

VERSATILE, LOW COST ELECTRONICS LAB PROTOBOARD

Timothy C. Scott, Kevin L. Knight

University of Virginia

Abstract

Purchased equipment for teaching basic electronics can be expensive. It may also be delicate and, in the case of many prototyping circuit boards, so small that students have trouble visualizing the circuit before them and instructors cannot easily figure out what the student has done wrong when asked for help. This paper describes a versatile circuit board system that can be built for about \$100 in parts. It contains its own DC power supply, voltmeters, and large blocks with which basic electronic components may be arranged and interconnected using large wires and banana plugs. Typical lab projects using the board involve DC and AC circuits, relays, diodes, op amps and other IC devices. These projects guide students through exercises using a combination of the actual circuit and a Multisim™ simulation. A web site is given from which lab manuals may be obtained.

Introduction

As electronics becomes a part of seemingly every device and system, it has become essential for all engineering disciplines to have some exposure to this topic. Since few students have any physical contact with even the most basic electronic elements (resistors, capacitors, inductors), providing a hands-on experience must be part of the electronics instruction.

A number of commercial resources are available that allow one to build and test various circuits involving electronic components. In the best scenario, we would like each student to have a general electronics "kit" such as those available from the local electronics store to work with on their own. In practice, we are constrained to one or more electronics workstations in a laboratory setting with one or more dozen students and often one instructor or teaching assistant. In such an environment, some significant difficulties arise.

In Mechanical and Aerospace Engineering at the University of Virginia, for many years we provided workstations using standard commercial circuit prototyping or "protoboards" for construction of various circuits involving op amps, transistors, and other basic components. The protoboard is a plastic block with rows of interconnected slots into which lead wires are inserted.

The first problem we were faced with is the small size of the commercial protoboards. Students have trouble seeing what is being created. More importantly, instructors have difficulty trouble shooting circuits because of so many wires configured in such a small area.

The second problem is that these boards are not sturdy enough to survive dozens of students pushing parts into them for hours on end. If one of the holes in the board is broken, students become frustrated when they have wired a simple circuit up and it still does not work.

Student Learning Characteristics Issues

When we used protoboards 20 years ago, we were able to turn some of these equipment failures into learning opportunities. There was also a willingness on the part of students to spend extra time as needed to figure out the problems. While there was some grumbling by students when circuits did not work, the majority were able to grasp the idea that equipment failure and other unpredictable events are a normal part of engineering.

In the present times, student expectations are greater and their patience with problems that are not their fault is small. Because of their relatively low level of intellectual development (Culver, [1]), students expect an experiment to work out with correct results within the time allotted. When these expectations are not met, there is a great deal of frustration which leads to dissatisfaction with the course. Most students do not see a broken circuit board as an opportunity to practice problem-solving skills. Nor are they patient when the instructor cannot locate the difficulty quickly.

In addition, fewer of our student assistants (undergraduate helpers or graduate teaching assistants) have much practical experience with electronics or problem solving. In large classes where graduate assistants must provide much of the help, student dissatisfaction was considerable.

