AC 2011-801: A NEW PEDAGOGY FOR THE ELECTRONICS LABORATORY

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Introduction

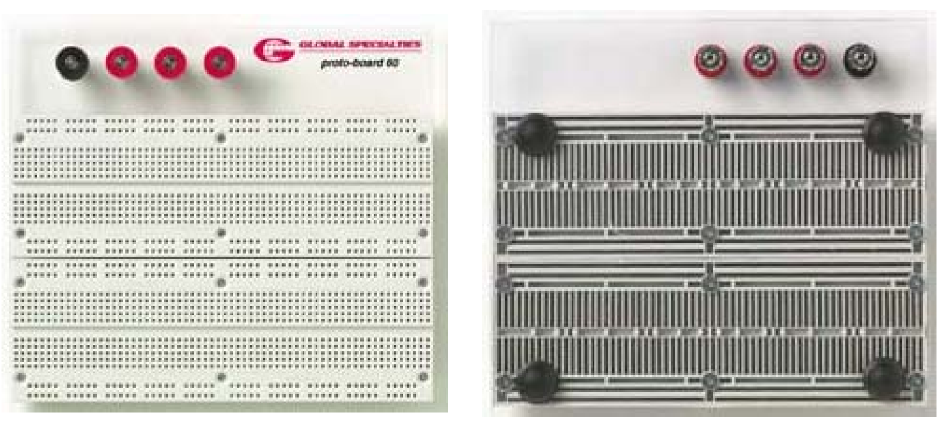
For decades, laboratory instruction of electronic circuits and devices has been centered on standard plastic dual-in-line (PDIP) components and integrated circuits such as the uA741 operational amplifier inserted in a breadboard for testing. Prior to this method many engineering programs used circuit board trainers for instruction. A current trend is to use trainers such as National Instruments ELVIS platform. Dedicated training systems are relatively expensive. The longevity of the dual-in-line IC and breadboard is due in part to it being relatively inexpensive. The combination teaches the student the invaluable skills of circuit layout and trouble-shooting. Proposed in this paper is a new concept in the art of laboratory instruction which combines the circuit trainer concept with the tried and true breadboard method. Using this concept, laboratory instruction can now be focused on modern surface mount components and ICs such as the uA741 (and others such as the TL081 and TL051) in the small outline (SO) package. The development of this concept is the direct result of collaboration between engineering faculty at Hochschule Harz (University of Applied Studies and Research) in Wernigerode, Germany and Southern Polytechnic State University in Marietta, Georgia, USA. The discussion that follows includes an overview of past and current methods in electronic circuit and device laboratory instruction, an overview of surface mount electronic components and devices used in current industry printed circuit board design, a design review of the new proposed system, and a discussion of how the system has been used in the laboratory to teach electronic design along with associated outcomes.

Past and Current Laboratory Instruction

Current electronics laboratory instruction involves several pieces of expensive test equipment: DC power supply, digital multimeter, synthesized function generator, and digital oscilloscope (see Figure 1). The least expensive is the breadboard (see Figure 2). The student assembles the electronic devices on the breadboard. The breadboard provides a simple mechanism to electrically interconnect the electronic devices. The top surface of the breadboard has 22 AWG gauge holes to insert the pins of the electronic device. The holes are referred to as contact points or tie points. Underneath the surface of the breadboard are strips of metal that form an electrical node. The metal strip has spring clips that hold the inserted wire in place. The spacing between holes is 2.54 mm or 0.1 inch. The node can be extended by daisy chaining 22 AWG wire to other breadboard tie points.

The primary advantage of using a breadboard is the quick, mechanical construction of the electronic circuit which is crucial for a typical electronics laboratory of three hour duration. If the student assembles the circuit incorrectly, with correct troubleshooting, the student can make the necessary corrections quickly by adding or removing the appropriate interconnecting wire. The primary disadvantage of the breadboard is that with time and student abuse, the mechanical interconnecting nodes become problematic. The connections can become weak and in some cases, nonexistent. The student will quite often strip the insulation of the interconnecting wire excessively and force the wire to snake underneath the surface of the board causing unwanted connections and even electrical shorts. Other disadvantages are contact resistance, inductance, capacitance, and low frequency range which usually do not factor into traditional electronics laboratory exercises. Fortunately, the breadboard is relatively inexpensive compared to the other test equipment. When the breadboard becomes troublesome it can simply be replaced.

