A. Deley

led-level

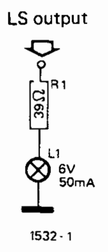
In general, analogue pointer instruments are used for level indicators. Another method of indicating amplitudes and power is to use LED's. The advantages of this system include higher resistance to shock, better legibility from greater distances and the fact that the response time is unaffected by the mechanical time-constant of a conventional meter.
Apart from a practical level meter additional circuits are discussed. The most important of these is a simple overload indicator.

Figure 1 gives a simple circuit with which the voltage amplitude on the loudspeaker output of an amplifier can be converted into light intensity of lamp L_1. The limiting resistor R_1 is necessary only if the lamp can be overdriven by the amplifier. Of course with a single supply rail amplifier the circuit of figure 1 must be connected after the loudspeaker output capacitor. Otherwise the lamp would be constantly fed from the d.c. mid-point voltage of the amplifier output stage.
Lamp L_1 must burn brightest at maximum output power. This power is normally limited by the supply voltage of the output amplifier. In most cases it can be said that the maximum output is obtained if the amplitude of the output voltage is about 2 volts less than the supply voltage (also in connection with increasing distortion). If, for example, the supply voltage of the amplifier is 24 volts, the maximum swing of the output voltage will then be about 22 volts peak-to-peak.
The maximum RMS output voltage of the output stage (from the example) is half the peak-to-peak voltage divided by $\sqrt{2}$. This is about 7.8 volts. The maximum voltage of the lamp is 6 volts, so the surplus of 1.8 volts must drop across R_1. The resistance value of R_1 can now be calculated by dividing the residual voltage (1.8 volts) by the 50mA which is the maximum current for the lamp.

The level indicator

Such a simple system can, at best, give only an approximate indication of output and its effectiveness depends on many factors such as ambient lighting and the eyesight of the individual user. A much better arrangement is to have a number of lamps or LEDs which light in sequence as the voltage is increased. This is the system used in the LED level indicator.
The circuit is shown in figure 2. The input of the circuit is formed by potentiometer P_1 with which the sensitivity is adjusted. The potentiometer is connected to the loudspeaker output of the amplifier. If the amplifier is fed asymmetrically (one supply voltage), potentiometer P_1 must be connected after the loudspeaker output capacitor.
The circuit operates as follows:

1



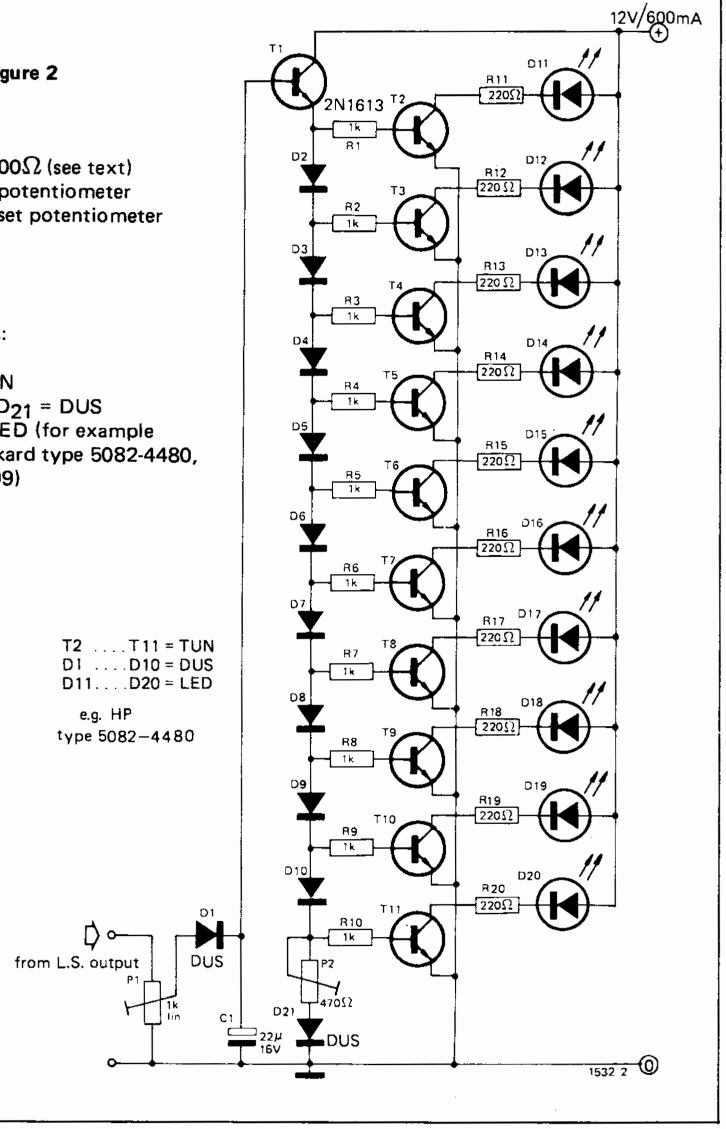
2

Parts list with figure 2

Resistors:
R_1 ... R_{10} = 1k
R_{11} ... R_{20} = 200Ω (see text)
P_1 = 1k, preset potentiometer
P_2 = 470Ω, preset potentiometer

Capacitor:
C_1 = 22μ/16 V

Semiconductors:
T_1 = 2N1613
T_2 ... T_{11} = TUN
D_1 ... D_{10} and D_{21} = DUS
D_{11} ... D_{20} = LED (for example Hewlett-Packard type 5082-4480, Texas TIL209)



Parts list with figure 4

Resistors:
R_1 = 1 M
R_2 = 330k
R_3,R_4 = 10k
R_5 = 270Ω
R_6 = 1k
R_7,R_8 = 47Ω
P_1 = 1 M, preset potentiometer

Capacitors:
C_1 = 0.47µ
C_2 = 100µ/10 V (see text)
C_3 = 100µ/35 V

Semiconductors:
T_1,T_2,T_3 = TUN (above U_b = 20 V: BC107a)
T_4 = 2N1613
T_5 = 2N2905
D_1,D_2 = DUS

The output voltage of the amplifier arrives on diode D_1 via potentiometer P_1. This diode rectifies the signal positively. Via D_1 capacitor C_1 is charged. If the voltage across C_1 increases, there will come a point where T_1 conducts. If the voltage on C_1 rises further, transistor T_2 will be driven into conduction via resistor R_1.

A resistor and LED are included in the collector of T_2. When T_2 conducts, the LED lights. If the voltage on C_1 rises still further, transistor T_3 conducts because its base is driven via diode D_2 and resistor R_2. Now LED D_{12} will also light. As long as the voltage on capacitor C_1 keeps rising, another diode in the chain D_2 ... D_{21} conducts. Each of the corresponding transistors (T_2 ... T_{11}) and LEDs (D_{11} ... D_{20}) also conducts. When the emitter potential of T_1 is about 7 volts, all ten LED's will be lit.

If the LED's are placed in line horizontally or vertically the result is a light track whose length is proportional to the output amplitude of the amplifier. Potentiometer P_2 in the emitter circuit of T_1 serves to adjust and limit the current. The indicator responds rapidly to an increase of the output voltage of the amplifier. The decay time of the meter (light track) depends on the value of capacitor C_1.