Circuit Board Description

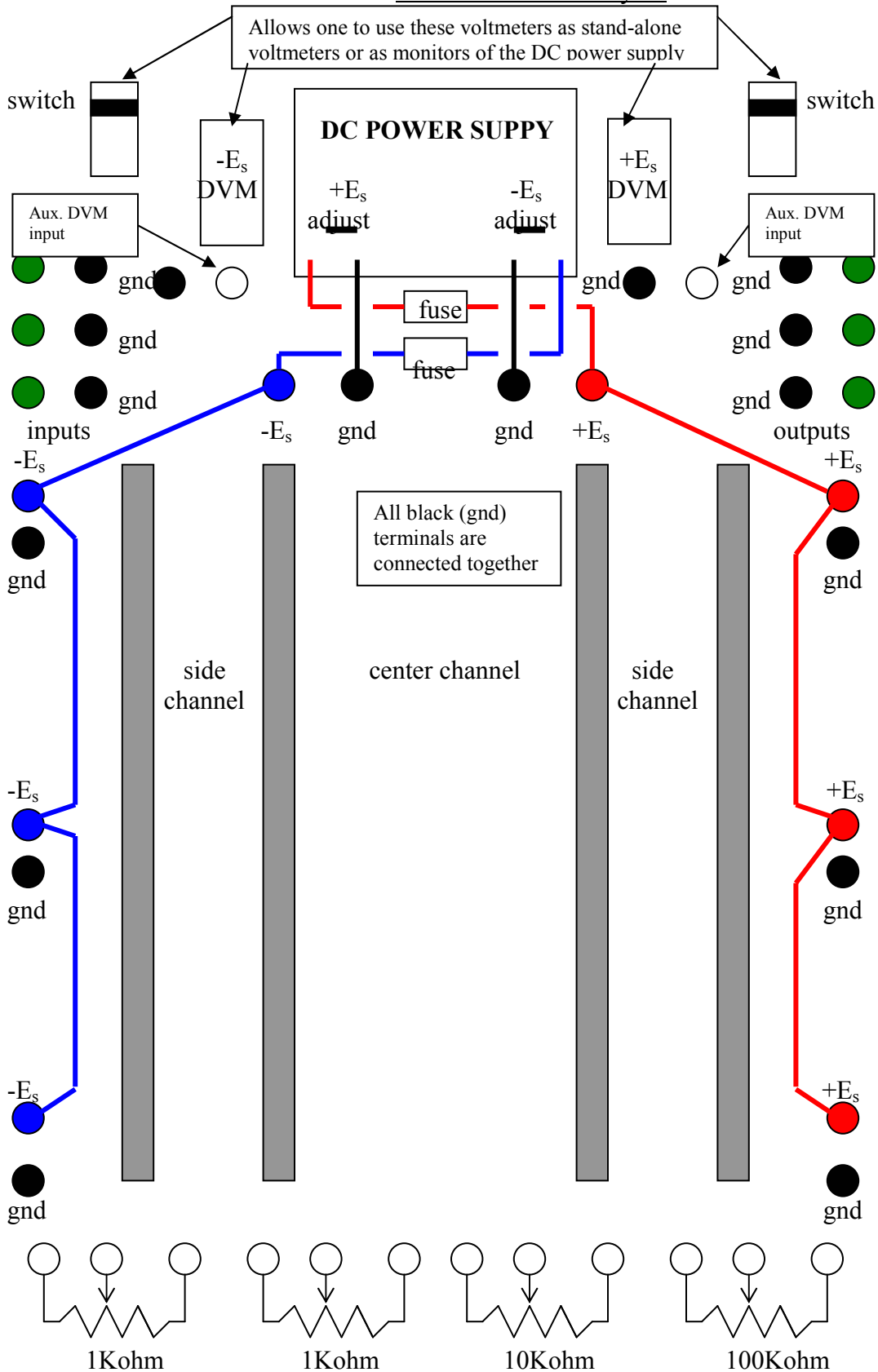
To overcome these difficulties, we decided to create a more rugged system large enough for students to see the circuit and easier for the instructor to troubleshoot. The result is the general circuit board shown schematically in Figure (1).

Figure (2) shows a top and bottom view of the actual board illustrating the general wiring of the unit.

The basic board is 3/4 inch plywood 40 by 100 cm. On this are three channels into which wooden boards containing devices can be aligned. All the terminals are wired up using large wires and banana plugs

At one end of the board is an adjustable DC power supply (Jamco 29225) which provides + and -15 volts at 1 amp. This is supplemented with fuses which are needed to deal with accidental shorting of the power supply. The + and - voltages are distributed to four banana terminals along the top and bottom of the board as shown.

