Session 2249

Application Specific Troubleshooting and Problem Solving Tools for the Electrical Engineering Technology Laboratory

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Abstract

Several application specific circuit boards and techniques have been designed for use as instructional tools in the Electrical Engineering Technology (EET) laboratory. The primary use of these boards is to serve as an efficient, productive and user friendly platform to introduce electronic circuit problem solving concepts to EET students. Two application specific boards are currently in use. The first is a three-stage transistor amplifier circuit with movable jumpers to configure it into different circuits. The second is a two stage Op-Amp board that allows standard components to be easily configured into Op-Amp circuits for use in the laboratory. These instructional tools provide an opportunity to introduce graphical problem-solving techniques and team concepts into practical student laboratory experiences

This paper describes the circuit boards, the methodology involved in their design and a description of the layout and construction. Laboratory problem solving applications and simulation projects based on these boards are described, and laboratory scenarios are presented.

Introduction

Electronic troubleshooting is a skill that can take a number of years to develop. Mastering this skill is critical for Electrical Engineering Technology (EET) graduates entering the modern workplace. A prime objective of educators is to develop tools and techniques that can significantly shorten this time frame for students with limited electronic experience.

This paper describes instructional tools and techniques developed for use in teaching the troubleshooting course (EET 276) at Purdue University Statewide Technology (PST) sites.

Methodology for the Discrete Amplifier Board

Troubleshooting is typically considered to be an integral part of all EET courses. At Purdue University, EET 276 reinforces the electrical and electronic concepts presented in the first three semesters in EET by presenting actual circuits/systems situations in the laboratory for the student to diagnose and repair. This course is considered to be a capstone course for the two-year EET graduate. The utilization of an application specific transistor amplifier circuit board provides an excellent opportunity to reinforce and apply previously presented circuit techniques.

To achieve sufficient complexity and versatility the circuit board was designed around a three-stage discrete transistor amplifier utilizing NPN and PNP transistors. The following features were used as design guidelines:

1) Complexity - Contain a multi-stage amplifier circuit that was typical of those presented in prior course material.
2) Stand Alone - Operate as a single board experiment platform while withstanding normal wear and tear.
3) Programmable - Provide opportunities for easily introduced faults that would be critical to the circuit's performance, repeatable, but blind to the student.
4) Cost Effective - Utilize parts and construction techniques that were both inexpensive and readily available.
5) Simulation - Use parts that are modeled in the student versions of circuit simulation packages currently in use.

Circuit Board Design

The circuit that resulted from the previously stated design considerations and the course objectives of EET 276 is shown in Figure 1.