At a greater capacitor value the decay time becomes longer. At the indicated value for C_1 the decay time is about 0.3 seconds.

The circuit may also be fed from higher voltages. But then the values of R_{11} up to and including R_{20} must be adapted. The proper values can be calculated if we assume that the supply voltage drops at least 1.5 volts across a LED and that the current through the resistors is about

Figure 1. The simplest form of level indicator can be made with a lamp and a resistor. As the output voltage increases, the lamp will produce more light. The indication of such a system is not accurate, and for small voltages the lamp does not light.

Figure 2. The LED level indicator fitted with ten LED's. Each time the output voltage increases by about 0.7 V an additional LED will light up. If the LED's are mounted in line horizontally or vertically) the result is a "thermometer" type indication. The length of the track is an indication of the amplitude of the output. It is possible to use lamps instead of LED's. Depending on the type of lamp used, the load resistors R_{11} up to and including R_{20} may be omitted.

3

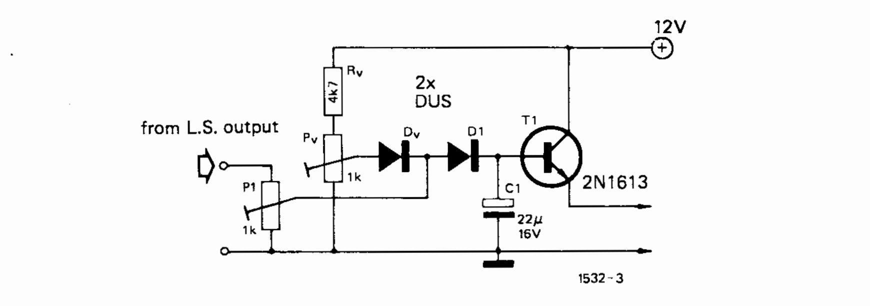


Figure 3. To obtain an indication at low output voltages the anode of diode D_1 of figure 2 must receive a bias voltage. This is done by means of an additional adjustment potentiometer (P_v), resistor (R_v) and diode (D_v).

4a

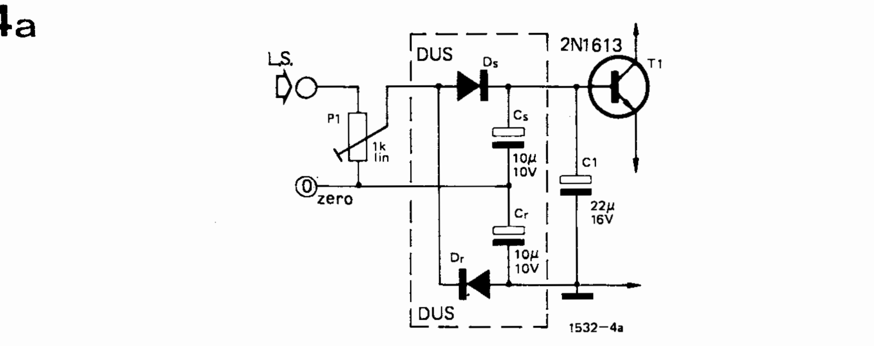


Figure 4. If the level indicator must be driven from a high-output-impedance or low-voltage source a preamplifier circuit can be used. Its voltage amplification is 100 or more, depending on the gain of T_3.

4

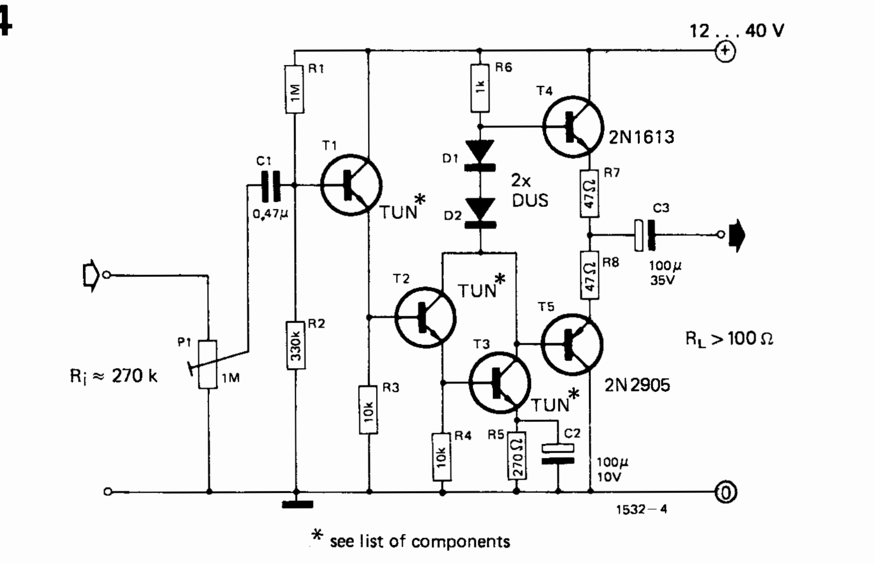


Figure 4a. This voltage doubler can replace diode D_1 (figure 2) if the indicator fails to give full deflection. The voltage doubler consists of two diodes (D_s and D_r) and two capacitors (C_s and C_r). The doubler can only be used if the meter has an independent supply. As appears from the diagram, the loudspeaker zero and level meter zero (minus terminal of C_1) are not D.C. connected.

..mA. (Ensure that the LED's used will stand this current).
If the supply voltage is more than 20 volts it is not possible to use a TUN. Up to a supply voltage of 40 volts the TUN's can be replaced by BC107a or BC107b.

Instead of LED's ordinary incandescent lamps can be used. Their operating voltage can best be chosen to equal the supply voltage. In that case a load resistor (R_{11} up to and including R_{20}) is not needed.
A drawback of the circuit of figure 2 is that the first LED begins to conduct only after a bias has been built up. If this is unacceptable, the circuit can be pre-biased with a resistor, potentiometer, and diode. Figure 3 gives a detailed drawing of the input circuit of figure 2 with the additional components. The bias is adjusted with potentiometer P_V. Diode D_V serves only to avoid extra loading of the positive-going loudspeaker signal.

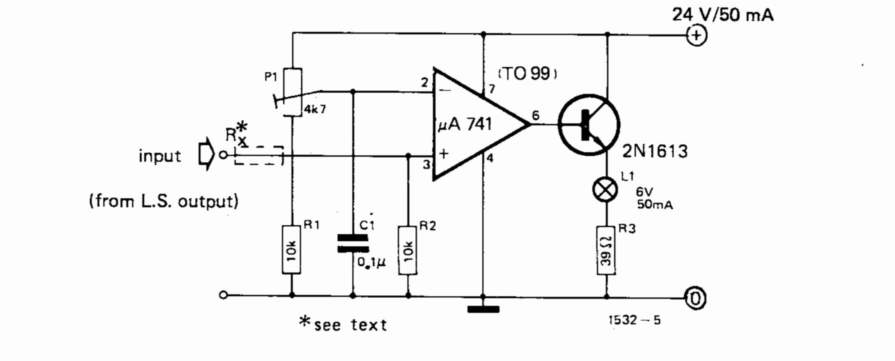
Figure 5. This overload indicator can be used universally. The input must be connected to the output of the amplifier before the output capacitor.

