ALCUL

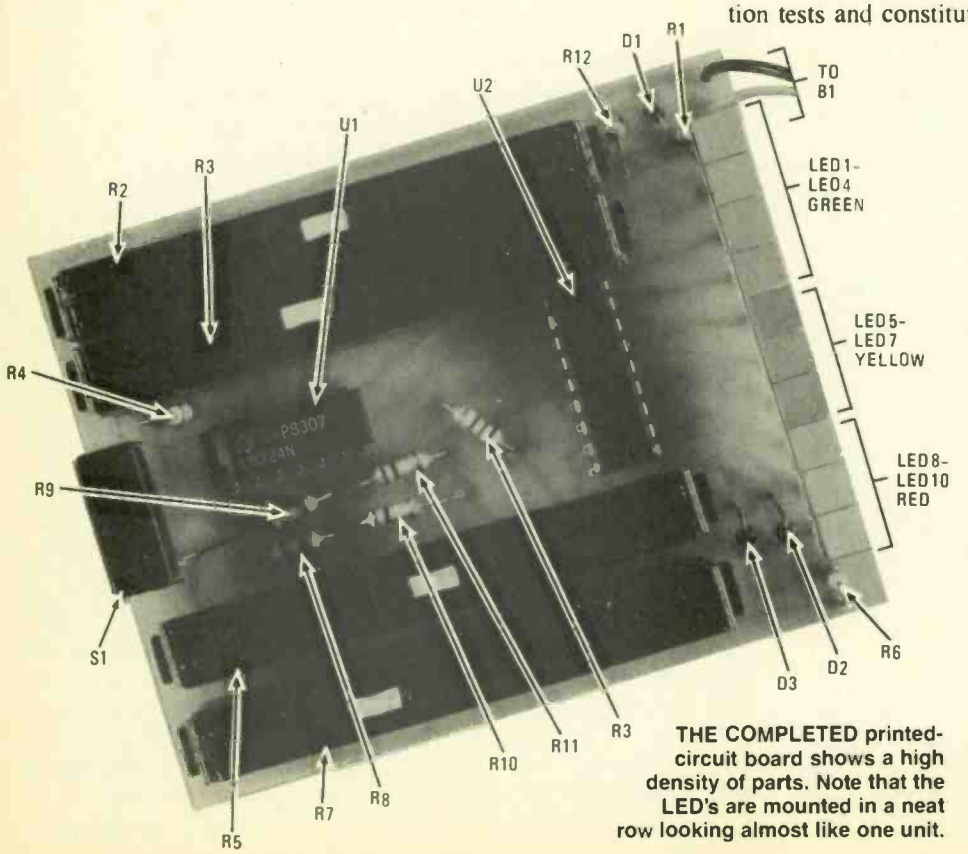
An analog computer calculates the probable blood alcohol level!

By R. Craig Virnelson

DRINKING DRIVERS HAVE BEEN RESPONSIBLE FOR HALF OF all traffic fatalities. But only recently with the formation of organizations like M.A.D.D. and other groups have the laws been stiffened to discourage drinking and driving. General Motors Corporation has advertised heavily to announce their efforts to reduce drinking and driving by designing an ignition system that an intoxicated person would have difficulty operating. Other companies have proposed ignitions with integral breath analyzers. Unfortunately, like seatbelt buzzers these devices could easily be defeated.

A number of personal breath analyzers are now on the market, but they suffer from several drawbacks. The sensors are not specific for ethanol, and even when they work, the information is too late to be really helpful. The ALCULATOR information can be used to anticipate the blood alcohol level that will result from drinking a known amount of alcohol and can thereby help prevent a person from having *one too many*.

Normally, law enforcement agencies use the Breathalyzer (tm) or similar instrument to determine blood alcohol levels of drivers who are suspected of driving while intoxicated (DWI). A blood alcohol level of 0.10 percent is usually sufficient to result in prosecution regardless of any coordination tests and constitutes *legal* intoxication. Blood alcohol levels between 0.10 percent and 0.05 percent are interpreted as impairment and can, along with poor coordination tests, also result in prosecution for DWI.