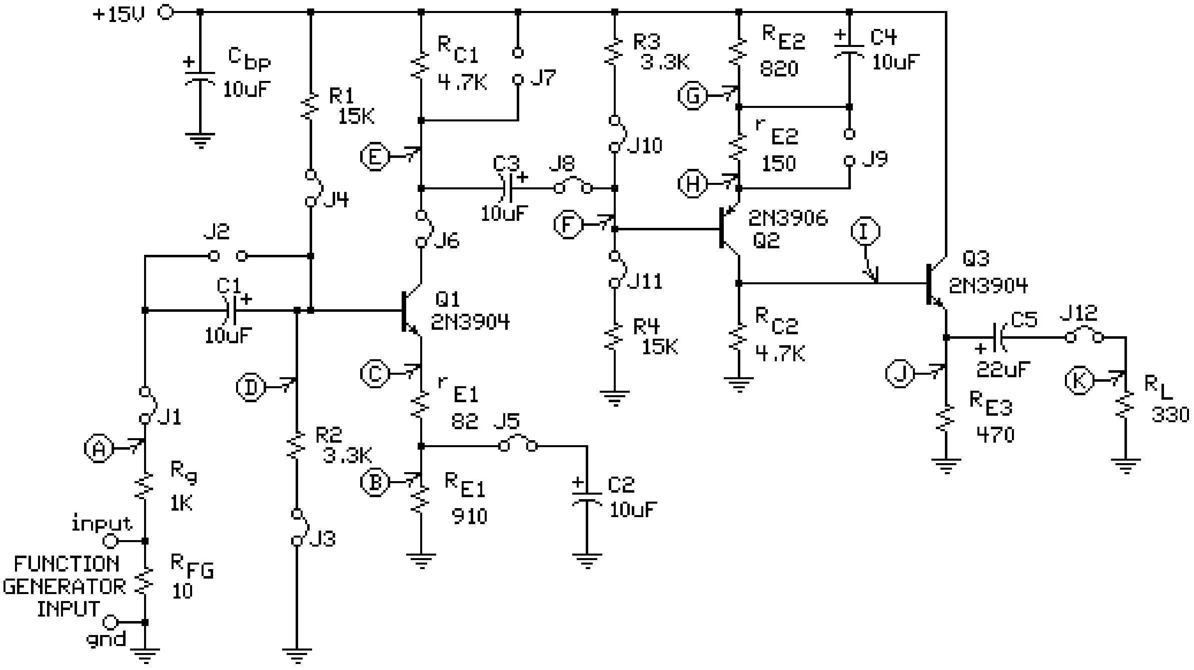
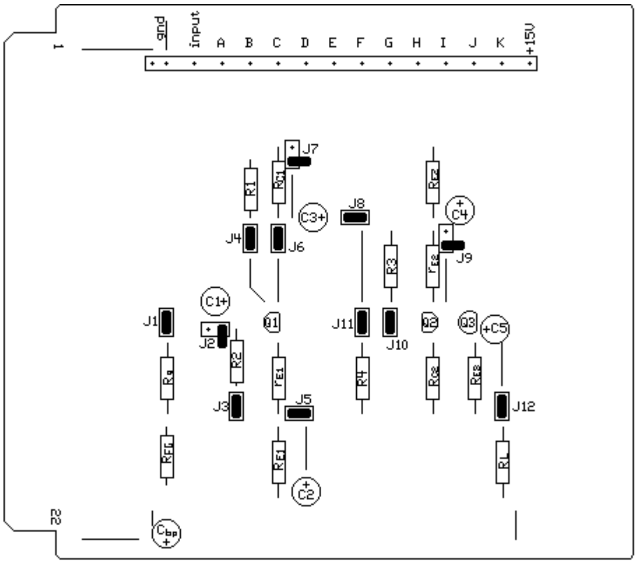


Figure 1-Instructor Schematic

Figure 1 illustrates the versatility of the board with its nine movable jumpers that can be physically "programmed" to provide a number of singular fault situations or combined to provide compound faults. The student's schematic is identical except that the jumpers have been removed, but the test points A, B, C etc., remain and are accessible on the edge of the circuit board.

The component layout is shown in Figure 2. The current boards are constructed on a standard proto vector board featuring 0.1 inch centers and push on jumpers. A three inch diameter plastic cover is mounted over the components, allowing the instructor easy access but still concealing what jumpers have been changed. The left side of the circuit board contains contacts that allow it to be plugged directly into a backplane platform to receive power or into a separate edge connector socket as a stand-alone platform. The test points, A, B, C, etc., that students have access to are pinned out along the top edge of the circuit board. Also included is a listing of the function of each jumper for the instructor's information.

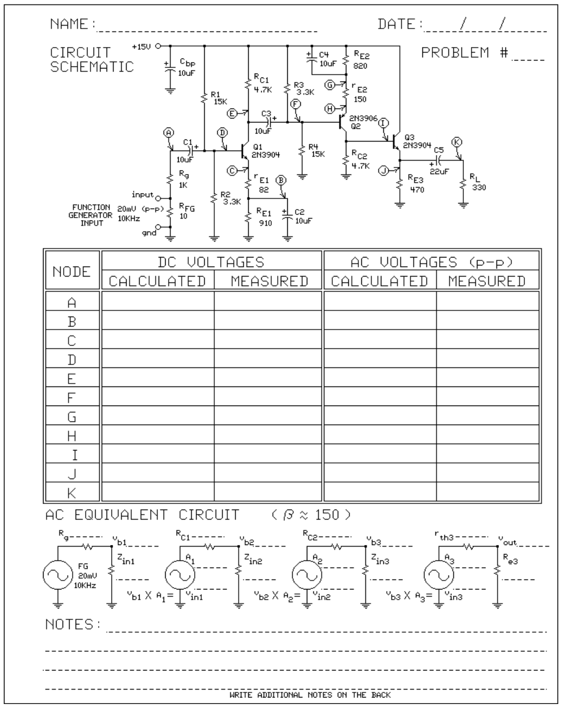


ALL JUMPERS SHOWN IN THEIR NORMAL OPERATING POSITION.

