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CONSTRUCTION

An LED-Readout Audio Power Meter

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Measures amplifier output, indicates speaker balance, compares speaker efficiencies, and doubles as a VU meter with easy-to-read displays.

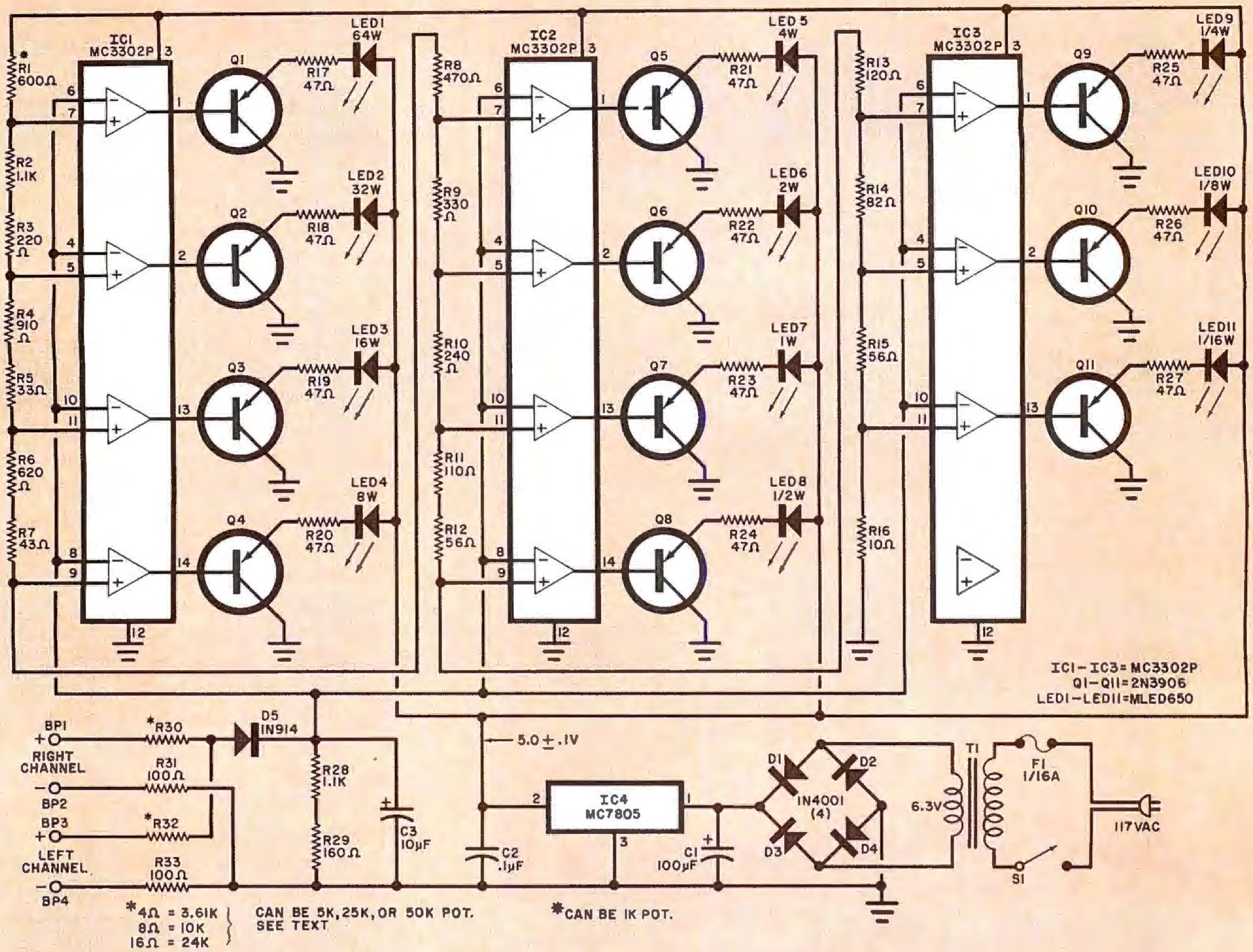
HOW MUCH power does your audio amplifier really put out? How is your stereo channel balance? Which is the more efficient speaker in your unmatched set? These are just a few, among many, questions that are difficult to answer unless you have some very specialized test equipment.

