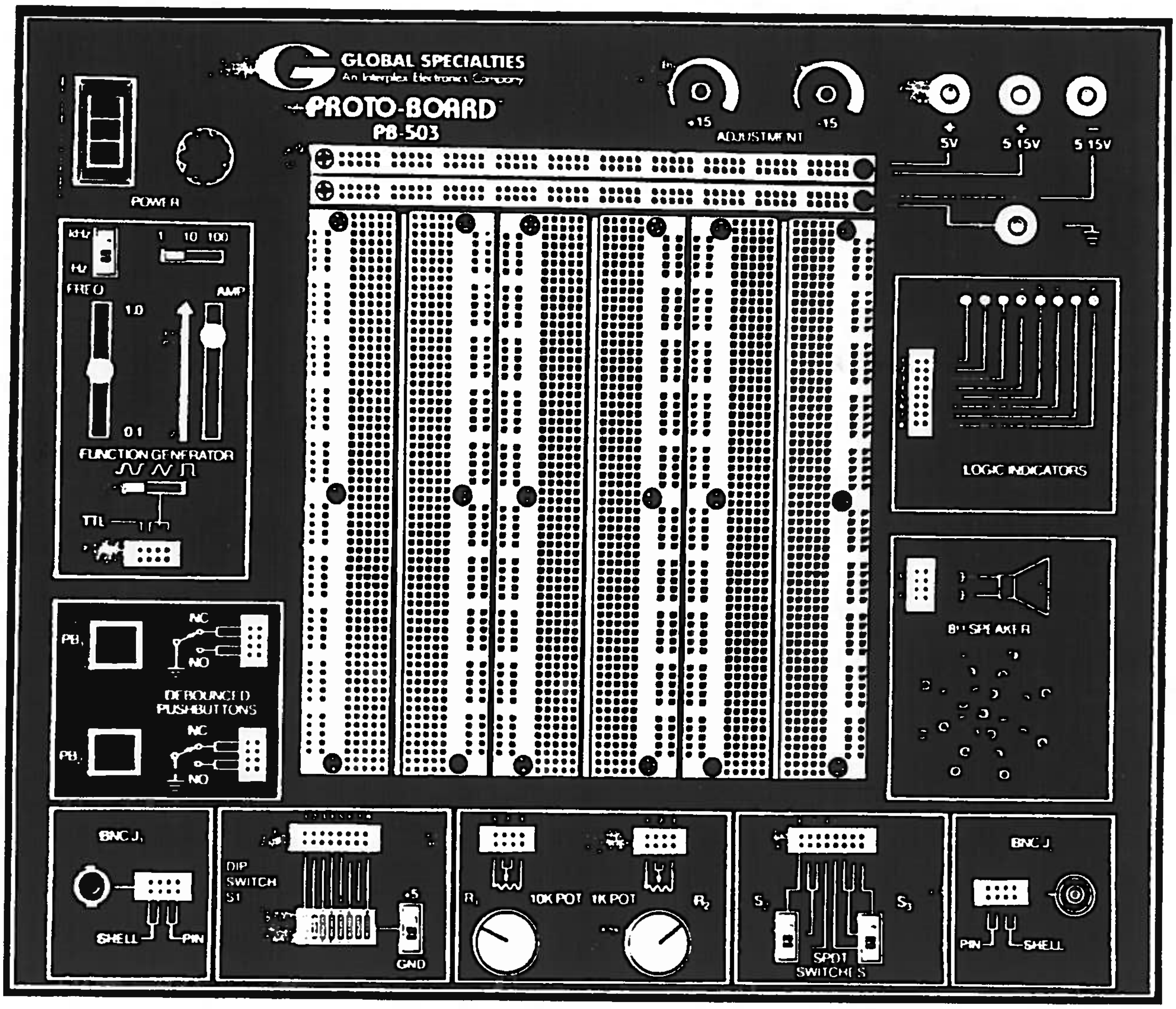

Figure 2. The PB-503 proto-board (© Copyright 1990 Interplex Electronics, Inc.)

Finally, along the left side of the proto-board lie the function generator and the debounced pushbutton switches. The function generator produces three waveforms, sine, triangle and square (TTL is a squarewave with a predetermined amplitude). The frequency of the waveform is adjusted using the left-hand slider and the units and multiplier switches. The amplitude is similarly adjusted with the right-hand slider. The debounced pushbuttons are active devices (capable of sourcing current) which will be useful in digital circuits, they cannot be used to switch signals on the proto-board.

