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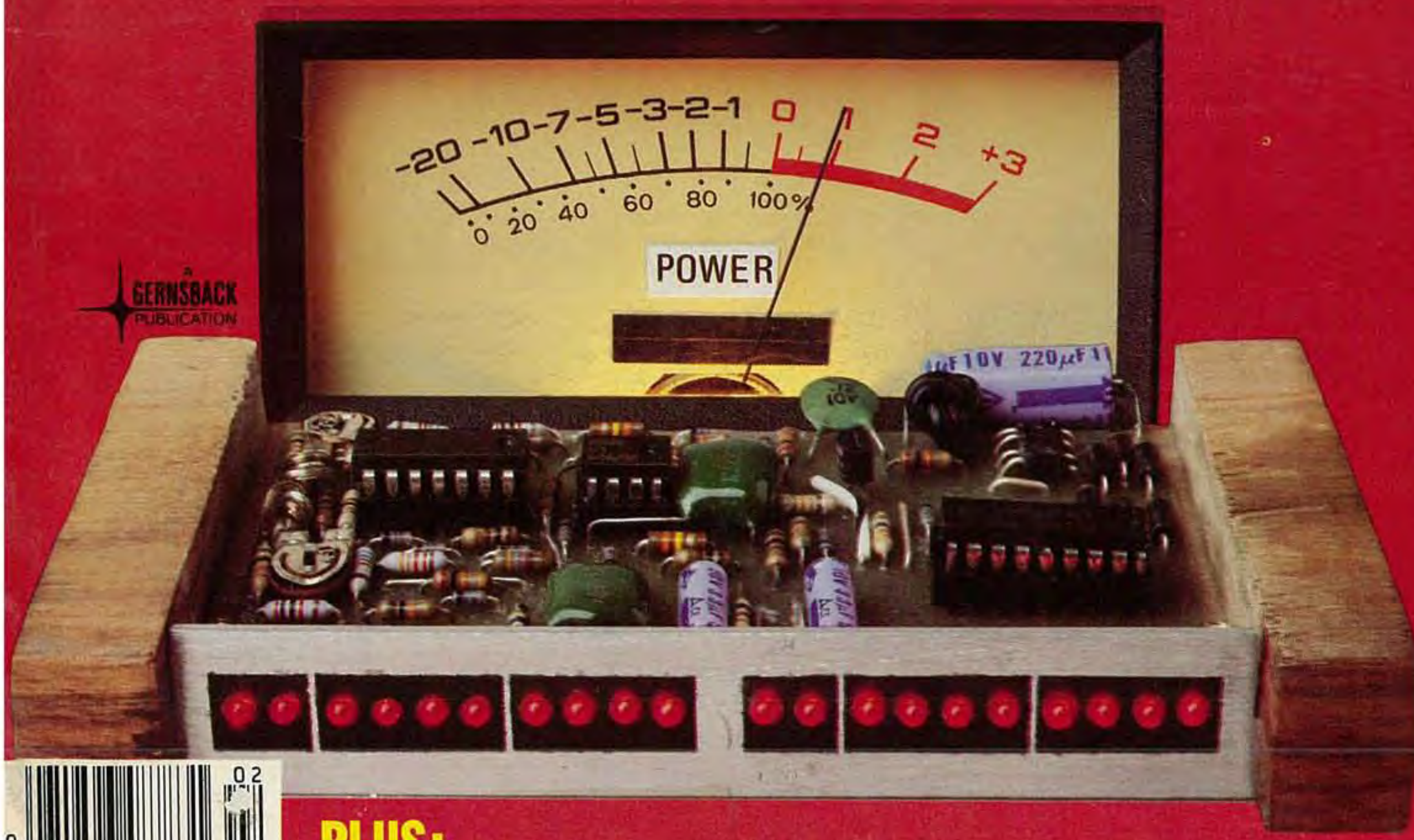

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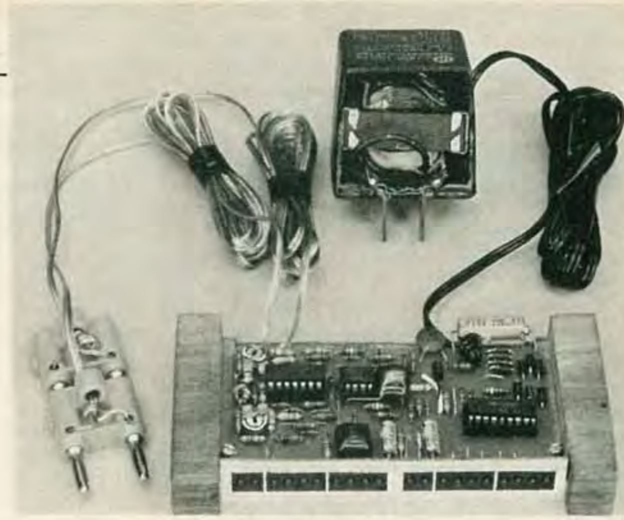