FIG. 1: Lab Circuit Board Layout



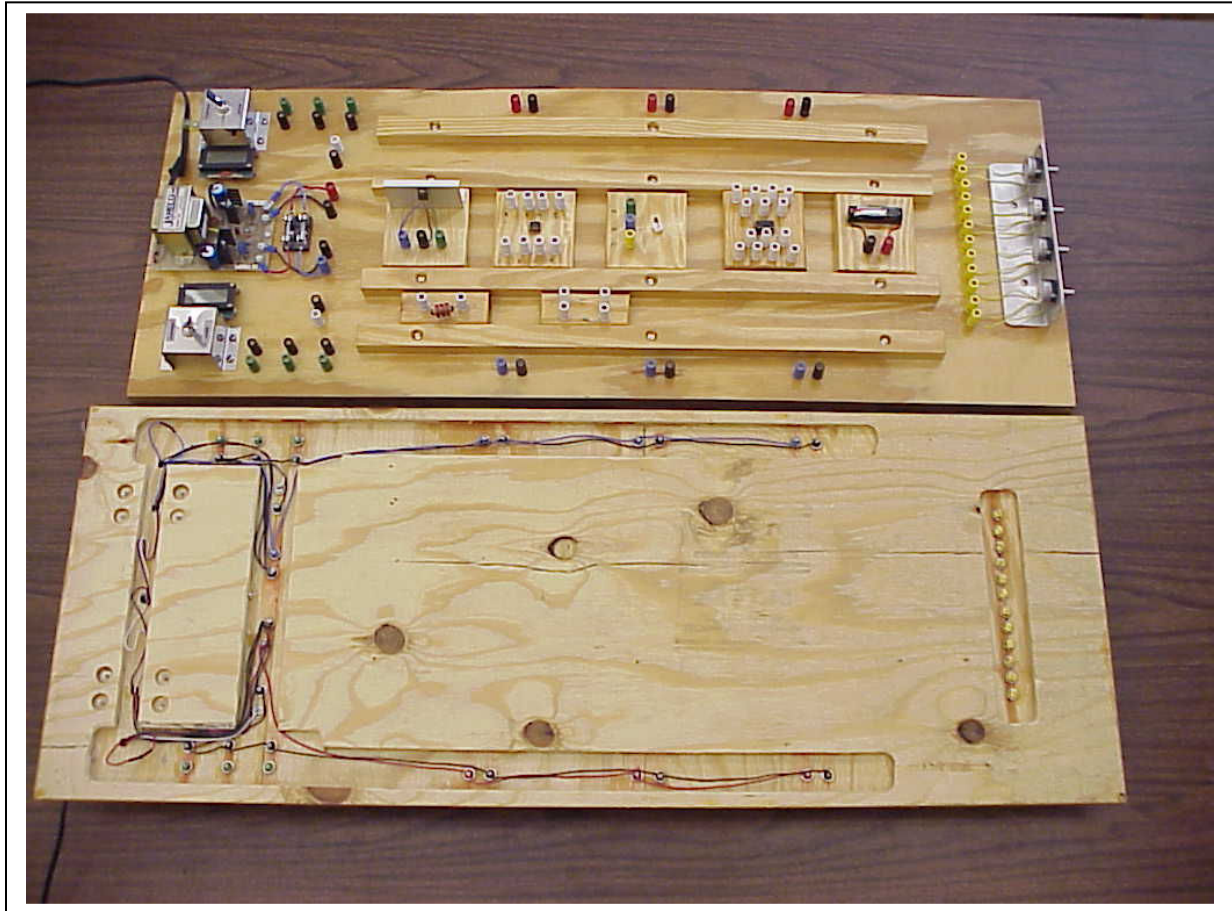


FIG. 2: Photo of Top and Bottom of Board (cover removed).
Showing some component blocks in the channels

Two digital voltmeters (Modutec 176 panel meter) are set to monitor the plus and minus supply voltages respectively with a switch so that they may be used as separate voltmeters as well.

