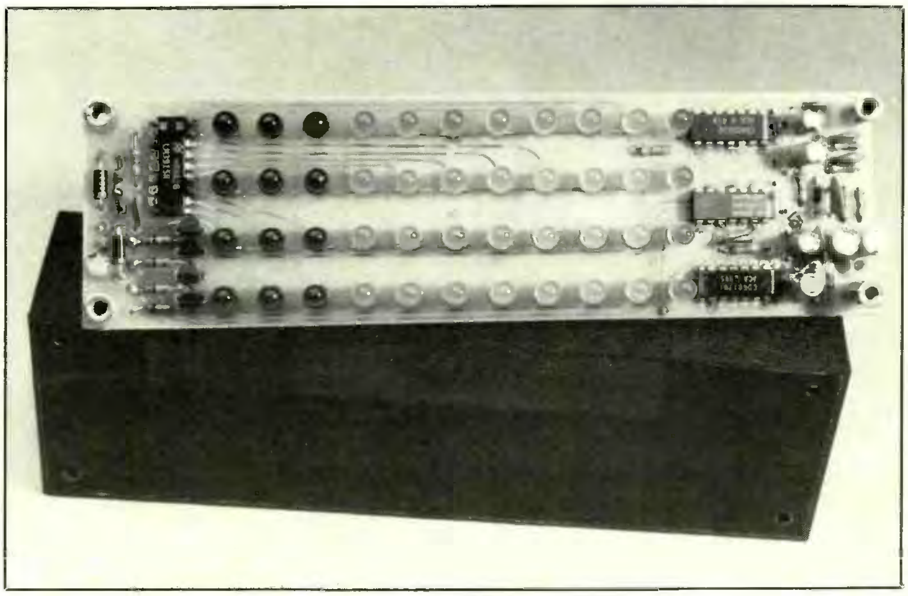
Two-Band Stereo LED Power Meter

Lets you visually monitor your car stereo system's high- and low-frequency output power

By Ross Ortman



Many modern car-stereo amplifiers are so powerful that they can put your normally rugged speakers in jeopardy of burning up. A stereo power meter like the dual-band one described here provides an excellent means for guarding against this type of hazard.

The Two-Band Stereo Power Meter offers an unusual bargraph-like display. Unlike most power meters that provide a single display for each channel, this project has two per channel. Input signals are split into high- and low-frequency groups that are separately monitored for each channel. This allows you to keep an eye out for dangers to your woofers and mid-range drivers/tweeters separately, making displayed data much more meaningful.

All power information is displayed in four attractive horizontal "bargraphs" made up of discrete LEDs. The LEDs are of different colors, with green at the low-power end, yellow in the medium-power middle range and red in the high-power "danger" end. Consequently, not only is the Power Meter a practical device, it is also a very attractive high-tech addition to your vehicle.

About the Circuit

As shown in the block diagram in Fig. 1, the Power Meter consists of three main sections. The first is the input filter, which separates the left and right outputs from an amplifier into high- and low-frequency groups, with a crossover frequency of about 3 kHz.

Second in the chain is the multiplexing circuit. This circuit's oscillator, operating at about 380 Hz, is used to clock a 4017 decade counter/divider that supplies 10 decoded outputs, four of which are used to sequentially pass the filter outputs to the display driver and turn on its corresponding row of light-emitting diodes. A 4066 quad bilateral switch selects the filter output dictated by the counter/divider.

Outputs from the bilateral switches are sent to the display circuit, which is the third section. This circuit consists of four rows of LEDs, an LM3915 bar/dot driver and switching transistors that selectively supply power to individual rows of LEDs. The LEDs display the amplitude of the signal delivered to the Power Meter, as filtered and switched by the preceding sections, in a bargraph-like display format.

Now that you have an idea of system architecture, refer to the schematic diagram in Fig. 2. Power for the circuit is supplied by the electrical system of the vehicle in which the project is used. It is protected against transients and incorrect power connection by *D1*, *D2*, *C1* and *C13*.

