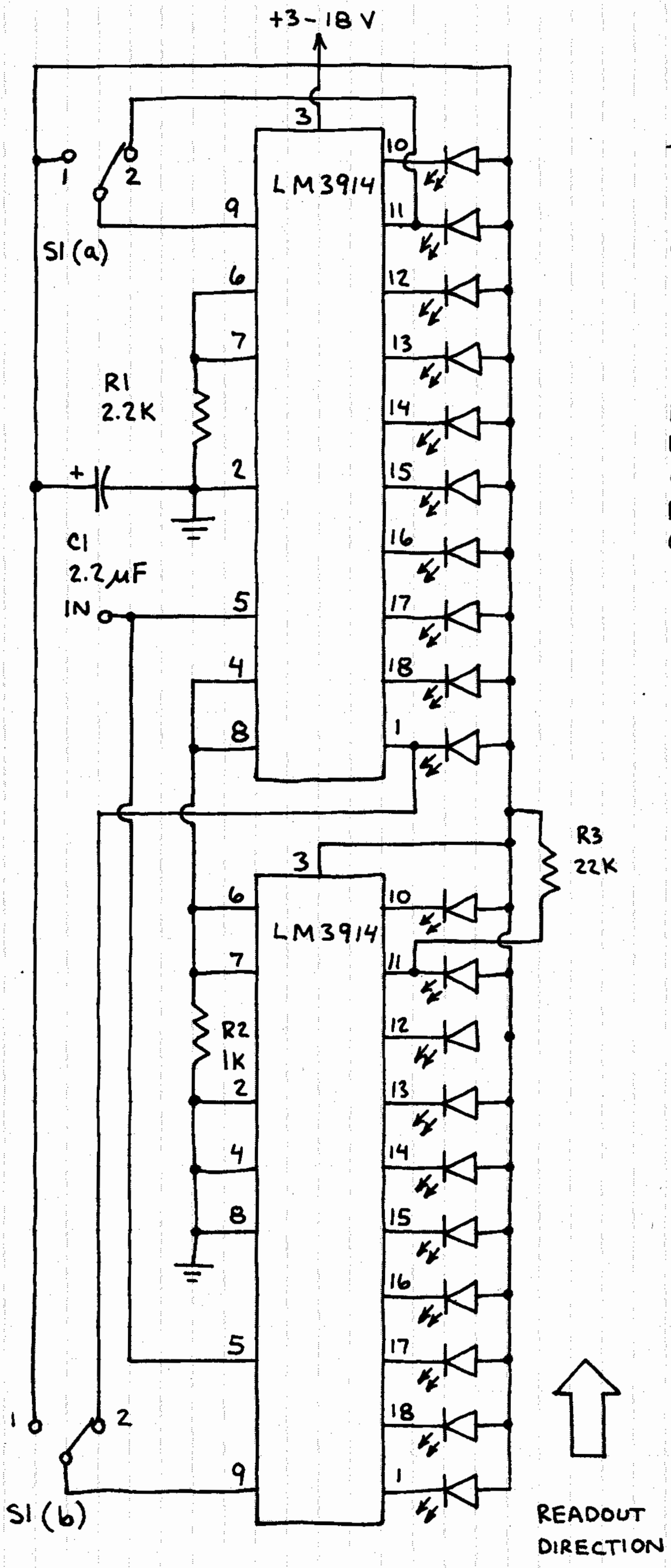
DOT/BAR DISPLAY DRIVER (CONTINUED)
LM3914N

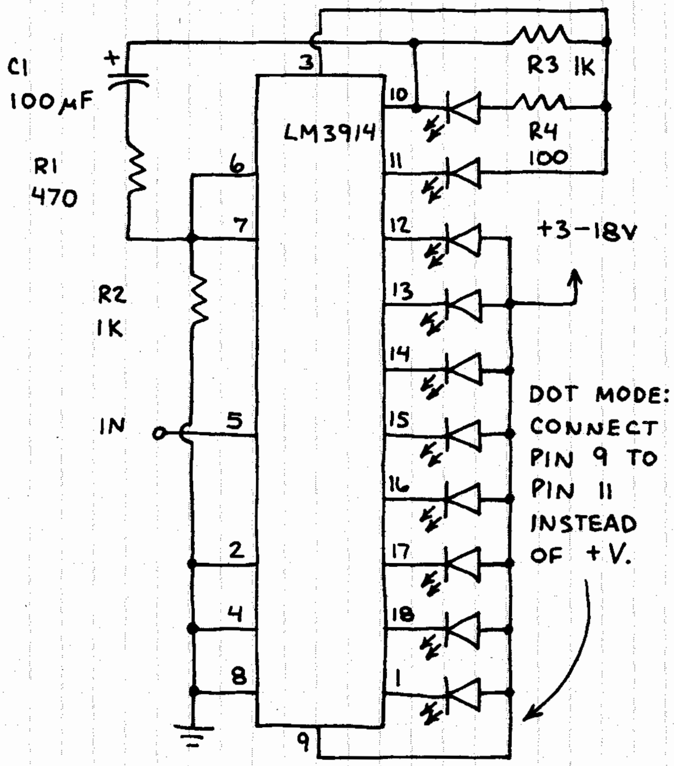
20-ELEMENT READOUT



THIS CIRCUIT SHOWS HOW TO CASCADE 2 OR MORE LM3914's. WHEN + V = 5 VOLTS, THE READOUT RANGE IS 0.14 V TO 2.7 V. HIGHEST ORDER LED STAYS ON DURING OVERRANGE. AVOID SUBSTITUTIONS FOR R1, R2 AND R3.

S1 IS THE MODE SWITCH. USE A DPDT TOGGLE. POSITION 1 SELECTS BAR AND POSITION 2 SELECTS DOT. OMIT S1 IF ONLY ONE MODE IS REQUIRED. SIMPLY WIRE IN THE CORRECT CONNECTIONS.

FLASHING BAR READOUT



DOT MODE: CONNECT PIN 9 TO PIN 11 INSTEAD OF +V.

THE CIRCUITS ON THIS PAGE ARE ADAPTED FROM NATIONAL SEMICONDUCTOR'S LM3914 LITERATURE. BOTH WORK WELL.

WHEN ALL 10 LEDs ARE ON THE DISPLAY FLASHES. OTHERWISE THE LEDs DO NOT FLASH. INCREASE C1 TO SLOW FLASH RATE.

RONALD AJEMIAN

The New Breed of VU Meters

Fast response, easy reading, characterize the new led vu meters.

BEFORE WE GET involved with the new led (light emitting diode) vu meters, let's first discuss the term *vu. Vu,* volume units was developed in April, 1939 by the Bell Telephone Labs and Columbia Broadcasting System (CBS) with National Broadcasting Company (NBC). The volume in vu is numerically equal to the number of decibels (dB) which expresses the ratio of the magnitude of the waves to the magnitude of the reference volume. Volume units, like decibels, are logarithmic and involve a power ratio. Therefore, if they are used to measure a signal (voice or music) a reference must be established. The standard reference for the volume unit is one milliwatt of power dissipated across 600 ohms of resistance. Now we can express the number of vus with the equation

$$N_{vu} = 10 \log \frac{P}{0.001}$$

where P represents the rms power of the signal to be measured. If P is equal to one milliwatt (1mW), the ratio in the equation is unity—therefore, making N_{vu} equal to zero. Because of this, circuits operating with 1mW are said to be at zero reference, or zero vu. So when P exceeds 1mW, values of N_{vu} are positive; for values of P less than 1mW, N_{vu} becomes negative.

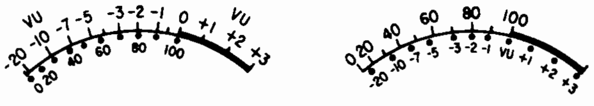
Since 1mW of power across 600 ohms corresponds to 0.775 volts across the same value of resistance, the equation can be modified to

$$N_{vu} = 20 \log \frac{E}{0.775} + 10 \log \frac{600}{R}$$

in which E is the rms signal voltage and R the resistance across which the signal voltage is measured. The values 0.775 volts and 600 ohms are, respectively, the voltage and resistance references for vu measurements.

The vu meter must conform to all specifications on ANSI Standard C16.5-1954 entitled "American Recommended Practice for Volume Measurements of Electrical Speech and Program Waves." All vu meters employ either TYPE A scale for recording applications, or TYPE B scale, which emphasizes percent modulation for broadcast use (FIGURE 1). The meter reading is zero vu, or 100 per cent, with application of 1.228 volts across a 3,600 ohm resistor in series with the vu meter. This reading represents 4 dB above one milliwatt into 600 ohms. In accordance with Standard C16.5-1954, all vu meters must have response time to a step change of 0.3 second, ±10 per cent. Overshoot is 1 per cent to 1.5 per cent. Calibration follows circuit conditions as defined in the Standard.

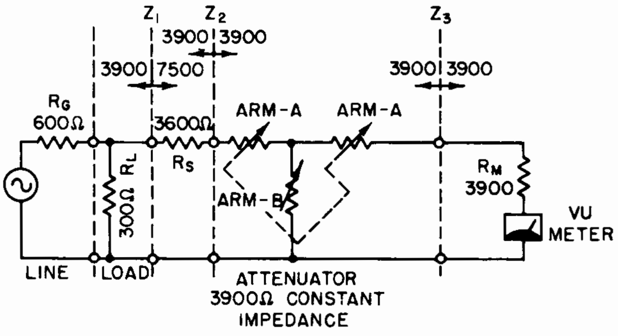
When a vu meter is used on a conventional 600 ohm line, a constant impedance attenuator is used to match the meter's impedance (in series with 3,600 ohms) with the 600 ohm line. The resistor is usually built into attenuators intended for vu meter use. FIGURE 2 shows the standard vu meter as used with 600 ohm lines.



(A) (B)

Figure 1. Vu meter scales. (a) Type A scale. (b) Type B scale.

Figure 2. Circuit of vu meter for operation on 600-ohm lines.



Ronald Ajemian is with the New York Telephone Company.

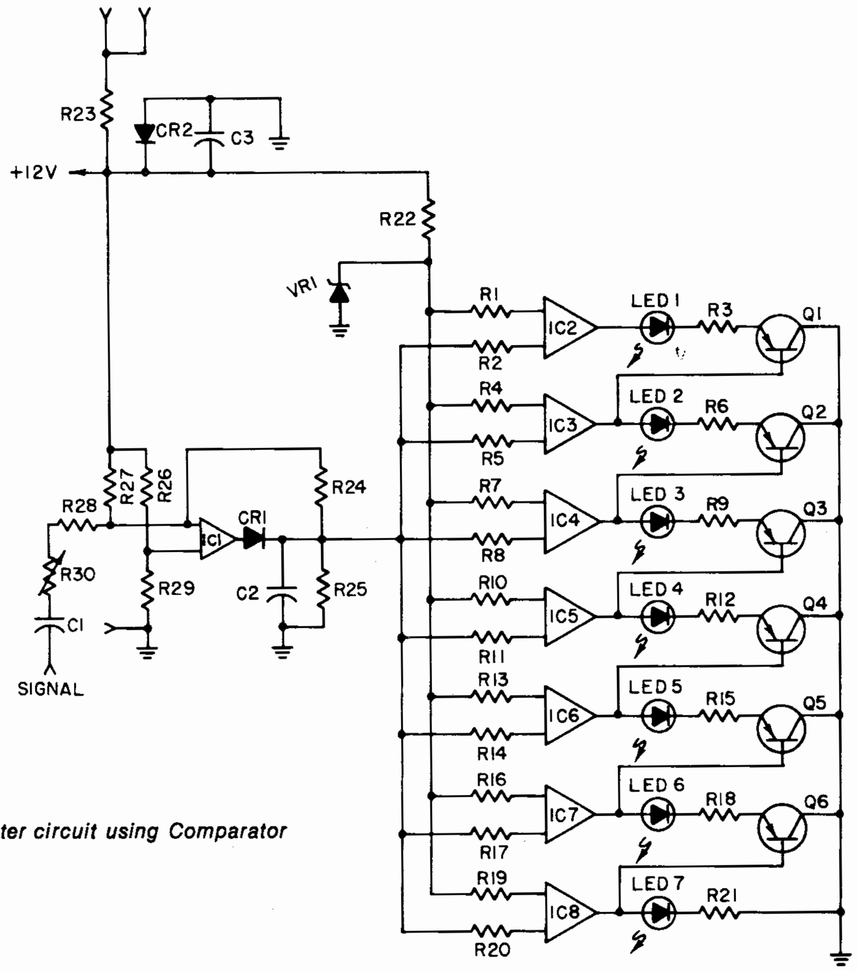


Figure 3. Led vu meter circuit using Comparator Principle.

LED VU METER

With the ever growing field of solid state technology, we have a vu meter which has no moving parts. The meter uses leds to represent the vu meter scale. There are some advantages over the conventional vu meter in that it can respond much faster to the short term signal peaks. Also there is the elimination of inertial response limitations and wearpoints. The result is a meter capable of being read at greater distance without excessive size.

The led vu meter works on the *Comparator Principle* which is basically simple. In the led vu meter circuit diagram (FIGURE 3) one comparator (IC1) is connected as a conventional peak detector, charging C2. The amount of charge time is limited by the output impedance of IC1 and the size of C2. Discharge time is controlled by R25 and the parallel combination of R2, R5, R8, R11, R14, R17 and R20, thus determining basic time constants for the meter. R23 and C3 form a decoupling circuit for any switching transients produced in the circuit. R22 and VR1 form a regulated voltage standard for the device. R3, R6, R9, R12, R15, R18 and R21 limit current through the light emitting diodes (leds). Led 1 through led 7, which are (in a volume unit (vu) meter) labeled —15 through +3 vu as shown in FIGURE 4.

Application of the led vu meter is as follows: R1, R4, R7, R10, R13, R16, R19 set an equal current level into each current-sensitive comparator, IC2 through IC8, determined by the voltage of VR1 and the size of the resistors. This assures that each comparator will trip at the same operating point for maximum accuracy. When the signal applied reaches sufficient amplitude to force current through R2 in excess of that through R1, IC2 output will go positive and conduct current through led 1, R3 and transistor Q1 which is held on by the low output of IC3. Led 1 then lights and indicates a —15 vu signal level. As the signal increases still further, IC3 output goes positive, turns off Q1 and led 1 and turns on led 2, indicating the next higher signal level. The remaining stages operate in the same manner with increasing signal level. The last stage (IC8) remains on with large signal levels, thus indicating an overload.

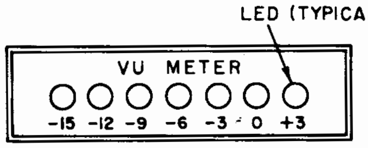


Figure 4. Led vu meter face.

In the led vu meter just discussed, we have seven leds. However, there are others with more leds for a wider scale, using the Comparator Principle.

The led vu meter has a couple of disadvantages. It doesn't indicate the loudness of the program and can't read the rms of the signal. The conventional vu meter is still necessary, enhanced by the led vu meter. ■

References:

Bernstein, Julian L. *Audio Systems.* John Wiley & Sons, Inc., 1966.

Weston Instruments, Application Data A-4800-1, May, 1950.

Pulse Dynamics Mfg. Corp., Technical Data on M-241 led meter.

API Instruments, Bulletin 0514-PB4, February, 1975.

POWER METER for your STEREO

More than just a peak-reading power meter, this easy-to-build project disconnects your speakers before your amplifier does the job—permanently!

MARK S. COHEN

IT'S NOT UNCOMMON TO see loudspeakers with power ratings of 500 watts or more. Now, you might think it safe to connect such speakers to any amplifier of 500 watts or less, and expect that combination to comfortably run at full power. Unfortunately, that's not so!

While some speakers may be able to handle instantaneous peaks of that magnitude, they can also be destroyed by continuous operation at substantially lower power levels. For example, the author's speakers are rated at 680 watts but are only capable of handling *30 watts* in continuous operation!

While most amplifiers have some sort of built-in protection circuitry, that circuitry does nothing, of course, to protect the speakers. That circuitry is designed to protect the amplifier *only*, and therefore will not kick in until long after the speakers have begun to smoke!

Here's something else to consider: Many of today's otherwise fine power amplifiers have no turn-on delay. At power up, the output may swing briefly to the positive or negative supply rail. (We've all heard that loud, dull thump at turn-on.) Even if that doesn't destroy the speakers outright, it certainly does nothing for their performance.

From what we've seen it is clear that a proper speaker-protection device must pass large power levels for musical peaks, but disconnect the speakers if the amplifier produces a sustained high-level output. The circuit described here does that, and also provides a turn-on delay.

If that doesn't peak your interest, included in this circuit is a peak-reading LED dot display that shows the output level being fed to your speakers. Not only is the circuit helpful in protecting speakers, but it also provides a fascinating demonstration of the power required to handle musical transients. The power monitor is designed so that successive LED's are turned on by a each 3-dB increase. That allows high resolution at low power levels.

Circuit description

Figure 1 is a schematic diagram of our circuit. It consists of four parts: an input buffer and peak detector, power-metering circuit, relay-control section, and, of course, the power supply.

Let's see how the circuit works. The left- and right-channel inputs are independently rectified and their peaks sampled. That information is sent to the metering circuits for display, and to the relay-control section. That section disconnects the speakers from the amp when the continuous power level is above a user-defined level (which is determined by the rating of your speakers). The relay-control section also contains the turn-on delay.

Let's take a closer look at the individual sections. **Note:** From here on, we'll only discuss the left channel as both left and right are identical. At the input, resistors R1 and R3 form a voltage divider to attenuate the input signal. Those resistors are selected to yield an output of 10 volts when the amplifier is delivering its maximum rated output. Table 1 is provided to help in the selection of R1 (R7 for the right channel) for various amplifier power and speaker impedance combinations.

Transistor Q1 is configured as a voltage follower. The Q1 output is rectified by diodes D1 and D2, which conduct only when the emitter voltage exceeds that at capacitor C1.

The parallel combination of R5 and C1 produces an extended time constant for the peak-reading operation of the meter. Capacitor C1 charges rapidly through resistor R4 (at the Q1 collector) and discharges slowly through R5. That allows easy viewing of peak power-levels.

The speaker protection circuit is formed by comparators IC3, IC4, relay RY1, and a few discrete components. Potentiometer R24 is used to set the circuit trip point, which is equal to your speakers' continuous power-handling rating (we'll explain just how that's done in a moment). That trip voltage is applied to pin 2 of IC3-a.

TABLE 1
ATTENUATION RESISTOR VALUES

Speaker Impedance	50W	100W	200W	400W	800W
2 ohms	*	3.9K	10K	18K	30K
4 ohms	3.9K	10K	18K	30K	47K
8 ohms	10K	18K	30K	47K	68K
16 ohms	18K	30K	47K	68K	100K

(*To read a maximum power level of 50W into 2 ohms, R1 and R7 should be replaced by a piece of wire between the appropriate printed circuit board pads.)

The voltage from the input section is fed to pin 3 of IC3-a via the series combination of R6 and C2. The values of the components in that R-C circuit are selected so that the capacitor charges almost instantaneously for high voltages, but slowly for lower voltage levels.

Should the voltage at pin 3 exceed the voltage at pin 2, the comparator outputs a high. When that happens, the voltage at pin 2 of IC4 rises above that at pin 3,

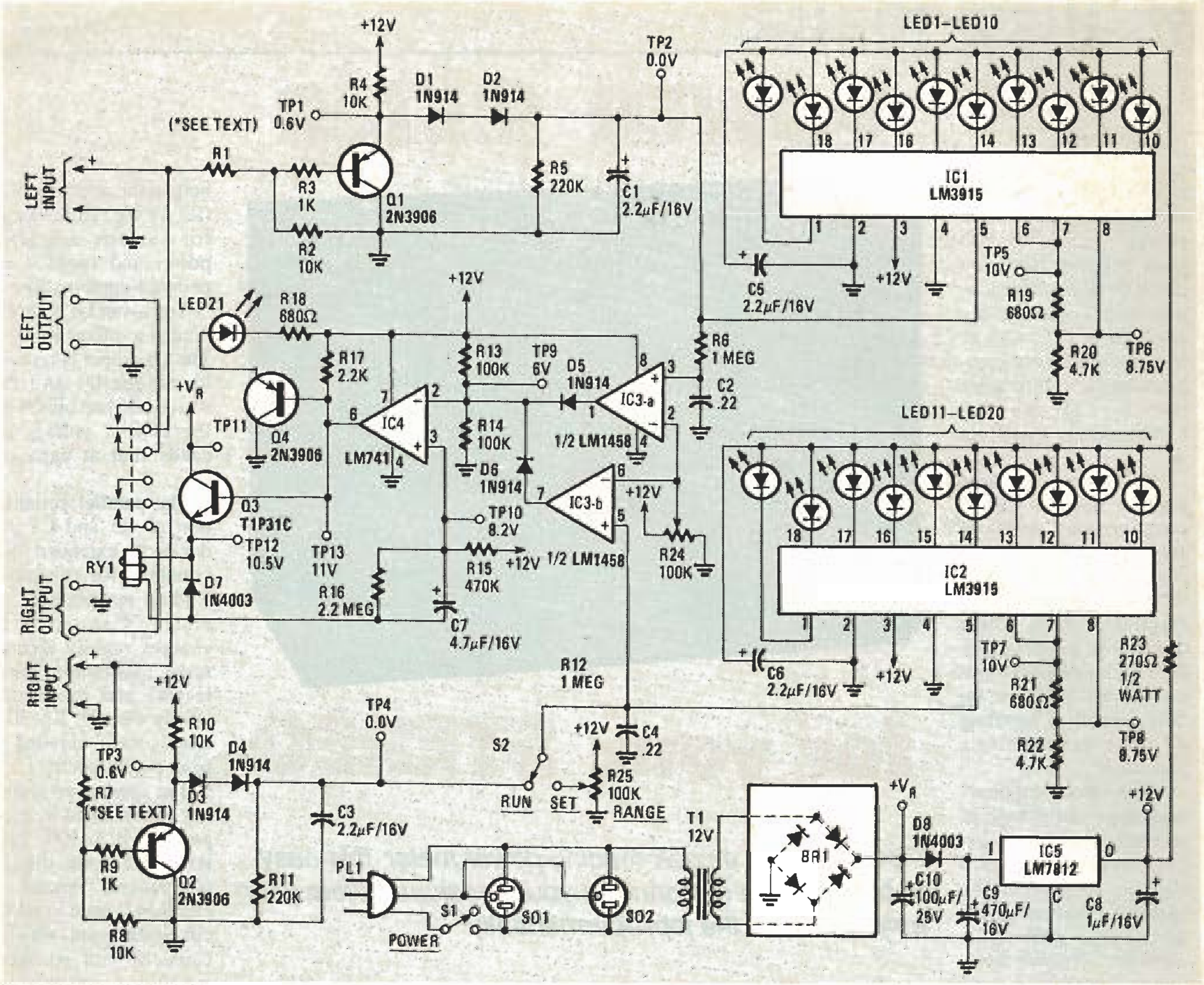


FIG. 1—THE SCHEMATIC DIAGRAM for the circuit is shown here. Note that a separate power supply is provided for transistor Q3.

causing that comparator's output to go low.

When the output of IC4 goes low, Q3 stops conducting. That, in turn, cuts of the current flow through RY1 causing the relay to open, disconnecting the speakers.

Also, when IC4 goes low, transistor Q4 begins to conduct. That causes LED21 to light, indicating that the protection circuit has been tripped.

Diode D7 protects Q3 against energy stored in the relay that might otherwise damage the transistor when the relay is turned off. Also, note that transistor Q3 is fed from a separate 16-volt power supply, $+V_R$. We will see later that $+V_R$ is designed to turn off rapidly so that the relay quickly opens when power is removed from the circuit, to protect the speakers from both turn-off and turn-on transients.

A six-second turn-on delay is provided by C7 charging through R15. At power up, the voltage at pin 2 of IC4 is set to 6 volts by a voltage divider made up of resistors R13 and R14. Diode D5 is included to ensure that the reference voltage at pin 2 of IC4 is not affected by a low at the output of IC3-a.

Pin 3 of IC4 is initially at ground; therefore, its output is low and the relay is turned off. At power up, capacitor C7 charges slowly through R15. When the charge on C7 (tied to pin 3) exceeds 6 volts, IC4 outputs a high, turning on Q3. That closes the relay contacts, connecting the speakers.

The display portion of the circuit is made of an LM3915 LED display driver (IC1). That IC can produce either dot or bargraph outputs. As shown in the schematic, it is wired as a dot-display driver. Successive LED's are turned on when the input voltage is increased by 3 dB (power doubled). Table 2 lists the peak power level at which each LED lights. As that table shows, those power levels depend on the maximum rated output of your amplifier, assuming that R1 has been selected as described earlier. For instance, if the maximum output of your amplifier is 50 watts, then LED's 1 and 11 light at 0.1 watt, and so on. Resistors R19 and R20, tied to pins 6 and 7 of IC1, control the brightness of the display and set the voltage level needed to light LED10. Resistors R19 and R20 are chosen so that a 10-volt input lights LED10.

If preferred, a bargraph display may be selected by connecting pin 9 of IC1 to the power supply; appropriate holes for a jumper wire are provided on the PC board. If you chose the bargraph mode, R23 (270 ohms ½ watt) should be replaced with a 39 ohm, 5 watt unit. Note that the LM3915 has a nasty tendency to oscillate under some conditions; C5 is in-

TABLE 2
PEAK POWER DISPLAYED

LED	50W	100W	200W	400W	800W
1,11	0.1	0.2	0.4	0.8	1.5
2,12	0.2	0.4	0.8	1.5	3
3,13	0.4	0.8	1.5	3	6
4,14	0.8	1.5	3	6	13
5,15	1.5	3	6	13	25
6,16	3	6	13	25	50
7,17	6	13	25	50	100
8,18	13	25	50	100	200
9,19	25	50	100	200	400
10, 20	50	100	200	400	800

cluded to protect against that.

The power supply is straightforward—a simple bridge rectifier and a single LM7812 regulator (IC5) gives a constant 12-volt output. The $+V_R$ supply is filtered only by C10, which is isolated from C9 by D8. That produces a fast turn-off of the relay when power is removed.

The power switch, S1, also turns convenience outlets SO1 and SO2 on and off. Those outlets are intended to be used as power connections for the rest of the stereo system. Using those outlets ensures that power is applied to all components simultaneously, and that all transients have ended before the speakers are connected. Thus, S1 acts as a master power switch.

Finally we come to S2 and R25. Switch S2 is a SPDT unit that is used to disconnect the right channel input and instead connect potentiometer R25 to the comparator and display circuitry. With S2 in the SET position, R25 is used to set the trip point (which is determined by R24 and your amplifier's maximum rated output) so that the speakers are disconnected at the desired power level.

Construction

The circuit is straightforward enough to be built on perfboard, but it is strongly recommended that a PC board be used. PC board minimizes construction errors and saves time in the long run.

A few factors had to be taken into account in the circuit layout. Capacitors C5 and C6 should be placed as close to the LED's as possible. All ground connections on the left and right input and display circuits should be returned directly to pin 2 of IC1 and IC2 respectively. That's done to prevent oscillation of the LM3915, which may occur under some circumstances. When LED's 1–20 are all turned on, R23 may have to dissipate as much as 5 watts; so it's a good idea to put some space between it and any other components.

The first step is to etch your own PC board or acquire one from the supplier given in the Parts List. The PC-board pattern is shown in Fig. 2; the corresponding parts-placement diagram is shown in Fig. 3.

First note that the IC's are not socketed (see Fig. 4), although sockets may be used if desired. Also note that some resistors and diodes are mounted vertically (like radial lead capacitors).

Turning to the resistors first, the holes on the board are spaced for ¼-watt units with their leads bent flush to the resistor body. Install all fixed resistors, making sure they are in their proper positions. Once that's done finish up by installing potentiometers R24 and R25.

The capacitors should be the next components installed. Observe capacitor polarities and be sure that all units are

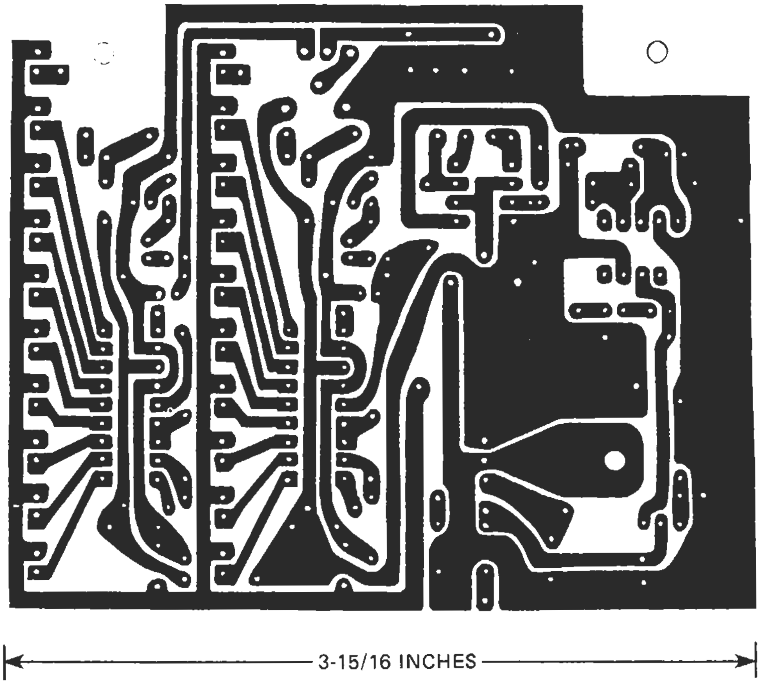


FIG. 2—THE FOIL PATTERN for our speaker-protection device/power meter is shown here full size.