Figure 1: Agilent Technologies Test Bench Photo
(courtesy of Agilent Technologies[1])



Top View Bottom View

Figure 2: Breadboard with clear acrylic base
(courtesy of Global Specialties[2])

From a historical standpoint, the modern breadboard has it origins in the late 1960's and early 1970's. The style shown was developed by Ronald J. Portugal of EI Instruments, Inc. and filed for patent in December of 1971 (US Patent D.228,136). The transparent breadboard shown in Figure 2 was developed by Eric Blauvelt of Interplex Electronics, Inc. and filed for patent in May of 2002 (US Patent 6,685,483 B2).

A current variation of the electronics test station centered about a breadboard is shown in Figure 3. The example shown is typical of electronic trainers. The trainer consists of a DC power supply and a function generator. Shown in the figure is an inexpensive hand-held digital multimeter.

The trainer allows the student to build circuits and perform limited tests outside of scheduled lab times.

Figure 3: Portable Analog-Digital Trainer
(courtesy of Elenco Electronics, Inc.[3])

Another variation is the National Instruments ELVIS system shown in Figure 4. The design is centered about a breadboard mounted on a printed circuit board (PCB). The breadboard connects to traces on the PCB that allow for easy connection to external test equipment. The PCB fits nicely onto a base unit that has additional test features.

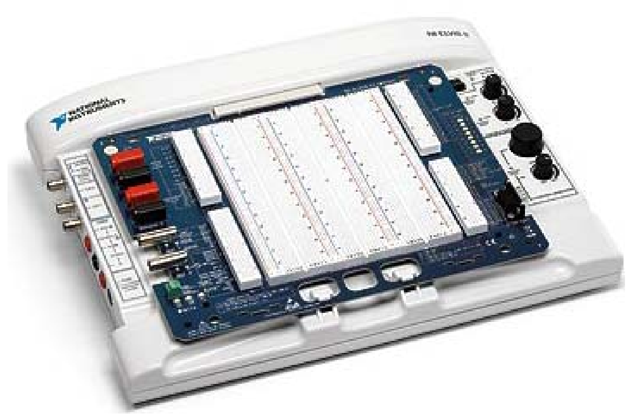


Figure 4. National Instruments ELVIS
(courtesy of National Instruments[4])

A departure from the systems shown centered on the breadboard is the concept of electronic circuit trainers. The electronic circuit trainers mount the electronic devices onto circuit boards. The concept predates the introduction of the modern breadboard of the 1970's. In most trainers, the circuit design is fixed allowing for only slight variations. A current example is shown in Figure 5. Laboratory instruction of this type centers on the usage of instrumentation and the reinforcement of theoretical calculations. Measurement points are available to verify circuit operation. The trainer may include its own power supply.

Figure 5: ME3200 Electronic Instrumentation and Measurement Trainer
(courtesy of Agilent Technologies[5])

Dual-in-line and Surface Mount Electronic Devices

Dual-in-line and surface mount are packaging types used in printed circuit board manufacturing. Dual-in-line is associated with through-hole printed circuit boards. Through-hole technology was the dominate method of printed circuit board design until the mid 1980's when surface mount began to take over the industry. Surface mount technology allows for a much denser population of electronic devices. Shown in Figure 6 is a TL081 Operational Amplifier in both the plastic dual-in-line package (PDIP) with 8 pins and the plastic small outline package (SO) with 8 pins.

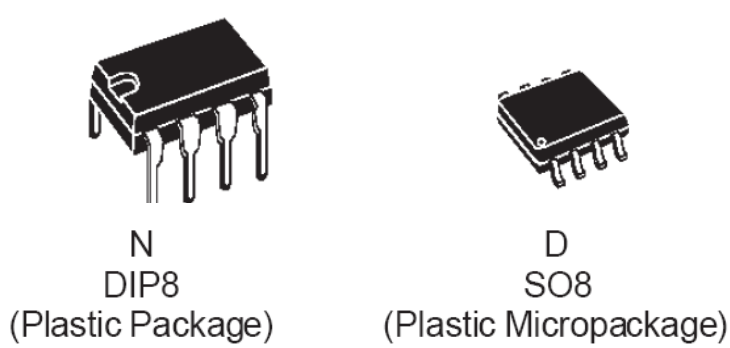
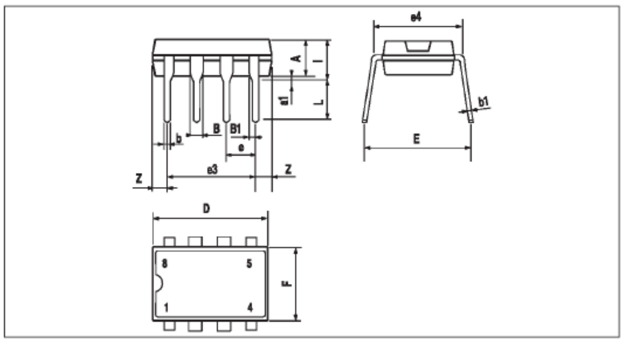


