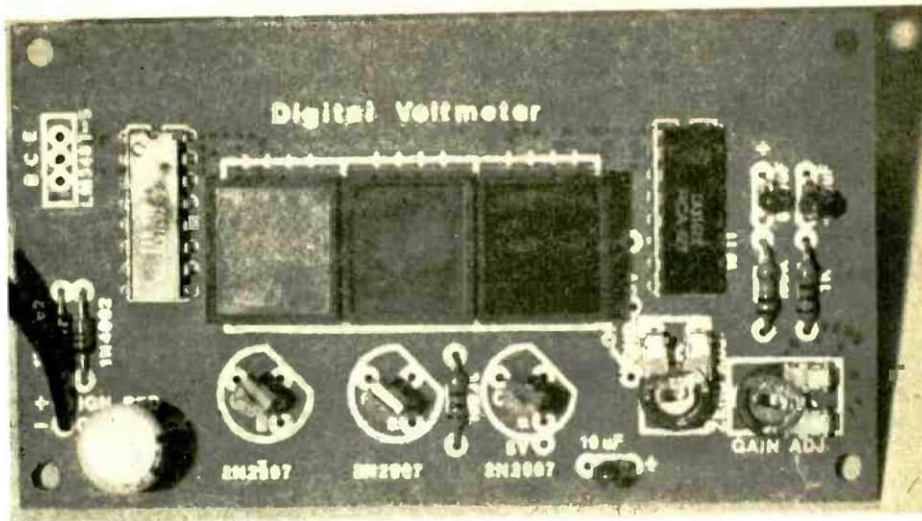


Dashboard Digital Voltmeter

Keep an electronic eye on the voltage level of your vehicle's electrical system and save on expensive repair bills later



YOU'RE MAKING TIME down the interstate at three in the morning, and all of a sudden you become aware that the lights on the dash seem kind of dim, and that the headlights don't seem to be reaching out as far ahead to warn you of darkened semis parked on the shoulder. Are your eyes just playing tricks on you, or is there something the matter with your car's electrical system? A quick glance down at the three glowing LED numerals on the dash gives you the instant answer. Either you pull into a rest area and grab a few hours of shuteye, or you pull into a service area and have the battery, alternator and voltage regulator given a good scrutinizing by the mechanic.

In either case, your car's digital voltmeter has given you the information sought about the state of the electrical system, and maybe saved you either a headache, a smashup, or a king-sized repair and towing bill. Maybe all three.

Recent advances in the design and availability of industrial integrated circuits have opened up many doors to the electronics hobbyists. Analog-to-digital devices have become more complex internally, thus making the portions of the circuitry which have to be assembled by the hobbyist that much more simple. The Dashboard Digital Voltmeter takes advantage of these advances, utilizing three ICs and a small handful of discrete components to give you an instrument capable of better than $\pm 1\%$ accuracy in reading the voltage level delivered by your car's (or boat's) electrical system.

Two New ICs. The system is built about three ICs: the LM340T-5 (a 5-volt regulator now available for several years); a CA3162E; a CA3161E; and a support combination of diodes, resis-

tors, and capacitors. It is the CA3161E and CA3162E that now open the door to new horizons in possible applications not only because of their unique capabilities, but also because they reduce substantially the numbers and types of formerly required support components. The heart of this system is the CA3162E, a dual-slope, dual-speed, A/D converter industrial chip. Its almost equally important companion, the CA3161E, is a BCD, 7-segment, decoder/driver chip. It is also unique in that it has a current-limiting feature. This eliminates the necessity of resistors in series with the 7-segment displays that were required in earlier designs.

The above feature not only reduces circuit board space requirements, but reduces the probability of component failure. Power required to operate this voltmeter is minimal (160 mA or less), a result of the multiplexing feature of the CA3162E. With that as a background, let's consider some of the more important operations of this simple, but very accurate digital instrument.

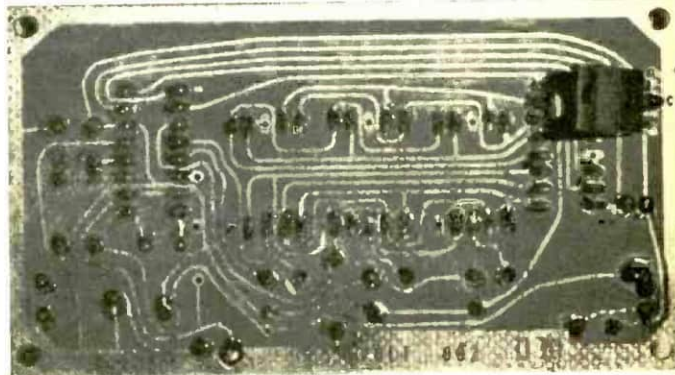
Circuit Function. Analog voltage from 000 mV to 999 mV can be applied between pins 11 (+) and 10 (-) of the CA3162E (U2). That IC converts the