KEY

JUMPER	FUNCTION
J1	OPEN C1
J2	SHORTED C1
J3	OPEN R2
J4	OPEN R1
J5	OPEN C2
J6	OPEN Q1 COLLECTOR
J7	SHORTED R_{C1}
J8	OPEN C3
J9	SHORTED r_{E2}
J10	OPEN R3
J11	OPEN R4
J12	OPEN C5

Figure 2-Circuit Board Component Layout



NAME: ______________________ DATE: ___/___/_____

CIRCUIT SCHEMATIC

PROBLEM # ____

NODE	DC VOLTAGES		AC VOLTAGES (p-p)	
	CALCULATED	MEASURED	CALCULATED	MEASURED
A				
B				
C				
D				
E				
F				
G				
H				
I				
J				
K				

AC EQUIVALENT CIRCUIT ($\beta \approx 150$)

NOTES: ______________________________

WRITE ADDITIONAL NOTES ON THE BACK

Figure 3-Student Worksheet

Laboratory Utilization

Shown in Figure 3 is the student worksheet used in conjunction with a circuit board problem. As previously discussed, the student schematic has no indications of jumper locations. The information used in the troubleshooting assignments comes from student calculations (expected DC and AC values at the test points), simulations and laboratory measurements using authorized test equipment. A typical assignment utilizing the circuit board prior to introducing faults involves the following:

1) DC & AC values calculated for the test points given.
2) PSpice verification of calculations.
3) Experimental verification of calculated values.
4) Development of a problem solving flow chart for the circuit.

Once the expected values are determined, the students use them as a basis to determine the exact nature of the instructor introduced fault.

Shown in Figure 4 is a typical student PSpice simulation showing several of the test points as DC values. This computer simulation of the bias points is intended to support and confirm the values produced in their normal calculation techniques. Figure 5 contains an example of the flow chart outline that the students use to establish their specific flow charts to use in the lab.

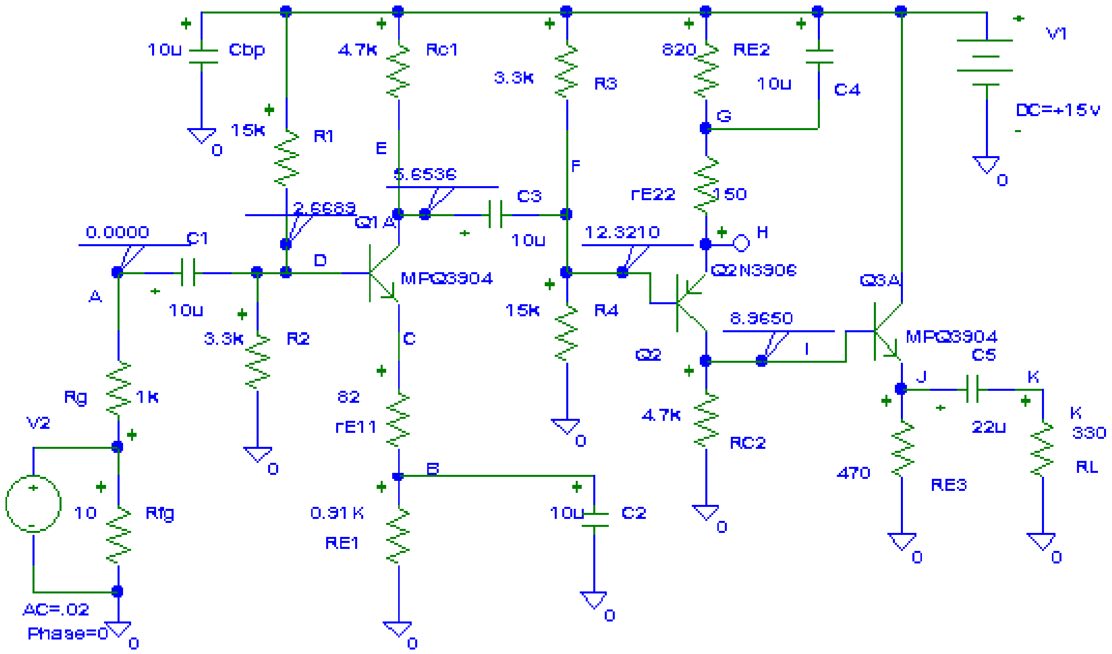


Figure 4-Student PSPICE Simulation (DC Values)

A Typical Fault Scenario

Since this circuit board is primarily intended to be used in the introductory portion of the troubleshooting course, the faults are normally introduced as singular faults. Multiple faults inserted on the same board are reserved for a more advanced situation such as a lab practical or a final exam. Students are also advised that induced faults will represent either an open or shorted component, but they have no knowledge of which parts can be altered.