Figure 6: Through-hole and Surface Mount packaging
(courtesy of ST Microelectronics[6])

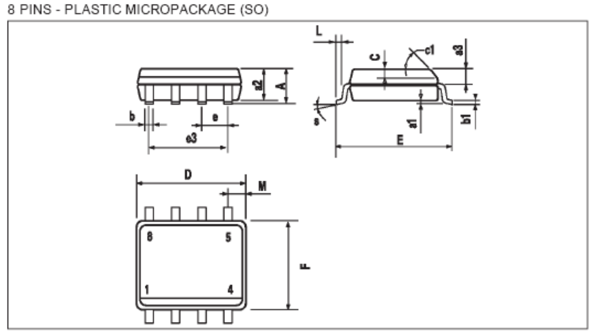
The dimensions of the PDIP8 package in length, width, and height are 10.92 mm × 6.6 mm × 3.32 mm. The pin spacing is typically 2.54 mm or 0.1 inch. The length of the pins from the base of the package is a maximum of 3.81 mm or 0.15 inch which is sufficiently long to go through the drilled hole of through-hole printed circuit boards and be soldered. The much smaller SO8 package dimensions are 5.0 mm × 4.0 mm × 1.75 mm. The pin spacing is typically 1.27 mm or 0.05 inch. The length of the pins from the base of the package is a maximum of 0.25 mm or 0.01 inch. The pins are designed to be soldered to the surface of the printed circuit board. Figure 7 shows the complete dimensions of each package type.

PACKAGE MECHANICAL DATA
8 PINS - PLASTIC DIP



Dimensions	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A		3.32			0.131	
a1	0.51			0.020		
B	1.15		1.65	0.045		0.065
b	0.356		0.55	0.014		0.022
b1	0.204		0.304	0.008		0.012
D			10.92			0.430
E	7.95		9.75	0.313		0.384
e		2.54			0.100	
e3		7.62			0.300	
e4		7.62			0.300	
F			6.6			0260
i			5.08			0.200
L	3.18		3.81	0.125		0.150
Z			1.52			0.060

PACKAGE MECHANICAL DATA
8 PINS - PLASTIC MICROPACKAGE (SO)



Dimensions	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			1.75			0.069
a1	0.1		0.25	0.004		0.010
a2			1.65			0.065
a3	0.65		0.85	0.026		0.033
b	0.35		0.48	0.014		0.019
b1	0.19		0.25	0.007		0.010
C	0.25		0.5	0.010		0.020
c1	45° (typ.)					
D	4.8		5.0	0.189		0.197
E	5.8		6.2	0.228		0.244
e		1.27			0.050	
e3		3.81			0.150	
F	3.8		4.0	0.150		0.157
L	0.4		1.27	0.016		0.050
M			0.6			0.024
S	8° (max.)					

Figure 7: Through-hole and Surface Mount packaging dimensions
(courtesy of ST Microelectronics[6])

Design Review

The SO-8 package is a surface mount version of the standard dual-in-line operational amplifier used in many electronics laboratories. Industry has increasingly adopted the surface mount technology for printed circuit boards. Unfortunately, the surface mount package is not student friendly and has not made it into educational laboratories. Consequently, the dual-in-line package versions of the operational amplifiers remain the de facto standard found in electronics educational laboratories. The design shown in Figure 8 is a new concept in electronic laboratory instruction. The surface mount SO-8 package is mounted on a small dual-in-line width printed circuit board. The board is designed so that typical supporting circuit devices like resistors, capacitors, and diodes are mounted in such a way to allow the student to configure common electronic circuits discussed in many electronic textbooks. Not only is the TL081 operational amplifier a surface mount device, but the supporting devices are also.

Figure 8 shows the schematic of the *Mini OpAmp Trainer*. It is equipped with a little security circuit to prevent damage when the power source is connected in the wrong orientation. It also offers components often used in standard applications. With a few bridges, standard circuits such as inverting and non-inverting amplifiers, low pass filters, high pass filters, adders, comparators, etc. can be realized and analyzed. The circuit of an offset adjustment is included in case it is needed.