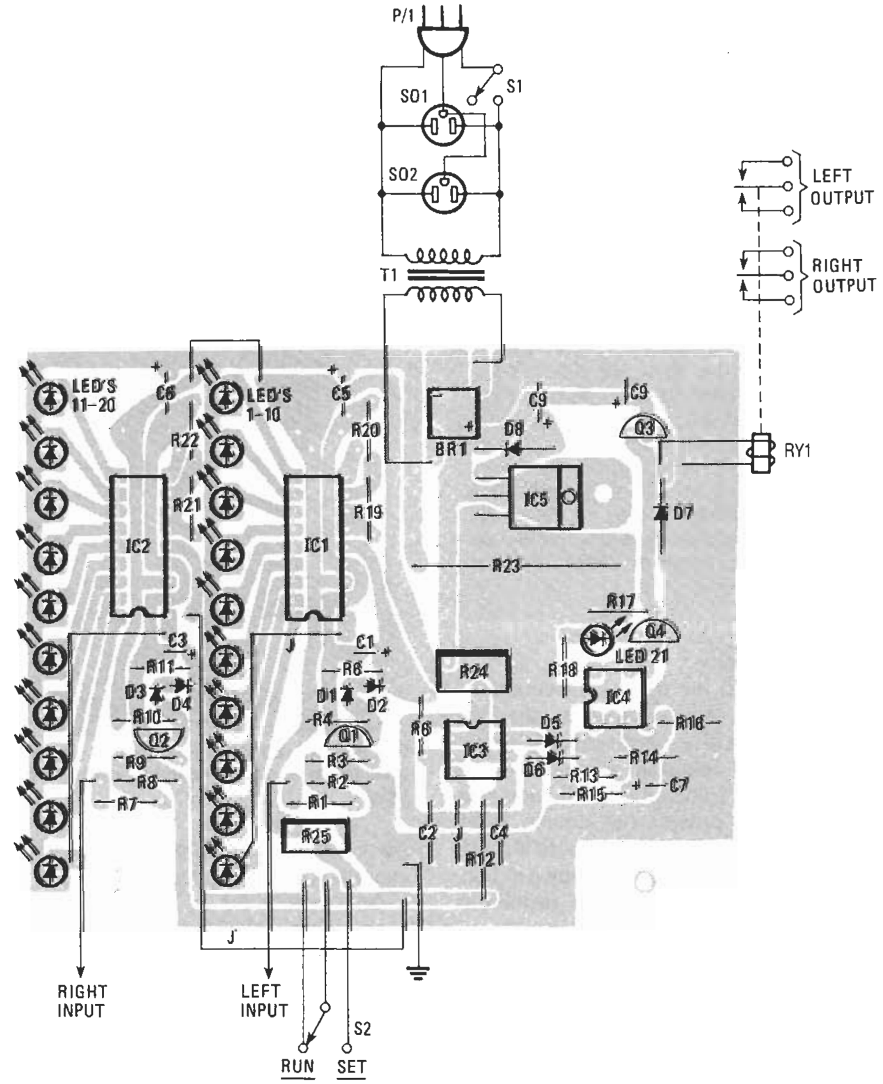


FIG. 3—PARTS-PLACEMENT DIAGRAM for the foil pattern given in Fig. 2 is shown here. Note that several of the holes are not used.

PARTS LIST

All resistors ¼ watt, 5% unless otherwise noted.

R1, R7—see Table 1
R2, R4, R8, R10—10,000 ohms
R3, R9—1000 ohms
R5, R11—220,000 ohms
R6, R12—1 Megohm
R13, R14—100,000 ohms
R15—470,000 ohms
R16—2.2 Megohms
R17—2200 ohms
R18, R19, R21—680 ohms
R20, R22—4700 ohms
R23—270 ohms, ½ watt
R24, R25—100,000 ohms, trimmer potentiometer

Capacitors

C1, C3, C5, C6—2.2µF, 16 volts, tantalum
C2, C4—0.22µF, ceramic
C7—4.7µF, 16 volts, tantalum
C8—1µF, 16 volts, tantalum
C9—470µF, 16 volts, electrolytic
C10—100µF, 25 volts, electrolytic

Semiconductors

IC1, 1C2—LM3915 LED dot/bar display driver
IC3—LM1458 dual op-amp
IC4—LM741 op-amp
IC5—LM7812 12-volt regulator
Q1, Q2, Q4—2N3906 PNP transistor
Q3—TIP31C NPN transistor
BR1—50 PIV, 500-mA bridge rectifier
LED1–LED21—jumbo LED's
T1—12-volt, 500-mA transformer
S1—SPST, rocker switch, 15 amps
S2—SPDT submini PC mount switch
RY1—DPDT 12-volt DC relay
SO1, SO2—grounded convenience outlets (see text)

Miscellaneous:—case, 3 conductor line cord, strain relief, PC board, jacks for input and output, screws, solder, wire, etc.

The following is available from Clearview Designs, Inc., 217 East 85 St., Suite 467, New York, NY 10028: complete kit including wire, solder, step-by-step instructions, and all components except case for $59.95, plus $3 postage and handling; circuit board only available for $10. New York State residents add 8¼% sales tax. Other selected components available by arrangement, contact Clearview Designs, Inc. for details.

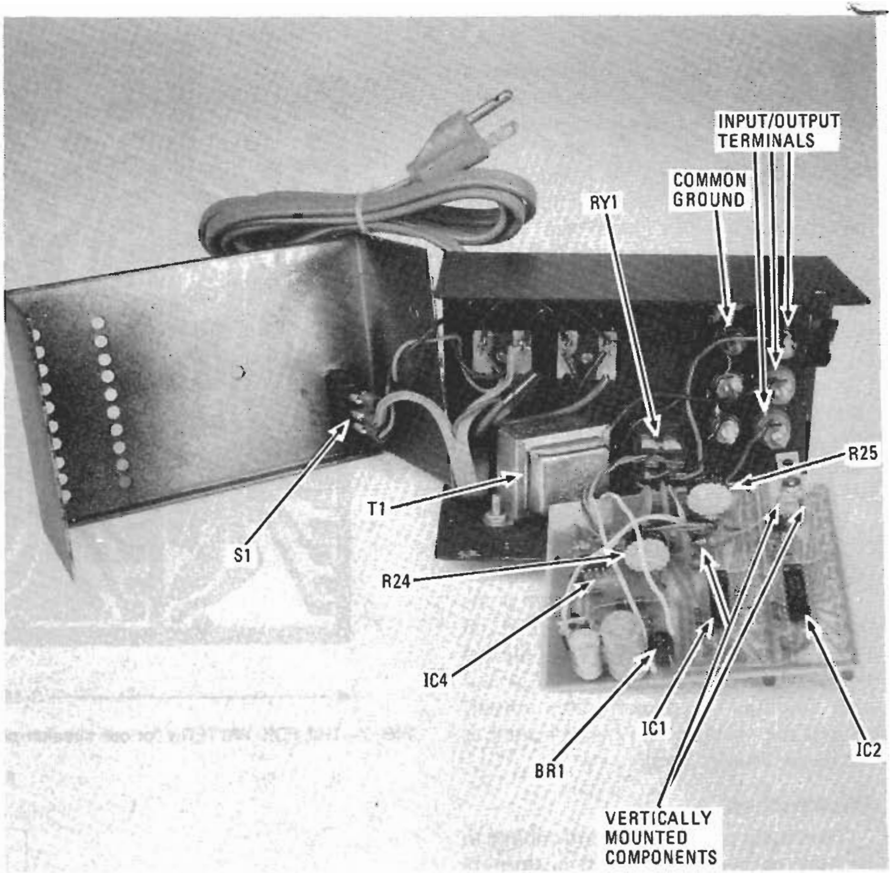


FIG. 4—INSIDE THE UNIT. Note that several components are vertically mounted on the PC board.

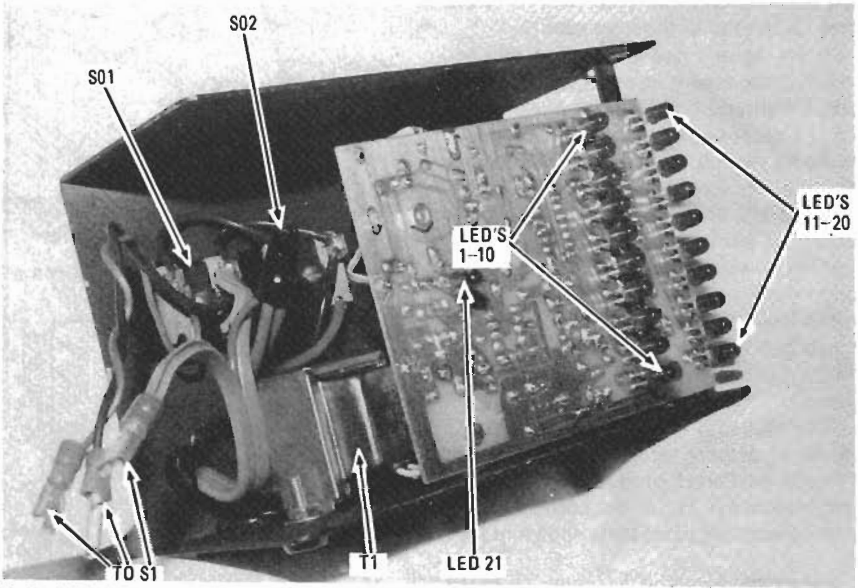


FIG. 5—LED1–LED21 ARE MOUNTED on the foil side of the PC board. Using a cardboard spacer during installation as described in the article helps ensure that all of the LED's are mounted at the same height.

oriented properly.

Next, install the diodes. Once again, carefully note their orientation (see Fig. 3). It is a good idea when soldering semiconductors to attach an alligator clip to the lead being soldered. The clip acts as a heat sink to protect the device from damage during soldering. Diodes D1–D4 are all installed vertically as shown in Fig. 4. When done with the diodes, install the transistors.

Install the IC's next, noting the orientation of pin 1. Pin 1 may be marked with a painted band, notch, or dot. With the marked end on top, pin 1 is in the upper left corner. The LM7812 regulator, IC5, should be installed so that when bent back, its flat side is flush with the board. Next install the bridge rectifier, BR1, again noting the proper orientation.

Next solder S2 in place on the PC board. Then install the five jumper wires; either bare or insulated wire may be used. The LED's, which mount on the foil side of the board (see Fig. 5), should all be positioned at the same height. To make the task easier, insert a cardboard spacer, about ¼-inch wide, beneath the LED's during soldering.

As the circuit does not require any special shielding, it can be placed in any appropriately sized cabinet. Prepare the cabinet by drilling carefully spaced holes into the front panel for each LED. Or you may cut out a single block and use a bezel with lens to improve the unit's appearance. The relay, transformer, power switch, AC outlets, and input/output jacks are mounted on the cabinet as shown

continued on page 119

POWER METER

continued from page 76

in Fig. 4.

Dry-transfer lettering may be used to mark power levels associated with each LED and give a professionally-finished appearance. It's also a good idea to mark the left and right output and input connectors as well.

Now run a single lead between all ground terminals of the output and input connectors to a ground point on the PC board. The "hot" terminals are connected as shown in Fig. 3.

The convenience outlets are wired together in parallel. The neutral terminals are connected to the green wire of the power cord; under no circumstances should neutral be connected to the PC board or chassis ground. Check the wiring and make sure all diodes, capacitors, and IC's are in the proper place and correctly oriented. Be especially careful about the power connections.

Test and calibration

With the power switch turned off, set S2 to the RUN position and plug in the power cord and turn on the power. LED 21, the protection lamp, should come on for a few seconds and then go out. As the LED goes out, you should hear the relay click as it closes.

Place S2 to the SET position. One left-channel LED should light. Adjusting R25 should change which LED is on. If the unit doesn't operate as expected, remove power immediately. To aid in troubleshooting, nominal operating voltages at various test points through out the circuit are shown in Fig. 1.

The only calibration necessary is done using R24 and R25. Note: For calibration, it is important that you know the continuous power-handling capability of the speakers to be connected; contact the manufacturer for that information.

Set R25 to about mid-range and turn R24 all the way in one direction until the relay opens and LED21 lights. Now rotate R24 all the way in other direction (the relay should close). With S2 still in the SET position, adjust R25 until the LED corresponding to the power handling capability of your speakers just turns on.

Wait several seconds and turn R24 until you hear the relay click open and you see LED21 turn on. Waiting several seconds ensures that the protection circuit turns on *only* after sustained high-power levels and not during large transients. Now set S2 to the RUN position, and the unit is ready for connection to your system.

Using the device

First, determine which speaker-output terminals are common between the left and right channels of your power amplifier (usually the ground terminals). An ohmmeter may be helpful here. Then connect the common terminals of the amplifier to the ground terminals of the protection circuit. Caution: The circuit should not be used with any amplifier that cannot accept common connection of the left and right speaker grounds. For most commercial amplifiers that's not a problem; but if you are unsure, consult your owner's manual or the amplifier's manufacturer.

Connect the positive (+) outputs of the amplifier to the left and right inputs on the unit. Occasionally the bottom-most LED on one or the other channel will remain lighted with no input to the speakers. If that happens, first disconnect the amplifier and ground the unit's inputs. If that turns the LED off, there may be a small amount of DC at your amplifier's output terminals.

Should that be the case, have your amplifier serviced immediately to save wear and tear on your speakers. If the LED stays on with the inputs grounded and S2 set to RUN, there may be a problem with Q1, Q2, or any one of diodes D1–D4. Normal variations among inexpensive components may cause that condition; the simplest solution is to replace those components in the affected channel.

While the unit should prevent most forms of speaker damage, *please* do not use it as an excuse to abandon all caution in using your stereo. **R-E**

FIG. 2—CONTROL PANEL of the Formula-7 speaker system.

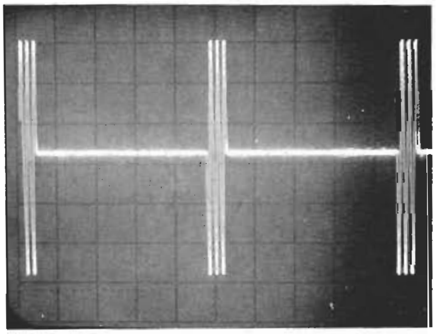


FIG. 3—TEST RECORD supplied with Formula-7 provides three cycles of 300-Hz signal every 100 milliseconds.

about this indicator is that it does not require that the user know or care what the dynamic (or music) power capability of the amplifier in question is in relation to its steady-state or continuous-power rating, since this is really of academic interest and not necessarily directly related to when the amplifier will begin to clip under actual listening conditions.

The clipping indicator feature, as well as two other major indicating and protecting features, will best be understood by referring to the complete schematic diagram of the Formula 7, shown in Fig. 4. Audio signals delivered by the power amplifier to J1-1 and J1-2 are fed to the usual speaker drivers and crossover network components, with which we will deal shortly. In addition, the audio signal is rectified by diode D2 and applied to the positive input of IC3-a. The trigger point of LED9 is determined by picking off a portion of the fixed 5-volts DC from a built-in power supply via R23 and applying it to the negative input of IC3-a. Thus, the trigger point of LED9 can be adjusted by means of R23 (the front panel AMPLIFIER CLIPPING control previously referred to) over a wide range corresponding to amplifier outputs up to around 125 watts-per-channel.

Now, suppose the user owns an amplifier that exceeds the safe power-handling capability of the speaker system. In that case, auditioning of the test record might result in speaker distortion or damage well before the amplifier begins to clip. To prevent overdriving of the speakers in this manner, additional indicator and protection devices have been incorporated.

Referring now to the portion of Fig. 4 that shows the four drivers you will note that there are three circuit breakers (CB1, CB2 and CB3) wired in series

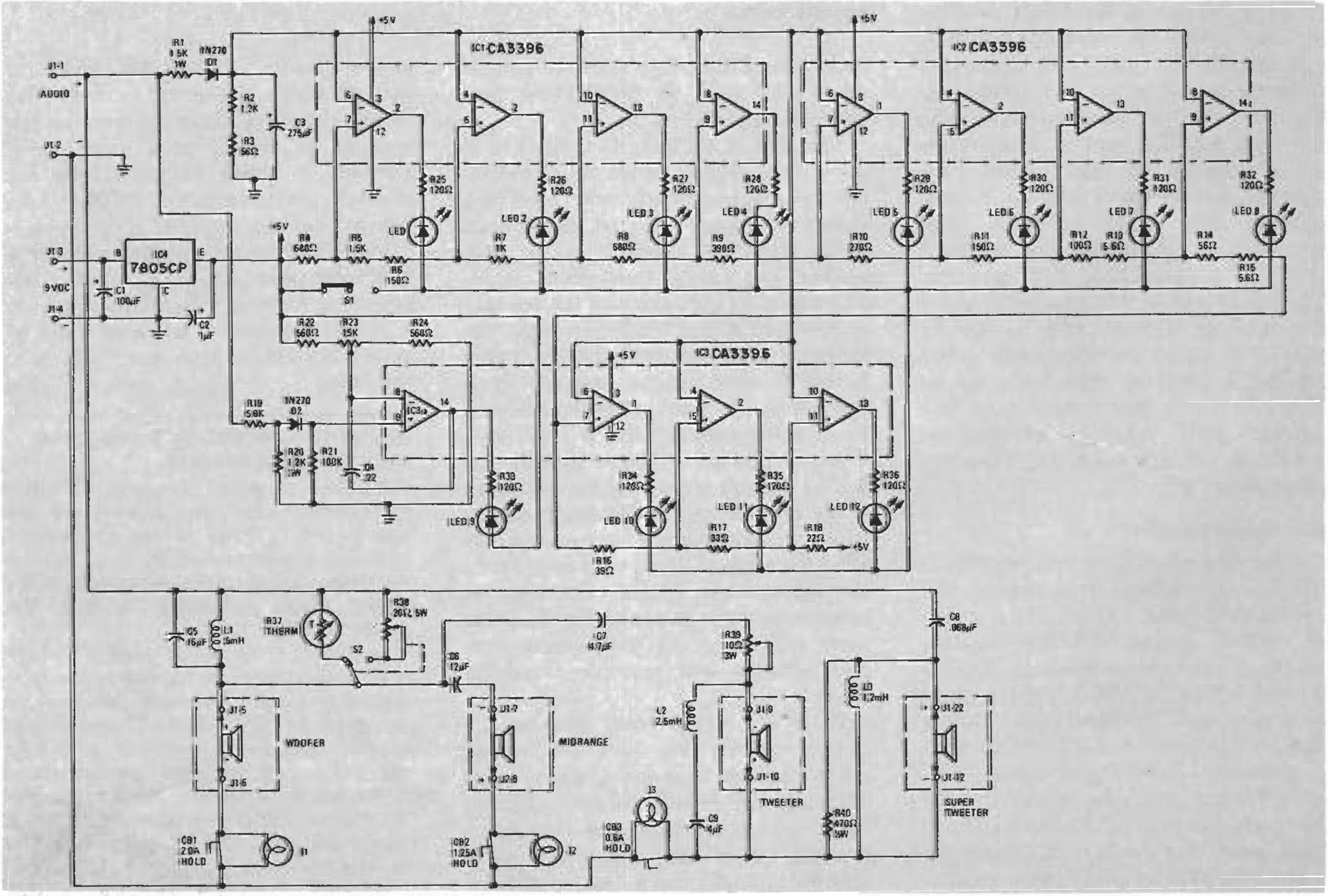


FIG. 4—INTERFACE AND CROSSOVER circuitry of the Formula-7 speaker system.

with each driver. Each circuit breaker is rated at an appropriate value from 2.0 amperes for CB1 to 0.6 amperes for CB3. When the current exceeds the circuit-breaker rating, the appropriate circuit breaker opens and an indicator light wired across that circuit-breaker flashes in accordance to the signal current that then flows through it.

The three circuit breakers are located on the sloped portion of the front panel and are manually resettable. Dividing up this indicating system instead of having a single circuit-breaker permits the user to determine *which* driver elements of the unit are being overdriven and even warns of trouble in the event of super-audible high-frequency oscillation that, while inaudible, might easily destroy the high frequency driver elements.

One other aspect of the Formula 7 is worth mentioning before we leave the speaker-driver section of the schematic. Thermistor R37 is the key component in what B.I.C. calls its "dynamic tonal compensation" system. When front-panel mounted potentiometer R38 (which varies the signal level fed to midrange and tweeter) is rotated fully counterclockwise, switch S2 is thrown to the position shown in Fig. 4. The value of thermistor R37 varies in accordance with the average current flowing through it. R37 is chosen so that when loud levels are reproduced, its resistance is very low (due to the heating effect of the thermistor) while at lower listening levels, its resistance increases and reduces the mid- and upper-mid frequency sound levels. This amounts to the same thing as boosting (relatively) the bass response and is designed to compensate for the well known Fletcher-Munson loudness effect in human hearing. This effect is often compensated for by the so-called loudness controls on amplifiers and receivers. The advantage in this approach is that the resultant response can be directly related to actual sound-pressure levels and not to arbitrary settings of a master volume control that cannot take into account such variables as program source signal levels, speaker efficiency or amplifier gain.

SPL indication

The audio signal from the amplifier is rectified and filtered by capacitor C3 and diode D1. (See Fig. 4.) This varying DC voltage is applied to the negative inputs of eleven comparator circuits (four in IC1, four in IC2 and the three remaining in IC3). The positive inputs of these comparators are supplied with progressively lower and lower DC voltages that are determined by the string of series resistors R4 through R18. Thus, when the lowest-level signals are applied, LED12 will light, while increasingly stronger input signals will trigger LED11, LED10 and so forth up to LED1 which flashes when the greatest audio signal levels are applied to the system.

The row of LED's on the front panel are calibrated in approximately 4-dB increments all the way from 75-dB SPL (*S*ound *P*ressure *L*evel) to 117-dB SPL. A chart inscribed right on the system's front panel (see Fig. 5) permits the user to translate the LED indications into actual sound pressure levels, measured at specific distances on-axis from the speaker system. Alternatively, the user can read the average sound pressure level atained in listening rooms varying in cubic volume from 1000 cubic feet (a room having floor dimensions of around 10 × 12 feet) to 6000 cubic feet (approximately 24 × 32 feet).

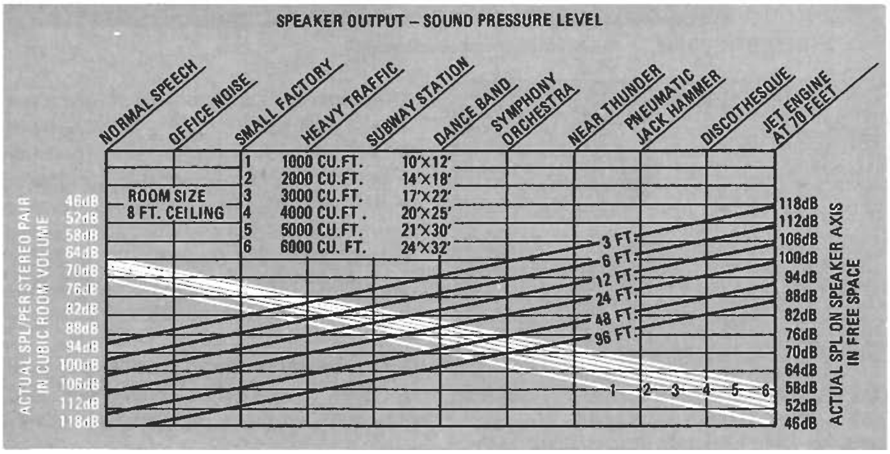


FIG. 5—GRAPH ON FRONT-PANEL enables user to translate power readings into actual sound pressure levels.

The idea of using LED indicators to show audio power levels is, of course, not new and is currently being used on a variety of higher-powered high-priced audio amplifiers available in the hi-fi market. The unique thing about incorporating such indicators on the speaker system itself is that, for the first time, the indicator readings are directly translatable to actual sound pressure levels and not just to wattage levels delivered by an audio amplifier into a fixed resistive load. The manufacturer (in this case B.I.C.), having control of the efficiency of the speaker system and being able to measure actual sound output (in dB SPL) for a given signal voltage input to the loudspeaker system, was able to prepare the chart shown in Fig. 5 so that users can relate the information supplied directly into perceived loudness levels.

From a practical point of view, the system enables the user to balance stereo channels in terms of actual audibility and also permits listeners to judge how loud various programs they listen to really are, as compared with familiar reference levels such as symphony orchestra, dance band, discotheque and several others inscribed over the various LED's below the chart. Observing the flashing lights while listening to music for extended periods may appeal to some hi-fi fans while others may wish to just listen and not look, having established desired levels. For this reason, the Formula 7 has a switch (SW2 in the schematic diagram) that permits you to turn off the sound pressure level indicators at will.

Much of what B.I.C. has built into the Formula 7 is fairly simple in terms of circuit complexity, and the information it provides could be obtained if you owned a good SPL meter and an accurate audio power meter. But few serious audio enthusiasts want to become audio technicians as well. The incorporation of these features in this speaker, as well as in a lower-priced Formula 5 system announced by the company (that one lacks the SPL indicators but has the amplifier clipping indicator as well as the speaker protection indicators and dynamic tonal compensation feature) will, at least, provide a certain amount of peace of mind to users who tend to push their systems to the limit. **R-E**

Higher hi-fi recording group goes back to direct-on-disc

A Canadian record company, Nimbus 9 Productions Ltd., has abandoned the tape-recording stage of disc production. The new direct-on-disc albums, bearing the Umbrella trademark, will be sold in the United States by Audio-Technica, the phono cartridge firm.

According to Jon Kelly, general manager of Audio-Technica, bypassing the tape recording stage eliminates problems of distortion, limited dynamic range, and of course, tape noise. Because engineers mix and record the studio performances direct onto a master disc, Kelly points out: "Musicians and engineers must display a high degree of professionalism. There is no room for error.

Records were expected to be available early this winter at $12.95 retail.

Moving-dot indicator tracks bipolar signals

by Ted Davis
Riverton, Ill.

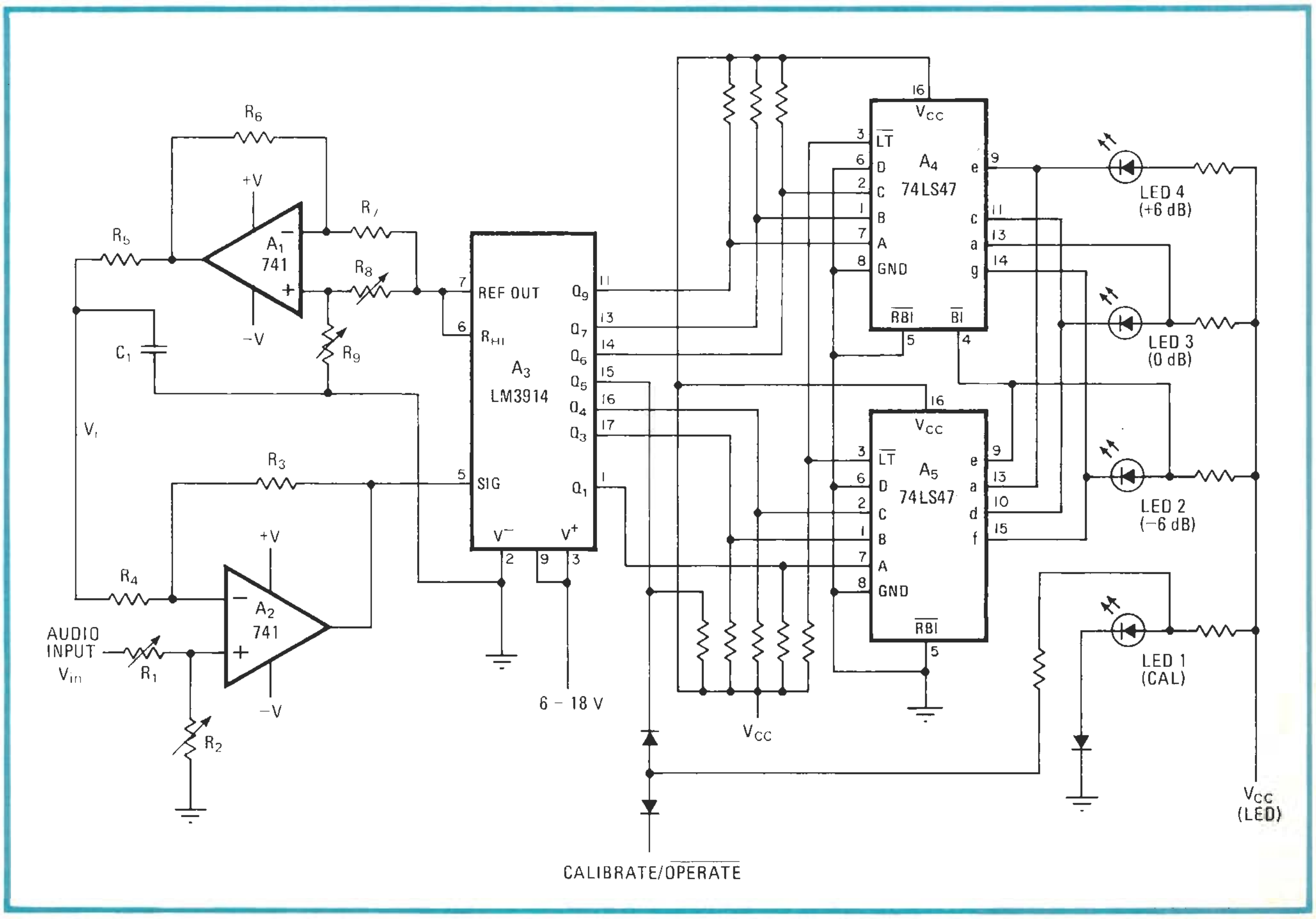
Although bar- or dot-display chips are a simple means of indicating the instantaneous value of a signal, they respond only to unipolar levels, a definite drawback in processing audio-frequency signals with asymmetrical (bipolar) inputs. If reduced resolution is acceptable, one solution is to offset the audio voltage to the display chip. In this way it will be centered at half scale to allow for positive and negative signal excursions. Such a method is implemented in the scheme shown here.