Inputs to the project are ac coupled through *C2* and *C3*. This allows the Power Meter to be used with floating ground and high-power car stereo systems that usually have a dc component in their outputs. Separ-

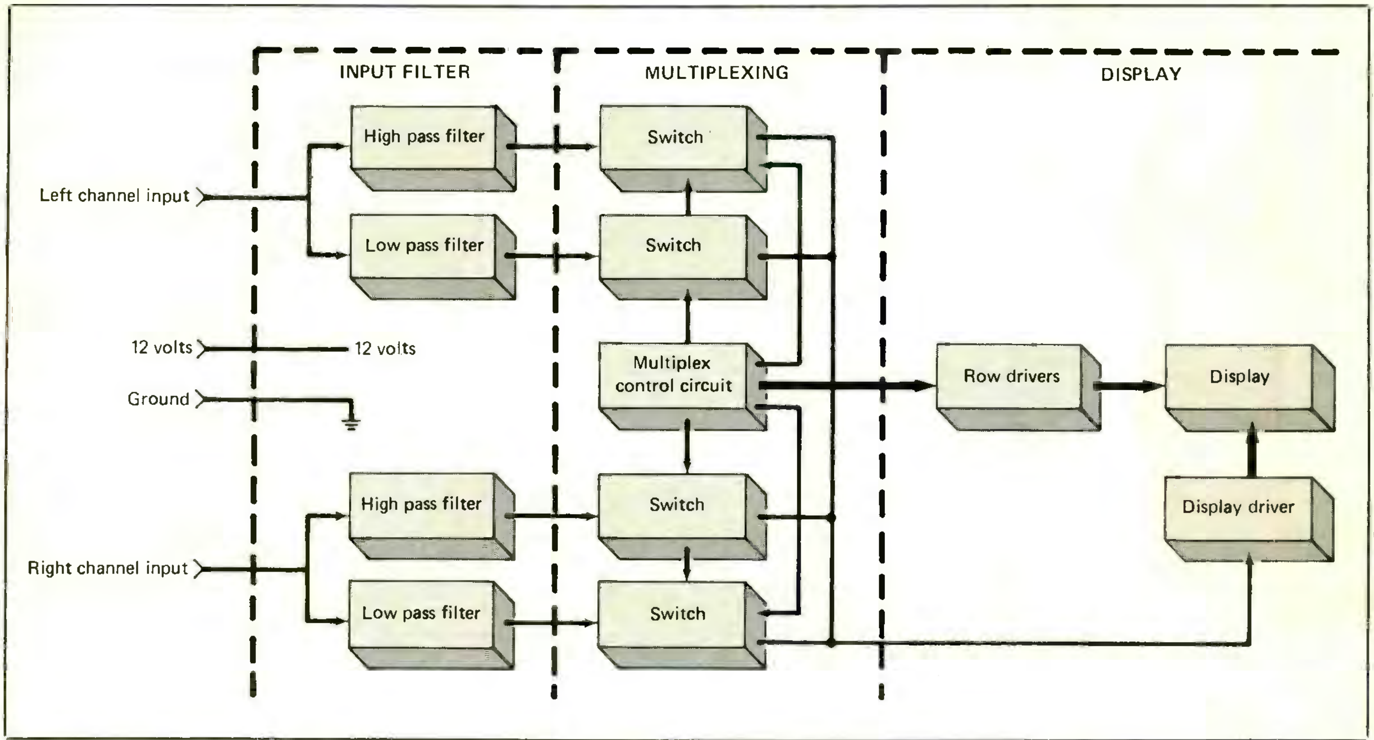


Fig. 1. Stereo Power Meter consists of an input filter, a multiplexer and a decoder/driver/display system.

ate low- and high-pass filters are provided for each channel: *C4/R3* for the high- and *R1/C6/R5* for the low-pass filters in the left channel and *C5/R4* for the high- and *R2/C7/R6* for the low-pass filters in the right channel.

Once the inputs are filtered, *D3* through *D6* rectify them and store their relative amplitudes in *C8* through *C11*. Individual level adjustments for each channel are provided by *R7* through *R10*. At the wiper of each of these controls is a calibrated dc voltage that is relative to the level of the power present at the inputs of each channel.

Since the input power is separated into two separate frequency bands, the amount of high- and low-frequency power in the left channel are the dc voltages at *R7* and *R9*, respectively. In the right channel, the appropriate controls are *R8* and *R9*, respectively.

Sections A and B of *IC2*, along with *R11* and *C12* make up a 380-Hz oscillator. Decade counter/divider *IC3* provides a sequential set of four pulses that are used to control the multiplexing. The multiplexing circuit is used to scan the four filtered voltage levels and display their amplitudes on their respective rows of LEDs. It does this by selecting each filter output in sequence and turning on the transistors for each respective row of LEDs. Using this scheme, only one row of LEDs is on at any given instant in time. However, because of the high-speed scan rate, all rows appear to be on simultaneously.