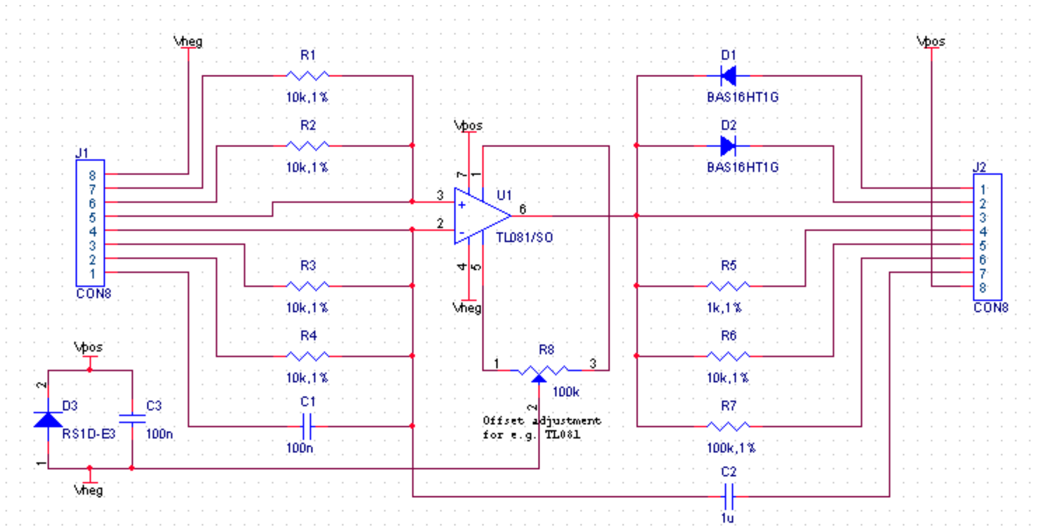


Figure 8: Mini OpAmp Trainer

Figure 9 shows a photo of the *Mini OpAmp Trainer*. The board is using the TL051 as the enhanced TL081. This device does not need the offset adjustment, so it is not soldered in. Nevertheless, the board itself can be used for different op amp devices to show the differences in time behavior of e.g. uA741, TL081, TL051 and others with the same pin layout.

Top View

Bottom View

Figure 9: Photos of the *Mini OpAmp Trainer*

The pin spacing within the rows of the *Mini OpAmp Trainer* shown in Figure 9 is 2.54mm or 0.1 inch. This will allow the board to fit into the spacing of the breadboard. The width of the trainer is 6 × 2.54mm (0.6 inch). The board itself is made as a standard 2 layer printed circuit board. This size allows a little circuit diagram to be printed on the top the board as seen in Figure 9. The symbol of the opamp is clearly visible on the top of the board. The vias close to the signal pins of the symbols go with these signals and can be used as test points for test tips during trouble shooting. The opamp in the SO-8 package is connected underneath to allow for the space of the symbol. Also the capacitor to stabilize the supply voltage and the protection diode, which will avoid damage if the voltage source is connected the wrong way by the student, is underneath the board. All pins of the opamp can be accessed via the pins connected to the breadboard and the opamp can be used disregarding the additional components on it. For standard circuits found in educational textbooks, the necessary resistors with values often used for examples are offered on the *Mini Board*. These are two resisters on each of the inverting and non inverting input with the value of 10k with the package size 0603. Feedback loop resistor values of 1k (1206), 10k (0603) and 100k (0603) are soldered on the top of the Mini Board. These components can be seen merged with the schematic printed on the top. Additional values can be realized in using series or parallel circuits of these resistors. For further circuits, the board offers a 100nF (0603) and a 1uF (1206) capacitor connected to the inverting input of the opamp. With these components, simple low and high pass filters and integrator circuits for control engineering tasks can be realized without additional components. For more advanced laboratory exercises, the diodes (SOD-323) connected to the output pin of the opamp are also offered by this board. Nonlinear components can be applied within the feedback loop of the opamp circuit as used for rectifier circuits.

When the *Mini OpAmp Trainer* is inserted into an inexpensive breadboard in a way similar to standard dual-in-line ICs, the student can interconnect the pins using 22 AWG wires into the desired op amp circuit configuration of most electronic laboratory circuits.