The circuit is configured to detect signal changes in 6-decibel steps, making it useful for audio-level monitoring. Other steps may be ordered by rewiring the output circuit appropriately. The unit may also be used as a bin-sorter or percent-change indicator for ac inputs or, with removal of capacitor C_1 and consolidation of resistors R_4 and R_5, dc inputs.

Operational amplifier A_1 applies a reference voltage to the inverting input of A_2 so that it and the LM3914 bar/dot display may be offset by the desired amount. The value of the reference voltage, which is derived from the LM3914, is $V_r = 1.25[-2R_9/(R_8+R_9)+1]$ assuming that $R_6 = R_7$ and the reactance of C_1 is negligible. The offset signal thus applied to the signal input (pin 5) of the LM3914 is $V_r k$, where $k = R_3/R_4$.

Assuming also that $R_5 = R_3 - R_4$, the offset voltage can be made to vary linearly from $-1.25k$ to $+1.25k$ and be centered at any value simply by adjusting R_8 and R_9. To set the value at the mid-level digital output of the LM3914 dot or bar display, for example, R_8 and/or R_9 is varied so that Q_5 trips and, through the 74LS47 BCD-to-seven-segment decoder/driver, dims light-emitting diode 1. The user should then back off on the setting until Q_5 goes high again and then move the corresponding potentiometer halfway towards the position that would dim the LED once more.

Superimposed on the reference signal will be the component added by the audio signal, which at the



Plus and minus. Input of bar- or dot-display chip LM3914 is biased at user-set dc level so that it will respond to bipolar excursions of ac signals. Three LEDs serve as moving-dot indicator with a resolution of 6 dB. Truth table outlines circuit operation.

TRUTH TABLE: SIGNAL-LEVEL INDICATOR

INPUT V_{in}	A_4										A_5									LED			
	D	C	B	A	$\overline{RBI}$	$\overline{BI}$	a	c	e	g	D	C	B	A	$\overline{RBI}$	a	d	e	f	2	3	4	
below 10%	0	1	1	1	1	1	0	0	1	1	0	1	1	1	0	0	1	1	1			λ	(+6 dB)
10% to 20%	X	X	X	X	X	0	1	1	1	1	0	1	1	0	0	1	0	0	0		λ		(0 dB)
20% to 40%	0	1	1	1	1	1	0	0	1	1	0	1	0	0	0	1	1	1	0	λ			(−6 dB)
40% to 60%	0	1	1	1	1	1	0	0	1	1	0	0	0	0	0	1	1	1	1	ALL OFF			(underrange)
60% to 70%	0	0	1	1	1	1	0	0	1	0	0	0	0	0	0	1	1	1	1	λ			(−6 dB)
70% to 90%	0	0	0	1	1	1	1	0	1	1	0	0	0	0	0	1	1	1	1		λ		(0 dB)
above 90%	0	0	0	0	1	1	0	0	0	1	0	0	0	0	0	1	1	1	1			λ	(+6 dB)

X = don't care Input voltage V_{in} normalized to full scale at pin 5 of LM3914

output of A_2 is equal to $V_{in}R_2(k+1)/(R_1+R_2)$. Thus positive and negative excursions of the ac signal will be detected by the LM3914. The scale factor is adjusted by applying the user-standard audio level to the input and adjusting R_1 and/or R_2 until the 0-dB LED just lights up.

The truth table outlines the overall operation of the circuit as a function of signal level. Note that the e segment of the low-order 6 shunts LED 2 in order to resolve a switching conflict between the 4 and 6 outputs. The 6 is also used to blank the high-order decoder when a negative-going 0-dB level is detected.

The values of the current-limiting and pull-up resistors depend on the logic family utilized; for TTL devices, 1-kΩ components will suffice throughout. Care must be taken to ensure that the voltages developed at the e output satisfy the noise-margin requirements of the BI input of A_4; that is, the total sink current at e must not raise the voltage above the maximum logic 0 level and the drop across LED 2 in series with the sink transistor must exceed the minimum logic 1 level. R_8+R_9, in parallel with R_7, set the sink current of the outputs of the LM3914.

The programmed current must be high enough to saturate the output transistors given the pull-up resistors used. The values of most of the other resistors are determined by the values of R_7 through R_9. The value of C_1 is determined by the value of R_4 and the lowest frequency of V_{in}. □

LED Bar-Graph 8 Best Applicati

Looking for a simple but useful electronic gadget you can build for your home or car? Here are some good one-evening projects you'll like.

IN THE MARCH 1979 ISSUE WE PRESENTED an application note covering the GL-112R3 bar-type LED array and the IR-2406 driver that works with it. In the editorial you were invited to send in innovative applications for these novel devices. As a measure of encouragement, we offered $50.00 each for the three best applications and $10.00 each for the others that we selected for publication.

We were surprised to find that two monitors for automotive electrical systems were among the top entries. Rather than have our judges select the one to use, we decided to publish both and let you decide which one you'd use in your car, van or RV.

Electronic thermostat

This circuit (Fig. 1) shows an energy-saving thermostat designed to control home heating and air conditioning systems. Minor modification would allow it to control any heating or cooling function. Thermistor RT1 is the temperature-sensing element that develops a voltage proportional to the temperature in a ratio of 11 mV-per-degree-Celsius. This voltage is amplified and scaled to the range required for the IR-2406, whose reference voltages are +1 VDC and +6.2 VDC. The IR-2406 then drives the GL-112R3 and two AND gates whose outputs are amplified to a level suitable for driving a relay. Jumpers J1 and J2 select the temperature at which the voltages are fed to the gates.

The onboard power supply provides +17 VDC unregulated and +1 VDC and +6.2 VDC regulated voltages for the references for IC3. The +17 VDC source is applied as V_{CC} for IC1, IC2, IC3 and the LED array DIS1. The power supply requires 24 VAC from the existing thermostat transformer.

In Fig. 1, RT1 and R5 form a voltage divider whose output is proportional to the ambient temperature in a ratio of approximately 11.3 mV-per-degrees-Celsius. Amplifier IC2-a is connected as a differential amplifier that scales the input and amplifies with a gain of about 42. This voltage is then applied to IC3 that drives the display. The pins of DIS1 are connected to gates IC1-a and IC1-b by jumpers that select the operating temperature. IC1-b has one input connected to ground and the other to the input voltage so that as the temperature drops below the preset level its output goes positive. This is amplified by IC2-d to the required level to activate a control device for the heating system with the output level adjusted by R8. Gate IC1-a has one input connected to V_{CC} and the other to the high-limit bus that makes its output positive when the temperature exceeds the preset level. IC2-c amplifies this voltage to the level required for the air conditioner control device with the level set by R4.

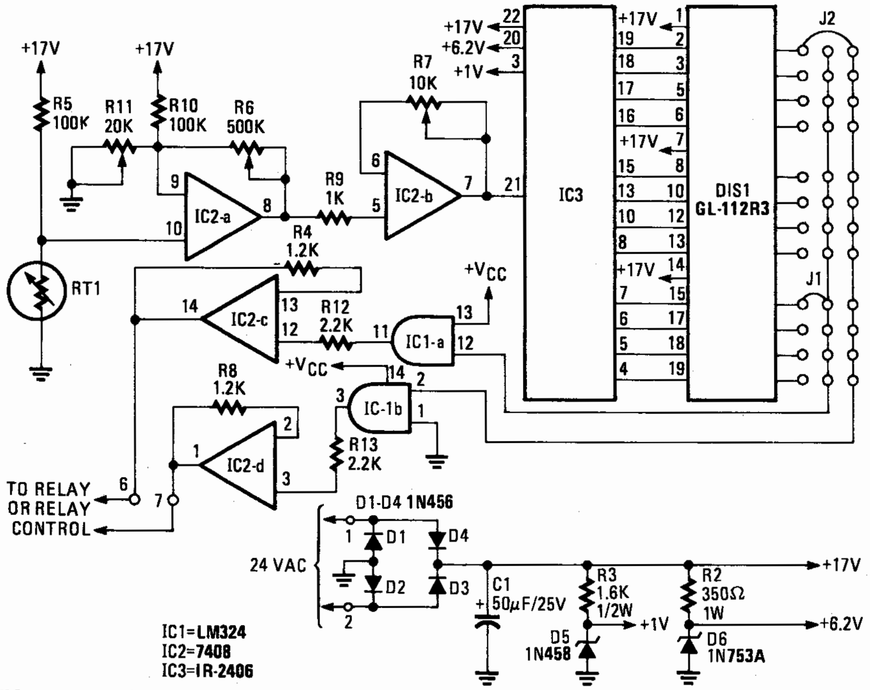
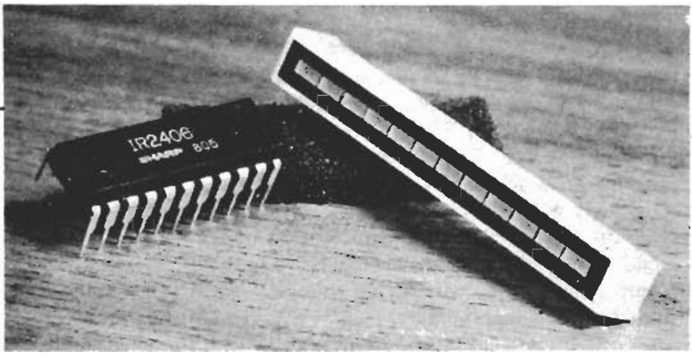


FIG. 1—ELECTRONIC THERMOSTAT has bar-graph temperature display. Two gates, fed from segments of the display, develop signals to control heating or cooling devices.

Figure 2 is the parts layout and printed circuit board component side with runs shown. Figure 3 shows the lower side of the board with the *shaded area being etched away* leaving the major portion for a ground plane. Figures 2 and 3 are scaled 1 line equals .1 inch and the circuit requires a 2.6×3.4-inch board. The labelled terminals on the circuit board and their functions are:

1. 24 VAC
2. 24 VAC
3. Sensor RT1
4. Ground
5. Ground



Display

ons

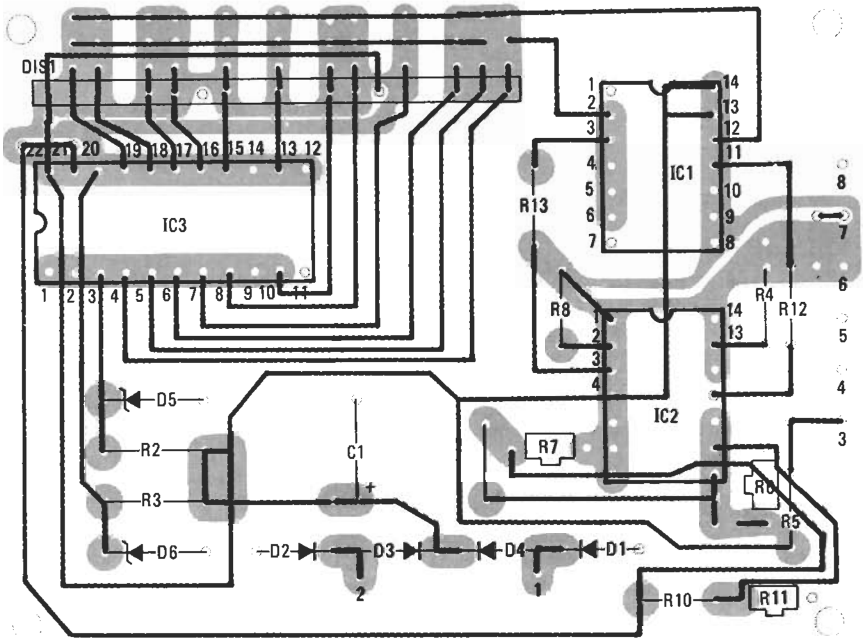


FIG. 2—PARTS LAYOUT as viewed from component side of the board. Note that the shaded areas have been etched away. Component connections can be soldered or wire-wrapped

6. Air conditioner control
7. Heater control
8. Ground

Initial Adjustment:

1. Adjust R11 to give 1.42 VDC at IC1 pin 9.
2. Set R6 so that the output voltage at IC1 pin 8 is (voltage on pin 9 — voltage on pin 10)×5.
3. Set R7 so that IC1 pin 7 reads a voltage of 8.475 × pin 5 voltage.

This will cause the GL-112R3 indicator to illuminate the first segment at 16 degrees Celsius and add one segment for each 1 degree Celsius increase until at 27 degrees Celsius all will be illuminated. Minor adjustments may be required (R11 adjusts linearity while R6 and R7 adjust gain and set indicator range.) Other settings of R11, R6, and R7 will make the reading and control in degrees Fahrenheit.—*Jerry V. Barrington*

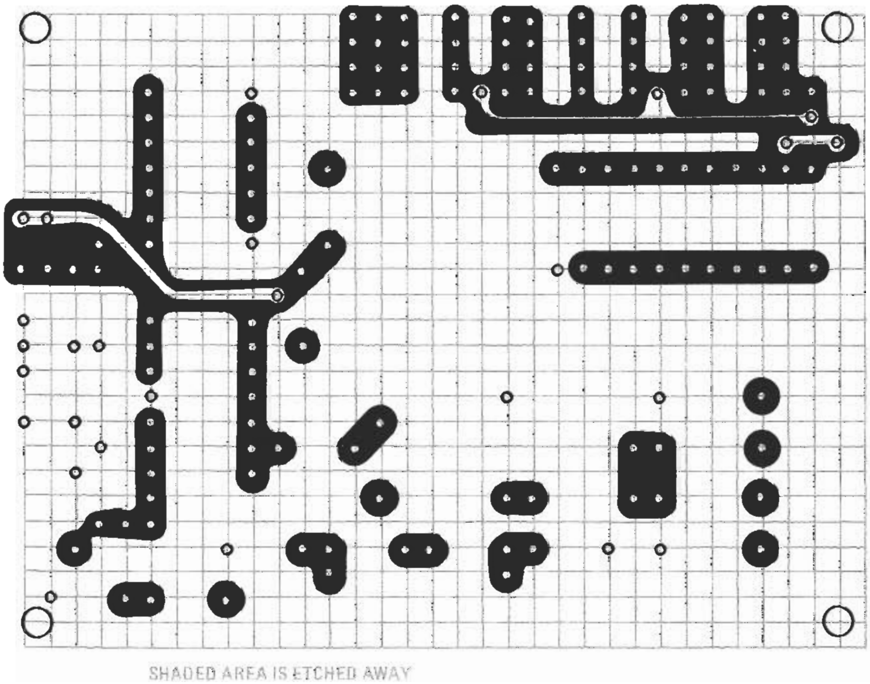


FIG. 3—FOIL PATTERN for the thermostat board can be drawn free-hand with each vertical and horizontal line representing one-tenth inch.

Two expanded-scale voltmeters

In response to your challenge in the March '79 issue, here are two designs using the GL-112R3 LED Array and IR-2406 LED Driver. Both designs are for expanded-scale voltmeters. The first is a line-voltage monitor which displays voltage in the range of 108 to 130 volts. The second design is an automotive charging system monitor/tester displaying voltage in the 10- to 16-volt range.

Line voltage monitor

The line-voltage monitor circuit (Fig. 4) lights the first LED in the array when line voltage exceeds 108 volts and lights successive segments for each 2-volt increase above 108 volts. All twelve segments are lighted when line voltage reaches or exceeds 130 volts.

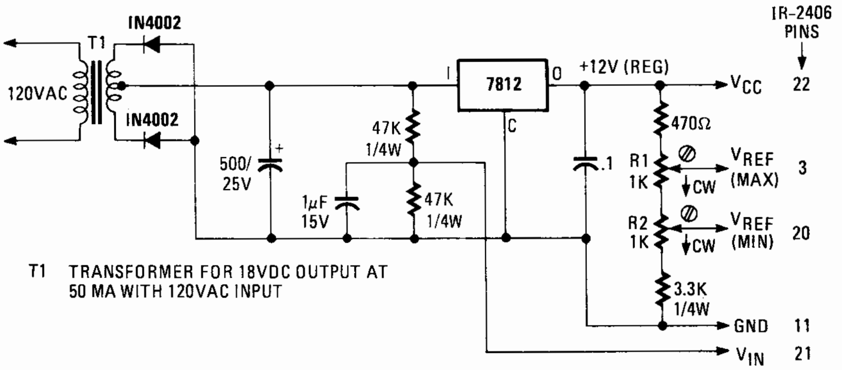


FIG. 4—LINE VOLTAGE MONITOR has bottom end set at 108 volts while the top end is adjusted so all twelve segments are lighted when input exceeds 13 volts.

Calibration requires an AC voltmeter and a method for adjusting the input voltage such as a variable transformer. Initially set R1 and R2 fully counterclockwise [highest V_{Ref}(Min) and V_{Ref}(Max)]. With the input voltage at 108 volts, turn R2 clockwise until segment 1 just lights. Set line voltage to 130 volts and turn R1 clockwise until segment 12 just lights.

Automotive charging system monitor/tester

The charging system monitor/tester (Fig. 5) lights successive segments of the LED array for each 0.5-volt increase in input voltage. The first segment turns on at an input of 10 volts and all twelve are on for inputs of 15.5 volts or more.

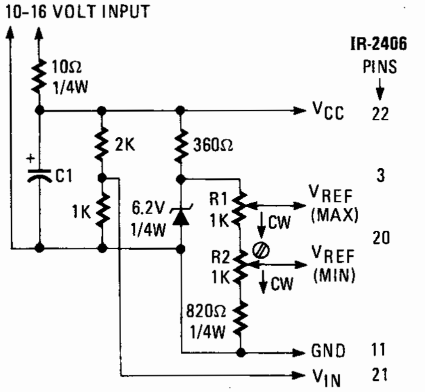


FIG. 5—VOLTAGE TESTER for car's electrical system. Checks voltage in 0.5-volt steps.

Calibration requires a DC voltmeter and power supply. First turn R1 and R2 fully counterclockwise. Set the input voltage at 10 volts and advance R2 until segment 1 just lights. Adjust input voltage to 15.5 volts and advance R1 until segment 12 just lights.—*J. R. Kinnard*

Car Battery voltage monitor

Auto manufacturers have long since given up ammeters and voltmeters for idiot lights. This is unfortunate since the idiot lamp is inaccurate and may not even be functional. The circuit in Fig. 6 will read out your battery voltage in 0.5-volt steps from 10.5 to 16.0 volts. This will show at a glance the condition of the battery, the charging system, and electrical load.

The advantage of this circuit is its simplicity and small size. Being small as a pack of cigarettes, the monitor can be mounted virtually anywhere on the dashboard.

A precision reference voltage is provided by the 78L08 and R3, and R4. This provides the min/max range for IC1. V_{in} is provided through the R1–R2 network with C2 to smooth out the transient response.

This circuit can be wired in any fashion to suit the case used. Hook-up requires only a ground lead and a voltage line to the accessory switch of the car so that power is removed when the ignition is turned off.—*John Damkier*

Position indicator for remote selector switch

Thanks for bringing these devices to our attention. We will use four sets of them in a remote indicating system to be installed at the Indianapolis Center for Advanced Research. A low-speed wind tunnel is used in studying wind effects on oil tanks like those used at refineries. There are six positions of four different variables. The information on these positions must be transmitted to the person logging the test conditions, some of which is fed to a computer. The test operator is in the computer room. Figure 7 shows the circuit that was devised.

The operator at the wind tunnel sets the switch to indicate one of the six test positions. The selected position is indicated on the LED readout.

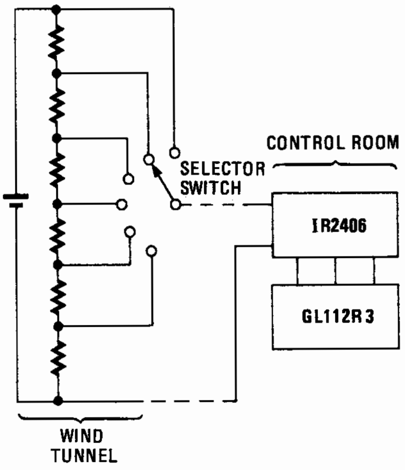


FIG. 7—INDICATOR CIRCUIT shows the position of a selector switch or control potentiometer at a remote location.

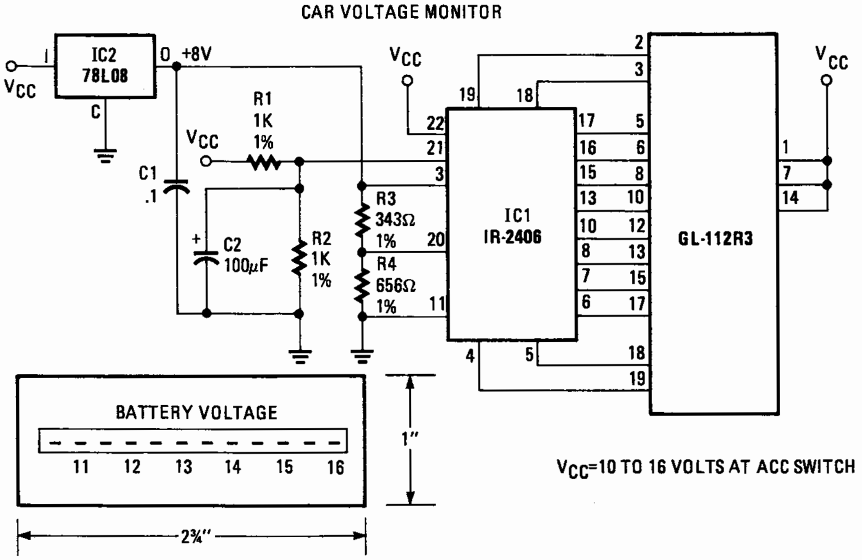


FIG. 6—CAR BATTERY voltage monitor replaces idiot light and indicates electrical system output voltage in 0.5-volt steps from 10.5 to 16.0 volts.

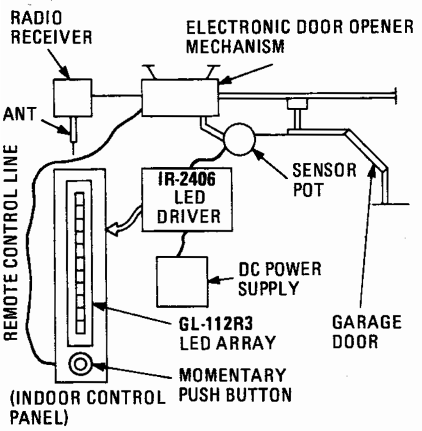
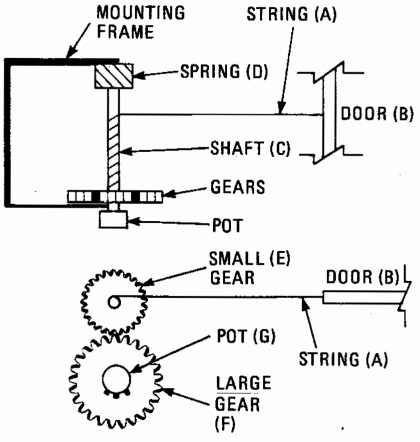


FIG. 8—BASIC ARRANGEMENT of the garage-door position indicator.



NOTE: STRING (A) IS ATTACHED TO DOOR (B) AND WOUND AROUND SHAFT (C). AS DOOR OPENS, SPRING (D) ROTATES SMALL GEAR (E), WINDING UP STRING ON SHAFT AND ROTATING LARGE GEAR (F) AT A MUCH SLOWER RATE. LARGE GEAR TURNS POT (G) THAT VARIES RESISTANCE IN PROPORTION TO AMOUNT THAT DOOR IS OPEN OR CLOSED.

FIG. 9—HOW THE SENSOR POT is controlled by the position of the garage door.

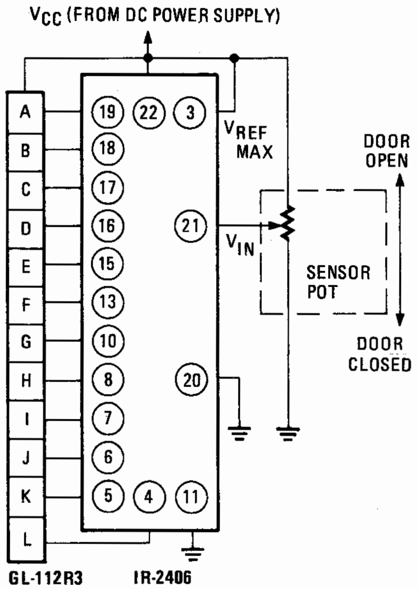


FIG. 10—HOW THE SENSOR POT connects to the IR-2406 LED driver.

Solar heating temperature indicator

In a study of solar heating, we have a water storage tank fitted with thermocouples measuring temperature at four different levels. We could amplify the resultant voltages and feed four of these displays. A quick glance will then show the temperatures at four levels within the tank.—*R. O. Whitaker*

Garage door position indicator

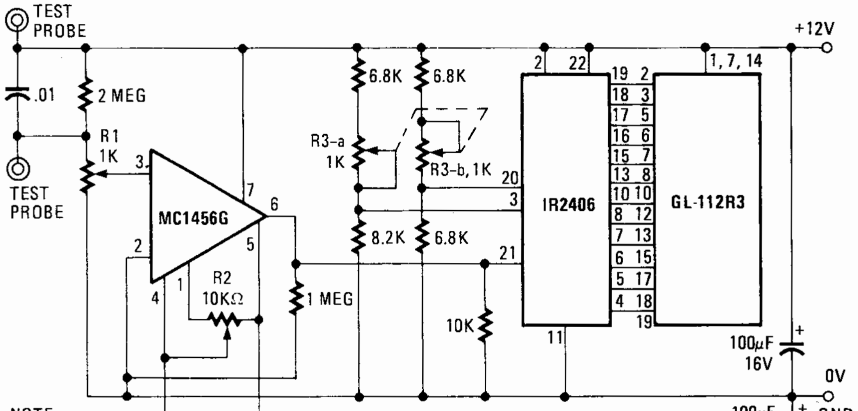
Well, let's fact it. . . . Lotsa' folks are buying automatic garage door openers. Those little transmitters are great for opening and closing the door from your car but, how about in the house where you can't even see the garage?

With my application, you can raise or lower the door from inside your home and know exactly what position the door is in at any time. The system consists of a sensor pot mechanically coupled to the garage door and the LED driver and display located with a remote pushbutton in the house. See Figs. 8, 9 and 10 for system hook-up, sensor pot assembly and electrical connections, respectively. As the door raises, the wiper of the sensor pot rotates, raising the input voltage to the LED driver IC. This causes the segments of the LED display to come on one-at-a-time until the door is at the top of its travel. All of the segments are then lit. The display will remain lighted until the door is lowered at which time the segments will extinguish in reverse order. When the door is completely down, the display is once again dark.—*John E. Shepler*

Lie detector

Conventional hobby-type "lie detectors" usually use indicators such as a meter or a change in audio frequencies. When using these devices, it is sometimes very hard to detect a change. However, this "lie detector" has two major improvements. One is the very easy detection of a rate of change through the use of a bar-graph LED display. The other is its extreme sensitivity which can be set to register changes as small as 125 μV. This is achieved through the use of the sensitivity bandwidth control, R3. (See Fig. 11.)

In typical use, you would tape the probes to two individual fingers of one hand after wiping the contact area with alcohol. Set pot R1 to about midway, and adjust the gain (R2) so that the LED display lights up about halfway. Control R3 can then be used to give reliable results.—*Rob Cameron* **R-E**



NOTE:
IF TEST PROBES
ARE TO BE MORE
THAN 1 METER IN
LENGTH, USE
SHIELDED CABLE.

FIG. 11—"LIE DETECTOR" is extremely sensitive to skin-conductivity changes. These changes occur in response to mental stress.

SOLID STATE NEWS

Second-generation VMOS device

Siliconix's second-generation VMOS power FET, the VN84GA, is rated at 12.5 amp and 80 volts which is a six-times current increase over previous transistors. With only microwatt input power, the VN84GA produces up to 80 watts output at low frequencies and a 50-watt output at 30 MHz. The devices do not show any of the secondary breakdown and thermal runaway characteristics of bipolar transistors. These FET's interface directly with CMOS, TTL, DTL and MOS families for use in switching regulators, motor controllers, audio amplifiers and microprocessor interfaces.

Using VMOS devices in linear amplifiers up to 30 MHz produces lower distortion because of the linear-transfer characteristics and good high-frequency behavior of the VN84GA, and the low distortion means that only small amounts of feedback are required. The devices can also be used in Class-D audio amplifiers because of their fast switching and zero storage time.