Figure 6. If the level indicator must give an audiophysiologically corrected indication, this network may be connected between the loudspeaker output and the input of the meter.

Level preamplifier

If the level indicator must be connected to a point in the amplifier where there is not sufficient voltage (and power) to drive it, the circuit of figure 4 may be used. This circuit is inserted between the connecting point in the amplifier and potentiometer P_1 of figure 2.
The input impedance of the circuit of figure 4 is about 270 k. The voltage amplification with P_1 at maximum is 100 x or more. This depends on the gain of transistor T_3. The circuit of figure 4 may be connected to supply voltages between 12 volts and 40 volts. For supplies higher than 20 volts the TUN's must be replaced by transistors which can withstand this voltage (for example BC107). Furthermore, the operating voltage of capacitor C_3 should be at least equal to the supply voltage.
If the supply voltage for the circuit of figure 4 is less than 20 volts, the level meter cannot be fully driven under normal conditions. To achieve this, diode D_1 (from figure 2) must be replaced by a voltage doubler, so that capacitor C_1 (of figure 2) receives about twice the voltage (see figure 4a).

5



Parts list with figure 5

Resistors:
R_1, R_2 = 10k
R_3 = 39Ω (see text)
P_1 = 4k7, preset potentiometer

Capacitor:
C_1 = 0.1μ

Semiconductors:
T_1 = 2N1613
IC_1 = μA 741

Lamp:
L_1 = 6 V, 50mA (see text)

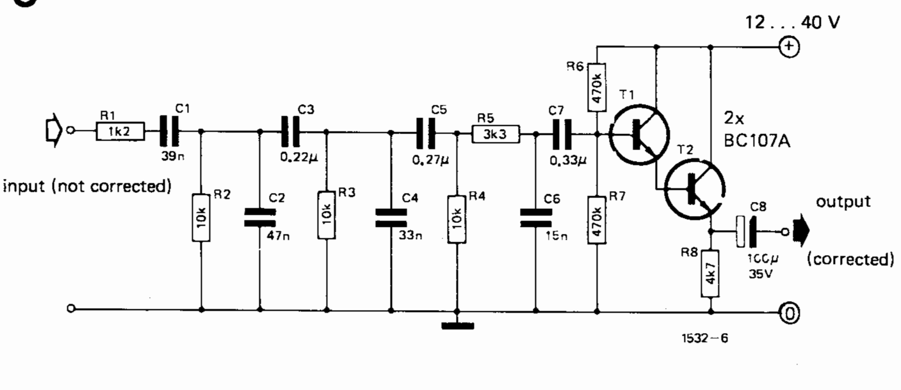
Parts list with figure 6

Resistors:
R_1 = 1k2
R_2, R_3, R_4 = 10k
R_5 = 3k3
R_6, R_7 = 470k
R_8 = 4k7

Capacitors:
C_1 = 39n
C_2 = 47n
C_3 = 0.22μ
C_4 = 33n
C_5 = 0.27μ
C_6 = 15n
C_7 = 0.33μ
C_8 = 100μ/35 V

Semiconductors:
T_1, T_2 = BC107a

6



Overload indicator

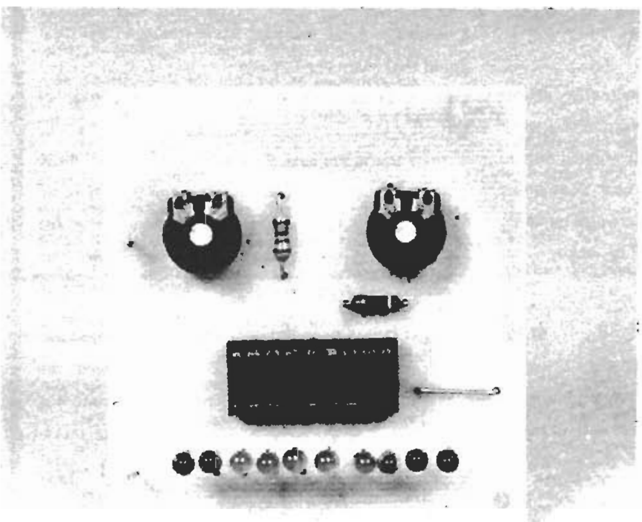
It can be quite handy if a power amplifier is provided with a device that indicates when the amplifier is overdriven: an overload indicator. Figure 5 gives a practical example. The input is connected to the output of the amplifier. Since we are now concerned with overdrive, the input must be connected before the loudspeaker elco.
The threshold level of the overload indicator may be adjusted by potentiometer P_1. This adjustment must be such that if a certain level is exceeded, the μA 741 switches, and produces a positive voltage. This voltage drives transistor T_1. The emitter circuit of T_1 includes an incandescent lamp or LED which then lights.
The overload indicator of figure 5 can also be used for higher voltages (up to 37 volts). The value of resistor R_3 must be increased in proportion with the higher supply voltage. To ensure the survival of the IC, the input voltage should not be more than the supply voltage. For this reason an extra resistor (Rx) of 10 ... 22k in the input lead may be needed.

Physiological correction

If the level indicator must give an audiophysiologically corrected indication, the network of figure 6 can be connected between the meter and the loudspeaker output. This network gives an attenuation of about 4 x. If the input voltage is then insufficient to drive the meter to maximum indication, there are two possible solutions. The voltage doubler of figure 4a can be used, or alternatively the circuit of figure 4 can be connected between the correction network output and the input of the level indicator. In that case potentiometer P_1 and the capacitors C_1 and C_2 can be omitted from the circuit of figure 4.
With the audio-physiologically corrected level meter it is necessary to use an overload indicator, because it is impossible to see when the amplifier is giving its peak power.

BARGRAPH CAR VOLTMETER

A 'must' for the proud automobile owner. An all solid-state 10-LED expanded-scale car voltmeter or battery-condition indicator.



A VOLTMETER IS A USEFUL accessory to have fitted to a car, since it can, when properly used, give the owner an excellent indication of the state of the battery and it's charging circuit. Under no-load conditions, with the engine turned off, a sound and well charged battery will give a reading of 12 to 13 volts. Any value lower than 12 volts indicates a defective battery.

With the engine turned off and all lights switched on, the battery reading should fall to 11 to 12 volts. Again, any reading lower than this indicates a faulty battery.

With the engine running at a fast idle and the electrical system lightly loaded, the battery reading should rise to between 13 and 14 volts. A reading below the lower value indicates a faulty dynamo/alternator or a defective regulator. A reading above the upper value indicates a defective regulator.

You'll notice from the above statement that the range of voltmeter readings that are of interest span only a very limited range, from say 10.5 volts minimum to 15 volts maximum, so a special type of 'suppressed zero' voltmeter should ideally be used in the car.

Our car voltmeter is very special. It is an all solid-state design that gives a readout on a two-coloured line of ten LEDs (light emitting diodes). The unit has excellent long-term and thermal accuracy once it has been initially calibrated to span the range 10.5 to 15 volts. The unit is very easy to install in the vehicle and has a total building cost of only 10 dollars or so. The unit gives a 'dot' display in which only one of the ten LEDs is illuminated at any one time.