THE COMPLETED printed-circuit board shows a high density of parts. Note that the LED's are mounted in a neat row looking almost like one unit.

Figuring It Out

Blood alcohol levels are the primary criteria for prosecution in DWI cases. For individuals who have been drinking, to know their maximum possible blood alcohol level there are four primary variables to consider; body weight, number of drinks, alcohol content of drinks, and number of hours since consumption began. This relationship is well known and has been published by Dr. Leon A. Greenburg of Rutgers Center for Alcohol Studies (Table 1). Many charts have been published showing two of the four variables, body weight and number of drinks, but these charts do not indicate the impor-

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tance of drink strength or time, which are necessary to accurately predict the maximum possible blood alcohol level.

Since these calculations can be done with a hand calculator, the first consideration was to build a dedicated digital device or a ROM look-up table with the necessary values stored for recall with a computed address. However, a simple graphic presentation of the information similar to a bargraph VU meter seemed more appropriate especially using the traffic light analogy of green for *go*, yellow for *caution*, and red for *stop*. This would correspond to blood alcohol levels of less than 0.05 percent, 0.05 percent to 0.10 percent, and greater than 0.10 percent, respectively.

Most hobbyists are familiar with the LM3914 operation and this project appeared to be a good application for it. The next step was to convert the blood alcohol formula to an appropriate analog circuit. The choice of of ranges had to be made without too much compromise. The drink scale was chosen to have ten drinks (more than enough for anyone), the maximum drink strength is equivalent to one ounce of pure alcohol and the minimum four tenths of an ounce, the weight scale of 100 to 260 pounds should suffice for most people, and the ten-hour time scale was used mostly for convenience. The LM3914 has a linear response between 0.0 volts and 1.2 volts, therefore, the steps are 0.12 volts each. Each 0.12-volt step was given the equivalent of 0.015 percent blood alcohol for a total range of 0.135 percent (only nine steps are used). The body eliminates alcohol at the rate of 0.015 percent per hour, or one step for each hour.

Tieing in the Circuit

Using the blood alcohol formula with the values for the maximum level (ten drinks, one ounce of alcohol, 100 pounds, and 0 hours) and converting that value to voltage necessitates an input voltage of 6.0 volts. The starting voltage is 6.0 volts, all other computed values will be less. In this way the simple series of dividers shown in Fig. 1 can be used with the first two op amp stages serving as followers and the initial voltage supplied by a 6.0-volt Zener diode.