voltage into a Binary Coded Decimal (BCD) equivalent. The BCD leaves pins 2, 1, 15, and 16 (the group represents the 1's, 2's, 4's, and 8's) and enters pins 7, 1, 2, and 6 respectively of the CA3161E (U3). The latter IC takes the BCD code, converts the output, then uses it (in conjunction with the 7-segment display) to generate (form) the number that correlates to the BCD input of the CA3161E. The multiplexing driver pins 5, 3, and 4 (5 being the least significant and 4 the most significant) turn on that display by means of the PNP switching transistors. Concurrently, the CA3162E is providing the BCD information to the CA3161E driver/decoder.

As indicated earlier, the system includes a combination of diodes and capacitors. These are required to control or minimize the voltage spikes (positive and negative) that result from turning inductive devices on and off; e.g. windshield wiper, air conditioner, and electric windows, etc.

The maximum input differential between pins 11 and 10 of CA3162E is 999 mV. A resistor network (R1, R2) is used to attenuate the applied 13.8-volts to 138 mV. An Ohm's Law cal-

This view of the assembled PC board shows the voltage regulator, (U1) mounted on the underside of the PC board. This was done in order to accommodate a flush-mount installation in a smaller car. Let your space needs dictate placement of this component.



Digital Voltmeter

ulation would give a result of 136.6 mV. The gain-adjust potentiometer compensates for the slight drop. The FND 507s display this as 13.8-volts.

Note the point marked **OPTION** on the schematic. With Pin 6 of the CA-3162E grounded or disconnected, there are four conversions or comparisons made each second. Tying pin 6 to the 5-volt line will result in 96 conversions or comparisons per second. The 96/second rate moves with excessive rapidity, is not appealing to the eye, and usually results in the least significant digit appearing to be blurred. Of the two rates, the 4/second conversion (4 Hz) is by far the more pleasing to the eye, is easier for the eye to focus on quickly, and is the recommended rate. These rates could vary slightly because of capacitor difference and manufacturer variance from stated values.

Assembling the Voltmeter. The unit may be assembled quickly and relatively easily using a predrilled and etched circuit board. If a Digital World circuit board is being used, the four corner

holes will have been drilled. If a blank board is being used, drill the corner holes *before* starting to "stuff" the board. It is easy at this point to scribe the plexiglass panel and mark the corner holes on it for later drilling and perfect alignment. Additionally, examine the recess or place where the completed unit will be mounted. Determine how it will be secured (bolted, clamped, or glued), doing any additional drilling that may be required.

Get the workbench ready for soldering. Use a low wattage, electrically-isolated, fine-tipped soldering tool and fine solder. A blunt-nosed tool could damage or destroy the ICs and create foil bridges between pins. This is both expensive and frustrating. If you have had limited experience in soldering in small areas, it may be wise to practice on something else before you start.

Now, locate all resistors and potentiometers on the circuit board placement diagram and install them in their respective holes. Next, do the same for all capacitors, observing polarity. Install the CA3161E and CA3162E. *Caution!* When inserting the ICs, be careful *not* to fold the pins under or bend them in any way.

IC orientation is critical. Be sure

these chips (CA3162E and CA3161E) are aligned as shown on the diagram. Note the notch mark on the chips and the corresponding notch mark on the schematic, or the "1" on pin 1 on top of the plastic case. All manufacturers use one or both of these base reference directional indicators.

If you have doubts about your soldering ability or the type of solder tool you have (grounded or not grounded), place two 16-pin sockets in the chip holes. The ICs may then be placed (not soldered) in the sockets. Next, insert the three LEDs, noting the notch marks on the LEDs and the notch marks indicated on the diagram. For the final action on this side of the board, insert both diodes in their respective holes (observing cathode markings).