Construction And Use

The entire circuit, including the ten LEDs, is built up on a small PCB and construction should present very few problems. Note that IC1 is an 18-pin device and also that it should be fitted to the PCB via a suitable holder. We advise testing each one of the LEDs, to confirm it's functioning and polarity, before fitting it to the PCB.

To check each LED, connect it in series with a 470R resistor and then connect the combination across a 12-volt supply. If necessary switch the LED connections until the LED illuminates, under which condition the lead closest to the positive supply rail is the anode.

When construction is complete, double-check the circuit wiring and connect the unit to a variable voltage DC supply that can span the 10-15 volt range. Monitor the supply voltage with a reasonably accurate meter and calibrate the unit as follows.

Set the supply to 15 volts and adjust RV1 so that LED 10 just turns on. Reduce the supply to 10 volts and adjust RV2 so that LED 1 just turns on. Recheck the settings of RV1 and RV2. The calibration is then complete and the unit can be installed in the vehicle by taking the '0' volt lead to chassis and the '+12 volt' lead to the vehicle's battery via the ignition switch. ●

PROBLEMS? NEED PCBs? Before you write to us, please refer to 'Component Notations' and 'PCB Suppliers' in Table of Contents. If you still have problems, please address your letters to 'ETI Query' care of this magazine. A stamped, self addressed envelope will ensure fastest reply. Sorry, we cannot answer queries by telephone.

HOW IT WORKS

There is little we can say other than the IC1 acts as a LED-driving voltometer that has its basic maximum and minimum readings determined by the values of R2 and RV2. When correctly adjusted, the unit actually spans the approximate range 2.5 volts to 3.6 volts, but is made to read a supply voltage span of 10-10.5 volts to 15 volts by interposing potential divider R1-RV1 between the supply line and the pin-5 input terminal of the IC.

The IC is configured to give a 'dot' display, in which only one of the ten LEDs is illuminated at any given time. If the supply voltage is below 10.5 volts none of the LEDs illuminate. If the supply equals or exceeds 15 volts, LED 10 illuminates.

A comprehensive description of the functioning of the LM3914 IC is given elsewhere in this issue.

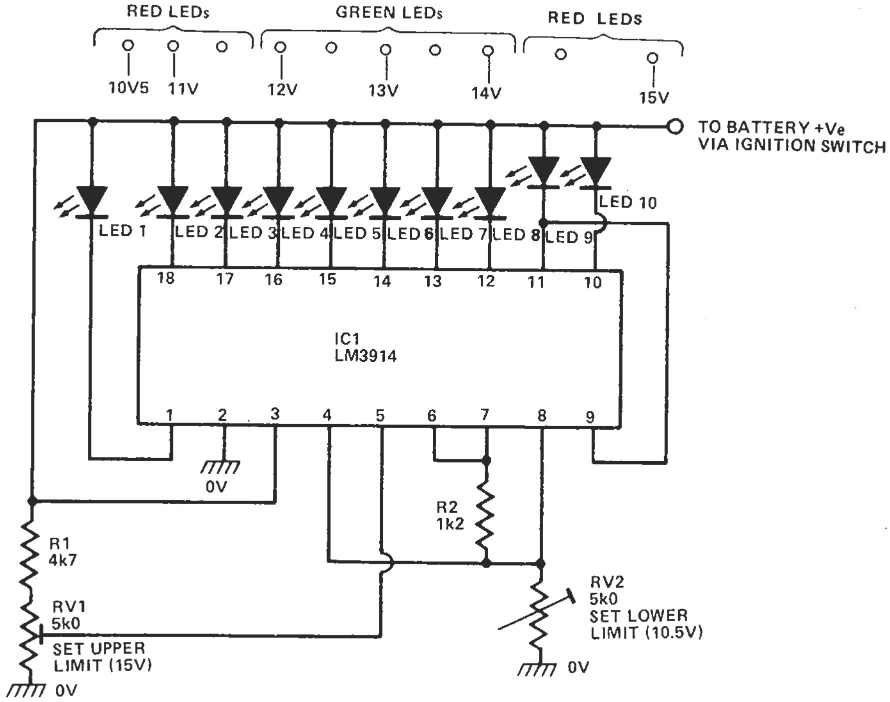
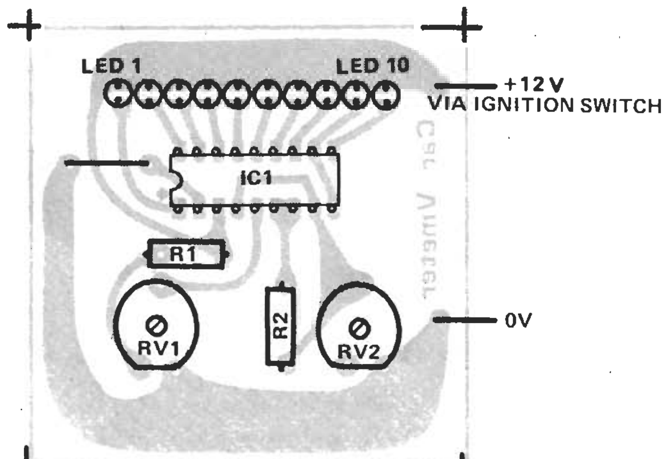
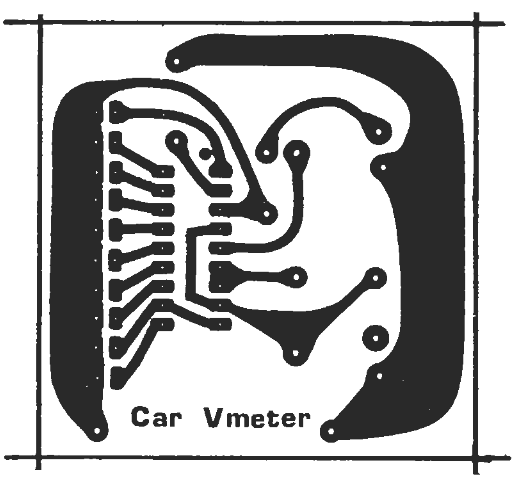
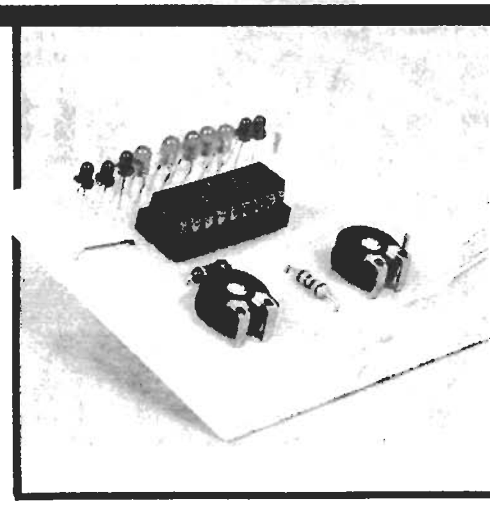


Fig. 1. Circuit diagram of the ETI Bargraph Car Voltmeter.
The choice of a box is decided by the type of installation required.