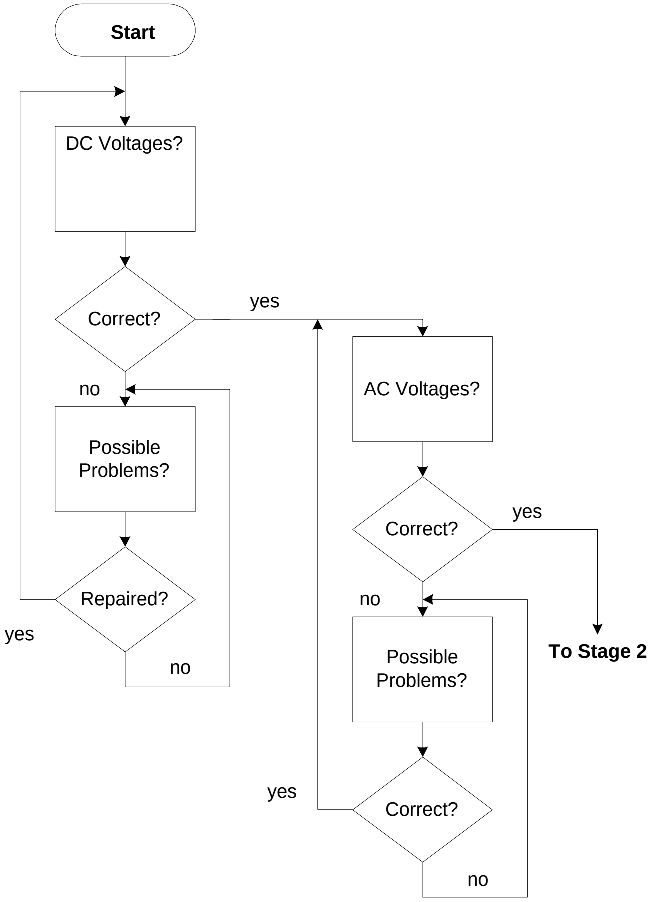


Figure 5-Student Flow Chart Guide

A typical fault that is used to provide a worthy challenge for most classes is the fault referred to as Problem # 9. This fault is inserted into the board by causing jumper number nine to short the swamping resistor r_{E2} (see Figure 1) of the second stage amplifier. Students tend to compare measured DC values to the calculated values at the test points to arrive at their conclusions as to where the problem lies. In this case, to find the DC voltage at G & H equal should indicate a shorted r_{E2} resistor. Normal operating conditions indicate only about a 0.3 volt DC difference between G & H, so there is a tendency for the students to move to another test point dismissing the small voltage as non-consequential (probably a meter error).

The obvious next step is to start signal tracing the circuit from the input to the output as presented in previous lectures. Since a quick look at the output shows distortion and clipping, there must be a problem with the input. Shorting the swamping resistor has drastically increased the gain of the second stage causing the clipping and reflects a change in input impedance back to the first stage. When the second stage transistor (Q_2) saturates, its input impedance no longer follows the small signal model used for calculations and loads the first stage causing it's output to clip also. Students home in on this clipped output as a symptom of a fault in the first stage and usually spend the allotted time spinning their wheels before mandatory help is given. The positive feedback on this problem is that once students experience the frustration of chasing the wrong symptom, they tend to be more open minded and cautious in their future troubleshooting.

Op-Amp Board

Shown in Figure 6 is the layout of the Op-Amp board as seen from the top of the board. The op-amps are indicated by the triangle with the inverting and non-inverting inputs identified.
This PC board is mounted to the top of a 12x7 inch aluminum chassis. Plastic push fasteners provide easy access to the bottom of the board where the ICs are mounted in sockets on a piggyback board. Plug-in options allow the instructor to use several different configurations of Op-Amps. Power is supplied through banana jacks on the top side of the board and routed through the PC board to the op-amp sockets. Connection points on the top of the board allow the construction of a two stage inverting (non-inverting) op-amp circuit by placing jumpers or discrete components in the correct locations. The solid lines between connection blocks indicate wired connections and the Znx blocks indicate where discrete components can be connected to construct the exact circuit required.