AUDIO POWER LEVEL METER

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-

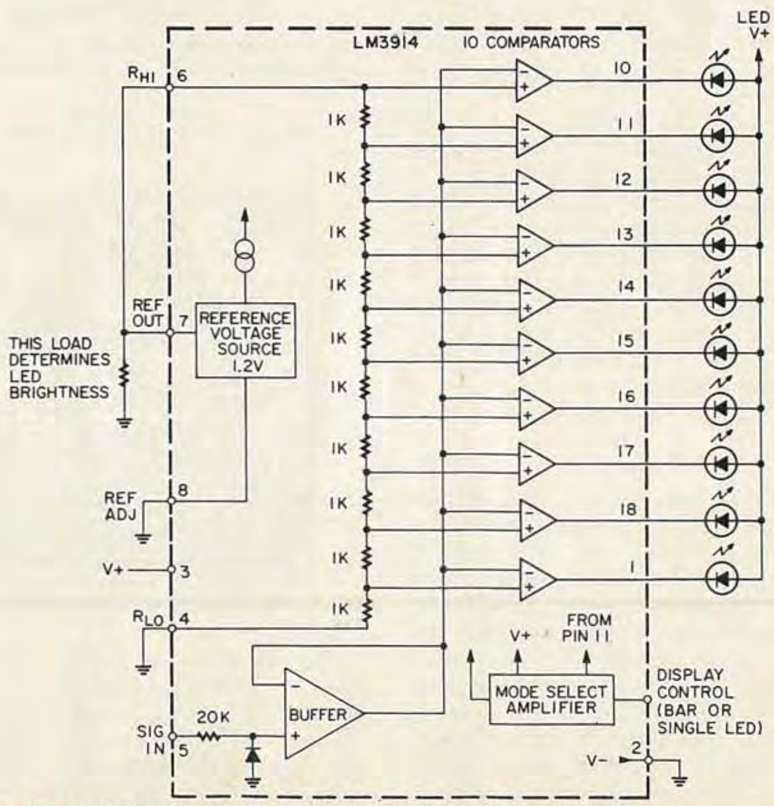


FIG. 1—BLOCK DIAGRAM of the LM3914 dot/bar display driver monolithic IC.

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 3/4-inch walnut 5 1/2 inches wide and 2 5/16 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.