There are separate power-level bargraph driver/display circuits for the high- and low-frequency bands for each channel. These are *Q1* with *LED2* through *LED11* and *Q3* with *LED24* through *LED33* arrangements, respectively, for the left channel. The right-channel arrangements are *Q2* with *LED13* through *LED22* and *Q4* with *LED35* through *LED44*. Not part of the actual power-measuring section of the project are *LED1*, *LED12*, *LED23* and *LED34*, which serve as power indicators that come on whenever dc power is applied to the circuit from the vehicle's electrical system, even if no input signal is present.

Quad bilateral switch *IC1* passes each filter's output to the input of bargraph display driver *IC4*. This IC then turns on from one to ten LEDs of the selected row. The number of LEDs that come on indicate the relative input power level.

Construction

You can build the Power Meter using any wiring technique that suits you. However, printed-circuit wiring is recommended to provide stability and safety in the harsh automotive environment. No matter where you decide to mount the Power Meter—in an overhead console or under the dashboard—make sure to house it in some type of enclosure to protect the circuit from accidental shorting to any exposed metal in the vehicle. An enclosure also provides a more readable and attractive display.

A double-sided printed-circuit

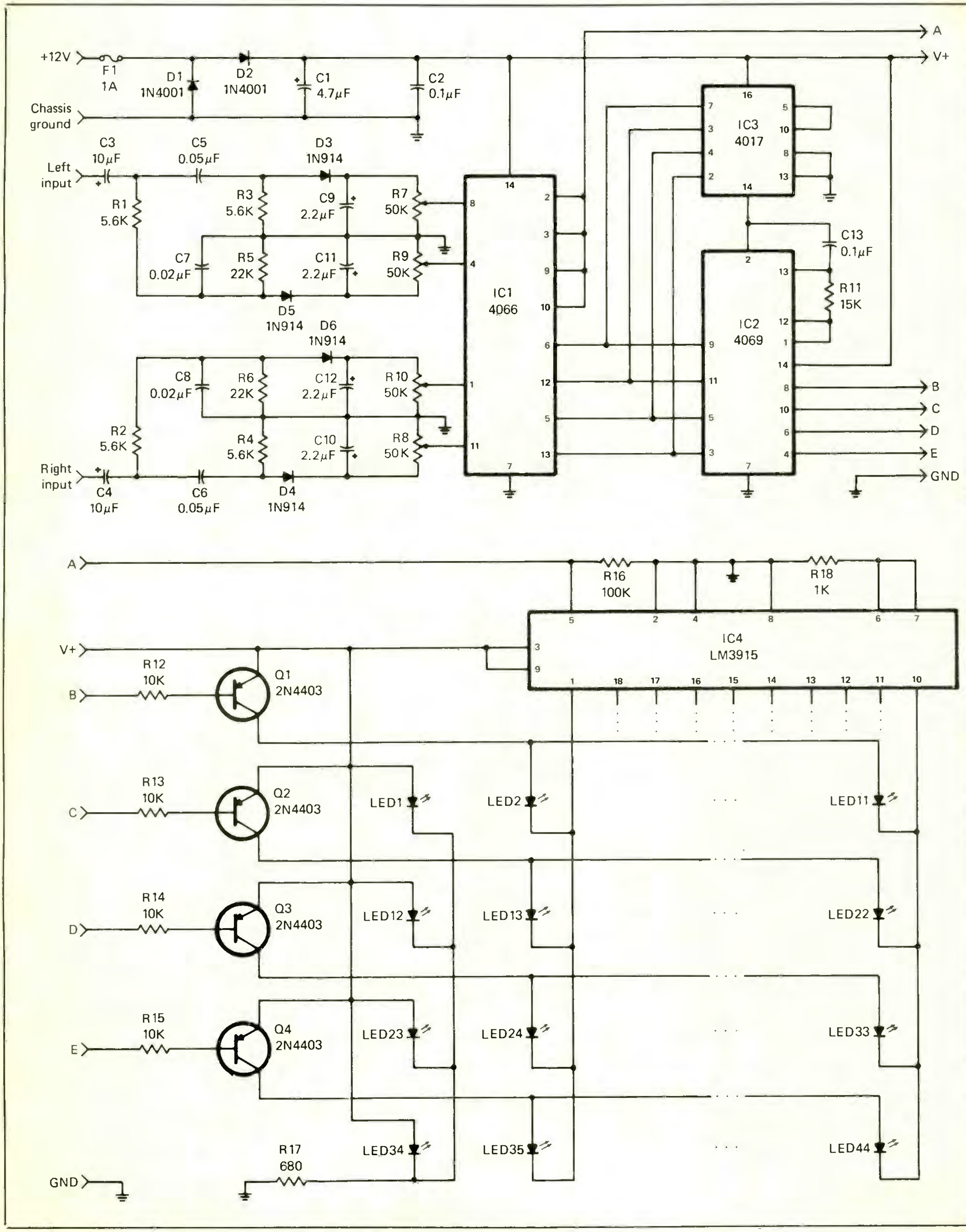

+12V
F1
1A
D1
1N4001
D2
1N4001
C1
4.7μF
C2
0.1μF
Chassis
ground
C3
10μF
C5
0.05μF
D3
1N914
Left
input
R1
5.6K
R3
5.6K
C9
2.2μF
R7
50K
C7
0.02μF
R5
22K
C11
2.2μF
R9
50K
D5
1N914
D6
1N914
C8
0.02μF
R6
22K
C12
2.2μF
R10
50K
R2
5.6K
R4
5.6K
C10
2.2μF
R8
50K
Right
input
C4
10μF
C6
0.05μF
D4
1N914
IC1
4066
IC3
4017
C13
0.1μF
R11
15K
IC2
4069
A
V+
B
C
D
E
GND
A
R16
100K
R18
1K
IC4
LM3915
V+
R12
10K
B
Q1
2N4403
R13
10K
C
Q2
2N4403
R14
10K
D
Q3
2N4403
R15
10K
E
Q4
2N4403
LED1
LED2
LED11
LED12
LED13
LED22
LED23
LED24
LED33
LED34
LED35
LED44
R17
680
GND

Fig. 2. Separate high- and low-frequency "bar" displays consist of 10 LEDs in each channel bar, plus one LED in each bar that comes on when dc power is applied. Only four LEDs are shown for each channel.

PARTS LIST

Semiconductors
D1,D2—1N4001 rectifier diode
D3 thru D6—1N4148 signal diode
IC1—4066 quad bilateral switch
IC2—4069 hex inverter
IC3—4017 decade counter/divider
IC4—LM3915 bar/dot driver
LED1 thru LED44—0.2" light-emitting diode (20 green; 12 yellow; 12 red—see text)