On the power supply end are also three sets of input and output plugs spaced to accommodate dual banana plugs from shielded cable. These can be used to bring in an input from a function generator and send an output to an oscilloscope.

On the other end of the board are four variable resistors as indicated.

All internal wires are run under the board in channels made with a router or milling machine. The bottom of the board is protected by a thin board cover (removed for this picture) for protection.

There are different component blocks for general two lead elements, 8 pin and 14 pin integrated circuits, and 3 terminal transistors. The blocks come in two sizes, 3.5 x 9 cm and 9x9 cm.

Figure (2) shows blocks for (in counterclockwise order starting from the upper right): AA battery, 14 pin IC , transistor, 8 pin IC, constant voltage IC, single component block (inductor illustrated), two component (two resistors illustrated). Details of the two component and 8 pin IC blocks are shown in Figure (3).

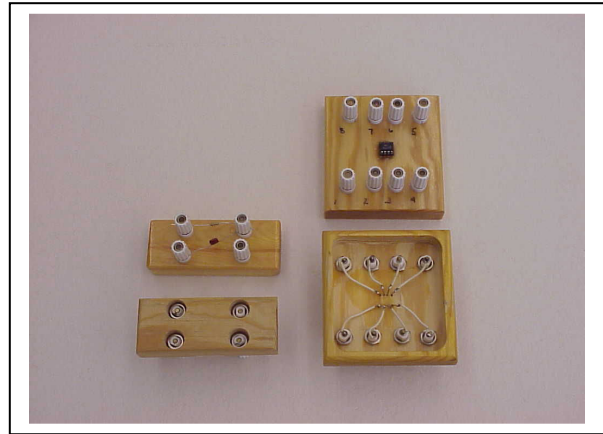


FIG. 3: Details of Two of the Component Blocks

Work Station Layout

Figure (4) shows the general workstation layout. There are eight stations in the lab room. The auxiliary equipment at each work station consists of a computer plus: oscilloscope, DMM, function generator, frequency counter, resistor/capacitor decade box, lead wires, cabinet of electronic parts, typical electronics supply company catalog.