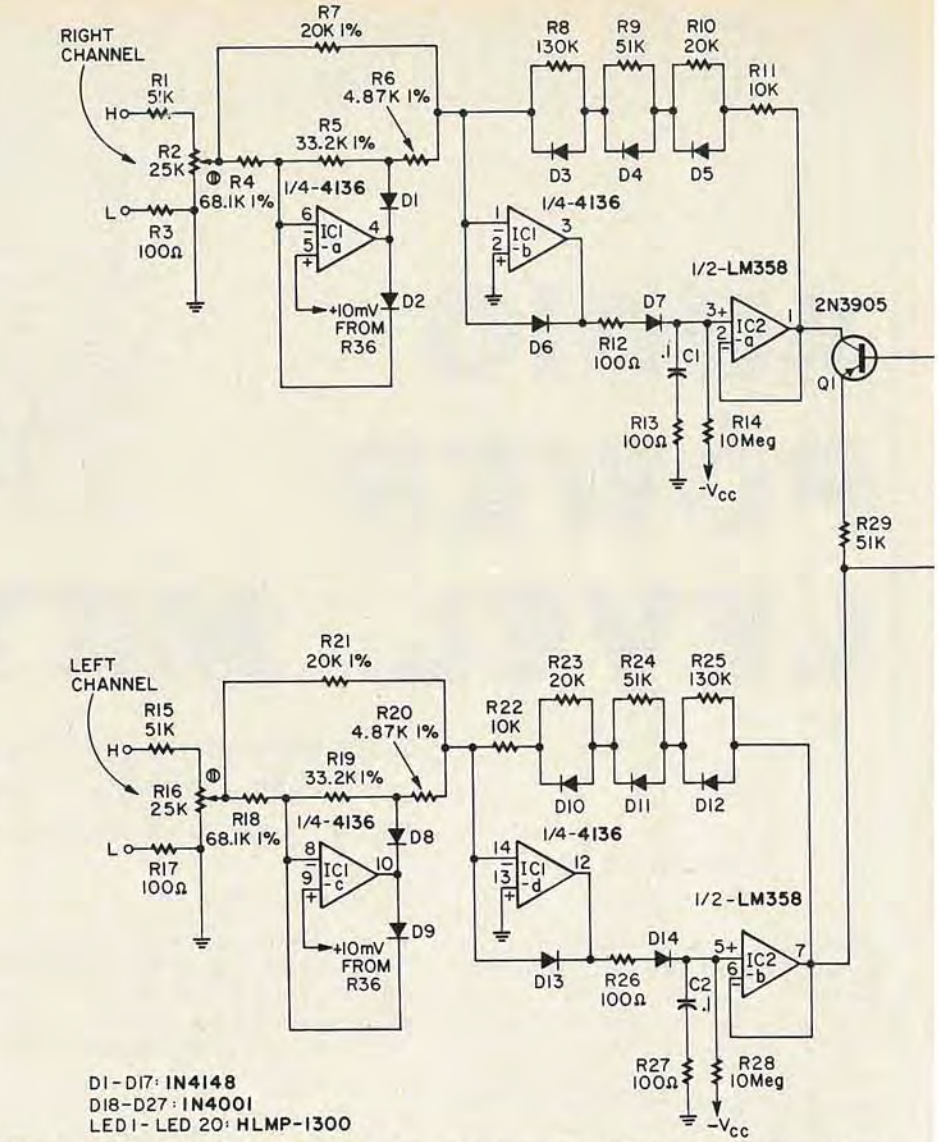


FIG. 2—COMPLETE SCHEMATIC of the LED power-level meter. The LED's in the two channels are multiplexed at a 60-Hz rate by half-sine voltages from the power transformer

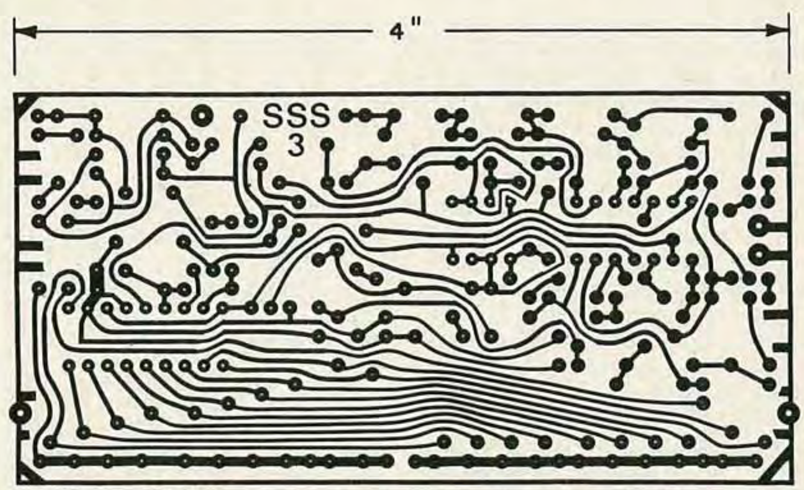
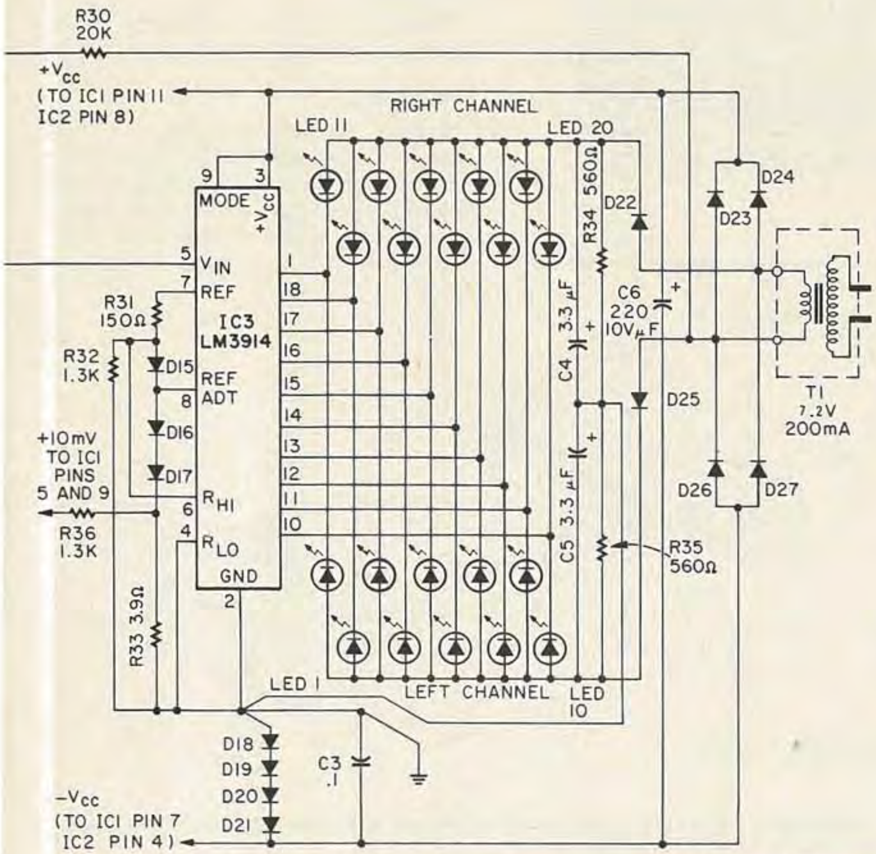


FIG. 3—FULL-SIZE FOIL pattern for the printed-circuit board. The single-sided design makes copying easy.