The VN84GA is mounted in a TO-3 package and is priced at $19.76 in quantities from 1 to 99. Siliconix Incorporated, 2201 Laurelwood Road, Santa Clara, CA 95054. **R-E**

Dot/Bar-Graph Display Drivers

New IC's simplify the design of LED displays. They're capable of doing a lot more than that, too!

MICHAEL X. MAIDA

THE USE OF MULTIPLE LED'S IN A BAR-graph fashion to display analog signals is becoming increasingly popular. The reasons include low cost, ruggedness, high visibility, ease of interpretation, fast response time, low voltage and current requirements, and long life. No other display technology combines all those advantages. For example, electromechanical meters can have better resolution, but they respond less quickly and are sensitive to shock and vibration. Liquid-crystal displays draw less power but are slow, and difficult to read in dim light. Bar graph displays based on LED's are used in stereo amplifiers for power meters, in tuners for signal-strength indicators, and in cameras for light meters. In all of those examples, the display must be interpreted quickly and easily, but high resolution is not required.

Recently, IC's have been introduced that considerably simplify the task of driving a LED array with analog signals. Examples of those include National Semiconductor's LM3914 and LM3915 LED Dot/Bar Display Drivers. Those extremely versatile devices have a reference, a voltage divider, and ten comparators all on one chip. Besides the LED's, only a few resistors and a capacitor are required to complete the display circuit. Either a bar or dot display (only one LED on at a time) is possible. The on-chip voltage reference is fully regulated, remaining constant while the power supply feeding the IC can be anywhere between 3 volts and 25 volts!

How it works

A block diagram of the LM3914 is shown in Fig. 1 where the IC is wired up as a simple 2.5 volt full-scale meter. The IC's internal reference forces the voltage drop across R1 to 1.25 volts, causing a current equal to 1.25V/R1 or 1.25 mA to flow thru R1 and R2. The small 75-microampere current from pin 8 can usually be neglected so that the voltage at pin 7 is approximately 1.25V × (1 + R2/R1) or 2.5 volts. The display range is set by the voltages at pins 6 and 4, the top and bottom ends of the LM3914's internal voltage divider. For the 0-to-2.5-volt meter shown, pin 6 is wired to the 2.5-volt reference while pin 4 is grounded. The reference load current (I_{REF}) in this example is equal to the 1.25 mA flowing through R1 plus the 0.25 mA flowing through the 10K divider or 1.5 milliamperes total.

The signal to be displayed is applied to pin 5, where it is buffered by a high impedance follower and fed to the inverting inputs of the ten comparators that drive the LED's. The comparators' non-inverting inputs are connected to the taps along the voltage divider. In the LM3914, those taps are all equally spaced. Here, another comparator turns on for every 250-mV increase of the input voltage, lighting up another LED.

Current drive to each LED illuminated is set at ten times the reference-

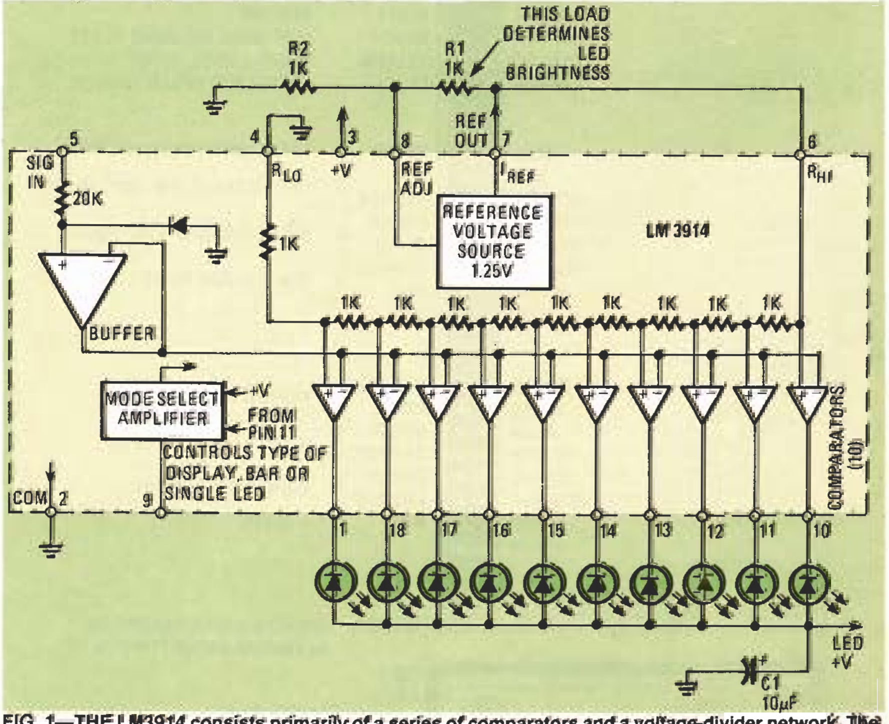
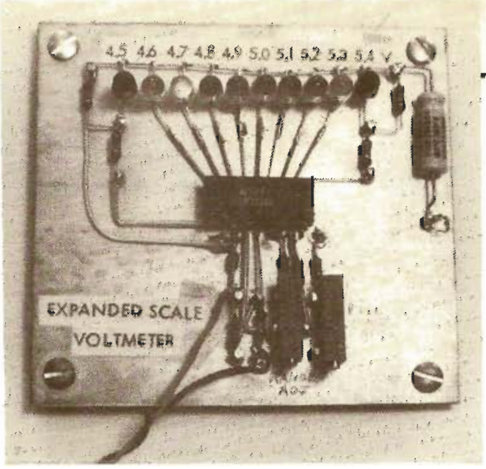
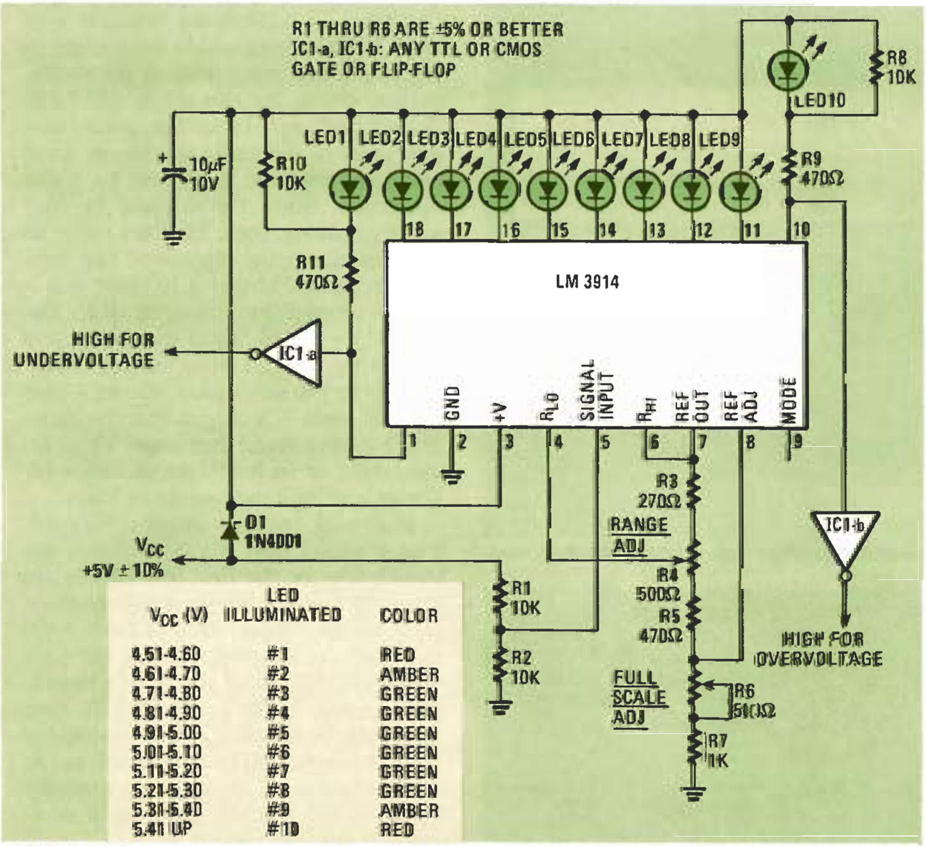


FIG. 1—THE LM3914 consists primarily of a series of comparators and a voltage-divider network. The trip point of each successive comparator is set higher than the previous comparator by the voltage divider. As the input voltage applied to pin 5 increases, the comparators trip in sequence. The comparators, in turn, illuminate their respective LED's.





V_{CC} (V)	LED ILLUMINATED	COLOR
4.51-4.60	#1	RED
4.61-4.70	#2	AMBER
4.71-4.80	#3	GREEN
4.81-4.90	#4	GREEN
4.91-5.00	#5	GREEN
5.01-5.10	#6	GREEN
5.11-5.20	#7	GREEN
5.21-5.30	#8	GREEN
5.31-5.40	#9	AMBER
5.41 UP	#10	RED

FIG. 2—EXPANDED-SCALE VOLTMETER for monitoring the output voltage of a 5-volt logic-power supply. Each LED corresponds to a predetermined voltage, as shown in the chart.

load current (I_{REF}) or 15 mA in this example. Generally, LED currents from 10 to 20 mA produce adequate brightness. A pot in series with a resistor connected from pin 7 to ground makes a simple intensity control, since it varies I_{REF} without affecting the reference voltage. Trimming the reference output voltage can be accomplished by varying R2.

For a DOT-mode display, pin 9 may be left open; for BAR-mode, pin 9 is connected to the LED supply, which can be different from the IC's V^+. Watch the IC's power dissipation in BAR mode, however. At 15 mA per LED, the LED supply should be no higher than 6 volts. To power the LED's from a higher-supply voltage, place a dropping resistor between the LED anodes and the supply. The LED supply should always be bypassed with a 10 μF electrolytic capacitor to prevent oscillations. The LM3914's $^+$V supply (pin 3) must be at least 1.5 volts above the pin 7 reference output and can be as low as 3 volts when the reference is run at 1.25 volts (pin 8 grounded).

Simple voltage monitor for TTL

The LM3914's low voltage-requirements and flexibility make for some interesting applications. Figure 2 shows an expanded-scale voltage monitor for a TTL system that runs off the same single 5-volt supply it monitors! As shown in the table, each LED covers a 100-mV range from 4.5 to 5.5 volts. A simple two-step calibration is all that's required.

Here the supply voltage is attenuated by a factor of two and fed to the LM3914 signal input. Resistor R6 sets the top of the internal divider network at 2.705 volts (5.41V/2) and potentiometer R4 sets the bottom of the divider at 2.205 volts (4.41V/2). Adjust R6 until LED10 just turns on with V_{CC} set at 5.41 volts. Then adjust R4 until LED1 just turns on with V_{CC} set at 4.41 volts. There's a slight interaction so that running through that procedure a second time may improve accuracy.

TTL and CMOS-compatible undervoltage and overvoltage signals are provided, which can be used to shut down a system before damage (to either data or hardware) occurs. Optional diode D1 protects the IC in the event the 5-volt supply leads are reversed. For a simple go/no-go display, use red LED's at pins 1 and 18 for undervoltage and overvoltage and wire-OR pins 10 through 17 to the cathode of a single green LED.

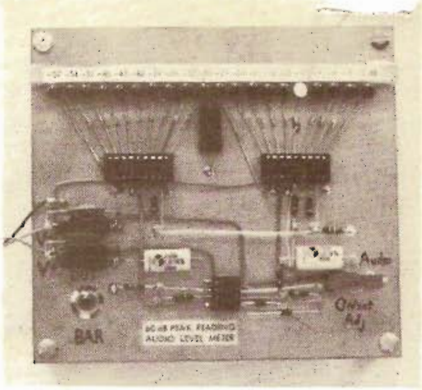
Audio metering

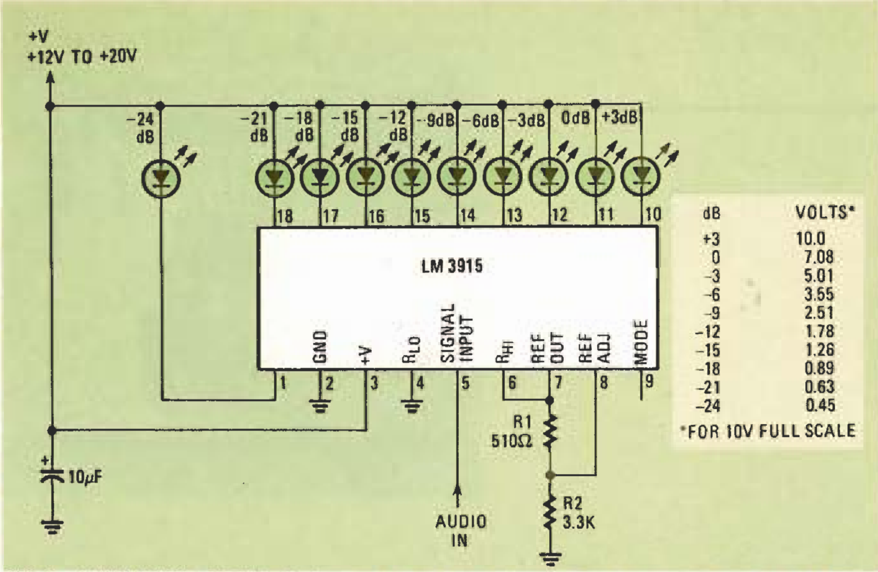
A logarithmic scale using the decibel (dB) is a convenient and popular one for measuring audio levels. A 3-dB increase corresponds to a 41 percent voltage increase and a doubling of power. The LM3915 features a (22K ohm) logarithmic voltage-divider for a 3-dB-per-step display; otherwise, it's identical to the LM3914. The LM3915 is useful for displaying signals with wide dynamic range, such as RF signal strength, power level, or light intensity, in addition to audio level.

Figure 3 illustrates how simple it is to construct an audio-level indicator with the LM3915. The audio is fed straight to the IC's signal input without any rectification. Using the DOT mode, the LED illuminated represents the instantaneous value of the audio waveform. Both peak and average levels can be easily discerned. Since the dot will be constantly moving, the LED's are run at 30 mA for adequate intensity. The full-scale reading (+3 dB) is 10 volts; that is easily altered by changing R2. The LM3915's signal input can withstand signals up to ±35 volts, which corresponds to 150 watts peak into an 8-ohm load. If there is a chance that the audio input could exceed this range, either attenuate it or include enough series resistance to limit the current to 5 mA.

If a peak-reading meter is desired, Fig. 4 shows how it's done. Since the thresholds for the first few LED's are less than 1 volt, a simple diode-capacitor peak detector won't do. The diode's 600 mV turn-on threshold would not pass low-level signals. In the circuit shown, the voltage drop across D1 is canceled out by the emitter-base voltage of PNP transistor Q1, connected as an emitter follower. These voltages usually track within 100 mV, causing a small error at low input levels.

The LED connections in Fig. 4 illustrate a tricky way to get a bar-graph display with very low current drain. With pin 9 left open, the LM3915 thinks it's in DOT mode, so only one output will be on at a time. For an input between −24 and −21 dB, the pin-1 current source turns on, lighting up LED1. When the input increases to −21 to −18 dB, the pin-18 current source turns on while pin 1 turns off. With the LED's in series, the pin-18 output current flows through LED2 and LED1, lighting them both. For every 3-dB increase in input voltage, the current shifts over to





dB	VOLTS*
+3	10.0
0	7.08
−3	5.01
−6	3.55
−9	2.51
−12	1.78
−15	1.26
−18	0.89
−21	0.63
−24	0.45

*FOR 10V FULL SCALE

FIG. 3—AUDIO-LEVEL METER displays the instantaneous value of the audio input signal. The LM3915 provides a logarithmic response.

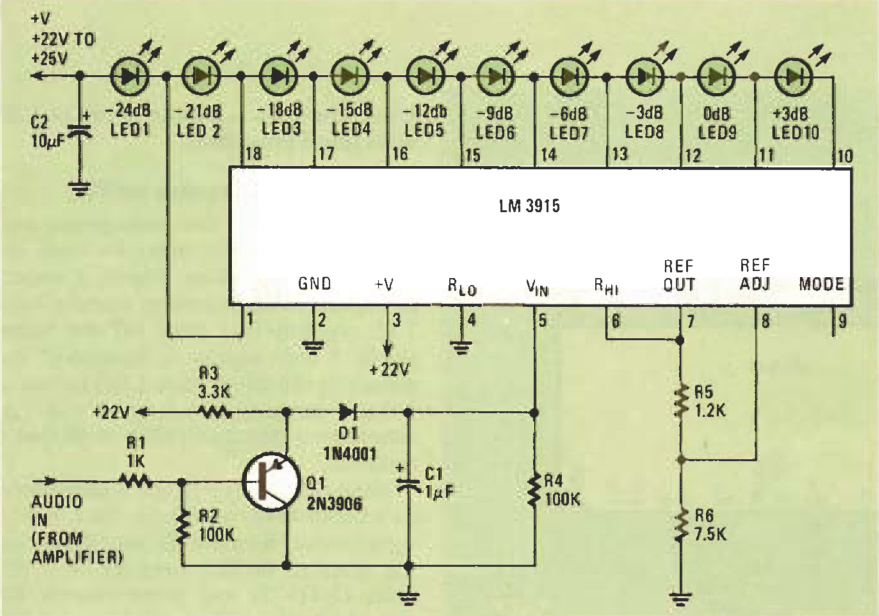


FIG. 4—PEAK-READING AUDIO-LEVEL METER is obtained by using a peak-detecting circuit on input pin 5.

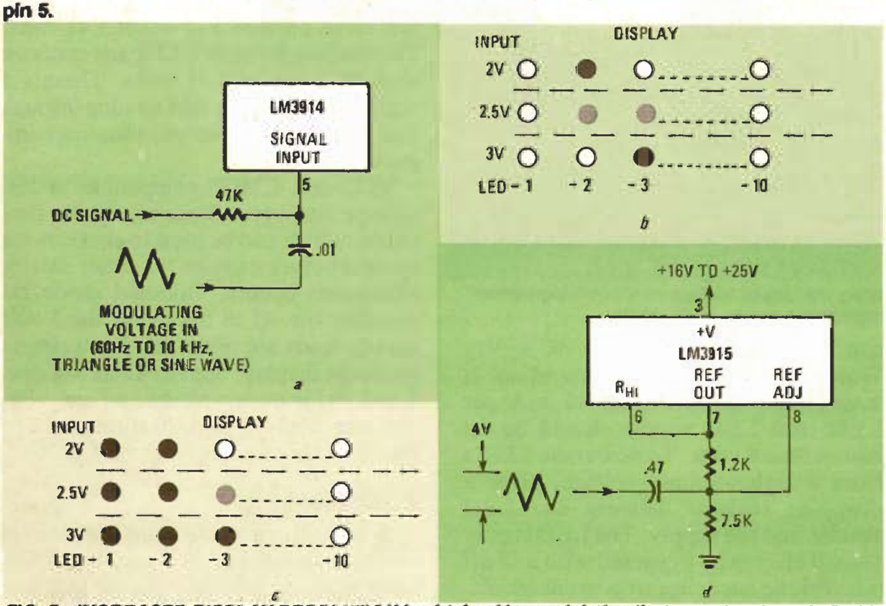


FIG. 5—INCREASED DISPLAY RESOLUTION is obtained by modulating the input signal on pin 5 with either a sine or triangular waveform as shown in *a*. The resulting display shown in *b* and *c* has twice the original resolution. (The display shown in *b* obtained in the DOT mode, while the display shown in *c* is obtained in the BAR GRAPH mode.) The same effect is obtained with the logarithmic LM3915 by using the configuration shown in *d*.

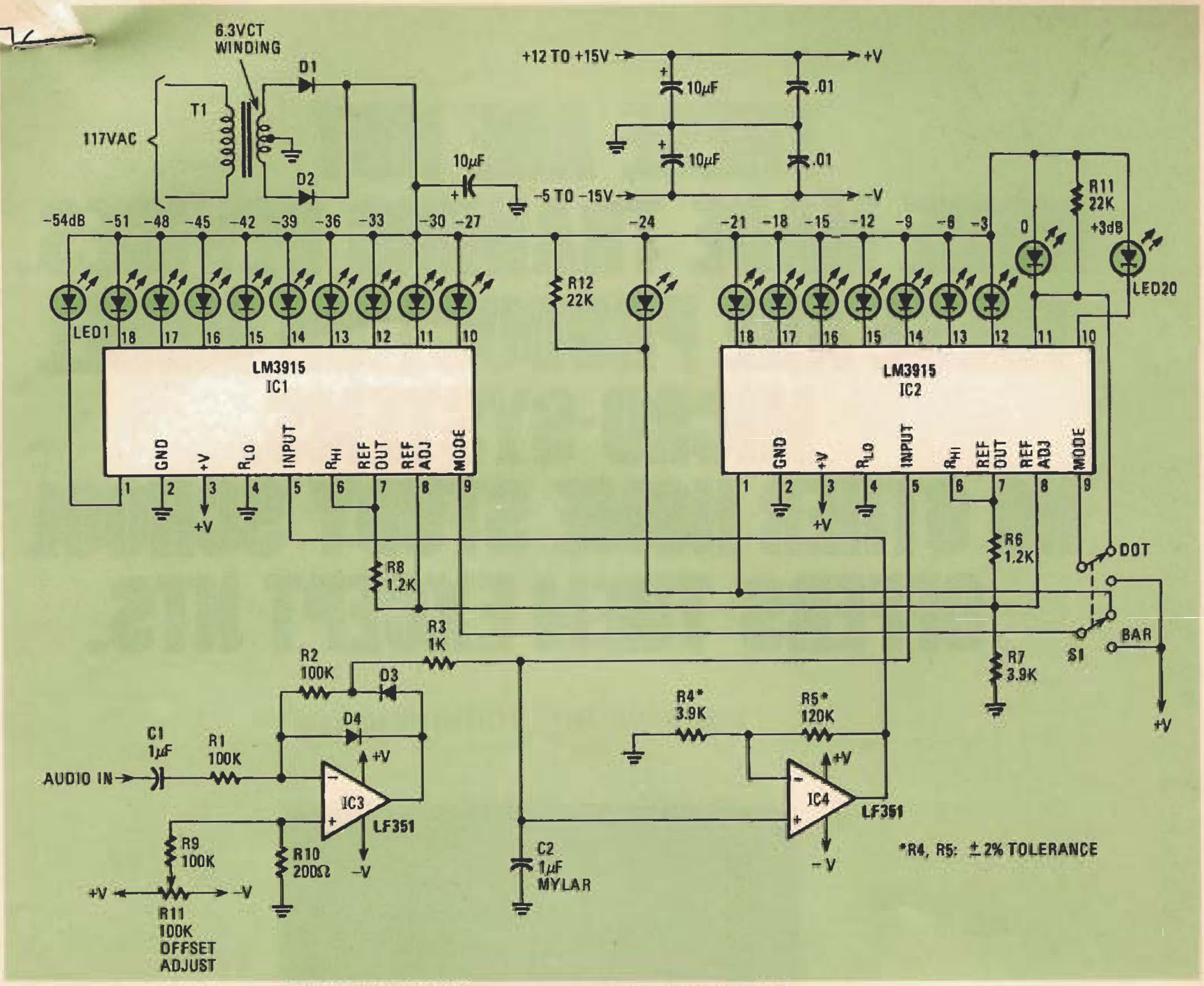


FIG. 6—TWO LM3915's can be cascaded together to obtain wide dynamic range. The circuit shown above is a peak-reading audio-level meter with a dynamic range of 60 dB.

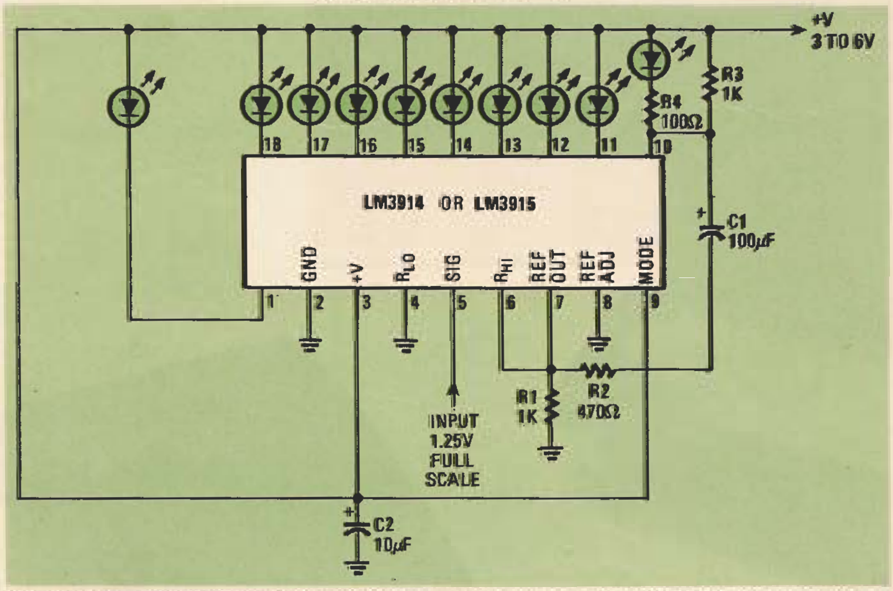


FIG. 7—OVERRANGE INDICATION with the bar-graph display is obtained with the above circuit. When the overrange condition occurs, the LED's flash.

another output pin and lights another LED. That results in a bar-graph display that draws only 20 mA while lighting ten LED's, instead of 200mA for the standard bar-graph configuration. A higher supply voltage is required, however, because all the LED forward voltages are in series. The IC still stays cool since the current drain is low. That connection may be useful when "stealing" power from pre-existing stereo equipment that cannot supply much current.

Other display ideas

For increased resolution, modulate the LM3914's input signal with an AC voltage as in Fig. 5-a. The LED's will appear to turn on gradually, producing a display that changes smoothly like a meter. For the modulating voltage, a triangle wave works best, although a sinewave (60 Hz from a transformer, for example) can be used. The peak-to-peak amplitude of the AC voltage should be equal to the voltage step between LED's. Figures 5-b and 5-c depict the resulting displays in either the bar or dot mode. To obtain the same effect using an LM3915, where the voltage step between LED's varies, one should modulate the R_{HI} voltage by 3 dB as in Figure 5-d.

Most program material has a dynamic range of over 40 dB. It's a simple matter to obtain a 60-dB display by cascading two LM3915's together, as shown in Fig. 6. A better peak-detector circuit is required because the threshold for the first LED is only 15 mV! The precision peak detector uses op-amp IC3 to overcome diode offset error. Operational amplifier IC4 is run at a gain of 30 dB or 31.6. BiFET op-amps, such as the

LF351, that combine low bias current with a high slew rate are recommended. The offset-adjust pot R11 is adjusted for a 0-volt output from IC4 with no audio input applied.

As that example shows, the LED's can be run from an unregulated, unfiltered power supply. The 6.3-volt center-tapped transformer, and diodes D1 and D2, provide a full-wave rectified voltage of about 4 volts to the LED anodes. That greatly reduces the load on the V$^+$ supply in the bar-graph mode and also reduces heat dissipation in the LM3915 integrated circuits.

In this circuit, resistor R7 sets the reference voltage for both IC's. Since both IC's have identical loading on their reference outputs, the reference voltage can be changed (from the 10 volts shown here) by lowering R5 without affecting the LED intensities. The time constant R3—C2 sets the display decay-time and can be optimized by varying the capacitance of C2.

It's very easy to add an alarm that will flash the LED's when the input voltage exceeds full scale. The circuit is shown in Fig. 7. If desired, that scheme can be used to flash the display when the input voltage exceeds the threshold of any of the ten LED's, by simply moving the resistor-capacitor network (made up of R2 and C1) over to a different output of the IC.

Timers and sequencers

Use an LM3915 to monitor the voltage on a discharging capacitor, as in Fig. 8, and you've got a simple timer. Even though the capacitor voltage decays to zero logarithmically, displaying it via an LM3915 results in equal time steps. Each time step is approximately R1× C1/3.

The sequencer shown in Fig. 9 is a variation on that. Capacitor C1 is charged linearly by the current source made up of Q1, LED11 and R1. When output 10 starts to turn on, Q2 and Q3 conduct and C1 is rapidly discharged. Cycle time is about 10×R1×C1. The LM3914 outputs could be used to drive relays, opto-isolators, or logic circuits, for example.