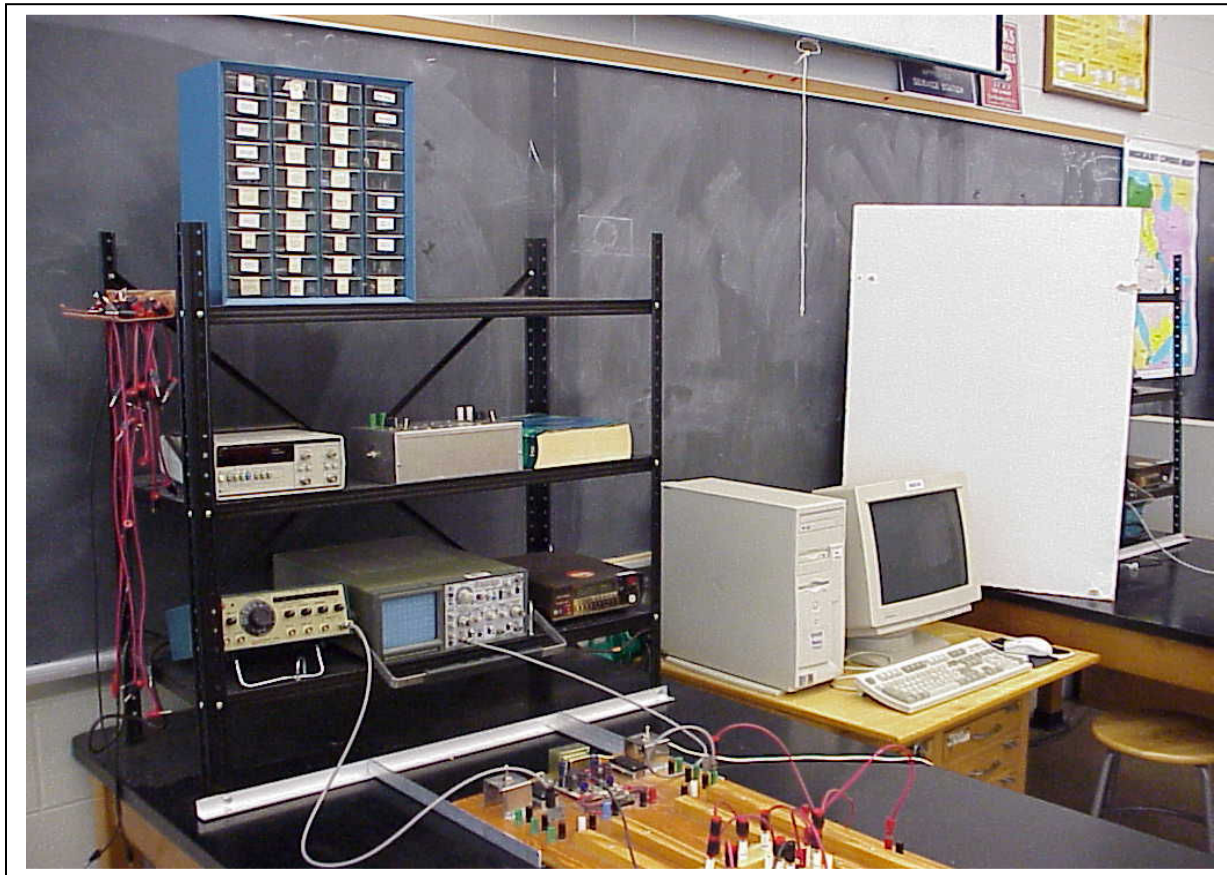


FIG. 4: Typical Lab Workstation

Simply providing the boards greatly reduced the problems of equipment failure and made it easy for students to see the circuits. But other issues had to be addressed as well.

Given a circuit to create, each student group would orient the board differently on the table. They would also take the associated instruments such as an oscilloscope off of the adjacent shelving and place it anywhere around the worktable. Thus when a problem arises, the instructor has to spend time getting oriented to the particular organization of each student group.

We solved this by bolting the board to the worktable in a fixed orientation and securing the other instruments to the associated shelving so that they could not be moved. The three aluminum angle brackets that clamp the circuit board to the metal shelves can be seen in Figure (4). These can be removed with two wing nuts allowing the board to be stored and the table cleared for other uses.

Finally, for complicated circuits, a working example is set up on one of the workstations. Students may look at this example as a visual aid when wiring up the problem themselves. They may also use the example to troubleshoot their own circuit. For example, students will often claim that their transistor is bad when their circuit does not work. They can take the transistor out of their setup and plug it into the block on the working example to check this.

The reader will note that in these paragraphs we have described some very simple and trivial details. However, incorporating these details is critical to a smooth running lab and a successful experience for the students. It has taken us twenty years to learn these lessons!

Applications Details

Until students have constructed a few circuits, they have trouble translating a schematic diagram into a physical circuit. To solve this problem, we lay out the board wiring in a diagram that they can follow. Figure (5) shows the diagram for a circuit to test the frequency response of an op amp as it appears in the manual. After constructing a few circuits, most groups are able to proceed without the need for such diagrams.

Figure (6) shows the board and auxiliary equipment set up for this experiment. Now when the instructor comes to the group to review progress or solve problems, he or she encounters the same basic organization at each workstation.

In most experiments, a simulation of the circuit using MultisimTM is conducted simultaneously. Students compare their experimental results with the simulation and use the simulation to explore issues that we cannot address with the test rig.

For example, once the basic operational amplifier circuit is working, students are asked to use the simulation to see what happens when the input impedance of the op amp IC is changed.