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

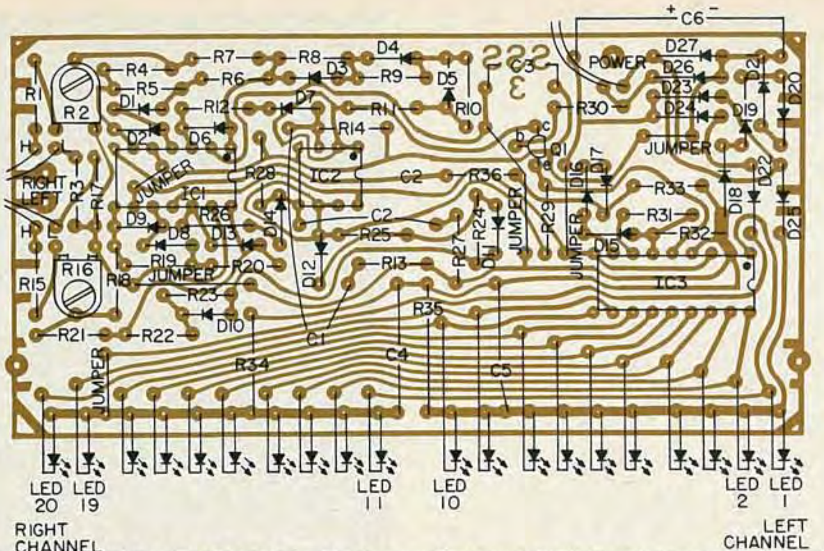
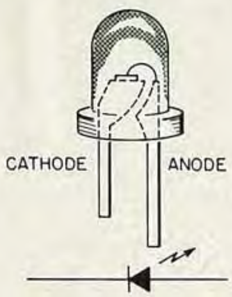


FIG. 4—COMPONENT PLACEMENT guide. Be sure that you include the six jumpers that must be installed.



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.

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 compo-

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.

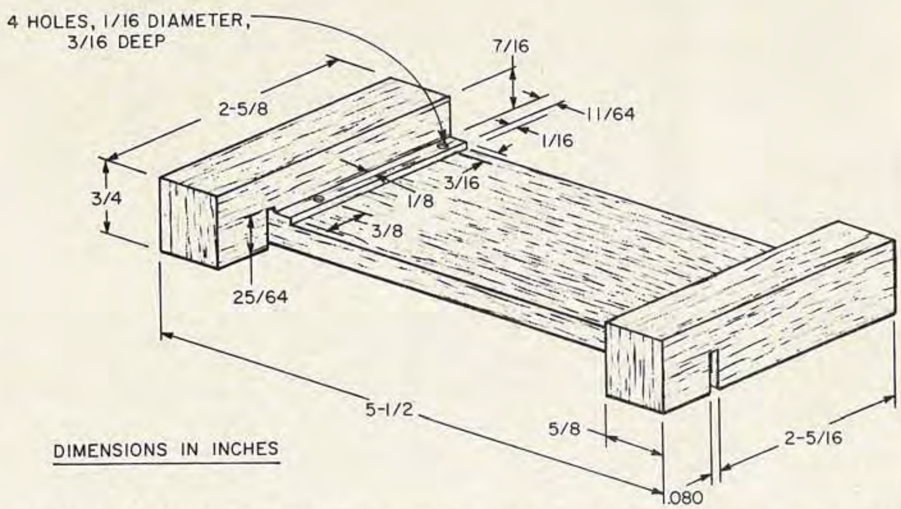
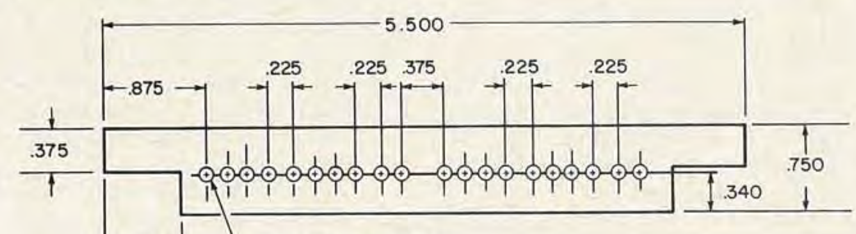


FIG. 6—THE CASE is cut out of a single piece of ¾-inch walnut or similar hardwood. Work can be done with a table or radial-arm bench saw.



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.

nents 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

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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**