PCB overlay for the Voltmeter, note the position of IC1.
(lower) PCB foil pattern, take care to avoid solder splashes.





The ETI LED Voltmeter.
See text for the setting-up procedure.

RESISTORS (all ¼W 5%)	
R1	4k7
R2	1k2
POTENTIOMETERS	
RV1, 2	4k7 preset
SEMICONDUCTORS	
IC1	LM3914
LEDs 1, 2, 3, 9, 10	TIL 209
LEDs 4, 5, 6, 7 8	TIL 211

COMPU-LINE
IS
COMING

Circle No. 20 on Reader Service Card.

AN AUDIO LEVEL METER

BY JOSEPH M. GORIN

USEFUL IN:

- *tape recording*
- *checking broadcast modulation*
- *balancing channels*
- *monitoring power amplifiers*

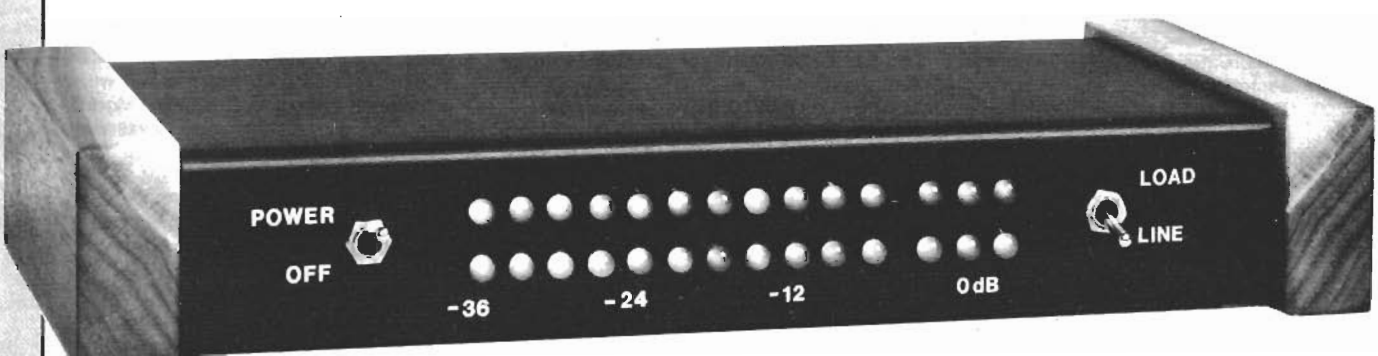
KNOWING the signal levels at which a piece of audio equipment is operating, is often necessary to avoid distortion. In tape recording, for example, the third-harmonic distortion increases quite rapidly above a certain threshold; and when tape saturation is reached, increasing input levels can cause decreasing output levels. At the same time, the recording should be made at as high a level as possible to keep the signal well above the inherent tape noise.

In power amplifiers, significant distortion is created when the output is driven beyond its maximum level. A process called "clipping" takes place, which flattens the top of the waveform. Although clipping usually is induced by low-frequency fundamental tones, the waveform contains appreciable high-frequency energy that is potentially dangerous to tweeters.

In either of these cases, a level meter would be of great help. Since the distortion is predominantly due to the largest signals encountered (because of the rapidly rising characteristic of the distortion VS level relationship), a peak-responding characteristic is desirable in a meter. Mechanical meters, due to the inertia of the pointer, do not respond rapidly enough to track peak levels, unless they have electronic circuits that hold the peaks. An unassisted mechanical meter is termed "average-responding" because its deflection shows the average of the absolute value of the signal. If all music had similar properties, this would be acceptable; but, in fact, the peak-to-average ratio can be anything from a few dB (as in compressed radio broadcasts) to around 20 dB in some live situations.

Once the peak is captured and held, we must decide how rapidly to let it decay. If decay is rapid, the advantages are having a lot of visual motion in the display, rapid feedback in level setting, and a good measure of how much the signal is above the noise floor at all times. If the decay is slow, we can look at it within a short time of hearing a high-level transient and still tell how close it was to maximum without having to keep our eyes glued to the meter. The meter described here can read out both short-term (rapid decay) and long-term (slow decay) peaks on the same display.

Having a dual-speed readout, the meter can also be used as a modulation analyzer for broadcast signals, especially FM multiplex. The long-term peak LED will remain constant on all stations that employ heavy limiting (which is most stations). If the long-term peak LED is *always* significantly lower on a given station than most of the other stations, that station is under-modulating. Looking at both channels simultaneously lets you see how well balanced they are. Observing the spacing between the long-term



and short-term peaks for different stations playing the same kind of music, and for records and tapes, lets you see the relative amount of compression being used by the stations.

Circuit Operation. Since both channels are the same, only the right channel is shown in the schematic in Fig. 1. Parts numbers for the left channel are the same but in the 100 series–that is, *R1* in the right channel becomes *R101* in the left channel.

Switch *S1* (common to both channels), selects either the speaker level signal (LOAD IN), attenuated by *R15* and *R17*, or the LINE IN signal, applied to *J1*. Resistor *R17* is selected in accordance with the Parts List. Resistor *R16* prevents undesired ground loops that can produce oscillation in some amplifiers. The *HI* side of the load input should be connected to the "hot" output of the amplifier being used, and the *LO* to ground.

In LINE operation, *IC1* amplifies the input signal level and provides a low driving impedance for the following peak detectors. The line input can be obtained from the Tape Record or Tape Out terminals of an amplifier. From *S1*, the input is fed to the fast peak detectors *IC2A* (negative) and *IC2B* (positive).

When a positive peak occurs, it is coupled via *R4* to *IC2B*. This causes the *IC2B* output (pin 4) to go high, turning on *Q1*, and rapidly charging *C3* until its voltage equals the input voltage to *IC2B*.

For negative peaks, *IC2A* operates *Q2* to charge *C3* until the output is the opposite of the applied input voltage (actually until $V_{out} = -V_{in} \times R8/R7$). When this signal is lower than recent peaks, *C3* is discharged through *R9*. Buffer *IC2D* has a gain of +1, a high input impedance to prevent loading of *C3*, and a low output impedance.

Op amp *IC2C* and its associated circuit forms a slow-release peak detector charging *C5*. On the positive peaks, (negative peaks have been made positive by the fast detector), *C5* is charged via *D5*, while resistor *R12* provides a slow discharge path.