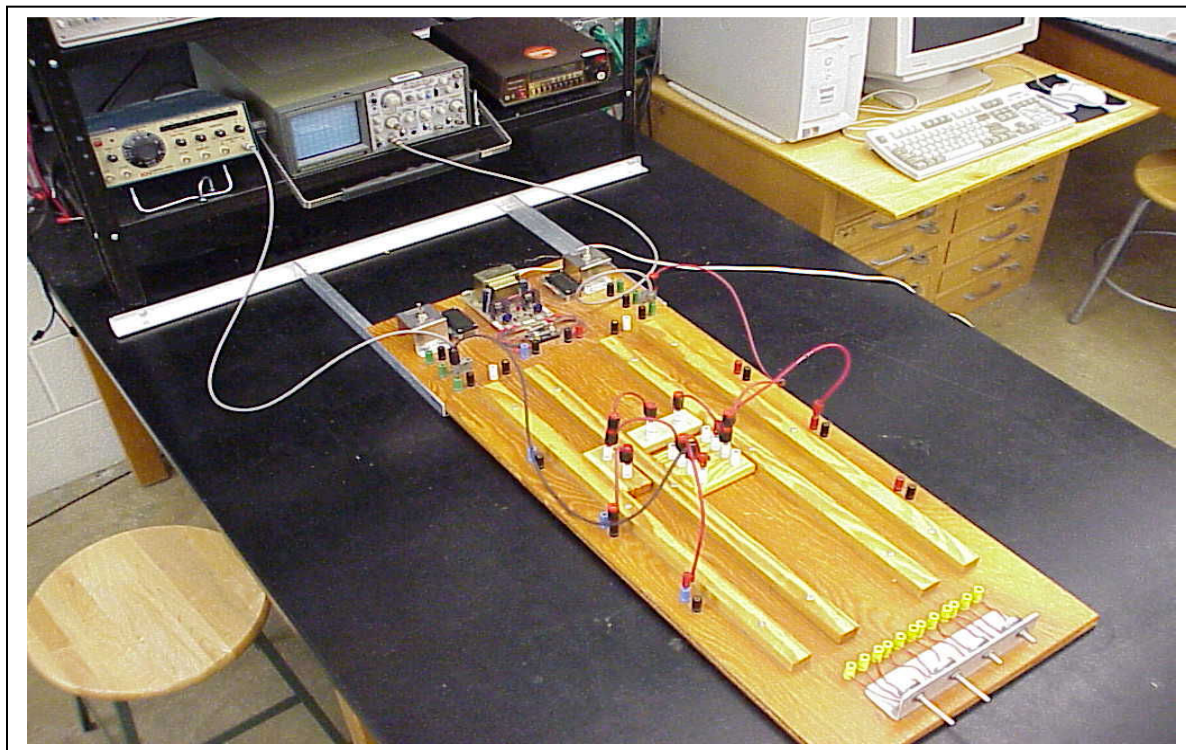
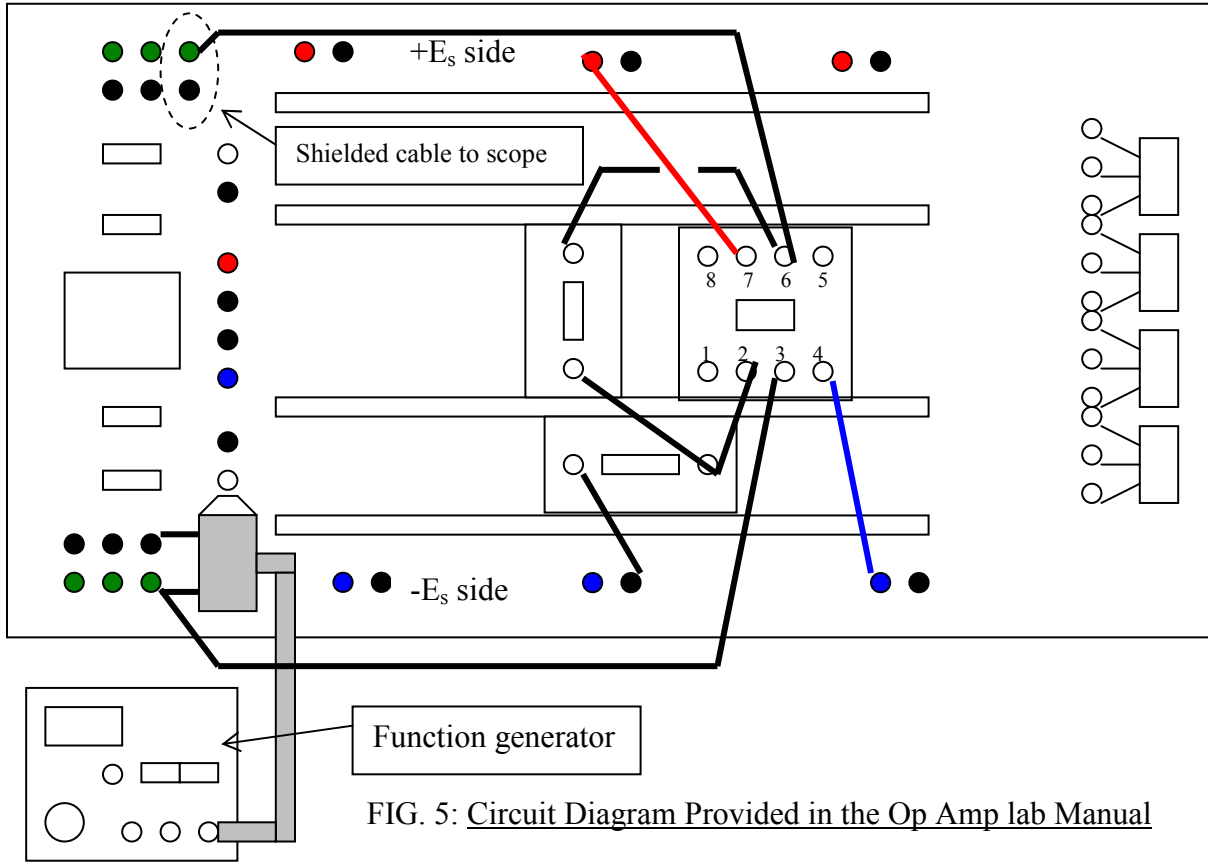