Other ideas

Don't think the LM3914 and LM3915 can drive *only* bars of LEDs. The LED's can be arranged in circles, or as X-Y displays, for instance. LCD's, vacuum fluorescents, and low-current incandescent bulbs can also be driven. As the examples show, outputs may interface with CMOS, TTL, opto-isolators and relays for a variety of automatic measurement and control functions. The decibel display of the LM3915 is especially attractive for audiophiles. Like the op-amp, applications of those display drivers are limited only by the imagination of the designer. **R-E**

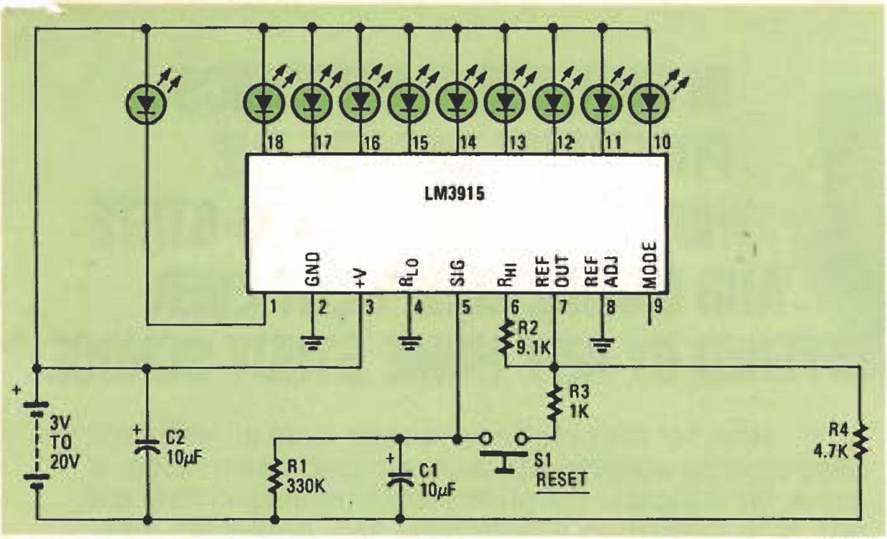


FIG. 8—TEN-STEP TIMER CIRCUIT. The LED's turn off sequentially, with each LED representing the time constant of R1—C1.

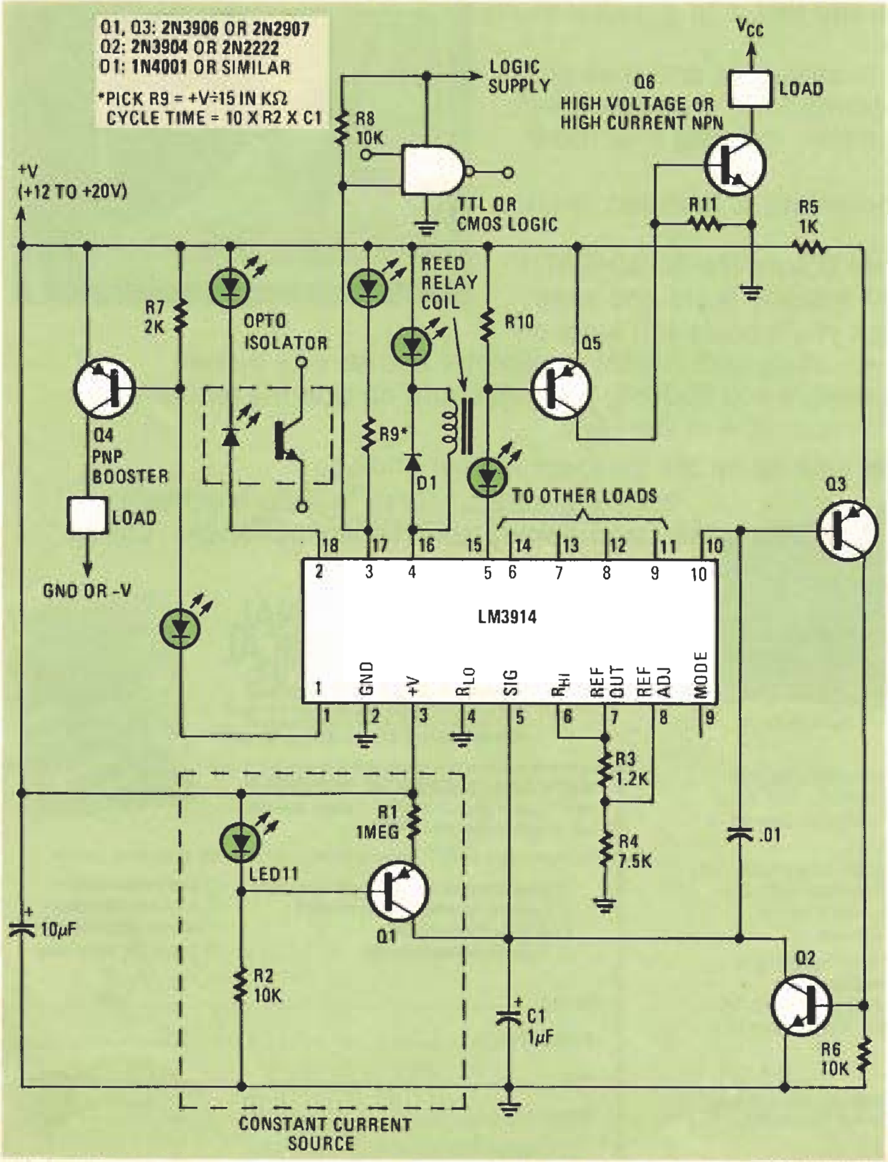


FIG. 9—NINE-STEP SEQUENCER is a variation of the principle used in the ten-step timer shown in Fig. 8 and can be used to turn various loads on and off sequentially.

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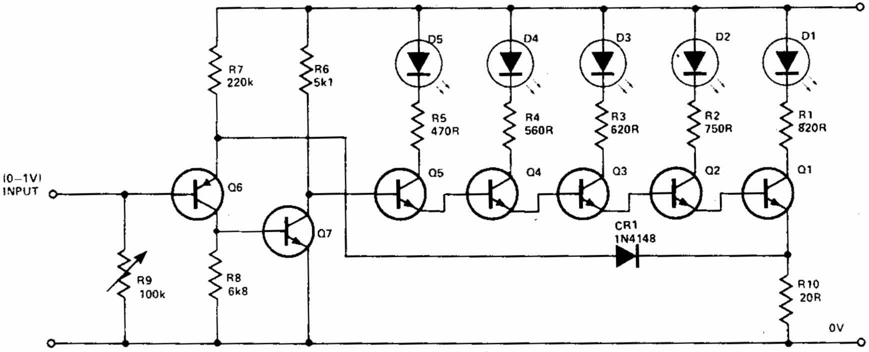
BARGRAPH DISPLAY

A bargraph display is a useful medium for seeing a monitored variable. Where low resolution (5 to 10 segments) is sufficient the display can be built with LED's and a few transistors.

With the 5 segment system shown, transistors Q1 to Q5 saturate successively as the input signal increases from zero. The resulting currents drive LEDs D1 to D5. As each transistor turns on, its emitter current flows through R10. Transistors Q6 and Q7 as well as CR1 and associated resistors, comprise a feedback amplifier that forces the voltage across R10 to equal the inputs voltage. This causes the display to 'deflect' linearly.



Q1 – Q5 2N3568 (OR EQUIV.) Q6 2N4250 (OR EQUIV.) Q7 2N3565 (OR EQUIV.)

For R10 = 20R and a current of 10mA per LED, the resolution is 200mV and the full scale input equals 1V (for five LED's). Diode CR1 cancels the V_{BE} offset of Q6. Resistors R1 through R5 control the LED currents. The voltage across R3 for example is 10V minus 1.5V (two transistors V_{BE}'s) minus 0.6V (30mA – R10). Since V_{CE} (SAT) of Q3 is negligable at 10mA, 6.4V must be dropped.

i.e. R3 = $\frac{6.4V}{.010A}$ = 640R. 620R being the nearest standard value.

Out of Tune

In "An LED-Readout Audio Power Meter" (March, p 35), note an error in Table II, "Ideal Threshold Voltages" for the comparators. The right column, "Voltage," is inverted. The last entry, 4.395, refers to Pin 7 of IC1; the next to last, 3.070, refers to pin 5 of IC1; and so on. The top entry, 0.011, is the threshold for pin 11 of IC3.—*Tim Henry*

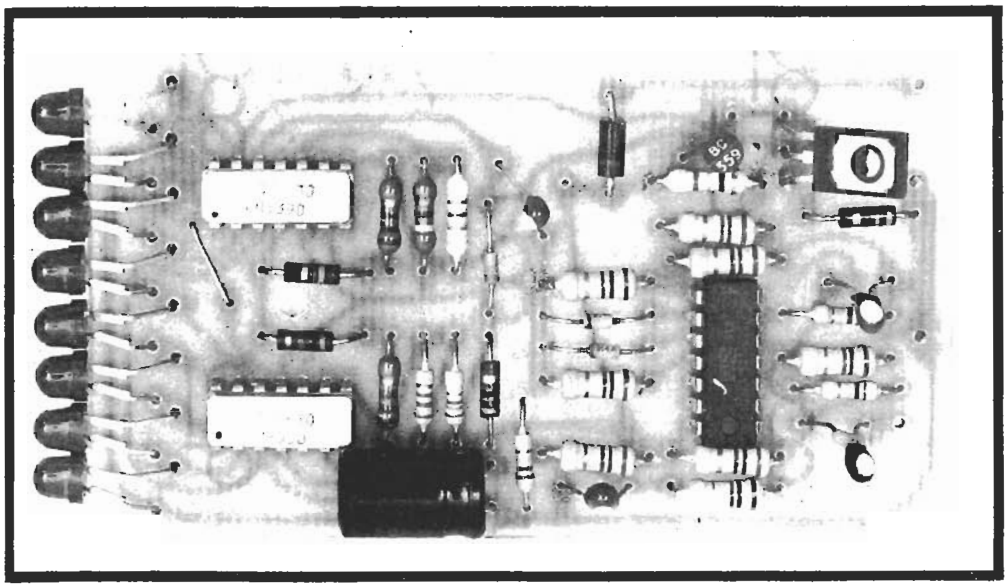
In "An LED-Readout Audio Power Meter" (March 1976, p 35), diodes *D1-D4* are shown in Fig. 2 with their polarities reversed. They should also be numbered *D3, D1, D2, D4* starting from the top. The polarity of *C1* is also shown reversed.

POPULAR ELECTRONICS

AUDIO LEVEL METER

eti project

438



Peak and average audio levels are indicated by a bar of light.

HIGH-POWER amplifiers usually incorporate meters to indicate the output-power levels in each channel. These meters are often called VU meters but in most cases they resemble proper VU meters only in the way they are scaled.

A professional VU meter is the industry standard for measuring the levels of complex music waveforms. It has a scale marked from −20 to +3 VU (on a steady state signal VU correspond to dB) where '0' VU corresponds to a level of one milliwatt into 600 ohms. The meter has a carefully controlled time constant such that if a reference tone level is applied the pointer of the meter will take 0.3 seconds to reach 99% of the reference level, and will then overshoot by not more than 1.5% and not less than 1.0%.

The professional VU meter is thus an instrument that has been designed to give a reasonable compromise between indicating the fast peaks and the average levels of a complex music waveform.

In contrast the meters fitted to some amplifiers have scales calibrated in VU but usually relying on the inertia of the meter movement to provide meter averaging. Apart from this the 0 VU point corresponds to the rated power output of the amplifier – not to 1 mW into 600 ohms (equivalent to 75 mW in 8 ohms). Strictly speaking therefore such meters should be called level or power meters, not VU meters.

Even the best of such meters are not fast enough to indicate accurately the peak levels which occur in music and hence are useless for detecting the onset of amplifier clipping. This is vital as at clipping amplifier distortion rises rapidly.

One alternative is to use in addition to the level meter a clipping indicator that detects fast peaks which exceed a preset level. The ETI 417 OVER-LED project (Nov. 73 issue) was such an instrument – it flashed an LED when a music transient exceeded clipping level.

The circuit described in this project is best described as a 'level meter'. It uses an array of LED diodes set to illuminate at successively higher increments in music level. With this type of display an estimate can quite easily be made of channel balance, and all transients, no matter how fast, are detected and indicated.

SPECIFICATION

Supply voltage	20 to 32 volts dc 15 to 20 volts dc
Supply current	16 mA dc approx,
Input sensitivity (VU meter)	500 k/v
Indication	8 LEDs 3 dB apart
Attack time	1 ms
Release time	0.5 sec.

DESIGN FEATURES

The ETI 438 Level Meter can be arranged to indicate levels either in 'VU meter' format or in output power format. In the 'VU-meter' format the eight diodes light at 3 dB intervals from −18 to +3 VU where 0 VU corresponds to the nominal voltage required. Alternately as a power meter (remember that an amplifier cannot be driven beyond the clipping point) the top LED indicates maximum power and each lower LED indicates half the power of the one above it. The LEDs of the meter could thus be labelled, for example (for a 100 watt amplifier) 100, 50, 25, 12.5 watts etc.

The fast attack time of the meter

AUDIO LEVEL METER

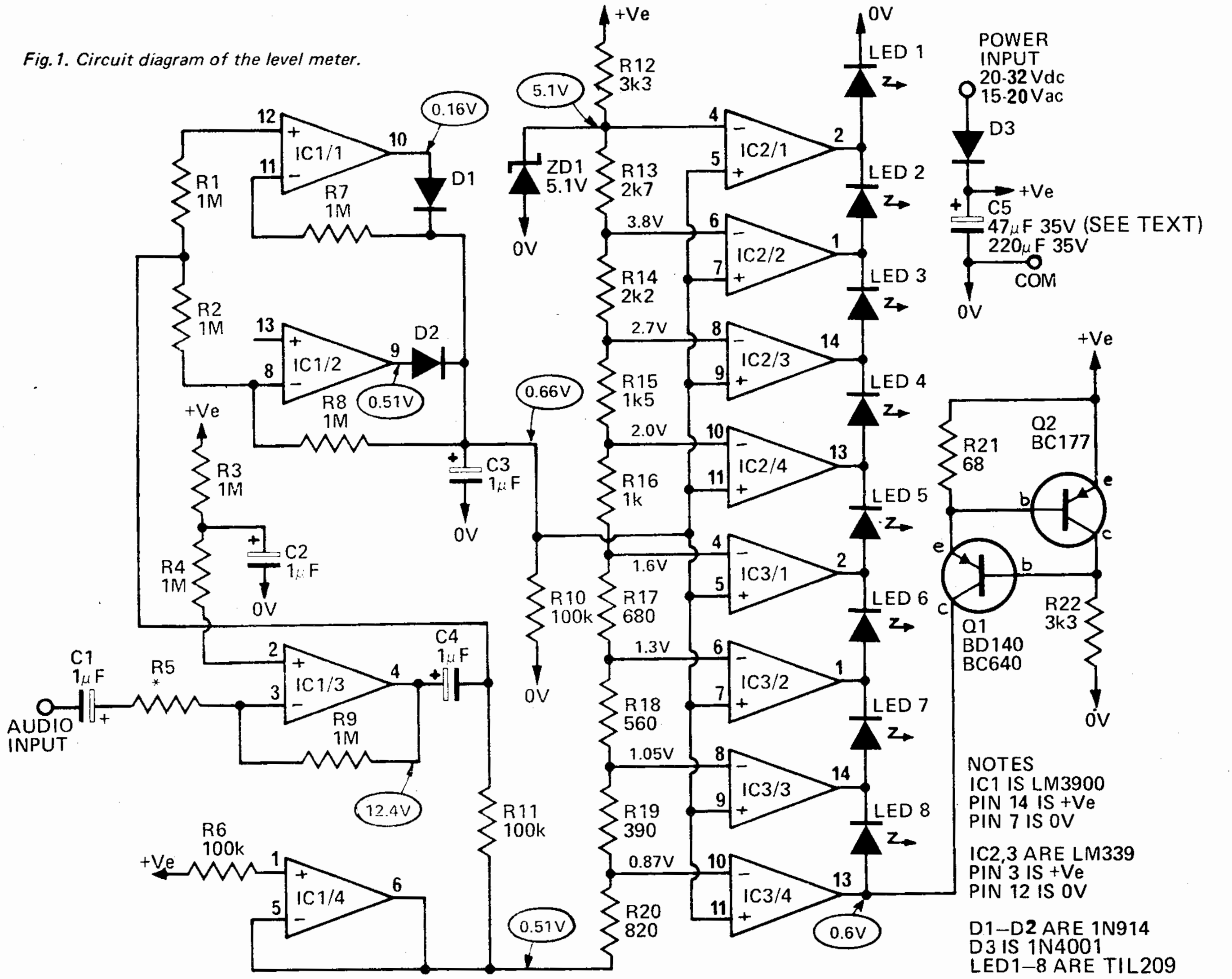


Fig. 1. Circuit diagram of the level meter.

NOTES
IC1 IS LM3900
PIN 14 IS +Ve
PIN 7 IS 0V

IC2,3 ARE LM339
PIN 3 IS +Ve
PIN 12 IS 0V

D1–D2 ARE 1N914
D3 IS 1N4001
LED1–8 ARE TIL209

VOLTAGES GIVEN ARE OF THE PROTOTYPE BUT SHOULD BE TYPICAL MEASURED WITH 25Vdc SUPPLY AND NO INPUT SIGNAL

HOW IT WORKS – ETI 438

Although the circuitry of the level meter looks complicated the complete instrument only uses three ICs. These are an LM3900 which is a quad amplifier and two LM339s which are quad voltage comparators.

The input signal is amplified and buffered by IC1/3 to provide about 2.5 volts out at 0 VU input. The value of R5 is selected to give the sensitivity required for amplifiers of different power outputs. The gain of this amplifier is equal to the ratio of R9/R5.

A positive peak detector, IC1/1, and an inverting negative peak detector, IC1/2, give an output which represents the absolute peak level. Capacitor C3 and resistor R10 provide the peak hold and decay time. IC1/4 provides compensation for the 0.6 volt offsets of the LM3900 inputs.

The eight comparators are connected to a resistor divider chain the top of which is fed from a 5.1 volt supply which is stabilized by a zener. The resistor values are calculated to provide reference voltage steps at 3 dB intervals. The output of the detector is applied to all the non-inverting inputs of the comparators.

The LEDs are all connected in series and supplied with a constant current of 10 mA by the source consisting of Q1 and Q2. The outputs of the comparators are via open collector transistors which are "ON" if the input is lower than the reference voltage at the particular comparator input. With no input signal at all the comparators are all on thus shorting out all the LEDs so that none is on. As the input voltage rises the comparators turn off in sequence allowing the 10 mA to flow through the LEDs. Thus as the voltage increases a bar of light of increasing height is formed by the LEDs.

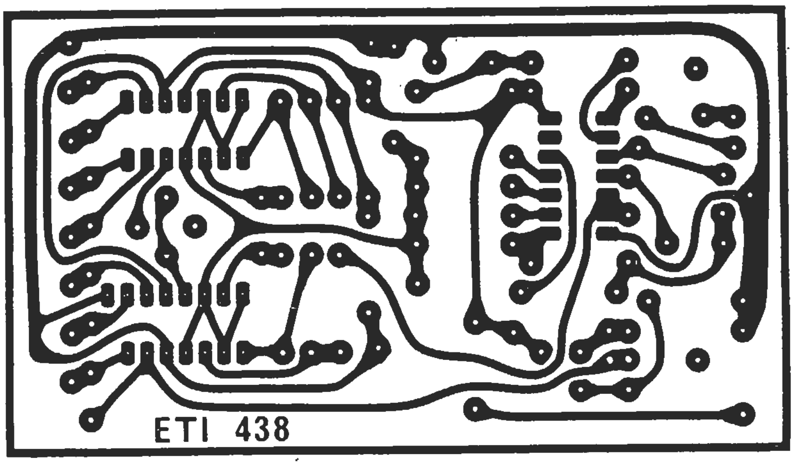
The current drawn from the power supply is about 16 mA and is independent of the number of LEDs which are on. Supply voltage is not critical and may be anywhere between 20 and 32 volts. Providing the supply is between these limits the unit will also be insensitive to supply ripple. When working from a dc supply a 47 microfarad filter capacitor is required but if an ac supply is used then the capacitor should be increased to 220 microfarad to minimize ripple. A single diode is used to both rectify the ac input and to prevent damage due to accidental reversed polarity if a dc supply is used.

PARTS LIST – ETI 438

R21	Resistor	68 ohm	½W	5%
R19	"	390 ohm	½W	5%
R18	"	560 ohm	½W	5%
R17	"	680 ohm	½W	5%
R20	"	820 ohm	½W	5%
R16	"	1k	½W	5%
R15	"	1k5	½W	5%
R14	"	2k2	½W	5%
R13	"	2k7	½W	5%
R12,22	"	3k3	½W	5%
R6,10,11	Resistor	100k	½W	5%
R1,2,7,8	"	1M	½W	5%
R3,4,9	"	See Table 1	½W	5%
R5	"	See Table 1	½W	5%
C1,2,3,4	Capacitor	1 µF	35V	
*C5A	"	47 µF	35V	
*C5B	"	220µF	35V	

* use 47 µF for dc operation 220 µF for ac operation

IC1	Integrated Circuit	LM 3900
IC2,3	Integrated Circuit	LM 339
D1,2	Diode	IN914, BA318 or similar
D3	"	1N4001 or similar
ZD1	Zener diode	5.1 V 400 mW
Q1	Transistor	BD 140,
Q2	"	BC177,
LED 1-8	L.E.D.	TIL209 or similar
PC board		ETI 438



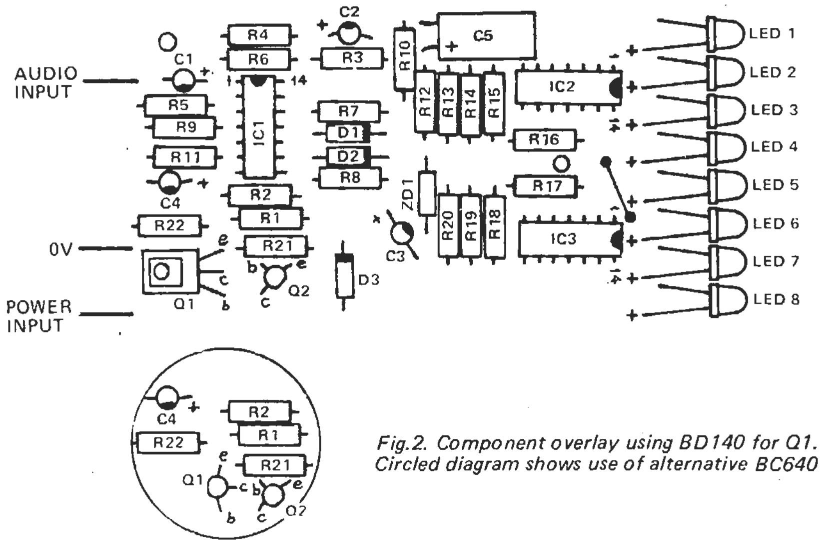


Fig.2. Component overlay using BD140 for Q1. Circled diagram shows use of alternative BC640

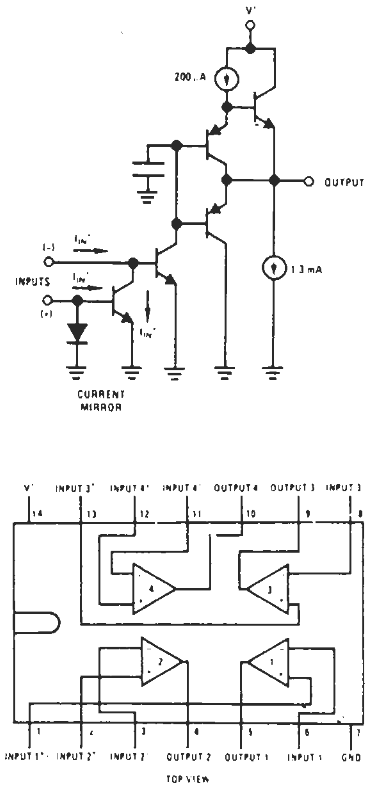


Fig.4. Internal circuitry and pin connections of the LM3900 IC.

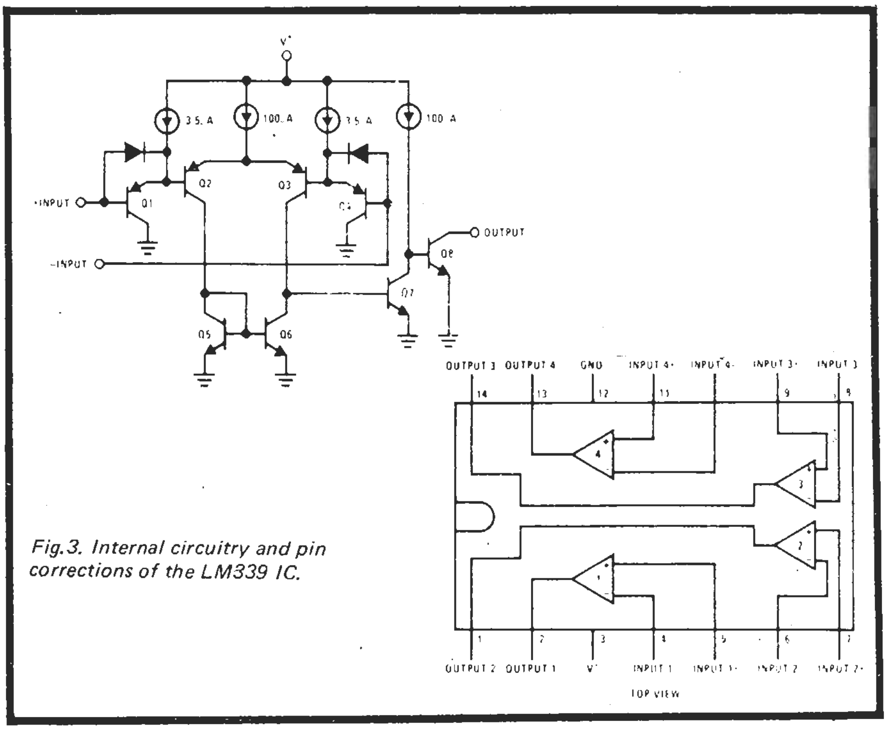


Fig.3. Internal circuitry and pin corrections of the LM339 IC.

(less than one millisecond) ensures that even very short transients are detected, whilst the relatively slow release time (0.5 seconds) provides a reasonably-accurate, average — level indication.

In most previous designs for such meters, discrete transistors were used to build level detectors. Temperature effects and variations in gain led to inaccuracies and to calibration difficulties. These problems have largely been overcome in the ETI 438 meter by using the LM339 IC which contains four accurate level detectors in one package. Additionally the LM339 also has an open-collector output stage which enables a constant current supply for the LEDs to be used. Thus the current and LED brightness are the same no matter how many LEDs are alight.

If required the interval between LEDs may be altered by changing the values of R13 to R20. Thus for example, a 6 dB interval could be used. Additionally the display could be extended to 12 or even 16 diodes by adding comparators and LEDs and by substituting another divider chain for R20 (values would have to be calculated for the levels required). The positive inputs of the comparators would also be fed from C3 and R10.

A separate current source would be required as there is insufficient supply voltage available to light 16 LEDs in series. If the bottom LED in such a system indicates a level more than 30 dB down it may also be necessary to use a trimpot as the bottom resistor of the second divider chain to adjust for offsets etc.

The LM3900 is a quad differential amplifier which uses a current balancing technique at the input rather than the voltage balancing that is used with conventional operational amplifiers. Both the inputs "look" like the base-emitter junctions of normal transistors and both are at 0.6 volts with respect to ground. The currents into the two inputs must be equal if the output of the amplifier is to be in the linear region. In the case of IC1/3 the current into the positive input is set at about 12 microamps by R3 and R4. Current into the negative input is provided from the output by R9. If the current into the negative input is too low the output voltage will rise thus increasing the current into the negative input until balance is achieved. This self balancing ensures correct static biasing.

Gain is obtained by feeding a signal into R5 which adds or subtracts current into the negative input. For the amplifier to remain balanced there must be a corresponding shift in output voltage. The voltage gain is the ratio of R9 to R5.

TABLE 1B – POWER METER

FSD = 0 dB

R3, 4 and 9 are 100 k

POWER OUTPUT IN WATTS	VALUE OF R5 4 Ohms	8 Ohms	16 Ohms
5	150 k	200 k	270 k
10	200 k	270 k	390 k
15	240 k	330 k	470 k
20	270 k	390 k	560 k
25	330 k	430 k	620 k
30	360 k	470 k	680 k
40	390 k	560 k	820 k
50	430 k	620 k	910 k
75	560 k	750 k	1.1 M
100	620 k	910 k	1.2 M
150	750 k	1.1 M	1.5 M
200	910 k	1.2 M	1.8 M
250	1 M	1.5 M	2 M

$R5 = 32\sqrt{PR}$ Where P = power in watts
R = speaker impedance in Ohms.

SPECIFICATION LM3900

Maximum supply voltage	32 V
Supply current	6 mA typical
Voltage gain	2800 V/V typical
Input current range	1 μA – 1 mA
Current balance	0.9 – 1.1 at 200 μA
Bias current	30 nA typical
Output current capability	18 mA source typical. 1.3 mA sink typical

The LM339 is a quad voltage comparator where the output of each is an NPN transistor which has an unterminated collector and its emitter connected to ground.

SPECIFICATION LM339

Maximum supply voltage	36 V
Supply current	0.8 mA typical
Voltage gain	200 000 V/V typical
Offsett voltage	2 mV typical
Bias current	25 nA typical
Response time	1.3 μS typical
Output sink current	16 mA typical
Input common-mode voltage range	0 to (V^+ – 2 volts)

CONSTRUCTION

The meter will most likely be mounted in an existing amplifier or piece of equipment and for this reason the board construction only is given.

Layout of components is non-critical but, as with any multiple IC device, construction is greatly simplified by using the printed-circuit board specified. The usual precautions with polarities of components, such as capacitors, diodes, ICs and transistors should be observed. Some care must be taken when mounting the LEDs in order to obtain even spacing and good alignment. The long lead of the LED should be inserted in the hole furthest from the edge of the board. Put a slight curvature in the leads so that the LEDs can be aligned against the edge of the board (see photo). Take care not to bend the leads too often or too close to the body of the LED as the leads break very easily.