Before we discuss the LED drivers as shown in Fig. 2, let us take a look at the power supply shown in Fig. 3. Transformer *T1* is a wall-socket mounted source that connects via POWER switch *S2* to the bridge rectifier formed by *D201* through *D204*. Using *C202* as a filter, this supply delivers about 9 volts. Diodes *D205*

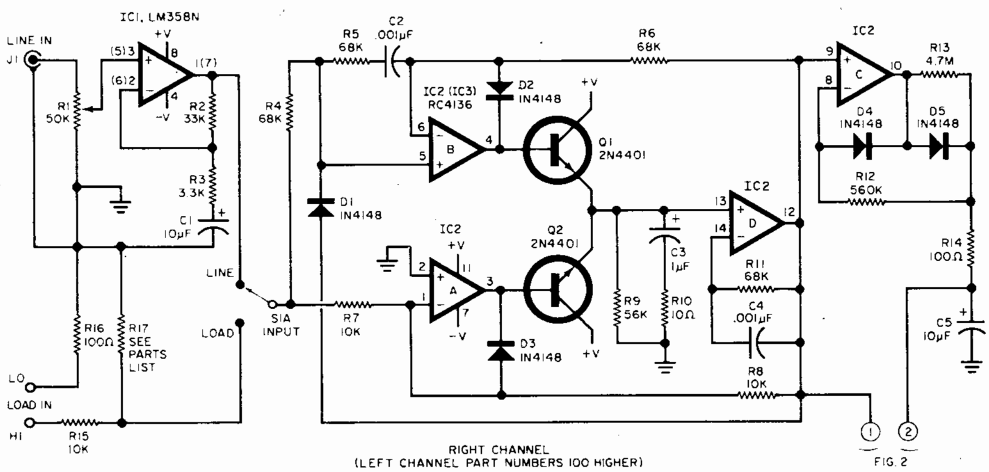


Fig. 1. Schematic diagram of one channel of the level meter.

PARTS LIST

C1, C101, C5, C105—10-μF, 25-V aluminum electrolytic
C2, C102, C4, C104, C205, C206, C207, C208—0.001-μF polyester film capacitor
C3, C103—1-μF, 16-V tantalum electrolytic
C201, C211—0.1-μF ceramic disc capacitor
C202, C203, C204,—220-μF, 16-V aluminum electrolytic
C209, C210—3.3-μF aluminum electrolytic
D1, D101, D2, D102, D3, D103, D4, D104, D5, D105, D209—1N4148 switching diode
D201 through D208—1N4001 rectifier
IC1—LM358N dual op amp
IC2, IC3—RC4136 quad op amp
IC4—CD4052 analog multiplexer
IC5, IC6—LM3915 LED bar-graph IC
J1,J101—phono jack
LED201 through LED228—Red T-1¾ light emitting diode (high efficiency)
Q1, Q101, Q2, Q102, Q201—2N4401 or 2N2222 npn transistor
R1, R101—50-kΩ potentiometer
R2, R102—33-kΩ, ¼-W, 5% resistor
R3, R103, R202—3.3-kΩ, ¼-W, 5% resistor
R4, R5, R6, R104, R105, R106, R11, R111, R201, R203, R204, R205,—68-kΩ, ¼-W, 5% resistor
R7, R107, R8, R108, R15, R115—10-kΩ, ⅛-W, 1% resistor
R9, R109—56-kΩ, ¼-W, 5% resistor
R10, R110—10-Ω, ¼-W, 5% resistor
R12, R112—560-kΩ, ¼-W, 5% resistor
R13, R113—4.7-MΩ, ¼-W, 5% resistor
R14, R114, R16, R116—100-Ω, ¼-W, 5% resistor
R17, R117—For 50 W at 8Ω, 1.27-kΩ, 1%; for 100 W at 8Ω, 845-Ω, 1%; for 200 W at 8Ω, 562-Ω, 1% resistor
R206, R207, R208—4.7-kΩ, ¼-W, 5% resistor
R209—120-Ω, ¼-W, 5% resistor
R210, R213, R214—560-Ω, ¼-W, 5% resistor
R211, R212—300-Ω, ¼-W, 5% resistor
S1, S2—Dpdt miniature toggle switch
S3, S4—Sp3t slide switch
T1—7.2-V, 200-mA wall-plug transformer (Dormeyer PS14206 or similar)
Misc.—Terminal blocks, mounting hardware, wire, solder, etc.
Note: Except for switches, ICs, and transformer, items in 1-100 series are for right channel, 100-200 are for left channel, 200-up are for both. **The following is available from Symmetric Sound Systems, 912 Knobcone Pl., Loveland, CO 80537: complete kit with cabinet with unfinished walnut end panels, Model #PLM-2, at $75.00. Also available from the same source; pc boards and all board-mounted parts, #PLM-2B, at $45.00; pc boards #PLM-2PC, at $10 (not available after 6/30/82). All prices include shipping on prepaid orders in U.S. Canadians, please add $5 shipping and handling (except PLM-2PC). Add $1.00, plus shipping, for charge-card orders. Colorado residents, add 3% sales tax.**

and *D206*, in conjunction with *C203* and *C204*, form a voltage doubler to generate the −8 V for the op amps.

On the ac power-line half cycles when the anode of *D208* is positive, this diode is forward-biased to power the left-channel LED bank formed by *LED215* through *LED228*. The right channel LEDs are off. On the other half cycle, the right-channel LED bank formed by *LED201* through *LED214* is powered via *D207*, while the left channel LEDs are off. During this half cycle, transistor *Q201* is turned on (via *R202*) producing a high-to-low transition at its collector. This 60-Hz pulse is applied to *IC4* as shown in Fig. 2. This switching action alternates the LEDs at a rate fast enough to make both banks appear to light up at the same time. This approach allows use of the same LED switching circuitry, saving components and money.

Since *IC5* and *IC6* have their associated LEDs switched at a 60-Hz rate, the inputs to these ICs should also be switched at 60 Hz. Dual-analog switch *IC4* is a two-pole, four-position electronic switch with the "rotors" at pins 3 and 13. The signal at pin 9 determines whether a slow or fast input is selected, while the input at pin 10 determines right or left LED selection. Since pin 10 is hardwired to the collector of *Q201* (switched at 60 Hz), the internal switches of *IC4* are operating at 60 Hz.

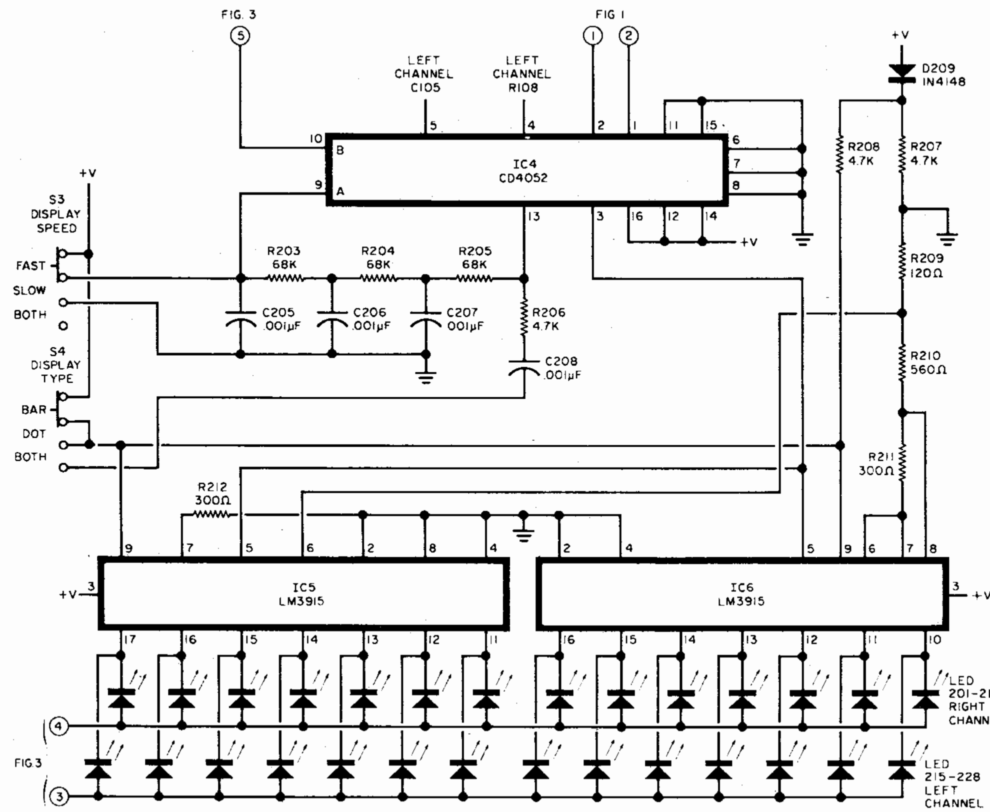


Fig. 2. Schematic of the display circuit for the level meter. The switching scheme permits use of the same circuit for both left and right channels of LEDs.