Q1 thru Q4—2N4403 transistor

Capacitors
C1—4.7-μF, 16-volt electrolytic
C2,C13—0.1-μF disc
C3,C4—10-μF, 35-volt electrolytic
C5,C6—0.05-μF disc
C7,C8—0.02-μF disc
C9 thru C12—2.2-μF, 25-volt electrolytic

Resistors (¼-watt, 5% tolerance)
R1 thru R4—5,600 ohms
R5,R6—22,000 ohms
R11—15,000 ohms
R12 thru R15—10,000 ohms
R16—100,000 ohms
R17—680 ohms
R18—1,000 ohms
R7 thru R10—50,000-ohm vertical-mount trimmer potentiometer

Miscellaneous
F1—1-ampere fast-blow fuse
Printed-circuit board; suitable enclosure (see text); power cable with in-line fuse holder; two-conductor zip cord; ½" spacers (4); machine hardware; hookup wire; solder, etc.

Note: A double-sided pc board with plated-through holes is available for $17.95 plus $1.50 P&H from: Dakota Digital, R.R. 1, Box 83, Canisota, SD 57012.

board was used for wiring the Power Meter's circuit in the prototype shown in the lead photo. You can fabricate this board, using the Fig. 3 actual-size etching-and-drilling artwork. Alternatively, you can purchase a ready-to-wire pc board with plated-through holes from the source given in the Note at the end of the Parts List.

Bear in mind that with a homemade double-sided board, all component leads and pins that contact the foil pattern on top and bottom must be soldered to the pads on *both* sides of the board. This means that if you wish to use sockets for the ICs, some of whose pins contact pads on both the top and bottom, you will have to use all-metal Molex Soldercons instead of the usual sockets. If you use the plated-through commercial board, however, you can use standard IC sockets. Capillary action will assure that all junctions on top and bottom of the board will be securely soldered if you solder on only the bottom of the board.

Referring to Fig. 4, begin wiring the board by installing and soldering into place the resistors. Follow with the diodes, making sure to properly orient them. Then proceed to the transistors. Bend the center base leads of the transistors slightly toward the flat of the case. Holding the board in the orientation shown in Fig. 4, install each transistor with the flat facing the top of the board. The bent-forward base lead in each case plugs into the offset hole in the solder-pad pattern. Adjust the height of the transistors to about ¼" from the surface of the board and solder the leads to the pads. Use heat judiciously to avoid damaging the transistors.