With the audio power meter described here, however, you can get the answers to many questions about your audio system—at a reasonable cost. The meter has an easy-to-read LED display and can also be used as a VU meter. The 11 LED's (light emitting diodes) are arranged in a row and are identified from 1/16 to 64 watts, with each succeeding LED indicating a doubling of audio output power. This means that the lights come on in sequence at 3-dB intervals. (A 3-dB increase means a doubling of power.) Since the human ear has a logarithmic sensitivity, 3 dB is about the minimum change that can be detected.

The meter is capable of operating with 4-, 8-, or 16-ohm speakers simply by changing the values of two resistors. The 0-dB point, or reference, was arbitrarily set at 1 watt.

System Operation. The meter (Fig. 1) is a form of analog-to-digital converter in that it takes the instantaneous voltage across the speaker (an analog signal) and converts it to digital indication to light the LED's. The only difference between this system and conventional A/D conversion is that here there is a nonlinear (logarithmic) relationship between the input and output. The 11 levels are used to create a 2048:1 change, rather than a 11:1 range if the system were linear.

The voltage measured across the speaker terminals is converted to power by using the nonlinear equation $P = E^2/R$, where E is the measured voltage and R is the speaker resistance. Then the 11 stages are designed to turn on their respective LED's at the desired power level. Table 1 shows the related values of voltage and power for the 11 steps used in this meter and for three difference speaker resistances. Note that, as the impedance doubles, the voltage values shift up one line. This means that a specific value of voltage, say 2.00, corresponds to a power level



PARTS LIST

BP1 to BP4—Five-way binding post (two red, two black)
C1—100-µF, 25-V electrolytic capacitor
C2—0.1—µF, 100-V ceramic capacitor
C3—10-µF, 15-V electrolytic capacitor
D1 to D4—Diode (1N4001 or similar)
D5—Diode (1N914 or similar)
F1—1/16-A fuse and holder
IC1 to IC3—Quad comparator (Motorola MC3302P)
IC4—5-volt regulator (Motorola MC7805CP)
LED1 to LED11—MLED650 (or similar)
Q1 to Q11—Transistor (2N3906 or HEP715)
Following resistors are ½-W, 5% unless otherwise specified:
R1—600 ohms (see text)
R2,R28—1100 ohms
R3—220 ohms
R4—910 ohms
R5—33 ohms
R6—620 ohms
R7—43 ohms
R8—470 ohms
R9—330 ohms
R10—240 ohms
R11—110 ohms
R12,R15—56 ohms
R13—120 ohms
R14—82 ohms
R16—10 ohms
R17 to R27—47 ohms
R29—160 ohms
R30,R32—See schematic
R31,R33—100 ohms
S1—Spst switch
T1—6.3-V filament transformer (Stancor P-6465 or similar)
Misc.—Suitable cabinet, line cord, grommets for LED's, press-on type, mounting hardware, etc.
Note—The following are available from MITS, Inc., 6328 Linn, N.E., Albuquerque, NM 87108: printed circuit board only, $6.50; complete kit of parts including pc board but not case, $38.

Fig. 1. As signal input voltage doubles, 11 comparators turn on their associated LED's.

of 1 W across 4 ohms, ½ W across 8 ohms, and ¼ W across 16 ohms. Thus the same circuitry can be used for any of the three impedances simply by changing the values of the input resistors (*R30* and *R32*).

About the Circuit. The input circuit consists of resistors *R30* through *R33*, diode *D5*, and an RC filter consisting of *R28*, *R29*, and *C3*. The filter has a time constant of about 80 Hz. Resistors *R31* and *R33*, in the common (−) inputs, allow the circuit to be used with amplifiers that do not have a common ground for both channels. They provide a low-impedance reference for the circuit but have no effect on the bias of the amplifier.

Resistors *R30* and *R32* reflect a high impedance to the program source because their values are insignificant in parallel with the few milliohms of output impedance of most amplifiers. These resistors take the algebraic average of the voltage across each of the speakers, which causes the power meter to indicate the average power being delivered by the amplifier. This could be extended to use on a four-channel system by adding two more resistors, with all four at 20,000 ohms to maintain a 5:1 ratio.