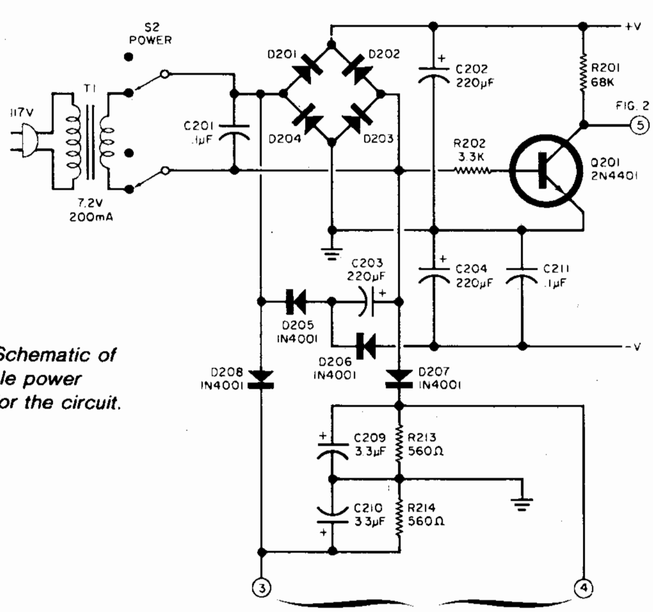


Fig. 3. Schematic of a suitable power supply for the circuit.

When *S3* (DISPLAY SPEED), is placed in the FAST position, pin 9 of *IC4* is high and selects only the "right fast" and "left fast" inputs. When S3 is at SLOW, pin 9 is placed low, and the slow inputs are selected. If *S3* is set to BOTH, the output signal at pin 13 drives the pin-9 input via the phase shifter composed of *R203* through *R205* and *C205* through *C207*. This causes the circuit to oscillate, therefore in this position of *S3*, the input to the LED drivers oscillates between fast and slow at a few kHz, while also oscillating between right and left at 60 Hz via pin 10.

Switch *S4* determines the DISPLAY TYPE. In the BAR mode, it connects pin 9 of *IC5* and *IC6* to the positive supply to cause the drivers to display a bar graph. When *S4* is in the DOT position, diode *D209* and *R207/R208* keep pin 9 about 0.6 volt below the positive supply, forcing *IC5* and *IC6* to display a single LED at a time in a moving-dot display. When *S4* and *S3* are both in the BOTH position, an interesting display results. Pin 13 of *IC4* will have a square wave of a few kHz on it, and on the rising edge of this waveform, when the input to *IC5* and *IC6* is changing from the fast to slow peak detector, the positive pulse is coupled to pin 9 of both *IC5* and *IC6* via *R206* and *C208*. This places the LED drivers in the BAR mode; and, when *C208* charges, the voltage at pin 9 places the drivers in the DOT mode. The visible result is a bright dot in the position of the fast input and another for the slow input. There will be a dim bar from the left end of the display to the slow LED. A bright dot makes it easier to watch the fast-decay signal; but in a dimly lit room, only the motion is visible, not its absolute position. The dim bar of the BOTH mode provides an excellent display with high readability.

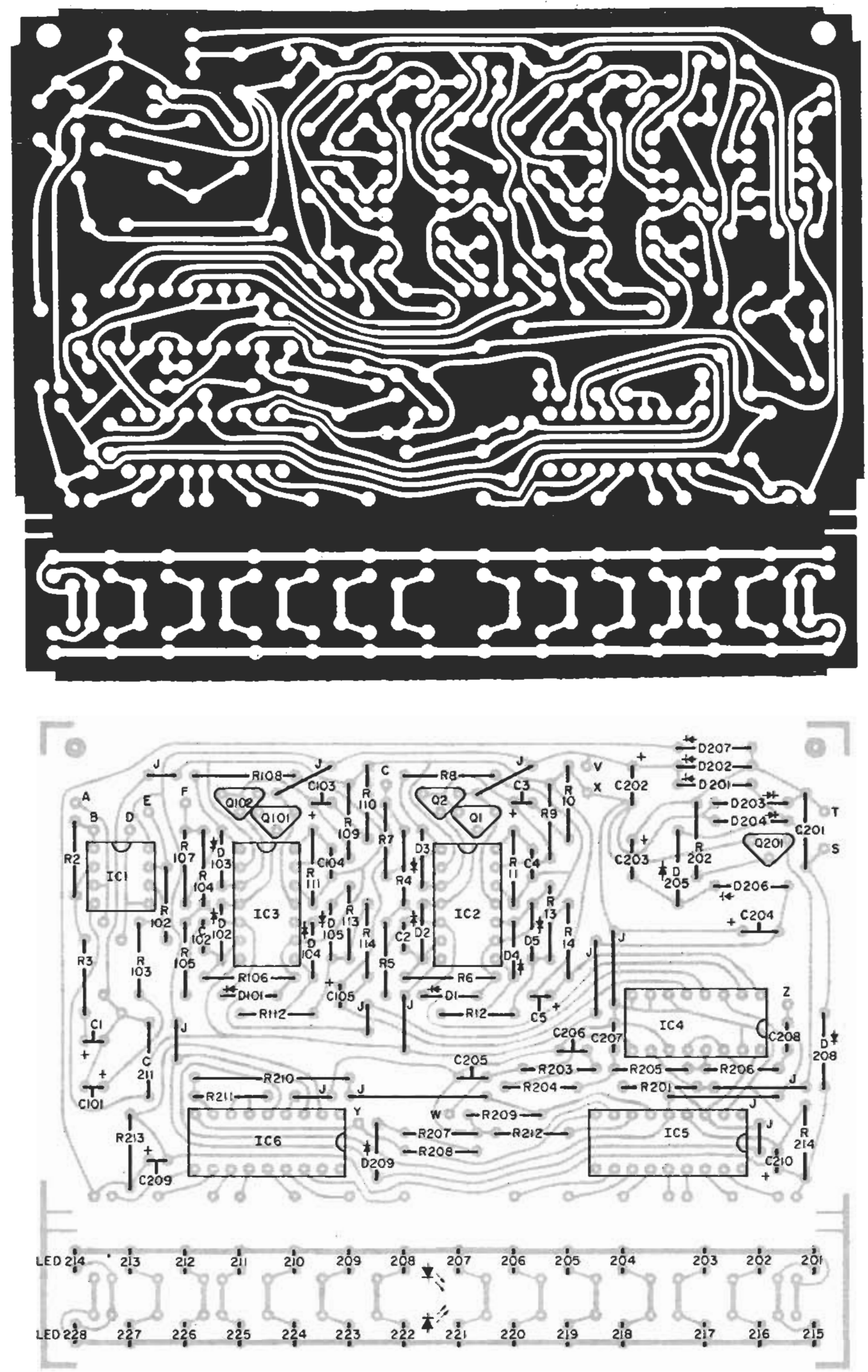


Fig. 4. Foil pattern (top) and component layout for the pc board, which is in two parts for control circuit and display.