Now install and solder into place the capacitors, making sure that the polarized electrolytics are properly oriented. You have the option of installing the ICs directly on the board, with their pins soldered to the foil patterns (on both sides if your board is homemade) or via sockets or Soldercons.

The most difficult step in assembly is installation of the LEDs because of the repetitive nature of the operation and the fact that all LEDs in each row and column must be carefully aligned and of uniform height to provide a balanced display. Keep firmly in mind that the cathodes in all cases go into the holes nearer the bottom edge when the board is oriented as shown in Fig. 4. There are two ways to identify the cathode lead: the lead near the slight flat in the case lip and the widened lead near the bottom of the case.

A good way to assure uniform LED height is to push the LED leads down until the widened portion of the cathode leads just touch the top of the board. Solder only the cathode leads of all 44 LEDs to the pads. Each horizontal "bar" in the display consists of green, yellow and red LEDs. The first five LEDs in each bar (e.g. *LED1* through *LED5* in the topmost bar) are green, the next three are yelow and the final three are red.

If you prepare an alignment template for the LED matrix, a lot of time can be saved in positioning the LEDs to make a symmetrical display. The template is made from heavy cardboard stock like Bainbridge board or thin but rigid plastic like ⅛"-thick Plexiglass cut to 5" long by 2" wide. Cut out and paste the actual-size template shown in Fig. 5 to the cardboard or plastic template blank. If you prefer not to cut up the page, place the blank behind Fig. 5, centering it in the outline, and pierce with a pin or needle at the center of each circle. Then remove the blank.

Drill an 11/64" or 3/16" hole through the center of each hole outline (or through each marked point). You should have a total of 44 holes arranged in a symmetrically balanced matrix. Place the template over the LEDs. Adjust the positioning of the LEDs so that their domes fit into all 44 holes. With the LEDs in place, position the template so that it is parallel with the top edge of the board. Check to make sure that all LEDs are at a uniform height. If any are not, reflow the solder and adjust as necessary. Then solder the cathode leads