Diode *D5* prevents the negative half of the audio signal from bringing the comparator inputs below ground and causing possible damage. The diode also rectifies the signal so that the meter can indicate a somewhat average power rather than peak power, which the 80-Hz (low-pass) filter provides. The filter was selected to give good LED response and still provide a reasonably slow LED switching time for the eye to follow.

The eleven differential comparators in *IC1* to *IC3* deliver logic outputs based on the states of their inputs. If a noninverting (+) input is higher than the associated inverting (−) input, the comparator output is high, and vice versa.

The inverting inputs of all comparators are connected together and driven by the input signal. The noninverting inputs are threshold voltages determined by the voltage divider made up of *R1* through *R16*. The divider values are based on the desired power-level increments. Since the inputs to the comparators should not be higher or lower than the supply voltage, the input circuit forms a 5:1 ratio and the corresponding thresholds are similarly reduced. As the output of each comparator switches from high to low, its associated transistor is turned on, causing the LED to glow.

Each LED requires about 20 to 40 mA, while the comparators can sink only 2 mA. Thus the transistors must be used, with series resistors (*R17* to *R27*) to limit the LED current. If more brightness is required, the series resistors can be reduced to 22 ohms.

The power supply is a conventional transformer-diode-filter combination with a voltage regulator (*IC4*) to provide 5 volts. Capacitor *C2* is used for transient suppression.

Construction. The meter circuit can be assembled on perforated board or a pc board (Fig. 2) can be used. Note that the 11 LED's are not mounted on the board. They are connected to the appropriate pads on the board by lengths of insulated wire.

Before installing the comparators (*IC1* to *IC3*), build and test the power supply. (The transformer is not on the board.) Install *IC3*, and the 1/16-watt LED (*LED11*). Connect the positive lead of one of the meter inputs (*BP1* or *BP3*) to the 5-volt dc line and tie the other input leads to ground. When power is supplied, *LED11* should light. If it does not, it may be connected backwards. Remove power from the circuit and install the other two IC's and the remainder of the LED's. The leads for the LED's should be long enough for them to be mounted on the front of the chassis selected.

With one of the positive inputs to the meter connected to the 5-volt supply, the lowest four LED's should glow. With both positive inputs connected to 5 volts, the lowest six LED's should light. This test indicates whether or not the circuit is operating properly. If desired, the threshold voltages can be checked with Table II, which gives the ideal values—though a 5% tolerance is permitted.