Keep in mind the following precautions when using the PB-503 to prevent damage and confusing results:

- Remember the properties of the built-in modules:
  - Don't use the logic indicators as LEDs or the debounced pushbuttons as switches,
  - Remember that the BNC shells are grounded.
  - Test the potentiometers, they are easily damaged.
- Watch out for power consumption:
  - Don't blow the speaker (watch that DC current).
  - Keep power consumption in mind, particularly unintended power hogs like misconnected circuits (you'll melt a hole in the proto-board).
  - Power components won't fit in the plugs and should not be used on the board.
  - If you're in doubt, kill the power.

Have fun!

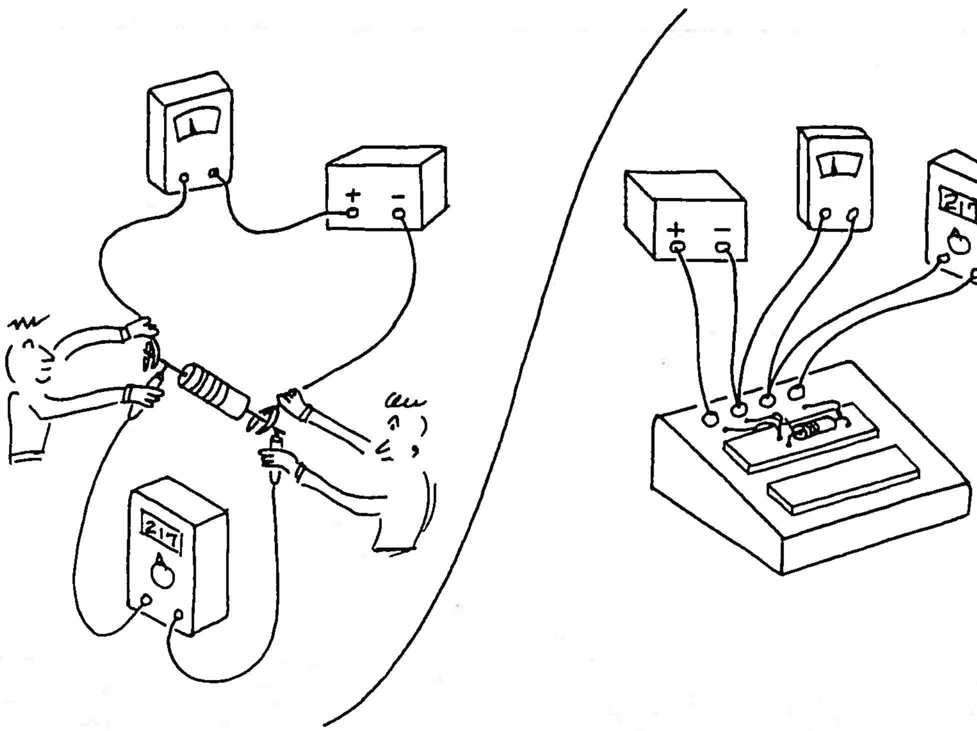

Figure L1.2: Bad and Good breadboarding technique: Left: labor intensive, mid-air method, in which many hands hold everything precariously in place; Right: tidy method: circuit wired in place

Have your instructor demonstrate which holes are connected to which, how to connect voltages and signals from the outside world, etc.

This is also the right time to begin to establish some conventions that will help you keep your circuits intelligible:

- Try to build your circuit so that it looks like its circuit diagram:
  - Let signal flow in from left, exit on right (in this case, the "signal" is just **V**; the "output" is just **I**, read on the ammeter);
  - Place *ground* on a horizontal breadboard *bus* strip *below* your circuit; place the positive supply on a similar bus *above* your circuit. When you reach circuits that include negative supply, place that on a bus strip *below* the ground bus.
  - Use ***color coding*** to help you follow your own wiring: use ***black*** for ground, ***red*** for the positive supply. Such color coding helps a little now, ***a lot*** later, when you begin to lay out more complicated *digital* circuits.

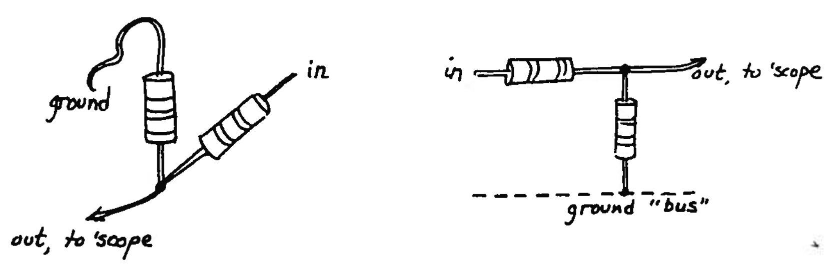

Figure L1.3: Bad and good breadboard layouts of a simple circuit

---

Use a variable regulated dc supply, and the hookup shown in the first figure, above, Fig. L1.1. Note that voltages are measured *between* points in the circuit, while currents are