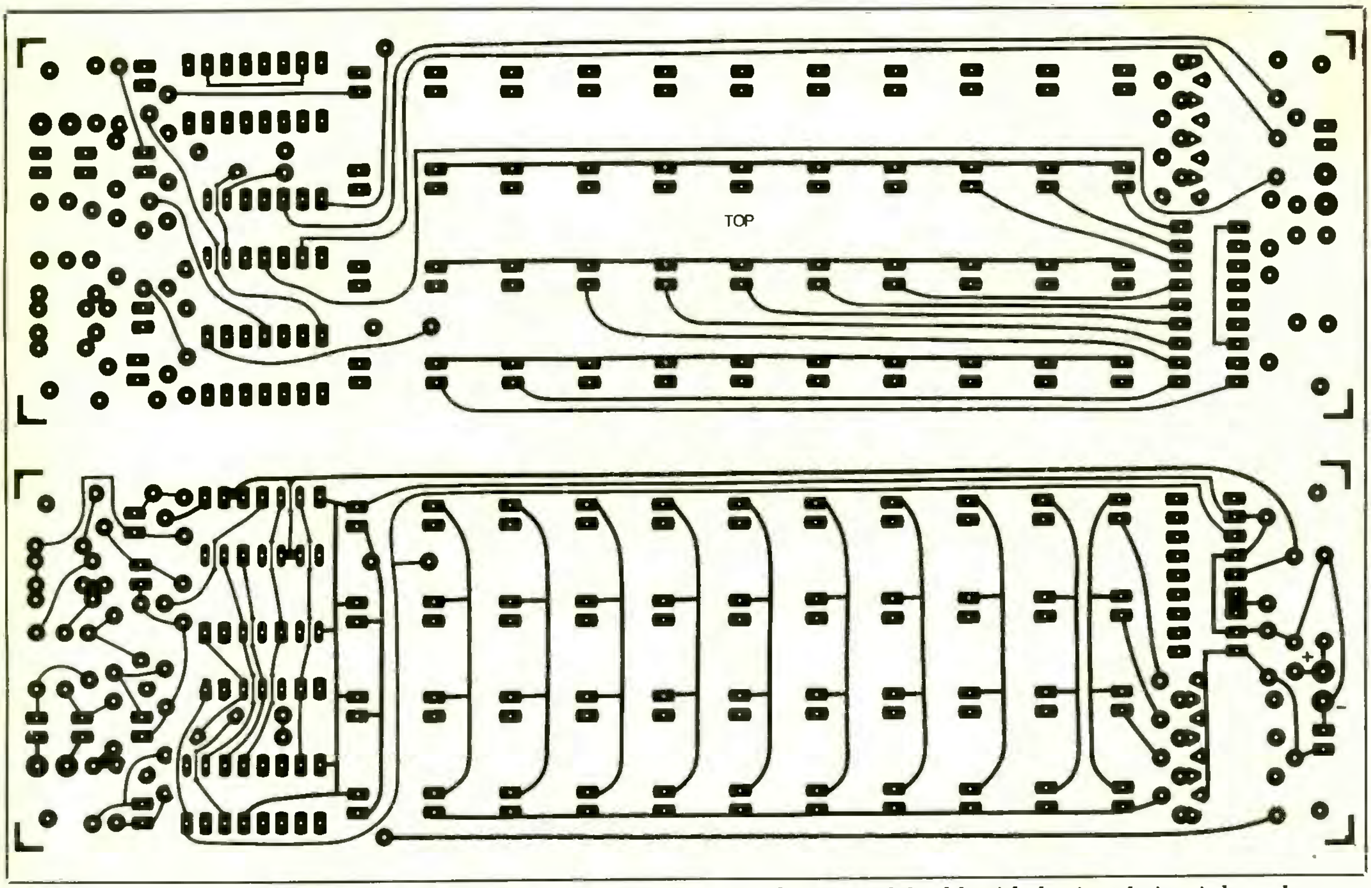


Fig. 3. Actual-size etching-and-drilling guides for top and bottom of double-sided printed-circuit board.

of first the top row of LEDs to the solder pads. Repeat for the second, third and fourth rows. Use heat sparingly to prevent damaging the LEDs.

Remove the template and discard it if you have no further need for it. If you plan to make more Power Meters, store the template away for later use.

You can, of course, arrange the LEDs without the aid of a template. In this case, you will have to perform the entire operation by eye. Needless to say, this can be a very time-consuming operation.

Referring back to Fig. 4, install the *R7* through *R10* trimmer controls on

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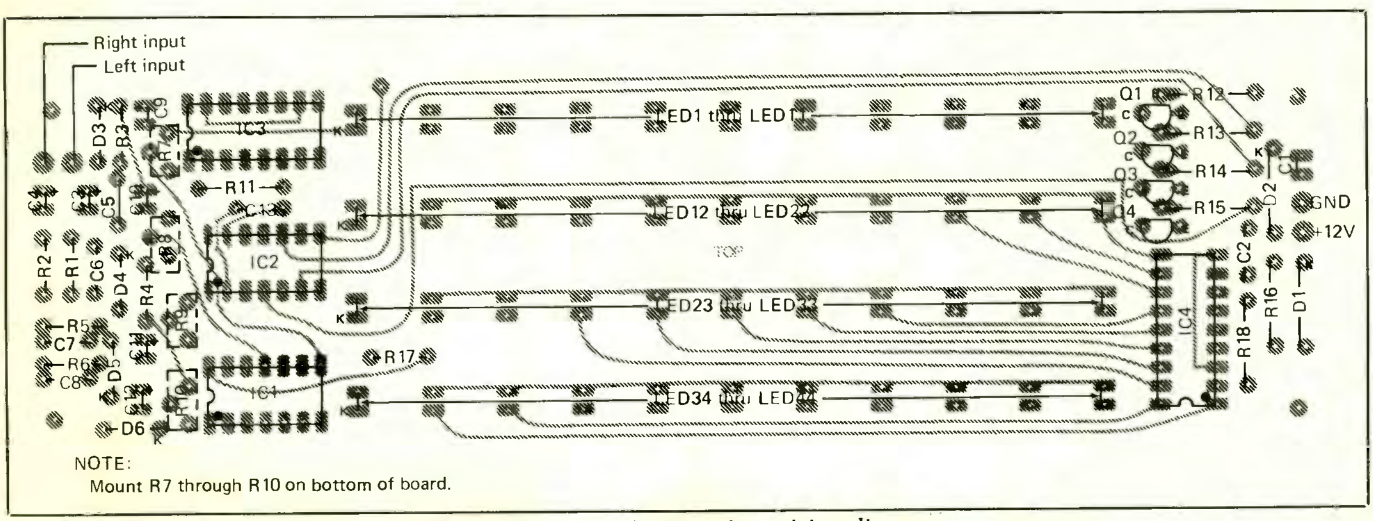

Fig. 4. Placement/orientation wiring diagram.