FIG. 6: Workstation Setup for Op Amp Experiment

Use in the Curriculum

The curriculum in Mechanical and Aerospace Engineering deals with electronics in three courses. The first two are experimental methods courses in the third (junior) year. There are 90 students in these courses broken down into 6 sections of 15 students each. We have eight workstations available in the lab. The circuit board is used for experiments in DC and AC circuits analysis, diode and transistor characteristics, operational amplifiers, frequency to voltage and voltage to frequency converters, relays and logic circuits, and several experiments involving various basic sensors.

Mechanical and Aerospace engineering students do not take a separate course in electronics.

A fourth year (senior) course in mechatronics uses the boards for several experiments in digital signal processing.

Conclusions

The experimental circuit boards described here may be constructed using easily available parts. We have used them for more than five years with only minor maintenance problems. A supply of extra meters and power supplies is cached since the models of these available from suppliers are subject to change over the years. It is important that all the student workstations be identical and, as noted, as student proof as possible.

Many of the lab manuals used in these courses can be accessed through the UVa student toolkit at toolkit.virginia.edu for the MAE 381 and MAE 384 courses.

Bibliography

1. Culver, R.S., and Hackos, J.T., "Perry's Model of Intellectual Development", *Engineering Education*, Dec. 1982, pp. 221-226

TIMOTHY C. SCOTT is Associate Professor and Director of Laboratories in the Department of Mechanical and Aerospace Engineering at the University of Virginia

KEVIN L. KNIGHT is Senior Electronics Technician in the Department of Mechanical and Aerospace Engineering at the University of Virginia