TABLE 1A – VU METER

FSD = +3 dB

R3, 4 and 9 are 1 megohm

SENSITIVITY	VALUE OF R5*
50 mV	22 k
100 mV	47 k
250 mV	120 k
500 mV	220 k
1 V	470 k

**Sensitivity equals R5 x 500 000 ohms.*

CALIBRATION

Resistor R5 is selected from Table 1 and this will ensure a result within 10 percent of that required. Greater accuracy may be obtained by using a variable potentiometer in series with R5. To adjust this potentiometer inject a signal (around 1 kHz) equal to 0 VU (VU meter) or maximum power ($E = \sqrt{RP}$, e.g. 4 ohms and 100 watts, E = 20 volts) and adjust such that the second top LED (VU meter) or the top LED (power meter) just lights. ●

LED BARGRAPH READOUTS

Measure voltage, resistance, and frequency

BY FORREST M. MIMS

IN THE ongoing revolution of digital electronics, the old-fashioned meter movement has almost been replaced by rows of plastic encapsulated LED digital display modules. Despite the accuracy and convenience of digital displays, however, the analog meter movement offers several important advantages over the more modern digital display.

Have you ever tried to observe trends on a digital voltmeter or frequency meter? Good luck, because the trend of a slowly changing voltage or frequency is tough to follow on a digital readout. For example, a meter needle will instantly indicate a fluctuating voltage by simply bouncing back and forth while a digital readout presents a series of seemingly unrelated readings.

The LED bargraph described here bridges the gap between the conventional meter and the digital display. Bargraph readouts consist of a linear row of LED's which light up in response to voltage, resistance, or frequency. Like meters, they present an analog readout and can therefore show trends. And like digital displays, they are solid state and have no moving parts. This means they are "inertialess" and have responses thousands or more times faster than conventional meters. It also means an LED bargraph readout has no undershoot or overshoot and, best of all, cannot be "slammed."

If LED bargraph readouts sound interesting, read on, as we show you how to build several different voltage, resistance, and frequency sensitive readouts.

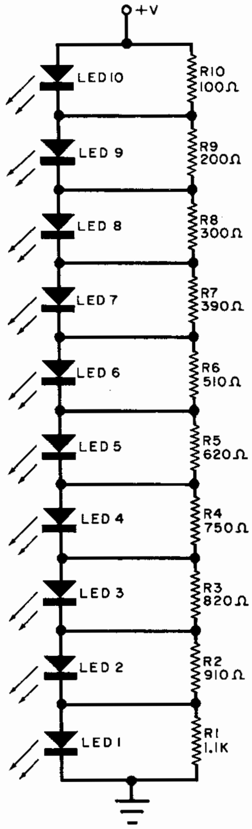


Fig. 1. Resistor voltage-sensitive bargraph.

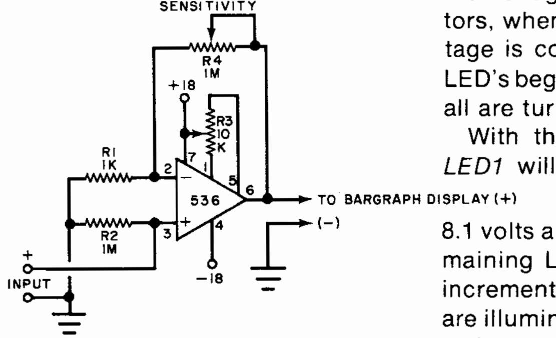


Fig. 2. Bargraph readout with op amp input.

Resistor Voltage-Sensitive Bargraph. You can make a simple but reliable LED bargraph readout from a string of resistors connected across a string of LED's as shown in Fig. 1. The resistors form a voltage divider. A single LED requires a certain forward voltage to produce light, and each LED in the circuit glows when the voltage across its resistor reaches this value. Since the voltage across the larger resistors increases faster than the voltage across the smaller resistors, when a gradually increased voltage is connected to the circuit, the LED's begin glowing sequentially until all are turned on.

With the values shown in Fig. 1, *LED1* will begin glowing with about 8.1 volts applied to the circuit. The remaining LED's will begin glowing at increments of about 1 volt until all 10 are illuminated. Different voltage indications can be obtained by changing the resistor values or by using green or yellow LED's.

The circuit draws about 20 milliamperes when all 10 LED's are on, and

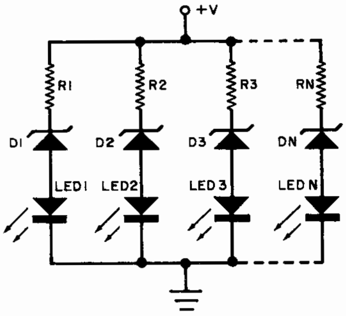


Fig. 3. Zener diode voltage-sensitive bargraph.

you can effectively isolate the readout from a circuit under test with an op amp. Figure 2 shows a circuit with an op amp input. The op amp will increase the input impedance of the readout to a few hundred thousand ohms or more. Also, since the gain of the op amp is easily adjusted, you can measure small fractions of a volt with this modified circuit.

Zener Diode Voltage-Sensitive Bargraph. The unique voltage-sensing property of zener diodes makes them ideal for LED bargraph indicators. Figure 3 shows a typical circuit.

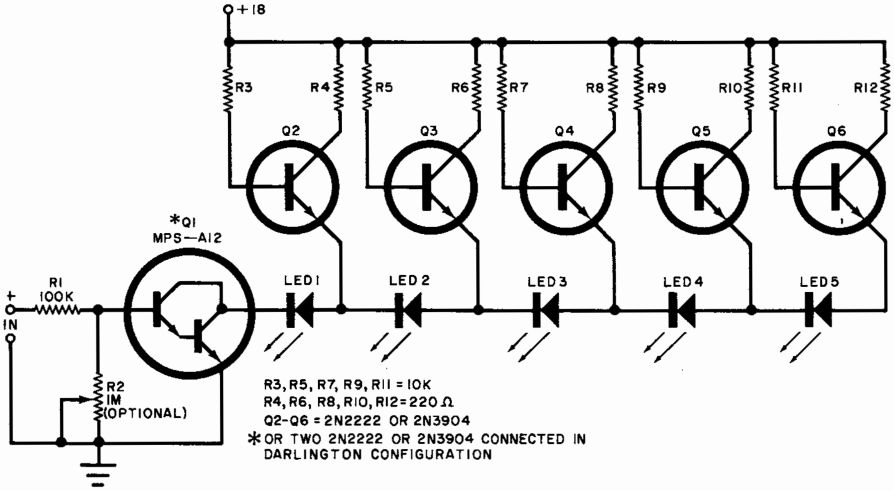


Fig. 4. Transistors can be used to switch on a series string of LED's in succession as in this circuit.

In operation, an increasing voltage applied to the circuit has no effect until the breakdown voltage of *D1* is reached. When *D1* breaks down, *LED1* receives forward current and glows, with *R1* limiting the current to a safe level.

Zener diodes *D2, D3 . . . DN* break down in succession as the voltage is increased. As with the voltage-divider readout, the zener diodes can be arranged for nonlinear response and other "custom" readout roles. Any number of LED-zener diode pairs can be used. You can also connect a zener diode bargraph readout to an op amp to provide a high input impedance and increased sensitivity.

Transistorized Voltage-Sensitive Bargraph. Transistors can be used to switch on a series string of LED's in succession as shown in Fig. 4. The circuit requires more components per resolution element than either of the previous two, but it works quite well.

The circuit in Fig. 4 is connected to a Darlington input stage to isolate the circuit under test from the display. Potentiometer *R2* can be used to adjust the sensitivity of the bargraph from 0.1 to 0.5 volts (0.1-volt increments) to 1.0 to 10.0 volts (2.0-volt increments). Current through the LED's is limited by *R4, R6, R8, R10,* and *R12*.

Even higher sensitivity and better linearity can be obtained by substituting an op amp for the Darlington input stage. See Fig. 2 for details.

Comparator Voltage & Resistance-Sensitive Bargraph. You can make an exceptionally versatile bargraph readout from a batch of op amp comparators. The input of each comparator is connected to one stage of a voltage divider and the output to an LED. When an increasing voltage is applied to the voltage divider, the comparators turn on in sequence and cause their LED's to glow. The same effect occurs when an external resistance is connected across the divider.

Fig. 5 shows one possible configuration of this concept. Three LM339 quad comparators are used to provide the ten comparators for the circuit. The voltage divider consists of *R1-R11*, while *R12* limits current through the LED's to about 10 milliamperes.

Potentiometer *R1* is the source of this circuit's exceptional sensitivity. When it is set for a resistance of several megohms or more, for example, the LED's will turn on in increments of a millivolt or so. By substituting a ro-

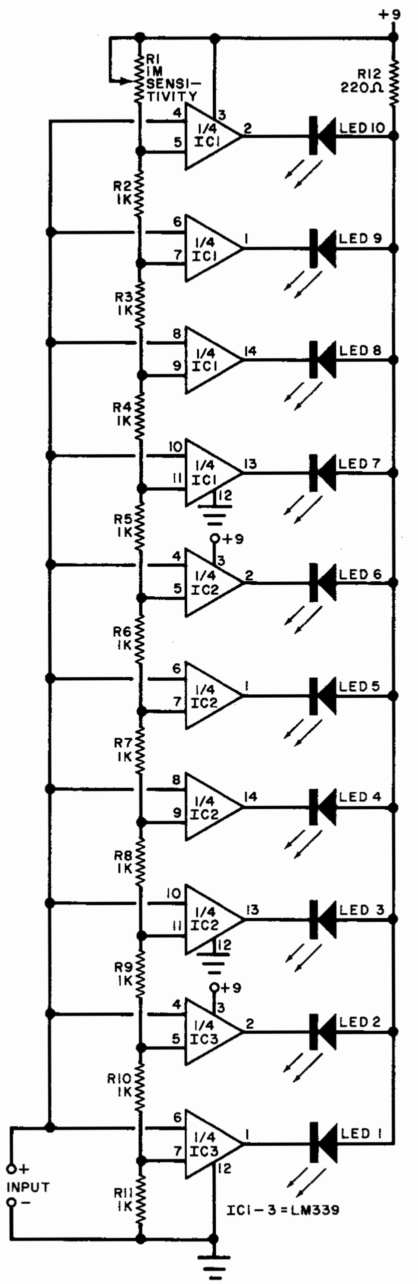


Fig. 5. Bargraph using comparator voltage and resistance-sensitive circuit.

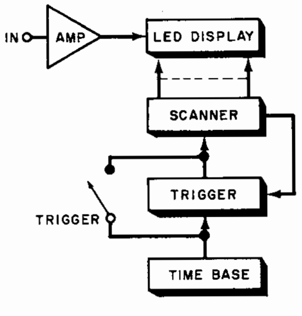


Fig. 6. Block diagram for bargraph frequency meter.

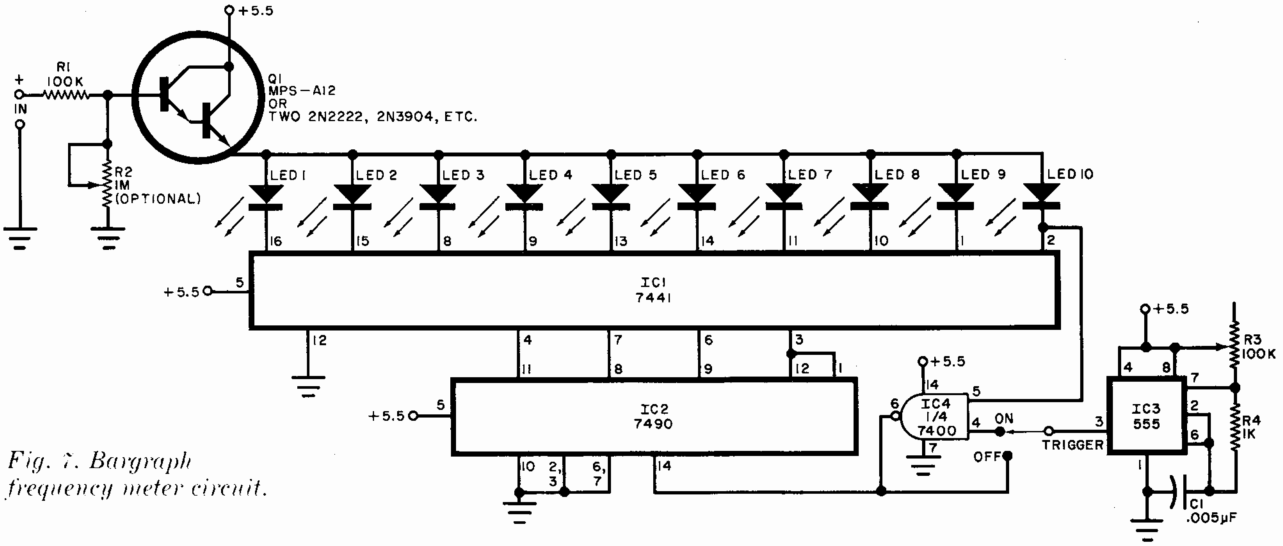


Fig. 7. Bargraph frequency meter circuit.

tary switch and several fixed precision resistors for *R1*, you can make a calibrated voltmeter which doubles as a resistance meter. In the resistance sensing mode, the circuit can be adjusted to indicate up to 10 megohms per LED.

This circuit can also be used as a timer or sensitive light meter. To operate it as a timer, connect a large-valued good-quality capacitor across the input leads. (Use at least 1 microfarad for best results.) As the capacitor charges, the LED's will glow in succession to indicate the charge on the capacitor. Intervals of a fraction of a second to more than a minute per LED can be obtained.

To use the circuit as a light meter, connect either a photovoltaic cell such as a silicon solar cell or a photoresistive cell to the input leads. The photovoltaic cell generates a voltage in response to light and the LED's glow in succession as the light level at the cell is increased. Photoresistors change their resistance in response to light, and the LED's react accordingly.

Frequency-Sensitive LED Bargraph. Believe it or not, you can make a frequency meter from a 555 timer, several TTL IC's, ten LED's, and a few miscellaneous parts. Figure 6 is a block diagram of the circuit; Fig. 7 is the schematic. Here's how it works:

The time base (555 timer) feeds clock pulses at an adjustable rate to a scanning circuit (7490 counter and 7441 decoder). An LED is connected to each of the decoder outputs.

Normally, all the LED's are off. However, a pulse applied to the input amplifier (a Darlington or FET stage) which is coincident with a clock pulse causes one or more LED's to be turned on. The number and arrangement of the LED's indicates the frequency of the incoming pulses *and* their width.

To view the individual pulses of the incoming signal on the display, the time base must be properly synchronized. This is accomplished by adjusting the time base's RC time constant. Calibration is accomplished in the same way.

Manual adjustment of the time base's time constant is adequate for pulses occurring at a rate of less than a few kilohertz, and faster frequencies require automatic synchronization. This is accomplished by a single NAND gate (7400 quad NAND gate) which is connected as an automatic trigger. The trigger operates much like the triggered sweep in an oscilloscope.

With the component values shown, the circuit will display frequencies ranging from about 20 microseconds per LED to 1 second per LED. You may have to increase C1 to 0.01 or 0.1 microfarad to obtain the full operating range.

Operation of the frequency meter can be a little tricky at first. You will need to calibrate the unit by using a known frequency source. For best results, a square or rectangular pulse shape should be employed.

Begin calibration by applying a known frequency and rotating R3 until the display resembles:

1 0 1 0 1 0 1 0 1 0

where "1" represents a glowing LED and "0" represents an LED which is off. If the input frequency is 1 kHz, each LED corresponds to 500 microseconds. Mark *R3's* shaft position accordingly, and continue calibrating for a range of input frequencies.

During calibration, you will notice that the LED's do not always glow in a uniform pattern. For example, the following pattern may appear:

1 0 1 0 1 0 1 0 1 1

This and similar effects are caused by slight changes in either the time base frequency, the input frequency, or noise.

After you have calibrated the circuit, you can use it to measure the frequency of a pulse train and the width of square pulses. For example, to measure the width of a square pulse, simply rotate *R3* until several LED's near the center of the display are glowing. The pattern might resemble this:

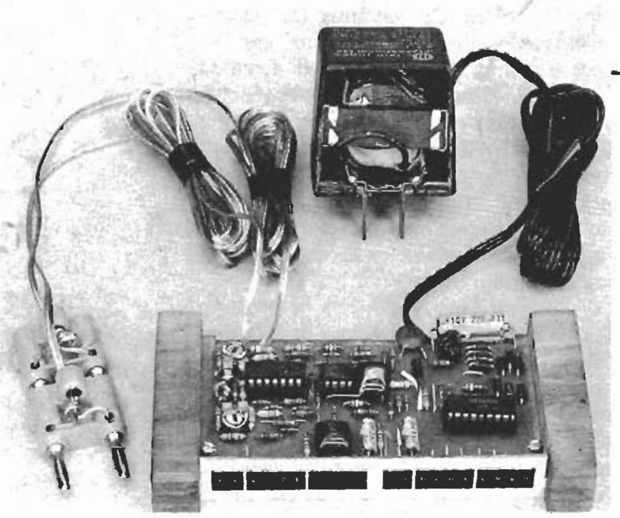
1 0 0 1 1 1 0 0 1 1

The 1 1 1 pattern near the center of the display is a single pulse (ignore the other LED's) and its width is found by adding the time increment represented by each LED. If R3 is set for 100 microseconds per LED, then the pulse is 300 microseconds wide.

Since the resolution of the 10 element readout is so limited, your measurements will not be very accurate. Nevertheless, you can get a good idea of both frequency and pulse width with the circuit. For best results, operate the frequency meter in subdued light since the LED's will not be very bright. This is especially true when measuring fast frequencies.

◆

BUILD THIS



AUDIO POWER LEVEL METER

Not a wattmeter but an honest-to-goodness power level indicator calibrated on your amplifier's clipping level. Use it to protect your speakers. Inexpensive and easy to build.

JOSEPH M. GORIN

OUTPUT METERS ARE BECOMING INCREASINGLY common on high-end audio amplifiers and receivers. They add visual excitement to a product and thus help its sales, but they have enough other uses so that many companies have introduced accessory meters in the over-$100 price region for audiophile use. The purpose of this article is to allow you to build a high-quality power-level meter (PLM) for a low price.

Before "moving up" to a higher power amplifier, an investment in a PLM, will tell you how often (if ever) you drive your current equipment into clipping. After a short period of use, the PLM will give you a good feel for the effects of doubling power (adding 3 dB) and answer the question of how much power is needed in a given installation. Users of biamplification (a system with separate power amplifiers for woofers and tweeters) can use the PLM to see how much more power is needed for the woofers than the tweeters. I found that my system with 300 watts available for the woofers and 25 watts for the tweeters, the tweeter amplifiers never come close to clipping while the woofer amplifiers clip frequently. This knowledge saved a lot of time and money by showing the folly of building higher power amplifiers for the tweeters.

The PLM can help prevent loudspeaker damage. Most loudspeaker failures are caused by running power amplifiers into frequent clipping. Although musical signals contain very little high-frequency energy—almost never enough to destroy a tweeter even at high levels, an amplifier driven into clipping creates a waveform with sharp edges that produce lots of high-frequency distortion. The crossover passes this energy on to the delicate tweeters; causing them to burn out. This happens most often with amplifiers in the 25-watt region. Lower-power amplifiers do not have enough power to destroy the tweeters and larger ones are run into clip-

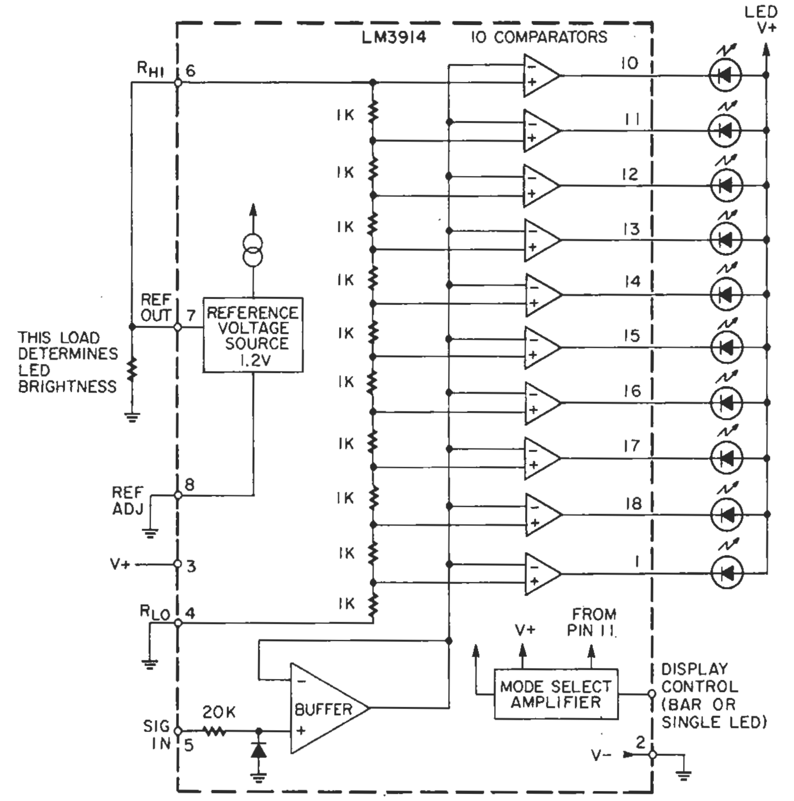


FIG. 1—BLOCK DIAGRAM of the LM3914 dot/bar display driver monolithic IC.

ping less often. By watching the power-level meter, frequent clipping can be observed and the level turned down to prevent it. This power-level meter is actually a *voltage* rather than power-reading device, as virtually all solid-state power amplifiers clip at a constant voltage (independent of load impedance), especially during transients, and therefore measuring voltage is a viable method of measuring maximum power.

A power-level meter can be used to compare the dynamic range of program sources (and explain much of the difference between FM broadcasts and records). It can help you set up the balance of your system. Since it is fast and peak-responding, it can be modified (see the construction section of this article) to aid in setting tape recording levels. But, like a seconds readout on a digital clock, it is very useful for making you feel good about your equipment's operation and just plain fun to watch.

How It Works

A new LED driver IC (LM3914) from National Semiconductor has allowed a truly low-cost circuit design which, when combined with the economies of kit construction, allow the PLM to sell in kit form for only $42. The LED driver IC takes an analog input and drives up to ten LED's in a bar-graph mode with constant current. It also provides a reference voltage. A block diagram is shown in Fig. 1.

The use of this IC for both channels with a "free" multiplexing technique allows the entire circuit to be constructed on a tiny 2 × 4-inch PC board and housed in a single piece of ¾-inch walnut 5½ inches wide and 2⁵⁄₁₆ inches deep—less than 0.1 board foot—thus saving lots of the cost and adding the elegance of smallness.

The complete schematic is shown in Fig. 2. Right and left channels operate identically. I'll use the right channel in discussing the circuitry. Pot R2 adjusts the gain of the system so that the highest LED indicates clipping in the amplifier. If the voltage of the wiper of R2 is positive (I'll call this voltage V_{in}), pin 4 of IC1 will go negative until the voltage on the anode of D1 is $-R5/R4$ times V_{in}. Since negative feedback always keeps pin 1 of IC1-b at zero volts, the current through R6 then is $-V_{in}\frac{R5}{R4 \times R6}$. This is twice as great as the current in R7 ($V_{in}/R7$) but of opposite polarity, making the net current approximately $-V_{in}/R7$. If V_{in} is negative, pin 4 of IC1-a goes positive by about 0.6 volt to keep pin 6 at zero volts. Diode D1 then is non-conducting, and there is no voltage on, nor current through, R6. The net current through R6 and R7 then is $V_{in}/R7$. IC1-a and its resistors thus form an active rectifier, such that the current is always $-|V_{in}|/R7$. In this way, the circuit responds equally to positive and negative peaks.

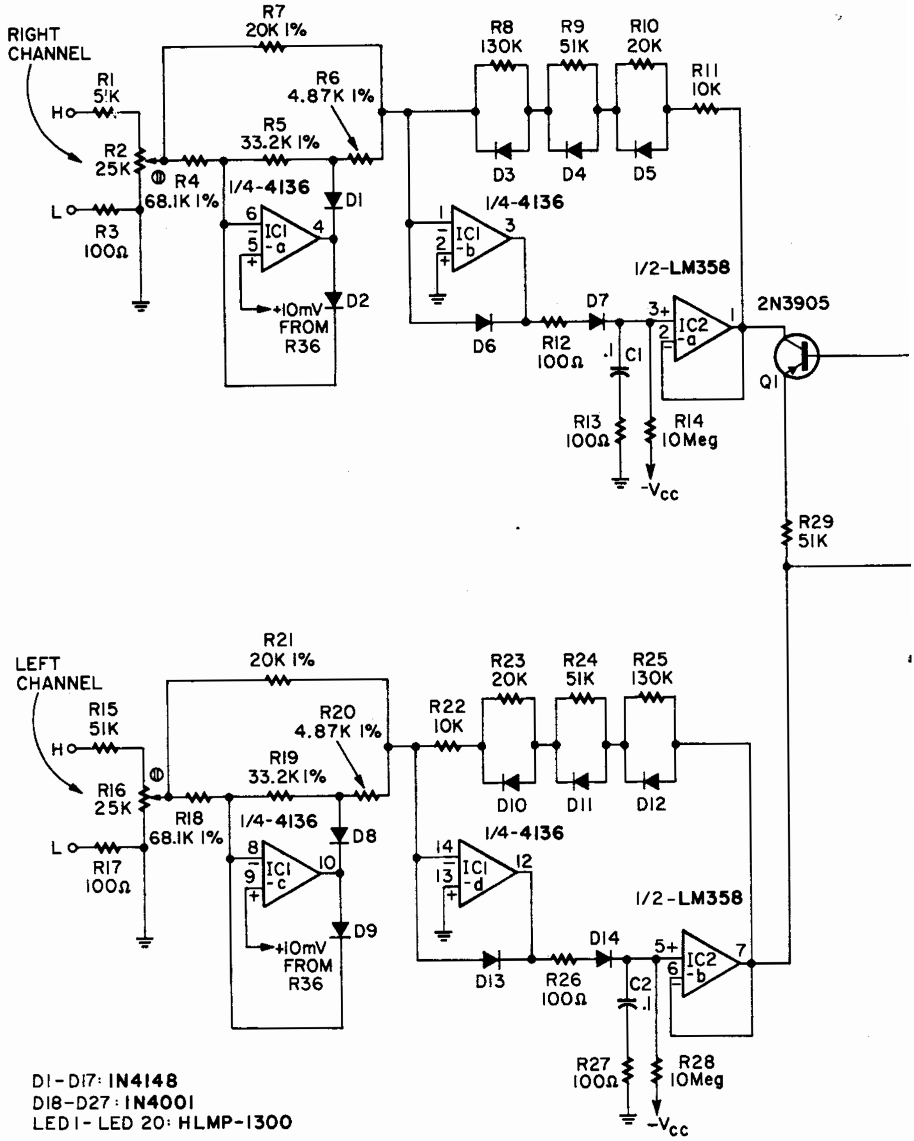


FIG. 2—COMPLETE SCHEMATIC of the LED power-level meter. The LED's in the two channels are multiplexed at a 60-Hz rate by half-sine voltages from the power transformer

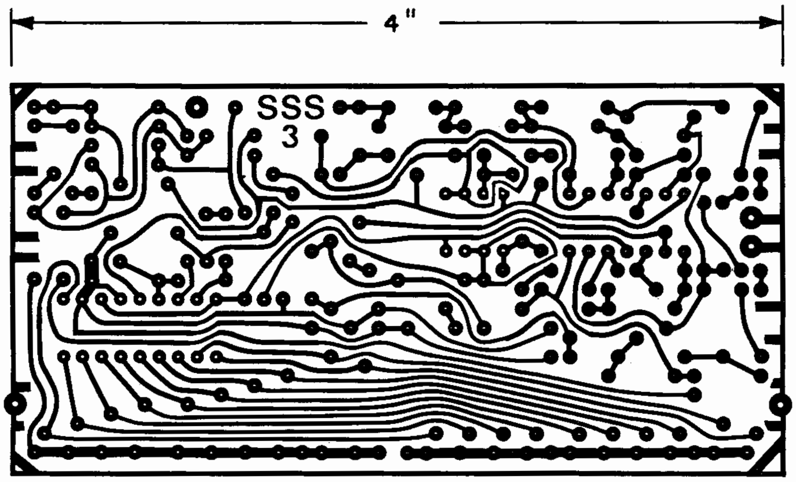
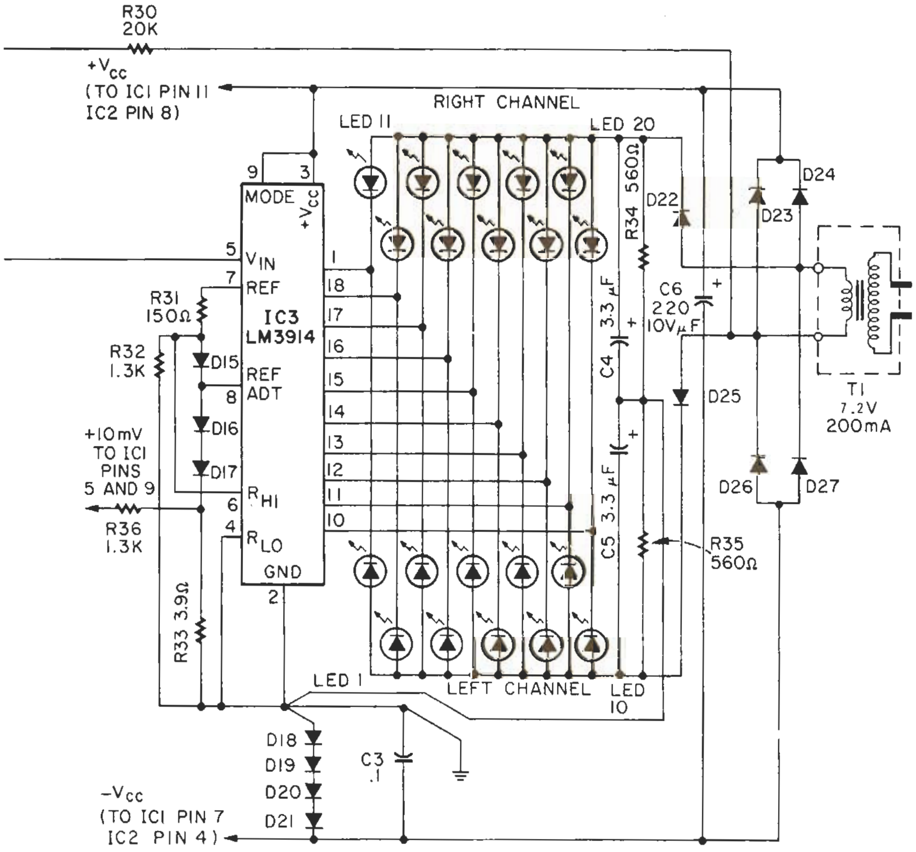


FIG. 3—FULL-SIZE FOIL pattern for the printed-circuit board. The single-sided design makes copying easy.