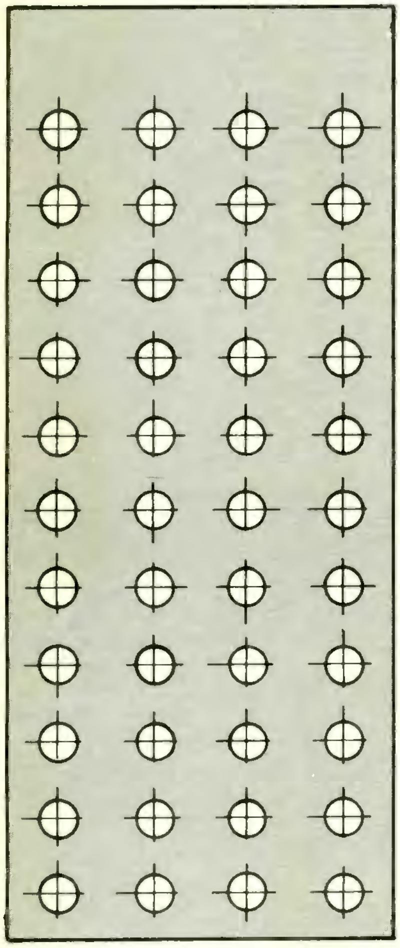

Fig. 5. Actual-size alignment template for LED installation.

the *bottom* of the board. Then prepare a two-conductor zip cord by removing ¼″ of insulation from the conductors at both ends. Tightly twist together the wires in each conductor and tin with solder. Make these cords as long as needed to route between your amplifier and the Power Meter after final installation in your vehicle. Solder one end of this cable to the pads labeled LEFT INPUT and RIGHT INPUT from the bottom side of the board.

Next, connect the red +12-volt and black ground power leads to the pads labeled +12V and GND on the bottom right side of the board. Make these leads long enough to reach the vehicle electrical system's ground and any point that is at +12 volts when the ignition is on and is off

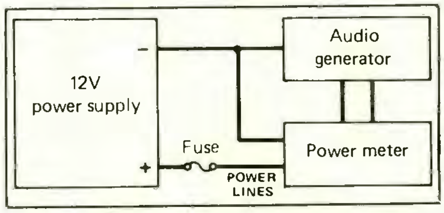

Fig. 6. Test setup for calibration.

when the ignition is off. The +12-volt wire should have an in-line fuse holder in it. Install a 1-ampere fast-blow fuse in the holder.

Any enclosure large enough to accommodate the circuit board and that has one panel that can be replaced with a clear or tinted panel can be used to house the project. An ideal size would have internal dimensions of 7¼″ × 2¼″ × 1½″. You can make such an enclosure from ⅛″-thick Plexiglass or ¼″-thick plywood, or you can modify an existing plastic or metal chassis to suit your needs. Just be sure to make one 7¼″ × 2¼″ panel from bronze or neutral-gray tinted transparent plastic to provide good contrast in relatively bright light for easy viewing of the display. Whichever material you use, paint all inside surfaces of the enclosure, except the faceplate, flat black to cut down on reflections.

Mask from view the left and right portions of the circuit board not in the LED matrix area. This can easily be done by applying black electrical tape or black paint to the appropriate areas on the inside surface of the faceplate.

Mount the circuit board inside the enclosure with four sets of ½″ spacers and 4-40 × ¾″ machine screws, nuts and lockwashers to the faceplate. The lockwashers between the nuts and circuit board are important because they prevent the hardware from working loose due to vibration from the road.

Because the display consists of LEDs whose different colors are self-explanatory, there is no need to label the faceplate. However, if you wish to give your project a more professional appearance, you can apply legends to the outside surface of the faceplate. Typical legends include LEFT LOW FREQUENCY, RIGHT LOW FREQUENCY, LEFT HIGH FREQUENCY and RIGHT HIGH FREQUENCY to the left of the individual bargraphs in the blanked-out areas. Under the bottom bargraph, you can bracket each color grouping and letter LOW POWER, MEDIUM POWER and HIGH POWER legends in the appropriate areas and then run vertical lines to separate the color groups.

All lettering should be done with a white dry-transfer lettering kit applied directly to the front surface of the faceplate. Since this type of lettering is very fragile, you should place an additional ⅛″ thickness of clear Plexiglass over the entire faceplate to protect the lettering. In this event, use 1″-long screws for mounting the board.

Checkout and Calibration

Referring to Fig. 6, connect the Power Meter's dc power leads to a 12-volt dc source. The first column of LEDs at the left (farthest from the transistors) should immediately light, indicating that power has been applied to the project. All other LEDs in the display should be off.