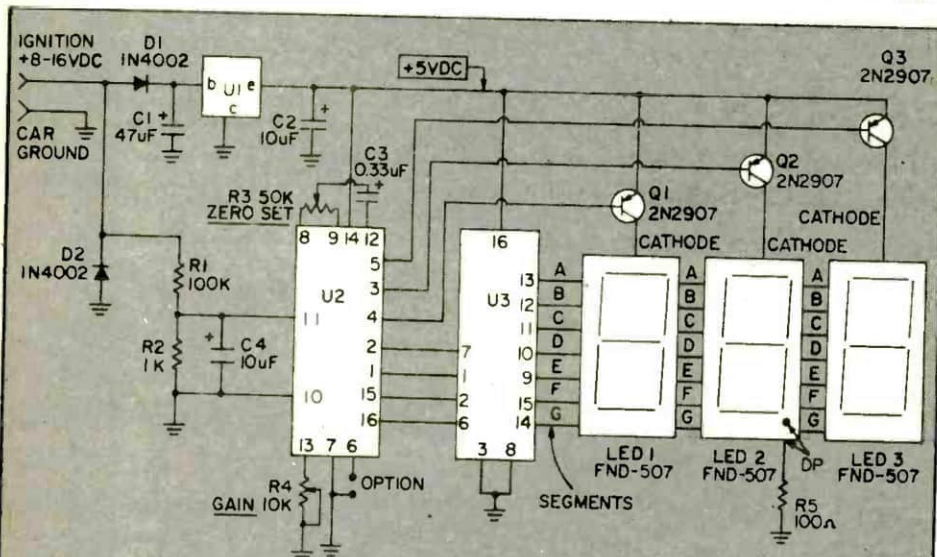
Reverse the circuit board and install the LM340T-5 regulator. *Caution!* This must be correctly placed or it will destroy your unit when power is applied. The *metal side* of the regulator must be facing the FND 507 pins. Recheck it to make sure.

Now, turn the board over again. Use a red wire for the ignition line and a black wire for the chassis ground. Determine the lengths required (usually three-feet is sufficient). Solder the red wire to the point marked **IGNITION** on the diagram and the black wire to the **GROUND**.

Calibration Procedure. Correct calibration determines the accuracy of your voltmeter. Follow these steps carefully and sequentially. Apply a *known* voltage source (above 10 and below 16-volts) to the **IGNITION** point. We recommend a 13.8-volt source. Next, for zero adjustment, ground pins 11 and 10 to the circuit board ground momentarily. Using a small screwdriver, slowly rotate the wiper arm on R3 until there is a reading of 000. Remove the ground from pins 10 and 11. Set the *gain control* (R4) by rotating the wiper arm until the displays are displaying the same voltage as is being applied.

Installation. One final action is necessary before your unit is ready to be mounted in the dash location of your choice. Secure the black wire to the metal chassis ground and the red wire to any accessory line that is active only when the motor is running. Secure and mount the voltmeter in the location of your choice.

A colored plexiglass facing (cover) is required and we recommend red for most display contrast. A location which is not usually exposed to the sunlight will make the displays easier to read during the brighter periods of the day. If the unit is going into an existing recess, the present glass cover may be



PARTS LIST FOR DIGITAL VOLTMETER

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| C1—47- μ F electrolytic capacitor, 25 VDC | R3—50,000-ohm PC trimmer potentiometer |
| C2, C4—10- μ F tantalum electrolytic capacitor, 16 VDC | R4—10,000-ohm PC trimmer potentiometer |
| C3—0.33- μ F tantalum capacitor, 35 VDC | R5—100-ohm, 1/4-watt resistor, 5% |
| D1, D2—1N4002 diode | U1—LM340T-5 5-volt voltage regulator |
| F1—1-amp fuse | U2—CA3162E Analog-to-Digital converter |
| LED1, 2, 3—FND-507 7-segment LED display | U3—CA3161E BCD display driver |
| Q1, 2, 3—2N2907 PNP transistor | |
| R1—100,000-ohm, 1/4-watt resistor, 5% | |
| R2—1,000-ohm, 1/4-watt resistor, 5% | |

Misc. include: hookup wire, red plexiglass (for display facing), IC sockets, transistor sockets, suitable enclosure, etc.

For pricing on parts and pre-etched, printed-circuit board for Digital Voltmeter write to Digital World, P.O. Box 5508, Augusta, GA 30906. Be sure to include a stamped, self-addressed envelope.