Laboratory Usage

Using the *Mini OpAmp Trainer* standard circuits can be realized in an easy way. Figure 10 shows the circuit of a standard clock generator based on an inverting comparator with R1 and R2 and a RC-circuit with R3 and C1 in the feedback loop.

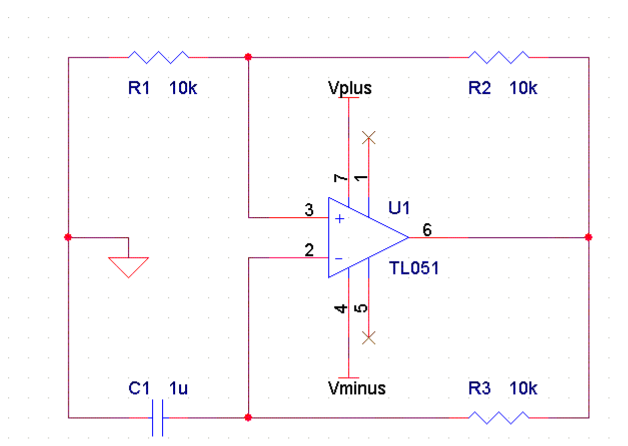


Figure 10: Schematic of a standard clock generator

Figure 11 shows a photo of the *Mini OpAmp Trainer* used as such a standard clock generator. It consists of 3 wires for the power source (wires from the top), 3 wires for the measurement with an oscilloscope (wires to the left) and 3 jumper cables to realize the circuit.

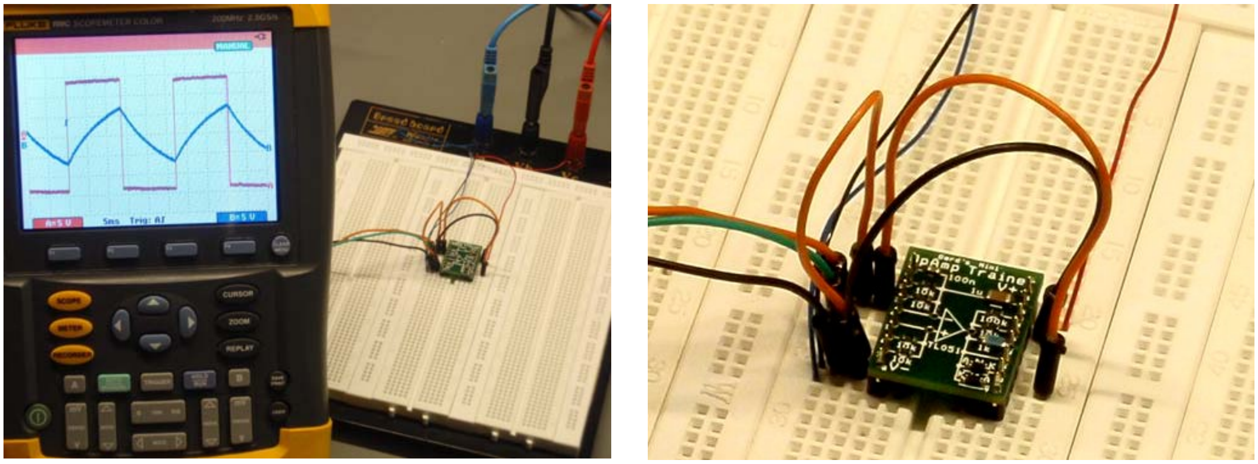


Figure 11: Photo of the *Mini OpAmp Trainer* as clock generator

As seen in Figure 11, there is still a lot of room on the breadboard for additional basic op amp circuits which can be realized with more *Mini OpAmp Trainer* boards. Such a bunch of different common circuits can be used as modules to realize quite complex circuits in a short amount time. This would allow for the time constrains of lab training. The *Mini OpAmp Trainer* boards combine the convenience of the expensive standard trainer circuits with the flexibility of the breadboard design.

Conclusion

The novel concept presented in this paper is the merging of flexible electronic trainers with tried and true bread-boarding instruction using modern surface mount technology. This concept allows for the experience of traditional trouble-shooting instruction of electronic circuits using discrete components and wiring. The student can build custom circuits with industry standard surface mount devices on inexpensive breadboards. The student can also build on more advanced trainers such as the NI ELVIS. The variations are limitless and the concept is not limited to operational amplifier devices. The concept presented in this paper sets the basis for a new art of electronics laboratory instruction thereby bringing electronic laboratory instruction in line with modern industry practices.

References

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