Apply an input signal from an audio signal generator or other audio source between the LEFT INPUT channel lead and the negative power-supply lead. Turn up the sound until the LEDs in the top and/or third row of the display begin to light. The row(s) of LEDs that turn on will depend on the frequency or frequencies delivered to the Power Meter's input.

If you are using an audio signal generator, sweep the frequency control from the low to the high end of the audio spectrum while observing the LED display. The LEDs in the top and third rows come on at frequencies above and below about 3 kHz, respectively.

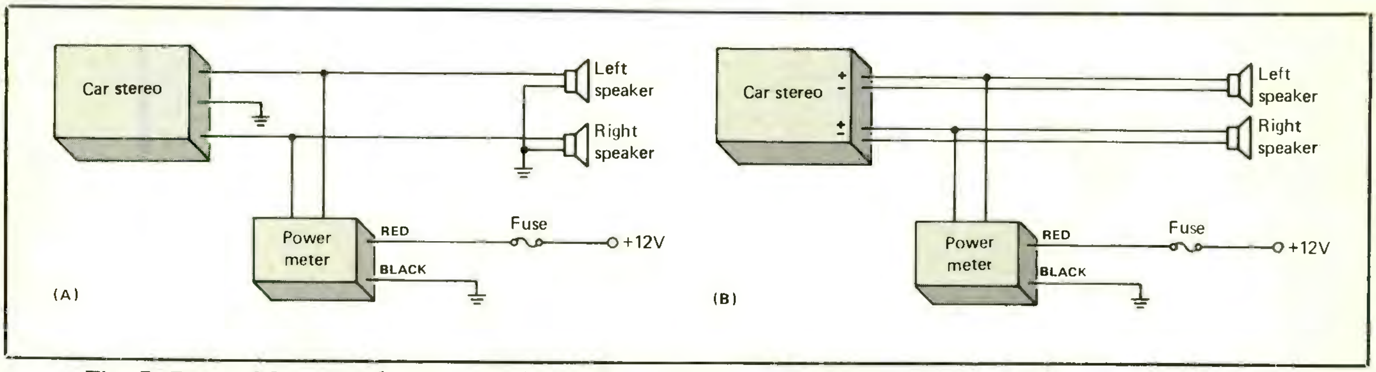

Fig. 7. Power Meter can be connected into conventional grounded (A) and floating ground (B) systems.

Disconnect the signal generator from the LEFT INPUT and connect it to the RIGHT INPUT. Repeat the above test, this time observing that the second and bottom rows of LEDs light when the signal is swept from the high to the low frequencies, respectively.

If everything checks out okay connect the Power Meter to the audio amplifier and electrical system in your vehicle. Refer to Fig. 7 for details. Determine whether your system has a conventional chassis ground or has a floating ground and use the hookup arrangement that applies to your installation. Do not perform final installation until calibration is done.

You can calibrate the Power Meter in either of two ways. One way is to tune to an FM station and turn up the volume control until the sound just begins to distort and then back off until the distortion just disappears. Then adjust the *R7* through *R10* trimmers until just the first red LED (third from the right) in each column comes on. If you are using a mono signal source, perform these adjustments separately for each channel. To make calibration as accurate as possible, set all tone and equalizer controls for a flat frequency response before you adjust the trimmer controls.

(Note: Always set the trimmer controls so that the *first* red LED in each bargraph display comes on with average signal levels. Do *not* set the controls so that all red LEDs come on with average signal levels. If you do, there will be no way you can tell from looking at the display when dangerous power levels and transient high-power peaks are being delivered to your speakers.)

For the second, much more accurate calibration procedure, make a calibration tape on a home cassette recorder. Record a minute or two each of 400-Hz and 5-kHz tones on both stereo tracks simultaneously. Play the tape back on your car stereo system while monitoring the output of your amplifier with an oscilloscope. If you have a 2- or more channel scope, you can observe both amplifier channels simultaneously. Otherwise, you must work on each channel separately. Turn up the volume to the point just before clipping of the signal appears on the scope's screen and adjust the trimmer controls so that the first red LED in each row (again the third from the right) in each of the respective bands comes on. Keep these tests as short as possible to avoid damaging your speakers, your amplifier and your ears!

If you want to use the Power Meter only as a visual display, accurate calibration is not necessary. Simply adjust the controls so that the first of red LEDs come on at your normal highest listening level.

During final installation, mount the Power Meter in a location where the display will be easy to view but not where it will interfere with the driver or passengers or will pose a hazard in an emergency situation. After you install the Power Meter in its final location, route all wiring to and from it so that it is not visible and will not be damaged. ME