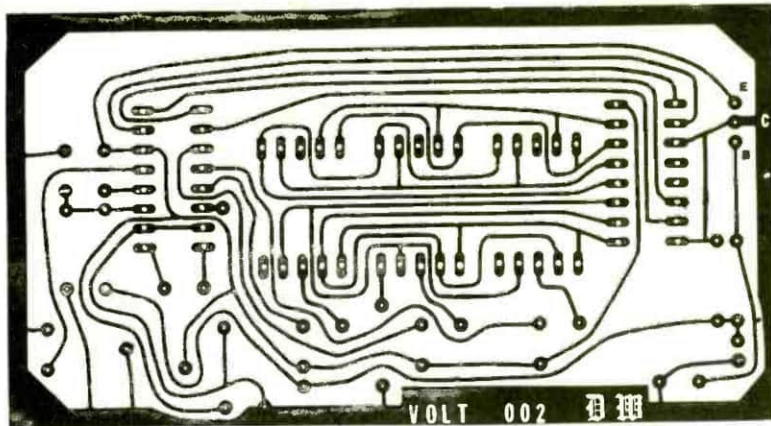
used as a template for the plexiglass cover dimensions. One-eighth or 1/16-inch thick plexiglass works well and is relatively easy to cut using a roofer's shingle cutter knife. Place two clamps on a straight line along the template edge, then cut one side at a time. Scribe it deeply with a dozen or more strokes, then break off the excess with a pliers. When drilling screw holes, use a small starter bit first, then the larger bit. This should prevent the larger bit from wandering across the plexiglass.

The plexiglass must be "spaced" away from the board by approximately 3/8-inch, using either spacers or the bolt/nut method. The latter method is to insert a bolt through the plexiglass corner hole and put a nut on the reverse side. Put a second nut on the bolt, allowing a 1/2-inch inside space between the two nuts. Do this on all corners. Next, insert the bolts into the board corner holes and put on the final nuts. We recommend securing all four corners, rather than just two.

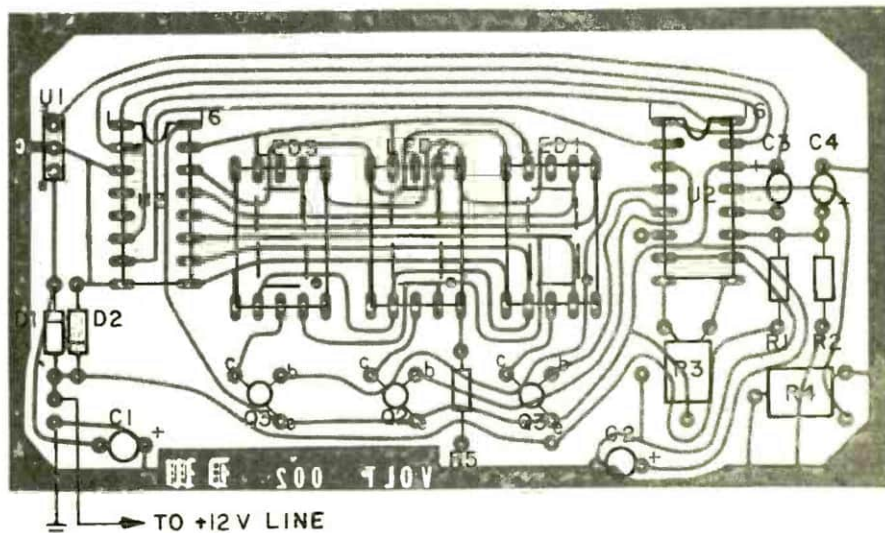
Troubleshooting. If the unit does not light up for the calibration procedure, first check that the wiper of R3 is centered. If it still does not light up, recheck your work. Carefully inspect for possible solder bridges and loose connections. If a solder bridge is discovered, remove it carefully. It is easy to destroy a chip during the removal process. If it still fails to light up, start a systematic test check to isolate possible faulty component(s).

If the unit does not function after installation, recheck for a good electrical connection on the line that supplies power from the car. Did you break or loosen the solder connections of the source wires during installation? If so, this will require removal and resoldering, plus a bit more care during installation the second time.

One Final Note. Some ICs, and quite possibly the ones used in this project, generate high frequency harmonics which might find their way into your car's radio. Try holding your LED readout pocket calculator next to the radio antenna with the radio tuned to a blank spot on the AM dial to see what we mean. If you experience any interference from the voltmeter circuit, try rerouting the antenna coax away from the voltmeter itself. A metal case around the voltmeter's PC board will also aid in the reduction of RFI. We suggest that you avoid using the radio's power lead as the voltage source for your voltmeter. The power lead to the horn (or horn relay) or the hot lead of the windshield wiper switch (find it at the fuse box) is probably the best place to attach the voltmeter. ■



This full-scale etching guide for the voltmeter's PC board is one of the trickiest we've offered. Unless you know your stuff, we suggest you use a Digital World board.



The component placement diagram for the PC board shows all IC and capacitor polarities. Take special care to observe them during assembly phases of project.



Even the best voltmeter in the world won't help you keep your car running if you don't take care of your battery. Check water level often and add only pure, distilled water.