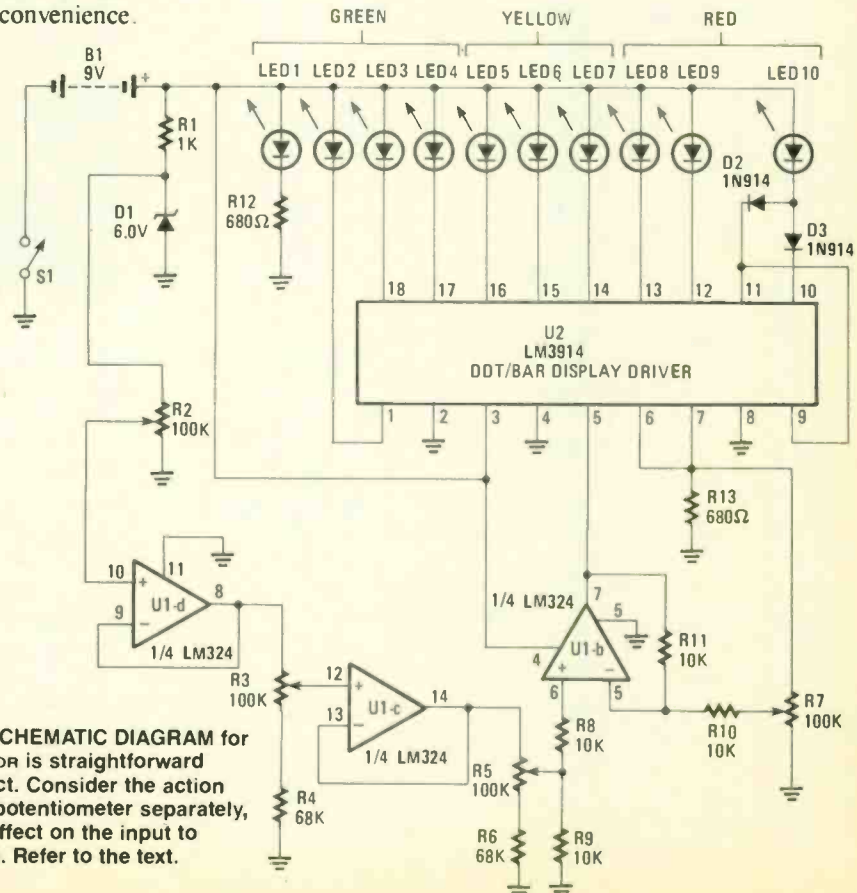

FIG.1—SCHEMATIC DIAGRAM for ALCULATOR is straightforward and direct. Consider the action of each potentiometer separately, and its effect on the input to B2, pin 5. Refer to the text.

PARTS LIST FOR ALCULATOR

SEMICONDUCTORS
D1—6-volt, ½-watt Zener diode
D2, D3—1N914 silicon diode
LED1-LED4—Green light-emitting diode, 5-mm square (AEG-Telefunken)
LED5-LED7—Yellow light-emitting diode, 5-mm square (AEG-Telefunken)
LED8-LED10—Red light-emitting diode, 5-mm square (AEG-Telefunken)
U1—LM324 quad op amp
U2—LM3914 dot/bar display driver integrated-circuit chip

RESISTORS
(All resistors are ¼-watt, 5%, carbon-film types unless otherwise specified)
R1—1000-ohm
R2, R3, R5, R7—100,000-ohm slide potentiometer, 20%, PC mount
R4, R6—68,000-ohm
R8-R11—10,000-ohm
R12, R13—680-ohm

ADDITIONAL PARTS AND MATERIALS
B1—9-volt transistor-radio battery
S1—SPST miniature slide switch
Printed-circuit board, battery clip, wire, solder, plastic case, labels, etc.

The following are available from ALCULATOR, Inc., Box 22051, Beachwood, OH 44122. Complete kit, including printed-circuit board and all parts including custom-molded case and labels—$29.95. Printed-circuit board, custom-molded case and labels only—$9.95. All prices include postage inside USA.

The first stage varies form 0.0 to 6.0 volts, the second stage is from 100 percent to 40 percent of the first stage (1 oz. to .4 oz. of alcohol), and the third stage varies from 100 percent to 38 percent of the second stage (260 pounds to 100 pounds). The tolerance on the slide potentiometers R3 and R5 are 20 percent, but the divider must be accurate to 5 percent. If the actual value of R3 and R5 are more than 5 percent off then R4 and R6 must be changed to maintain the specified range of 40 to 100 percent of the input voltage. A value of 80,000 ohms for R3 would mean that R4 would have to be changed to 53,000 ohms; or if R5 was 120,000 ohms, then R6 would need to be 80,000 ohms. The values of R2 and R7 are not critical.

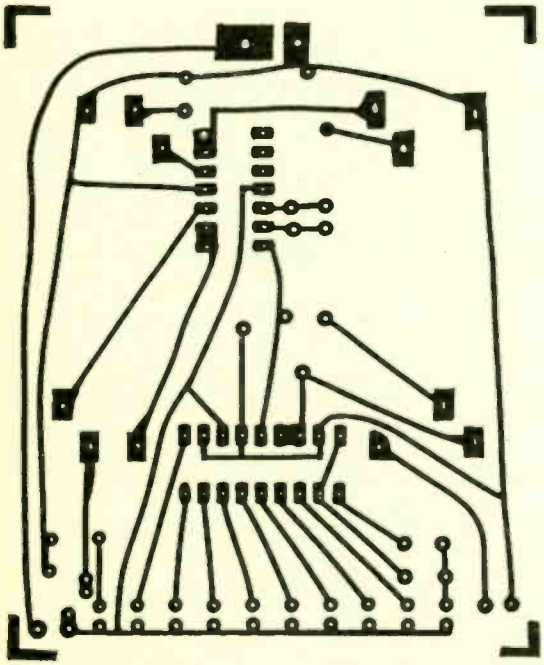

FIG. 2—FOIL PATTERN for the ALCULATOR is provided here on a 1:1 scale so that experimenters who wish to make their own printed-circuit board may do so.