The rest of the circuit forms a peak detector and logarithmic converter. Resistors R8 through R11 and D3 through D5 are wired so that their current vs. voltage response is approximately logarithmic. Therefore, if the logarithm of the output voltage is less than the input, IC1-b pin 3 will turn on D7 and charge up C1 until the output voltage is equal to the log of the input. If the log of the input is less than the voltage on C1, IC1-b will turn on D6 and C1 will slowly discharge through R14. Capacitor C1 then can charge very fast and discharge very slow-



PARTS LIST

All resistors ¼ watt, 5% unless otherwise noted

R1, R9, R15, R24, R29—51,000 ohms
R2, R16—25,000 ohms trimmer potentiometer
R3, R12, R13, R17, R26, R27—100 ohms
R4, R18—68,100 ohms, 1%
R5, R19—33,200 ohms, 1%
R6, R20—4,870 ohms, 1%
R7, R21—20,000 ohms, 1%
R8, R25—130,000 ohms
R10, R23, R30—20,000 ohms
R11, R22—10,000 ohms
R14, R28—10 megohms
R31—150 ohms
R32—1300 ohms
R33—3900 ohms
R34, R35—560 ohms
R36—13,000 ohms
C1, C2—0.1 μF, polyester film, 10%
C3—0.1 μF ceramic disc
C4, C5—3.3 μF, 50 volts, electrolytic
C6—220 μF, 10 volts, electrolytic
Q1—2N3905
D1—D17—1N4148
D18—D27—1N4001
LED1—LED20—HLMP-1300 series LED's (Hewlett-Packard)
IC1—4136 quad op-amp (Exar, Fairchild, TI or equal)
IC2—LM358 low-power dual op-amp (National)
IC3—LM3914 dot/bar display driver (National), Radio Shack catalog No. 276-1707
T1—wall-plug transformer, 7.2 volts AC, 200 mA
Miscellaneous: walnut cover, aluminum front panel, PC board, mounting hardware.

Note: The following parts are available from Symmetric Sound Systems, 912 Knobcone Place, Loveland, CO 80537. Complete kit model PLM-1 with unfinished walnut case and unpainted front panel $42.00. Semi-kit model PLM-SK consisting of PC board, IC1, IC2 and T1 $15.00. Both prices include postage in North America. Colorado residents add 3% tax. The semi-kit will not be available after September 30, 1980. No other separate parts or different combinations are available.

ly, allowing the eye to see peaks that don't exist for very long.

The right channel or left channel is routed to the LED driver IC depending on the polarity of the 60 Hz power input. If the power input is positive, D22 provides current to the right channel LED's, and the low voltage on the bottom side of the transformer pulls current through R30 to turn on Q1 and short the right channel output to the input of IC3. For negative transformer outputs, Q1 is turned off and the left channel is connected to IC3 through R29, and the left channel LED's are turned on through D25. Thus, the right channel and left channel operate alternatively 60 times a second, too fast for the eye to notice.

The LED's used should be high-efficiency T-1 (3.18 mm, 0.125 inch diameter) LED's, as the average current through each is limited to about 10 mA. Xciton's XC-309-R and Hewlett-Packard's HLMP-1301 both have typical and minimum brightnesses of 2 and 1 mcd (millicandella—a unit of brightness) at 10 mA, respectively, and thus are recommended. Monsanto's MV5774 is .75 mcd min. The 209 series of LED's is not recommended as the typical brightness is usually only .5 mcd at 10 mA and many manufacturers don't even specify minimums. Also, high-efficiency types have even greater advantages in pulsed applications, which is how they run here due to the multiplexing.

Diodes D23, D24, D26 and D27 form a full-wave rectifier that charges C6, the main power supply capacitor. Capacitor C6 can be small because the large LED currents do not come from it, just the power supply currents of the IC's. The power supply current of IC3, as well as any LED currents, flow out pin 2 of IC3 and through D18–D21. This biases the point defined to be ground at about 2.5 volts above the negative side of D6 and creates the dual supplies necessary to run IC1 and IC2. It also reduces the voltage across the outputs of IC3 by 2.5 volts, thus reducing the power dissipation.

Construction

The use of a PC board is almost mandatory unless you decide on a different mechanical design than mine. Should you wish to redesign the system, keep LED leads short, and C4 and C5 must have short leads to pin 2 of IC3 and the LED anodes. A note about the layout is in order. The "circles" (the unbroken trace from pin 2 that completely encircles the three pads connected to pin 3) around pins 3 and 5 of IC2 are a "guard;" they reduce leakage from these inputs through any contamination of the PC board on humid days. It is still wise to clean these areas with flux remover after assembly. If you are building without a PC board, D7, C1, R14 and IC2 pin 3 should all be soldered together in mid-air, away from any breadboard surface.

Construction with a PC board (Figs. 3 and 4) is straightforward. Load the resistors first, then the trimmers, diodes, LED's, capacitors and IC's. Because of the large number of polarity sensitive devices (almost everything but the resistors), extreme care must be exercised

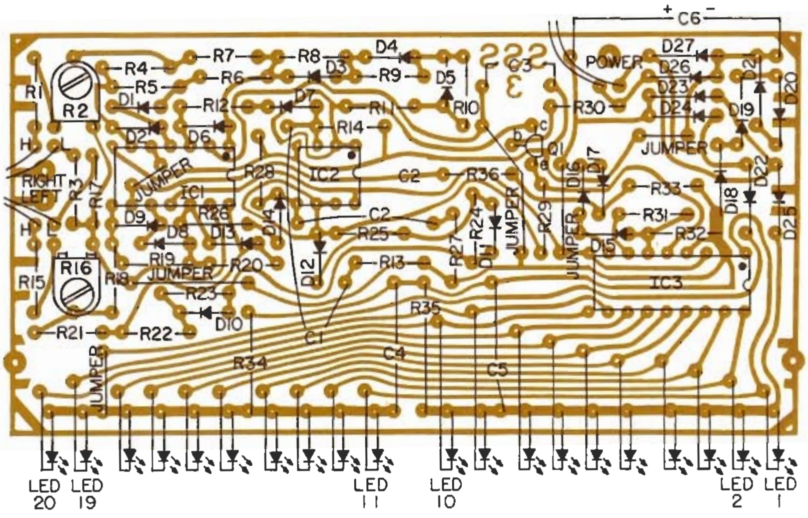
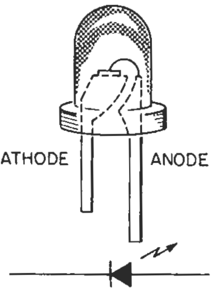


FIG. 4—COMPONENT PLACEMENT guide. Be sure that you include the six jumpers that must be installed.



THE CATHODE IS THE SHORTER LEAD, IT IS THE BASE UPON WHICH THE LED CHIP SITS. THERE MAY BE A COLORED DOT NEXT TO THE LEAD, OR AN ABERRATION IN THE CASE DIAMETER.

FIG. 5—OUTLINE of a typical T-1 size LED shows how the diode is polarized.

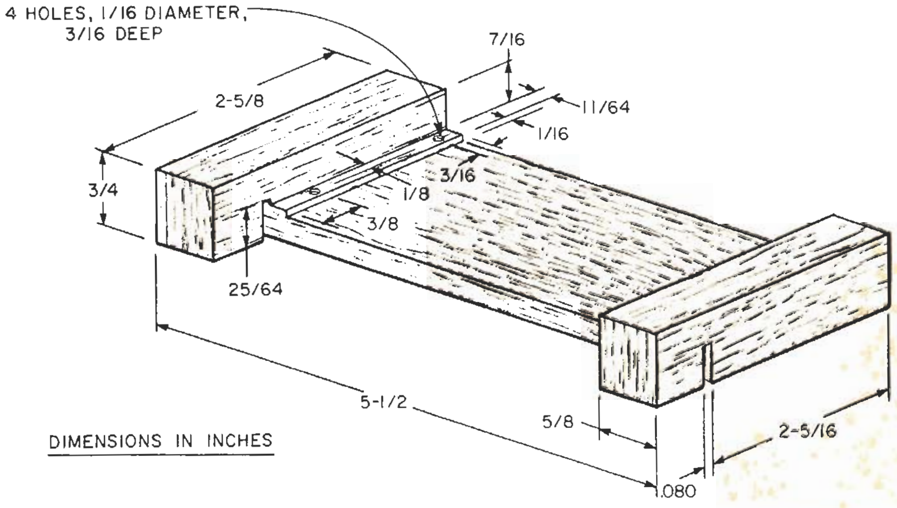


FIG. 6—THE CASE is cut out of a single piece of ¾-inch walnut or similar hardwood. Work can be done with a table or radial-arm bench saw.

when mounting components. The LED's are particularly easy to reverse, see Fig. 5 for polarity clues.

The LED's should be mounted as close as possible to flush with the PC board's edge for a uniform appearance. Some LED's might not have long enough leads for the holes on LED 7–10, in which case another lead can be soldered into the board and then onto the LED lead that was not long enough. Leads of all components should be cut very short after soldering because of the small clearance below the board. The construction of the walnut case and brushed aluminum as shown in Figs. 6 and 7, respectively.

Use No. 24 speaker wire for connections to the right and left channels and power transformer. Pass the wires through the holes in the PC board from the foil side and knot them on the component side. The knot will serve as a strain relief. Then solder the leads into the PC Board. The polarity is very important on the speaker connections; use the copper-colored side for low (L) and be sure to connect it to the ground or low side of the speaker terminals. A polarity error could damage R3 and R17 and the PC board.

Should you wish to use the PLM in a low-level circuit (such as at the tape monitor jacks) instead of at the speaker terminals, substitute a jumper for R1 and R15, and lift the ground pins of R3 and R16 off the board.

Slip the PC board into the case, screw it into position, and you are ready to go.

Calibration

Table 1 shows the performance of the calibrated prototype PLM. Your instrument can be calibrated in either of two ways when used with a solid-state amplifier. To use the PLM to monitor calibrated peak power, an oscillator and an accurate AC meter are required for calibration. Disconnect your speakers and drive your power amplifier with the oscillator at 1 kHz. Adjust the oscillator level until the amplifier output voltage is V_{out} (RMS) equals $\sqrt{P \times 8}$ where P is the power level in continuous watts desired for the maximum indication on the PLM and 8 is the load impedance in ohms. For example (V_{out} = 28.3 volts for P = 100 watts, 20 volts for P = 50 watts, etc.). Connect the PLM inputs to the amplifier

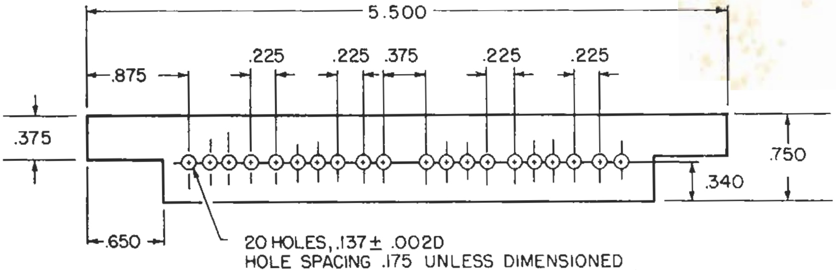
continued on page 81

TABLE 1

Number of LED's lit	Right	Input Left
10	0 dB	0 dB
9	−2.22	−2.15
8	−4.90	−4.78
7	−7.87	−7.53
6	−10.96	−10.46
5	−14.16	−13.52
4	−17.44	−16.67
3	−21.03	−19.84
2	−24.62	−23.32
1	−28.28	−26.61

Frequency Response
Left: 0—20 kHz @ −.75dB
Right: 0—20 kHz @ −.73dB

Pulse Response
Both channels with 2 dB in 40μS.



20 HOLES, .137 ± .002D
HOLE SPACING .175 UNLESS DIMENSIONED
ALL HOLE-TO-HOLE SPACING TOLERANCES ± .007
ALL OTHER TOLERANCES ± .020
MATERIAL: 1/16" BRUSHED ALUMINUM, GRAIN EITHER WAY
ALL DIMENSIONS ARE IN INCHES

FIG. 7—THE FRONT PANEL is formed from a sheet of 1/16-inch brushed aluminum.

LEVEL METER

continued from page 46

output, and adjust R2 and R16 until the highest LED lights up at half its maximum brightness.

To use the PLM as a clipping indicator, disconnect your speakers from your amplifier while leaving the PLM connected to the output. Dial your tuner to an FM rock station (these are usually the most compressed and limited stations) and turn your volume control all the way up. Adjust R2 and R16 until the highest LED just barely lights up. Then turn them higher by about 20% of the total angle they have been turned. When you reconnect your speakers, the highest LED will represent transient clipping of your amplifier.

When using the PLM with a vacuum-tube amplifier, always connect a load of approximately the right value (8 ohms for example) across the output in the first calibration technique. Vacuum-tube amplifiers are not safe to use without a load, and full-power sinewave testing with speakers connected isn't good either for the speakers or your ears! The second calibration procedure isn't of much use with vacuum-tube amplifiers, as they clip very differently. This wraps it up. Use and enjoy! **R-E**

This chip

Out of Tune

In "An LED-Readout Audio Power Meter" (March, p 35), note an error in Table II, "Ideal Threshold Voltages" for the comparators. The right column, "Voltage," is inverted. The last entry, 4.395, refers to Pin 7 of IC1; the next to last, 3.070, refers to pin 5 of IC1; and so on. The top entry, 0.011, is the threshold for pin 11 of IC3.—*Tim Henry*

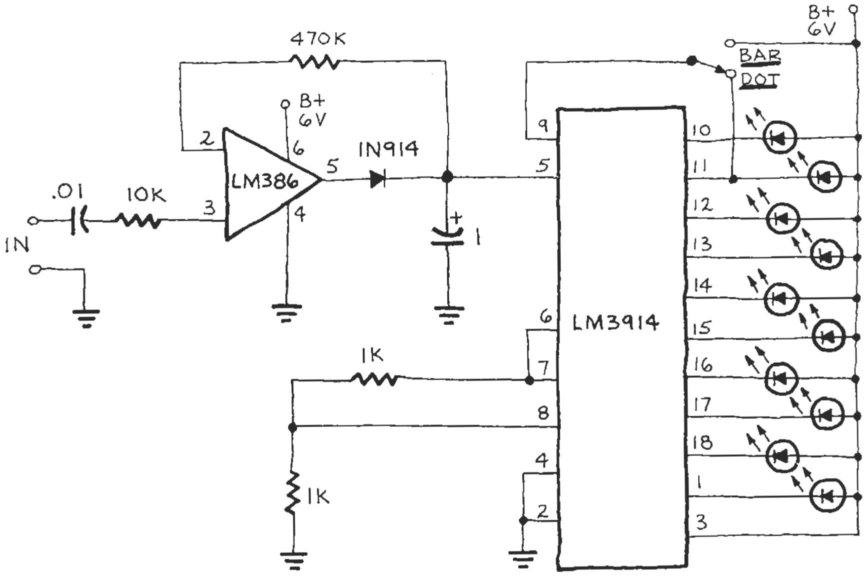
"Out of Tune," May 1976

In "An LED-Readout Audio Power Meter" (March 1976, p 35), diodes *D1-D4* are shown in Fig. 2 with their polarities reversed. They should also be numbered *D3, D1, D2, D4* starting from the top. The polarity of *C1* is also shown reversed.

LED PEAKMETER

I WOULD LIKE TO SUBMIT MY LATEST project to your New Ideas column. I call it the LED Peakmeter. It is a basic dot/bar readout built around the new National LM3914 display driver. The circuit also includes a peak detector that immediately drives the readout to any new higher signal level and slowly lowers it after the signal drops to zero. The readout is a moving dot or expanding bar display.

The diagram shows one channel of the stereo LED Peakmeter shown in the photograph. All parts are easily obtained and layout is not at all critical. Although not absolutely necessary, I suggest trying the circuit on a solderless breadboard before hand-wiring to check delay time and to match components in a stereo unit.



I used a spare piece of perforated board as a template to drill holes for the LED's in the project box's plastic front. A battery holder with four "C" cells is mounted on the back of the box.

The circuit has other possibilities. It can be expanded for a longer bar readout if desired. Tapping five or more LED Peakmeters into a frequency equalizer or series of audio filters should give a unique result. Physical layout of the LED's can also be changed to simulate the action of regular VU meters.

The bottom LED of each

ins on with no si

54 luminant

Various types of LED audio level indicator have been described in the past, both of the peak reading and of the average reading type. However, the Luminant represents a novel approach to the problem of audio level measurement, in that peak and average levels are indicated simultaneously on the same display.

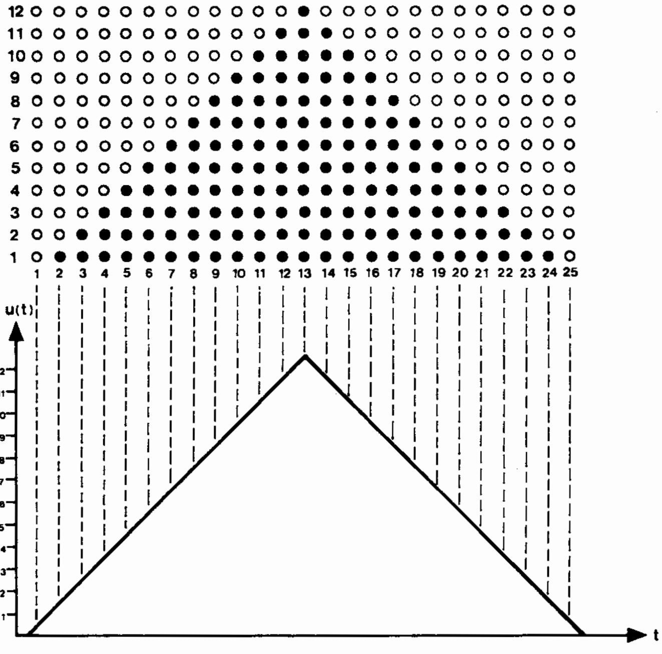
Arguments exist for the use of both peak and average reading audio level meters. In a peak level meter the AC voltage is rectified and the peak value stored on a capacitor and displayed on a logarithmic (dB) meter scale. In average reading meters such as the VU (Volume Unit) type of meter the AC voltage is rectified and fed through a lowpass filter so that the average value is indicated.

Proponents of peak meters argue that average reading meters do not respond to short transients, which can result in overload and distortion if the meter is used as a recording level indicator. Afficionados of average reading meters, on the other hand, claim that under-recording can occur with peak meters the ratio of the peak level to average level is high, which it is with much programme material. However, the Luminant offers the best of both worlds by providing simultaneous peak and average readings.

How this is achieved is illustrated in figures 1a to 1c. Figure 1a shows how a thermometer-type LED display responds to a ramp input voltage. As the voltage increases the LEDs light in succession until all are lit, and as the voltage decreases they extinguish in succession starting with the top one. Figure 1b illustrates how a spot-type LED display responds to the same type of input voltage. In this case only one LED at a time is lit.

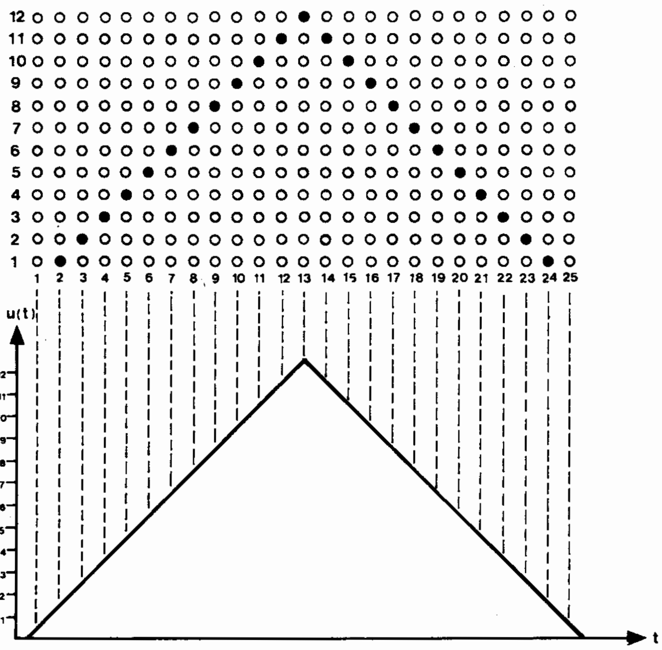
By using a spot scale for the peak indication and a thermometer scale for the average indication it is possible to

1a



9949 1a

1b



9949 1b

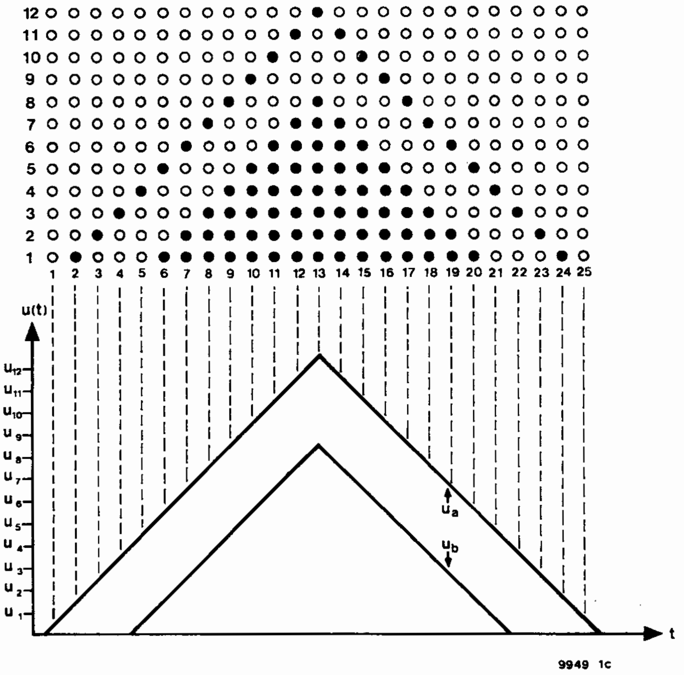
combine peak and average readings into one display, as shown in figure 1c. Since the average level can never be greater than the peak level the display will consist of a column of LEDs indicating the average value with a single LED above it indicating the peak value.

The difference between peak and average reading is illustrated in figure 2, which shows the response of peak and average instruments to a pulse input. The peak meter reaches the maximum value of the input signal very rapidly and decays slowly when the pulse terminates. The average meter, on the other hand, rises more slowly to the maximum value of the input signal, and only reaches it if the pulse is fairly long.

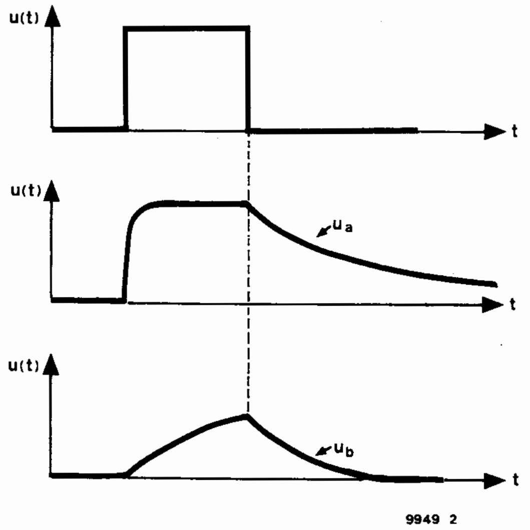
Figures 1a to 1c. Illustrating the difference between thermometer scale and spot scale LED displays, and showing how the two types of display may be combined.

Figure 2. Showing the different responses of peak and average rectifiers to a pulse input.

1c



2



When the signal finishes the reading decays with the same time constant as its attack time constant.

Display multiplexing

In order to display peak and average readings on the same LEDs the display must be multiplexed. This means that the input to the LED meter must be switched between the outputs of the peak and average rectifiers, and the display must also be switched between thermometer and spot scale. The multiplexing is taken a stage further by using the same LED voltmeter for both the left and right channels of a two-channel display, and switching the outputs of the meter between two sets of LEDs.

The principle of the display multiplexing is shown in figures 3a to 3e. Figure 3a illustrates the basic concept of a spot scale LED voltmeter. This consists of a chain of voltage comparators whose non-inverting inputs are fed with the input signal and whose inverting inputs are fed with reference voltages derived from a (logarithmic) potential divider chain. When the input voltage exceeds U_X the output of k_X goes high and D_X lights. When the input voltage exceeds U_{X+1} the output of k_{X+1} also goes high, so D_X is extinguished and D_{X+1} lights, and so on.

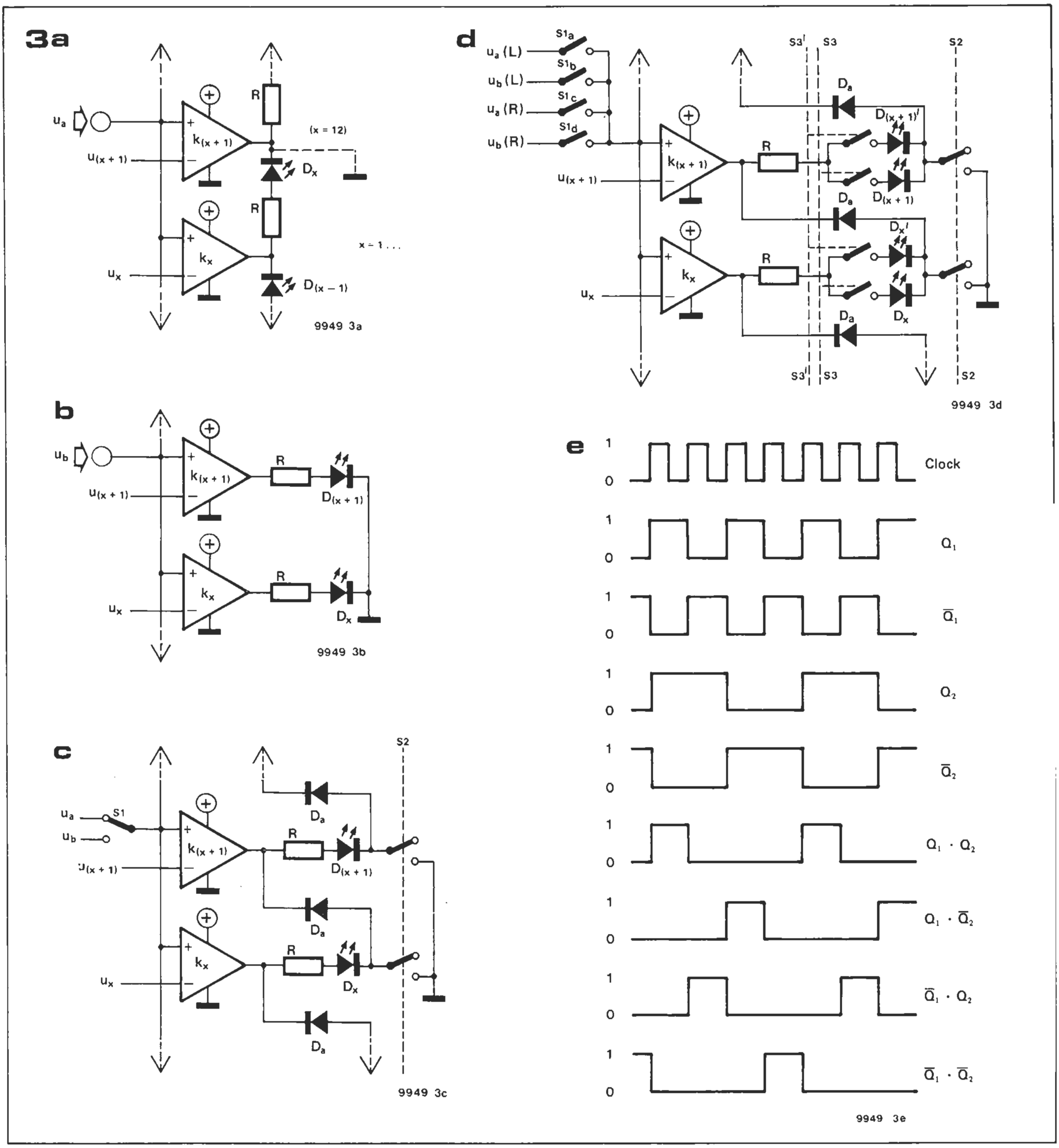
The thermometer scale LED voltmeter shown in figure 3b operates in a similar fashion, but the LEDs are connected to ground instead of between the outputs of the comparators. Once a LED is lit it therefore remains lit even when subsequent LEDs light.