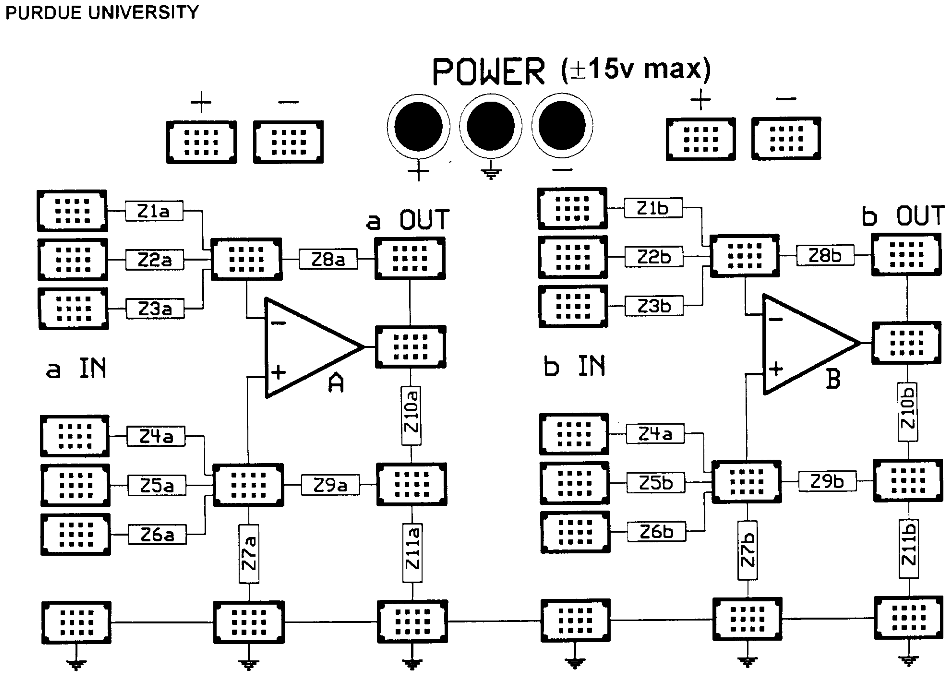


Figure 6-Op-Amp Board

The Op-Amp board allows students to construct circuits as they are schematically presented in their texts. In introductory electronics courses the visual effect of circuits that produce signal flow from left to right is a valuable addition to the lab experience. This instructional tool facilitates experimentally verifying a large number of different op-amp circuits in a relatively short period of time. Creating circuits that perform as expected is a confidence builder for students, as well as providing valuable laboratory experience in critical areas.

Typical Lab Application

Students are provided with lab material requiring a specific circuit to be constructed or designed. Preliminary calculations are done to find DC, AC values as requested and then the circuits are simulated on PSpice. Simulations include DC, AC or transient analysis as required.

After the circuit is constructed on the board using the prescribed discrete parts and jumpers, data is taken to support the calculations and simulations. Troubleshooting exercises are added by replacing components in the circuits with defective or wrong value parts. Since the students have access to the parts on the topside of the board, the instructor has to disguise the problem by painting or taping the defective part.

Future Plans

Experience is the best teacher and using these boards in several sessions of EET 276 has drawn attention to some areas for refinement. The first area that will be addressed in the next revision is to revise the student worksheet. The voltages calculated and measured that are recorded on the schematic drawing will move closer to the circuit point of their origin. Many times students were observed studying the table to determine the problem rather than relating the voltages to the component that was controlling them. This should improve student performance by reducing the time lost and confusion caused by having to refer back and forth between the schematic and the table.

A second area that will be addressed is to allow more up front time for the circuit analysis and simulation of the circuit so that any differences between theoretical answers and experimental measurements can be successfully addressed. Coverage of component tolerances, transistor model deficiencies and the accuracy of assumptions normally used in an EET program will be expanded.

Conclusions

Troubleshooting is a hands-on application of engineering theory and practice. Using instructional tools such as previously described, provides students with real world activities in the laboratory that apply principle and theory previously encountered in a more formal albeit less realistic context. Teaching troubleshooting has been described by some educators as “courting disaster.” However, with instructional aids that provide predictability, repeatability, productivity and understandability, teaching troubleshooting can be constructive as well as enjoyable for the instructor.

Bibliography

1) Malvino, **Electronic Principles,** Glenco, 1998.
2) Pease, R.A. “Troubleshooting is More Effective With the Right Philosophy”, EDN, V34 January 5, 1989.

3) Matsuda, Electronic Troubleshooting, Prentice-Hall, 1992.

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