The time function uses the 1.2-volt internal reference of the LM3914 to represent 10 hours, or a proportional fraction of that voltage for less time. The time can then be subtracted from the product of the alcohol content and body weight by using the third op amp as an analog subtractor. The output is then connected to the input of the LM3914 and displayed on nine LED's. A tenth LED was used to indicate power on. This necessitated connecting both the ninth and tenth outputs of the LM3914 to the last red LED because the tenth output is active for overvoltages.

TABLE 1
FORMULA FOR CALCULATING PERCENT ALCOHOL IN BLOOD

$$AB\% = \frac{7.3(N)(D)}{W} - .015H$$

where AB% = percent *A*lcohol in *B*lood, W = body weight in pounds, N = number of drinks, D = Alcohol content of drink in ounce/drink, and H = hours since consumption began.

Build It

Construction is facilitated by using the printed-circuit board layout in Fig. 2 and shown with parts mounted in Fig. 3. The only components that require particular care in mounting are the 10 LED's which must be at the same level for the sake of appearance. Those particular LED's were chosen because they form a continuous display without a special lens.

Although the case shown was specially molded for this application, early prototypes were constructed using commercially available cases. The slide potentiometer stems were shortened so they would rise just above the surface of the case. The scales along the slides are linear except for the weight which is an inverse relationship. The positions for the

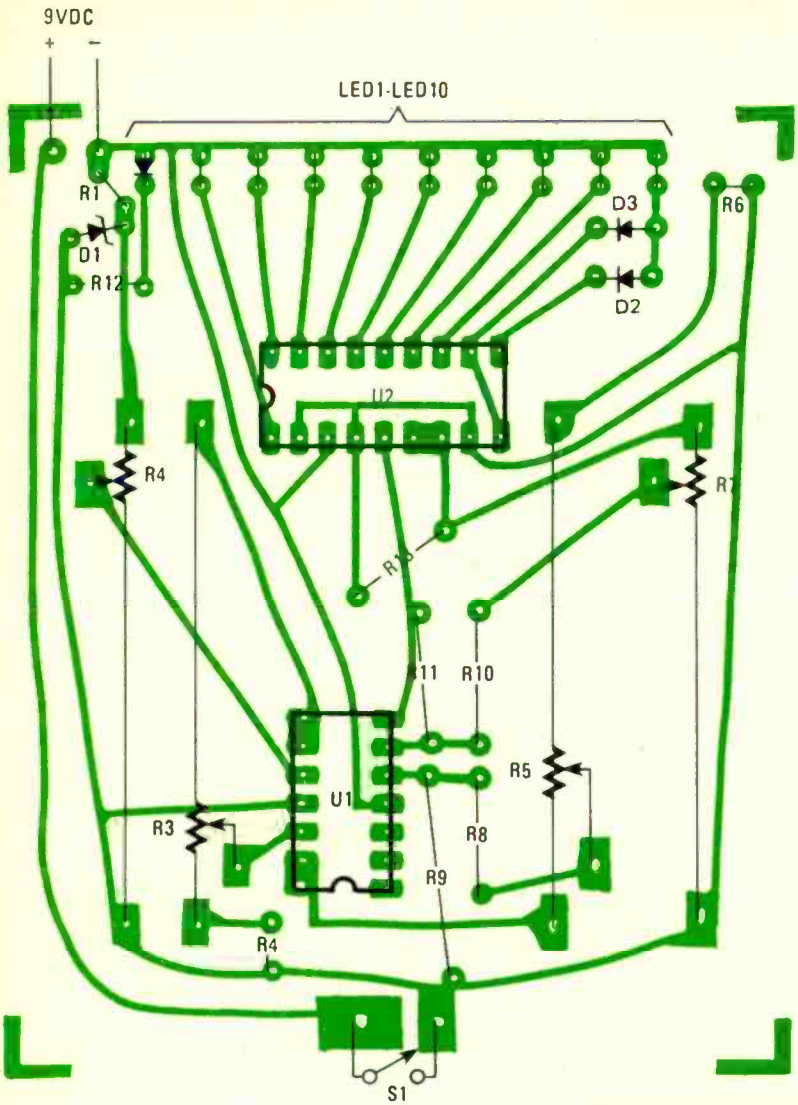

FIG. 3—X-RAY VIEW OF printed-circuit board with parts in place and foil side underneath. All parts are mounted on the board except for the battery and its clip connector.