The principle of multiplexing between these two types of display is illustrated in figure 3c. When the peak input signal, U_a, is fed in via S1, S2 is open and a spot scale results. However, when S1 is set in its other position to receive the average input, U_b, S2 is closed and the cathodes of the LEDs are grounded so that a thermometer scale is obtained.

Switching between left and right channels is shown in figure 3d. Switches $S1_a$ to $S1_d$ select left peak, left average, right peak or right average signals, whilst switches S3 and S3' select between the left and right channel LED displays. As before, S2 selects between peak and average readings.

By closing switches in the correct combination it is therefore possible to display left peak or average reading on the left-hand display and right peak or average reading on the right-hand display. If switching between the various inputs and displays is carried out at sufficiently high speed then the eye is, of course, fooled into thinking that it sees four continuous displays. In the practical circuit this switching is carried out electronically, using CMOS analogue switches for the signal inputs and transistors to switch the displays.

Switching between the four displays possibilities is under the control of a clock generator which consists of a two



Figures 3a to 3e. These figures show how the LED displays are multiplexed for left, right, peak and average readings.

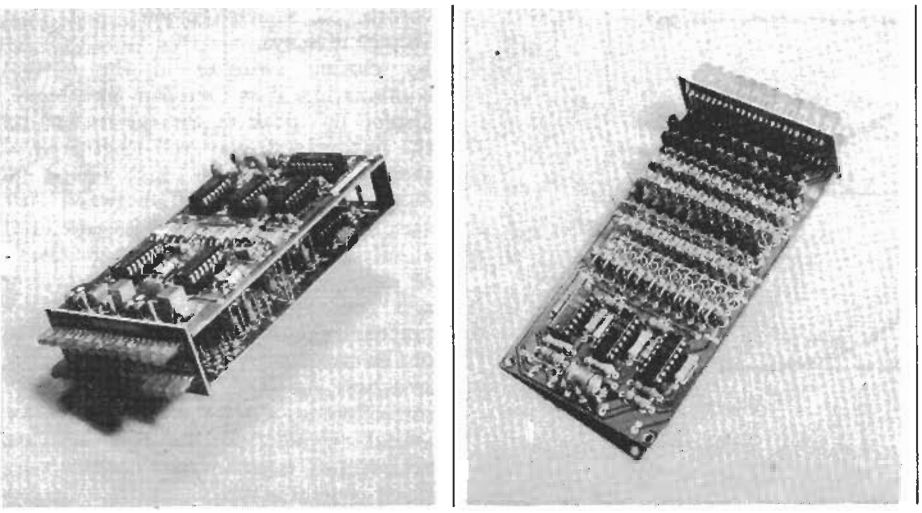
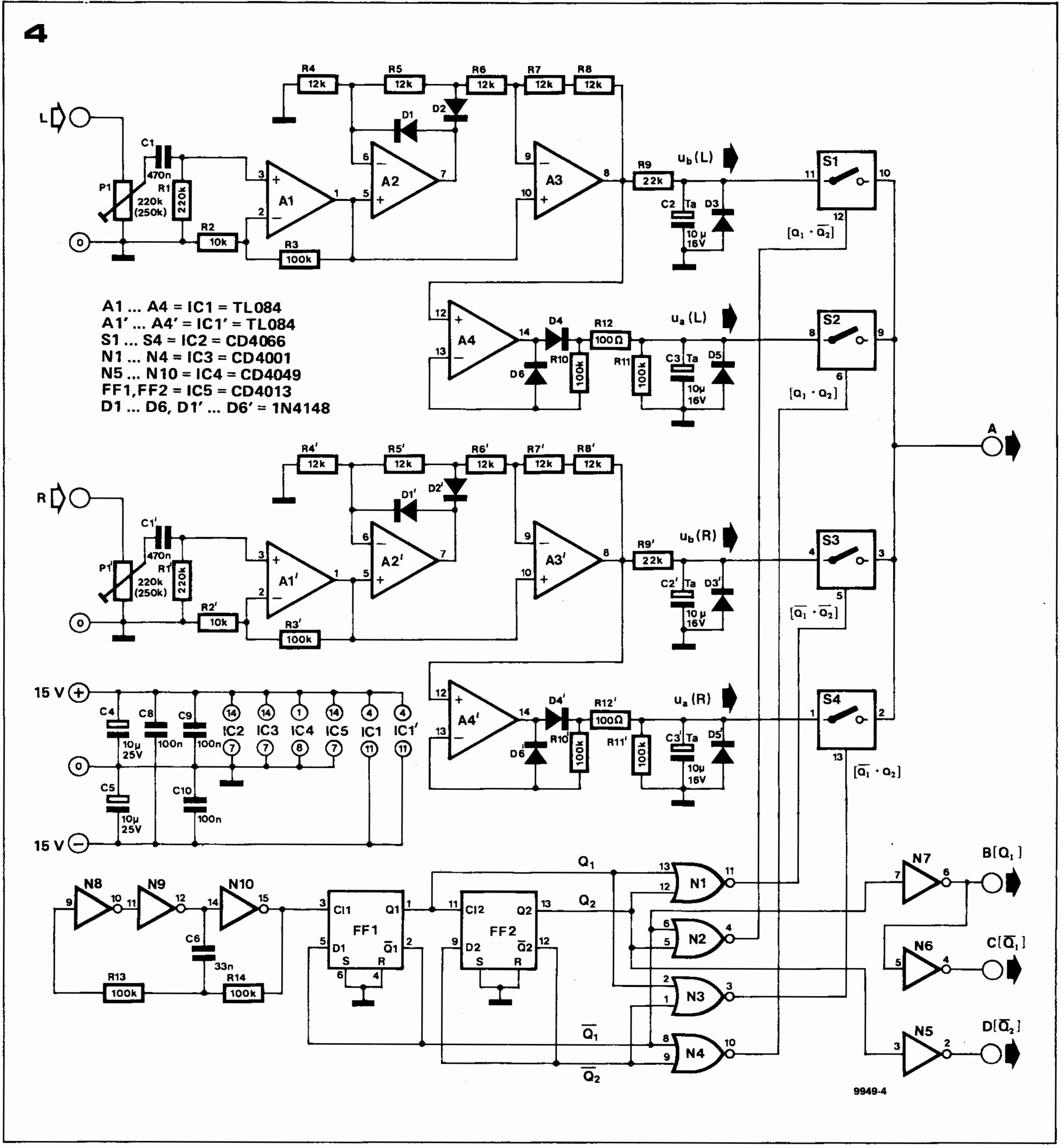


Figure 4. Rectifier and control section of the Luminant.



bit binary counter and logic gating. If the following values are assigned:
Q1 = 1 = left channel display
Q1 = 0 = right channel display
Q2 = 1 = peak display
Q2 = 0 = average display
then the following control signals are required for switches S1 to S3, assuming that a logic 1 is required to close a switch:

Q1·Q2 for S1a
Q1·$\overline{Q2}$ for S1b
$\overline{Q1}$·Q2 for S1c
$\overline{Q1}$·$\overline{Q2}$ for S1d
Q1 for S3
$\overline{Q1}$ for S3'
$\overline{Q2}$ for S2

These control signals are illustrated in the timing diagram of figure 3e. The multiplex clock frequency can be anywhere between 100 Hz and 200 Hz, which is sufficient to assure a flicker-free display without being so high as to cause such problems as 'ghosting' due to switching delays.

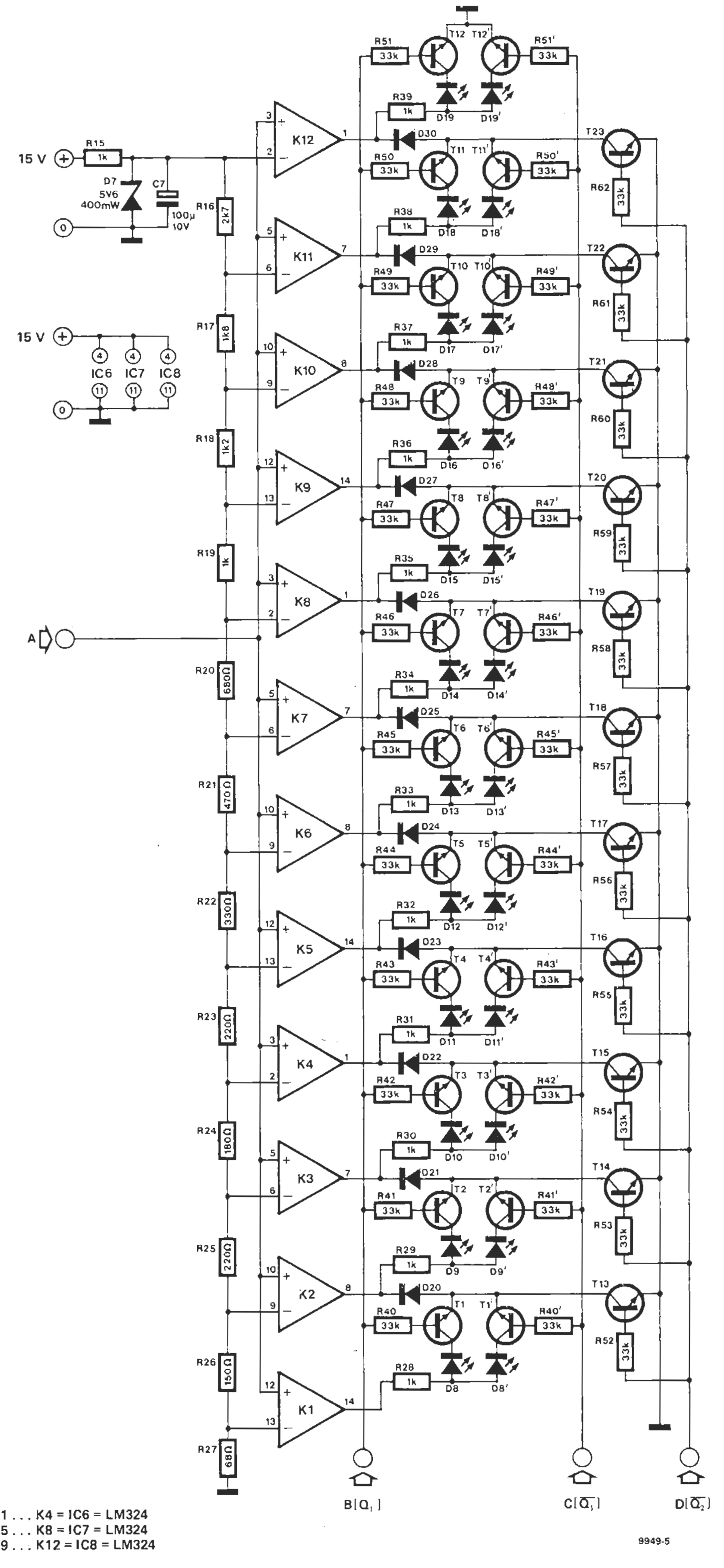
Complete circuit

The complete circuit of the Luminant is shown in figure 4 and 5. Figure 4 shows the signal rectifier and control section whilst figure 5 shows the display section. The left channel input amplifier and rectifier section is constructed around a TL 084 quad FET op-amp A1 to A3, the right channel being identical. A1 is an input buffer amplifier with a gain of 11. P1 allows adjustment of the input sensitivity to suit individual requirements. A2 and A3 form an active full-wave rectifier circuit, which gives a positive full-wave-rectified signal at the output of A3. Averaging is performed by a simple lowpass filter R9/C2, whilst peak storage is performed by A4 and its associated components. CMOS analogue switches S1 to S4 are connected to the outputs of the four rectifier circuits.

The clock generator consists of an astable multivibrator constructed around N8 to N10, a two-bit counter comprising FF1 and FF2, and decoding consisting of N1 to N7.

The display section shown in figure 5 consists of a LED voltmeter comprising comparators K1 to K12, together with switching circuits for the various display options. Switching between spot and

5



K1 . . . K4 = IC6 = LM324
K5 . . . K8 = IC7 = LM324
K9 . . . K12 = IC8 = LM324

T1 . . . T12,T1' . . . T12',T13 . . . T23 = TUN
D8 . . . D19,D8' . . . D19' = LED
D20 . . . D30 = 1N4148

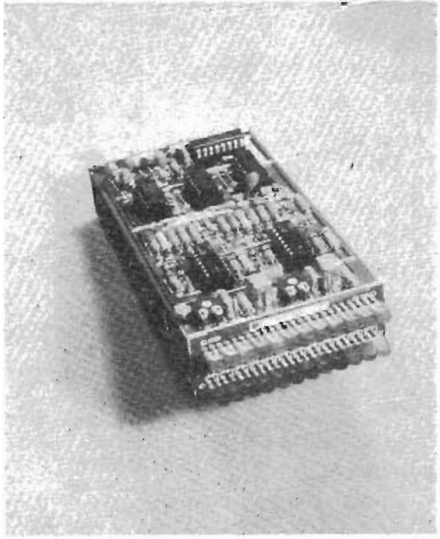


Table 1

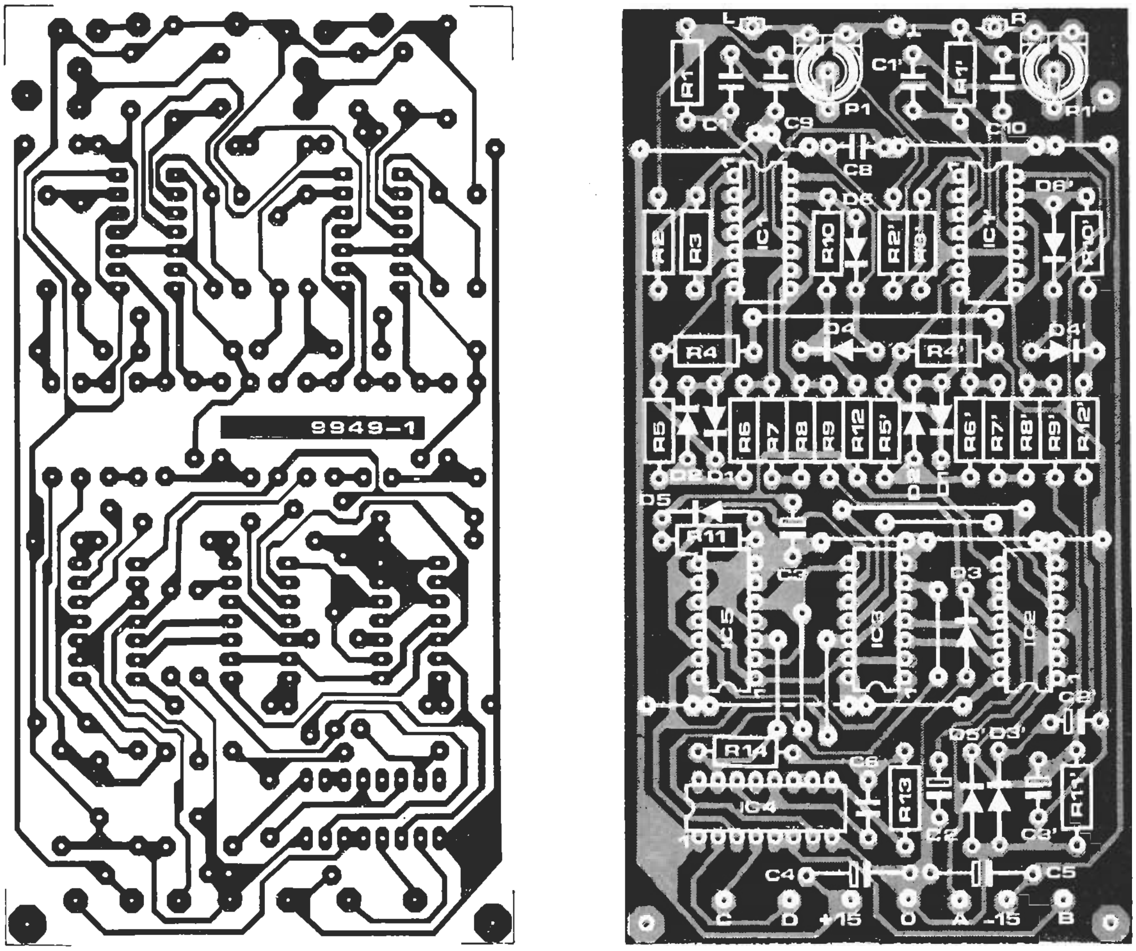
Luminant scale calibration

Top LED lit	nominal level (dB)	actual level (dB)
D19	0	0
D18	−3	−3.1
D17	−6	−6.0
D16	−9	−8.7
D15	−12	−11.8
D14	−15	−14.8
D13	−18	−17.8
D12	−21	−20.6
D11	−24	−23.3
D10	−27	−26.3
D9	−33	−32.3
D8	−42	−42.4

Figure 5. Display section of the Luminant.

Figure 6. Printed circuit board for figure 4 (EPS 9949 - 1).

6



Parts list to figures 4, 5, 6, 7 and 8

Resistors:
R1,R1' = 220 k
R2,R2' = 10 k
R3,R3',R10,R10',R11,R11',R13,
R14 = 100 k
R4,R4',R5,R5',R6,R6',R7,R7',
R8,R8' = 12 k
R9,R9' = 22 k
R12,R12' = 100 Ω
R15,R19,R28 . . . R39 = 1 k
R16 = 2k7
R17 = 1k8
R18 = 1k2
R20 = 680 Ω
R21 = 470 Ω
R22 = 330 Ω
R23,R25 = 220 Ω
R24 = 180 Ω
R26 = 150 Ω
R27 = 68 Ω
R40 . . . R51,R40' . . . R51',
R52 . . . R62 = 33 k (total of
35 pieces)
P1,P1' = 250 k (220 k) preset
potentiometer

Capacitors:
C1,C1' = 470 n
C2,C2',C3,C3' = 10 μ/16 . . . 35 V
tantalum
C4,C5 = 10 μ/25 V
C6 = 33 n
C7 = 100 μ/10 V
C8,C9,C10 = 100 n

Semiconductors:
A1 . . . A4 = IC1 = TL 084
(Texas Instruments)
A1' . . . A4' = IC1' = TL 084
(Texas Instruments)
S1 . . . S4 = IC2 = CD 4066
N1 . . . N4 = IC3 = CD 4001
N5 . . . N10 = IC4 = CD 4049
FF1,FF2 = IC5 = CD 4013
K1 . . . K4 = IC6 = LM 324
K5 . . . K8 = IC7 = LM 324
K9 . . . K12 = IC8 = LM 324
D1 . . . D6,D1' . . . D6',
D20 . . . D30 = 1N4148
D7 = zener 5V6 (5%) 400 mW
D8 . . . D19,D8' . . . D19' = LED
T1 . . . T12,T1' . . . T12',
T13 . . . T23 = TUN

thermometer displays is performed by transistors T13 to T23. When these are turned on (equivalent to closing S2 in figure 3c) a thermometer scale results, whilst if they are turned off a spot scale is obtained.

Switching between left and right channels is performed by transistors T1 to T12'. When T1 to T12 are turned on the left channel display D8 to D19 is active; when T1' to T12' are turned on the right channel display D8' to D19' is active.

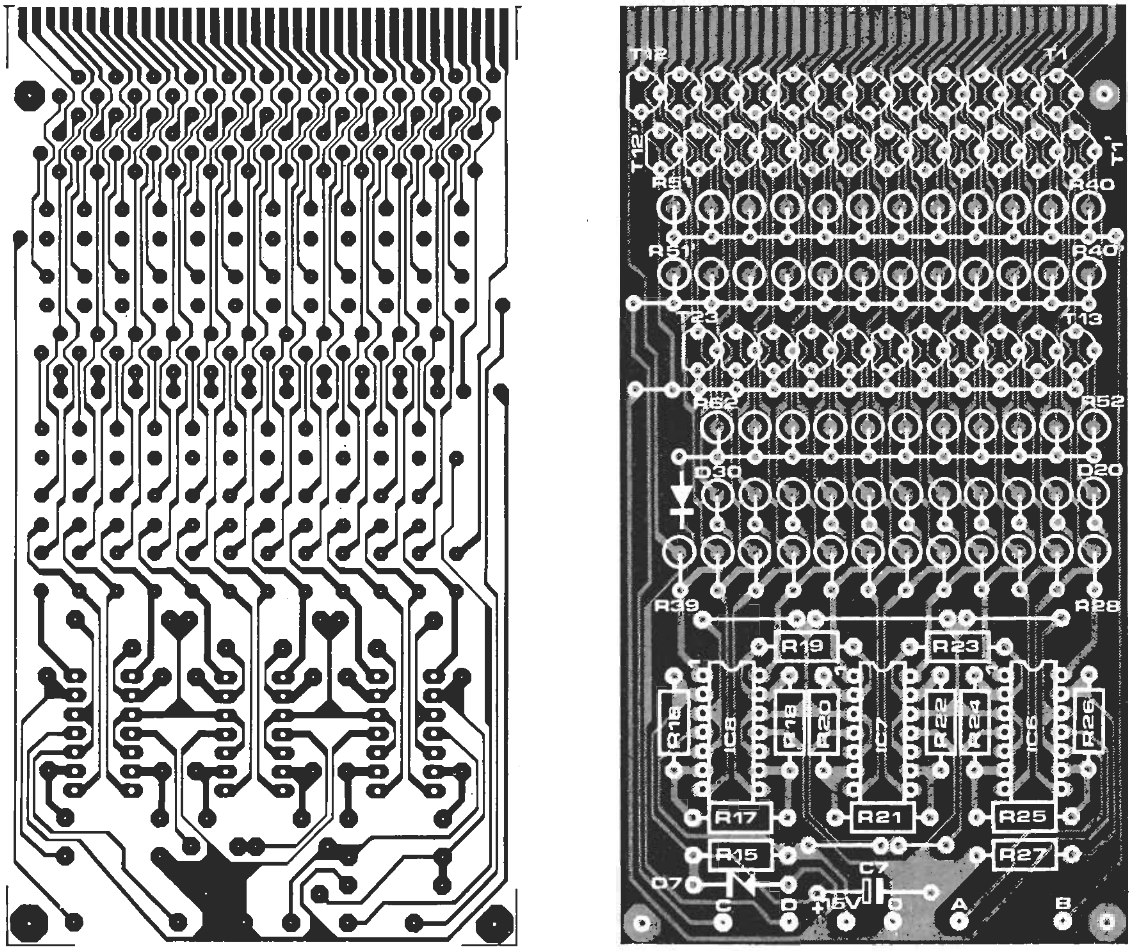
The reference voltages for the LED voltmeter are derived from zener diode D7 via a potential divider chain comprising R16 to R27. Taking the voltage applied to K12 as 0 dB the reference voltages are in approximately 3 dB steps down to about –27 dB (K3). The last two steps are approximately 6 dB and 9 dB. Due to preferred resistor values being used in the potential divider chain the exact values differ from the above figures, the actual values being given in table 1.

Construction

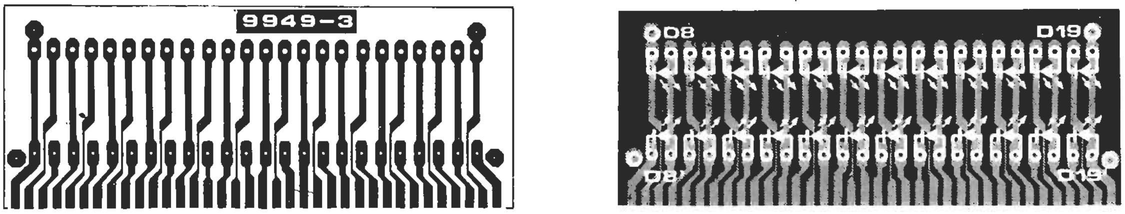
The circuit of figures 4 and 5 is accommodated on three printed circuit boards. The rectifier and control section is mounted on the board shown in figure 6, the display drive circuitry is mounted on the board shown in figure 7 and the LEDs are mounted on the board shown in figure 8.

To save space some of the components on the display board are mounted vertically. The commoned ends of R40

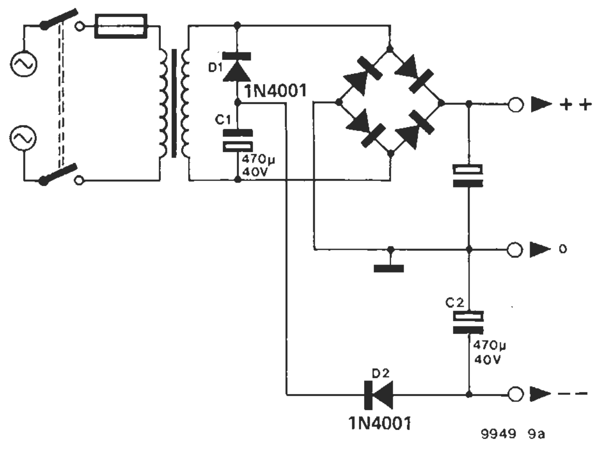
7


T12
T1
T12'
T1'
R51
R40
R51'
R40'
T23
T13
R62
R52
D30
D20
R39
R28
R19
R23
R16
IC8
R18
R20
IC7
R22
R24
IC6
R26
R17
R21
R25
R15
R27
D7
C7
C
D
+15V
0
A
B

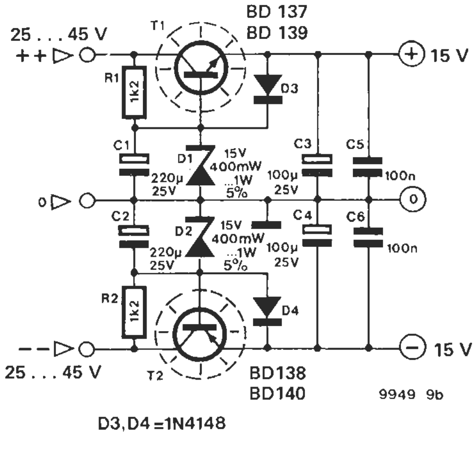
8


9949-3
D8
D19
D8'
D19'

9a


D1
1N4001
C1
470μ
40V
++
0
C2
470μ
40V
D2
1N4001
--
9949 9a

b


25 . . . 45 V
++
T1
BD 137
BD 139
+ 15 V
R1
1k2
D3
C1
220μ
25V
D1
15V
400mW
...1W
5%
C3
100μ
25V
C5
100n
0
0
C2
220μ
25V
D2
15V
400mW
...1W
5%
C4
100μ
25V
C6
100n
R2
1k2
D4
--
25 . . . 45 V
T2
BD138
BD140
− 15 V
9949 9b
D3, D4 = 1N4148

~~to R51~~ R40' to R51', R52 to R62 and the emitters of T13 to T23 are joined by wire links on the component side of the board, as shown in the component overlay of figure 7.

Particular care should be taken when assembling this board due to the compact layout. Once the three boards have been assembled the display drive board and the display board can be joined by butting them together at right angles and making solder bridges between the pads on the end of the display drive board and the corresponding pads on the display board. Extreme care should be taken during this operation to avoid any shorts between adjacent tracks. The control board may then be mounted parallel to the display drive board using spacers and the two boards interconnected with short wire links between points A, B, C, D, 0 and +15 V.

The only other points worth noting regarding the construction are that C2, C3, C2' and C3' should be tantalum types for low leakage, whilst IC1 and IC1' must be type TL 084. The temptation to use the cheaper, pin-compatible LM 324 should be resisted, as this IC does not have FET inputs and has poorer performance.

Power supply

The Luminant operates from a symmetrical ± 15 V supply. The current drawn from the negative supply is between 15 and 25 mA, whilst that drawn from the positive supply is about 25 mA plus 12 mA per LED, a total of about 170 mA with all LEDs lit. The circuit of a suitable power supply is given in figures 9a and 9b.

Figure 9a shows how an unregulated positive and negative suppky may be obtained from a transformer having a single, untapped secondary winding, whilst figure 9b shows a simple stabiliser circuit. If the Luminant is used with the Consonant control amplifier then the arrangement of figure 9a may be used to obtain the negative supply from the Consonant mains transformer. However, only the negative stabiliser need be used as the Consonant has provision for an on-board +15 V IC regulator.

If the Luminant is used with a power amplifier having a symmetrical supply then the circuit of figure 9b may be connected direct to the supply rails of the amplifier. Finally, if the Luminant is used with a preamp or control amplifier having a ± 15 V supply, it may be connected direct to the preamp supply without the need for stabiliser circuits.

Figure 7. Printed circuit board for the display drive circuitry (EPS 9949 - 2).

Figure 8. Printed circuit board for the LED display (EPS 9949 - 3).

Figures 9a and 9b. Power supply suitable for the Luminant.