The basic accuracy of the system is directly related to the input divider

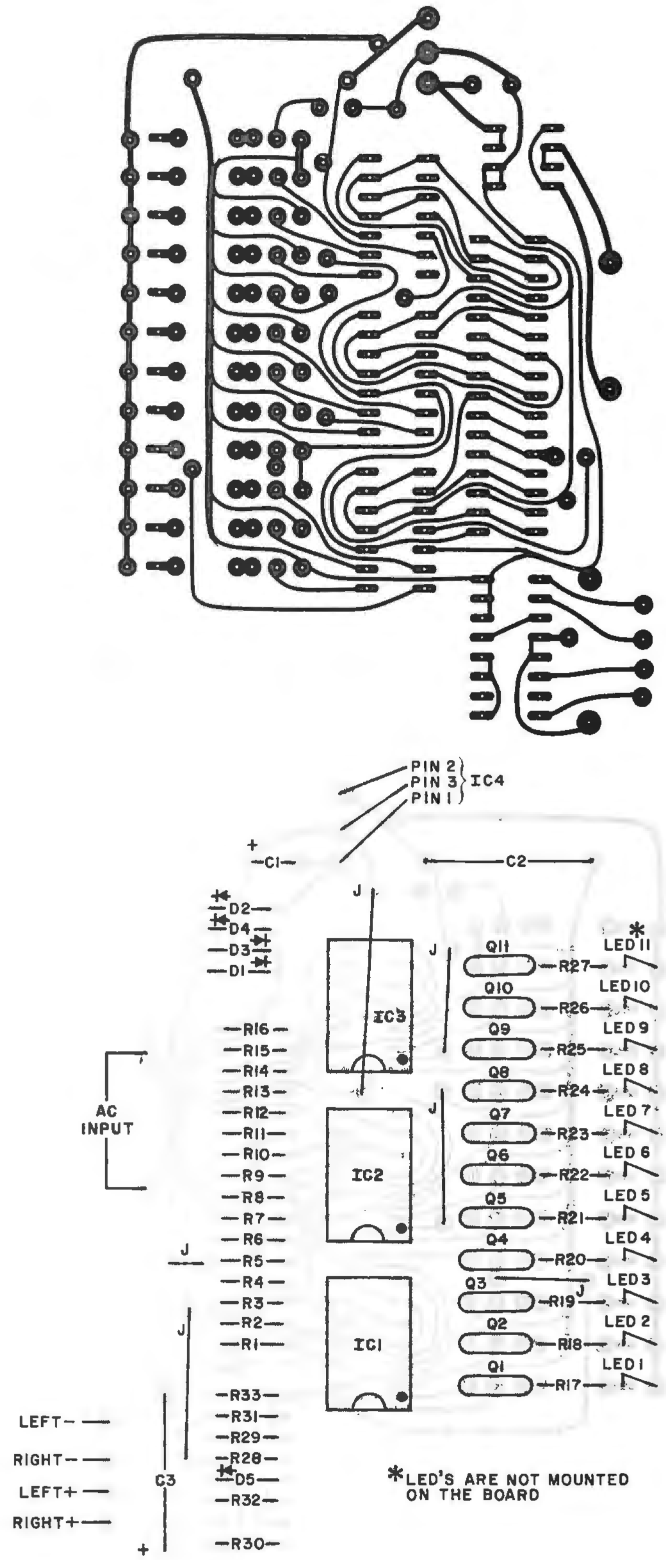


Fig. 2. Foil pattern (top) and component layout for the audio power meter.

TABLE I—VOLTAGES FOR SELECTED POWER LEVELS

Power (watts)	Voltage (across 4 ohms)	Voltage (across 8 ohms)	Voltage (across 16 ohms)
1/16	0.5	0.707	1.00
1/8	0.707	1.00	1.41
1/4	1.00	1.41	2.00
1/2	1.41	2.00	2.83
1	2.00	2.83	4.00
2	2.83	4.00	5.66
4	4.00	5.66	8.00
8	5.66	8.00	11.3
16	8.00	11.3	16.0
32	11.3	16.0	22.6
64	16.0	22.6	32.0

ratio and the voltage levels of the respective thresholds. With 5% resistors, the system has an absolute accuracy of 5%. A potentiometer can be used for *R1* for calibration adjustment. This allows correction for the input divider adjustment of the power supply threshold reference voltage, and setting any particular threshold to its exact value. To calibrate the meter with a potentiometer at *R1*, adjust the pot until the voltage at pin 7 of *IC2* is precisely 0.436 volt. All of the other thresholds should then have an accuracy of 2.5% or better.

If 5% (or even 2.5%) accuracy does not sound good enough, keep in mind that this is a power meter which indicates the continuously changing output of an audio system. It is not a laboratory-grade instrument.

Using the Meter. Besides being used to indicate the instantaneous output of an amplifier, the meter can also indicate channel balance, and response of bass and treble controls. It will also serve as a VU meter for recording and for comparing speaker efficiencies.

Connect the input leads across the amplifier outputs, noting the polarities. If one set of leads is reversed, the LED's will indicate the difference in power being supplied to each channel. This can be used as an indicator of channel balance and/or channel separation.

In bass response testing, the meter will indicate the amount of boost or cut provided by the bass control. For treble control testing, a single frequency should be applied to the amplifier. This is because most of the power is in the lower frequencies, and the presence of higher frequencies in the bass test is insignificant.

Relative efficiencies of speakers can be checked by connecting the meter across the amplifier output and measuring the output power required to deliver a certain "standard" listening level. ◈

TABLE II—IDEAL THRESHOLD VOLTAGES

IC	Pin	Voltage
1	7	0.011
1	5	0.070
1	11	0.153
1	9	0.270
2	7	0.436
2	5	0.670
2	11	1.001
2	9	1.470
3	7	2.133
3	5	3.070
3	11	4.395