weight scale values can easily be calculated in the following way: Divide 100 by the fraction of the input voltage at any point on the slide and that value in pounds will correspond to that position on the scale, i.e. if the divider is .40 of the input voltage that position corresponds to 250 pounds.

One option to consider is to use the fourth op amp on the LM3914 as a comparator to indicate low battery condition. The positive input would be connected to the 6.0-volt reference and the negative input to 90 percent of the supply voltage through a resistor divider. The output would go high if the supply voltage fell below 6.4 volts and light an LED.

To Operate

Operation of the ALCULATOR should start by checking to see that the battery is good and the unit is properly calibrated. When the slides are set to 10 drinks, minimum strength, maximum weight, and 0 hours, the first red LED indicates proper operation and a good battery. For an individual to compute their maximum possible blood-alcohol level they need only enter the appropriate information on the four slides and the blood alcohol level will be displayed on one of the nine LED's. Here's an example: If a 200-pound person drinks 5 beers in 2 hours, the first red LED should light indicating intoxication.

The completed ALCULATOR as pictured was the topic of a report by the ABC television network affiliate in Cleveland, Ohio, in which a group of people drinking at a bar were asked to keep track of their drink intake and submit to a Breathalyzer (tm) examination administered by a qualified police officer. These same people used the ALCULATOR to successfully predict their blood alcohol levels as measured by the Breathalyzer (tm). Hopefully, the ALCULATOR will function to educate and inform people when to stop drinking before they have *one too many*. ■

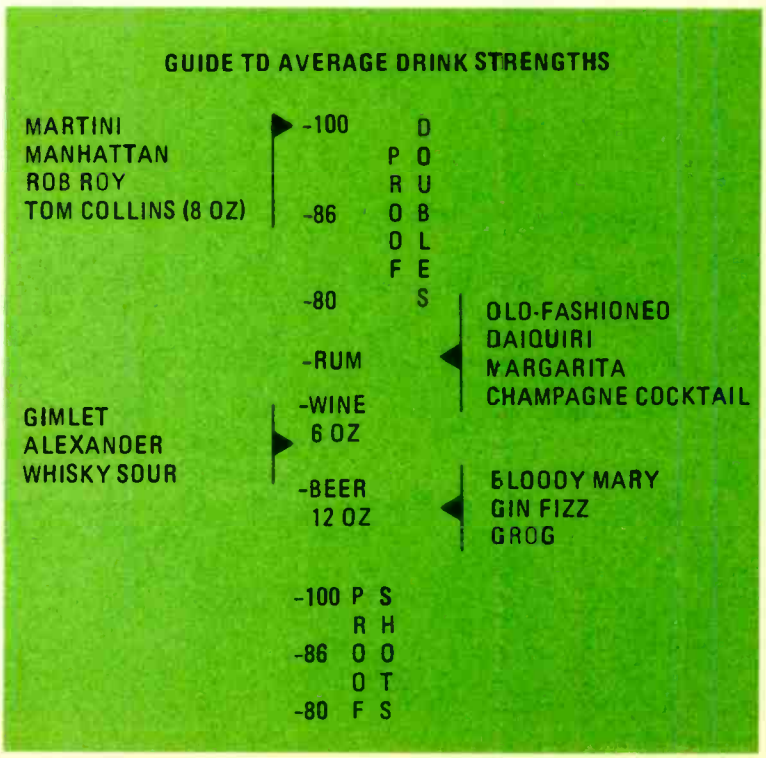

CHART indicates where to set average drink strengths on the ALCULATOR. As each LED lights, the blood alcohol level increased 0.015%. Push all controls to top to light all red LED's checking out the 9-volt battery.