Construction. Although the pc board shown in Fig. 4 simplifies construction, point-to-point wiring can be used. If you elect to go this route, keep the leads to the LEDs short.

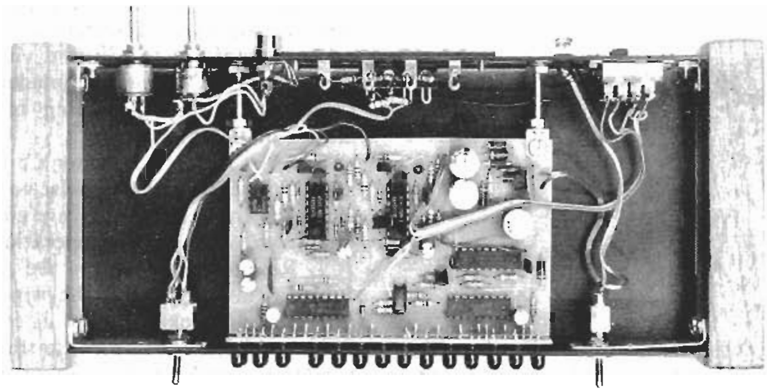
Note that two pc boards are shown in Fig. 4, one for the control circuit, and the other for the LEDs. There is a space between the top three LEDs and the others to make the display better for distance reading when it is indicating near the peak levels.

After selecting a suitable enclosure, mount the main pc board on spacers, and the LED board as desired on the front panel. The various off-board components (*J1*, *R1*, the LOAD IN connector, *R15*, *R16*, *R17*, and *S1*, power on/off switch *S2*, and *S3* and *S4*) are mounted as desired on the front and rear panel. Drill a hole, and use a grommet to allow the power cord from wall-mounted *T1* to enter the enclosure. Use suitable markings to identify each front-panel item.

Calibration. The LOAD IN terminals are for speaker-level signals. Select *R17* and *R117* in accordance with the Parts List. For example, if you are using a 50-watt amplifier, *R17* will be 1.27 kΩ. This will allow a peak signal as large as a sine wave that will put 50 watts into an 8-ohm load to light the 0-dB LED. In this case, the +3-dB LED will be the equivalent of 100 watts, and the −3-dB LED will equal 25 watts, etc.

For power levels not in the Parts List, $R17 = 5\ k\Omega \times (X/1\text{-}X)$ where X = 4.083 volts divided by the square root of the power in watts times the impedance in ohms. Typical error from this form of calibration is ±0.3 dB, but it can be as high as ±1.5 dB.

There are several ways to calibrate the input circuit. If *R1* and *R101* are set to the center of their ranges, 0 dB will correspond to the peak level of a 0.775-volt sine wave. This latter is 0 dBm into 600 ohms, or 1 mW at 600 ohms impedance. An input of 400 mV or more can be used to light the 0-dB LED by adjustment of the calibration potentiometer.



Internal view of the author's prototype level meter.

Dolby reference level tape may be purchased from Integrex, Box 747, Havertown, PA 19083, for $9.00 ppd. (specify reel or cassette).

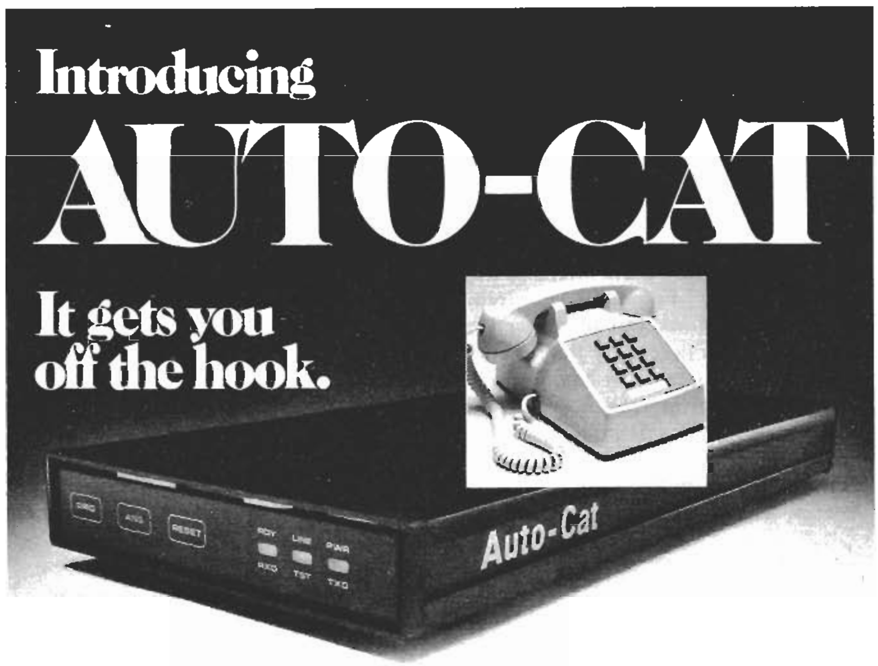
The Audio Level Meter, with its simultaneous display of short-term and long-term true peak levels, will allow you to set your record levels more accurately, for the optimum trade-off between distortion and noise. It also helps you prevent amplifier clipping and makes for a pretty visual show! ◇

Use. To use the line-level section to help with tape recording, there are many different techniques with different accuracies and instrumentation requirements. First, the Audio Level Meter should be connected *after* the record level controls of your tape deck. This connection can be at an internal point, or at the output jacks. We will describe techniques that assume the latter point; note that, if you have the level adjustments that affect the outputs, the system will be calibrated only for the setting you use then, so mark that setting.

One technique is to find the signal level of a 400-Hz tone that results in 3% total harmonic distortion and let that be the 0 dB to which you set your meter. If you only rarely exceed this peak level during recording, average distortion will be very low.

Another technique would be to play FM interstation noise into your tape deck and adjust the level control to read −6 dB on the deck's meters—if they are of the typical average-responding type (or 0 dB if they are peak-responding). Calibrate the Audio Level Meter to 0 dB. The reason for the 6-dB difference is that noise has a peak-to-average ratio of about twice the peak-to-average ratio of sine waves, for which average-responding meters are calibrated.

A final technique would be to play a Dolby reference-level tape and adjust your meter so that a signal recorded at a similar level causes the meter to read −3 dB. With good quality tape, optimum record level will then be a setting that allows the 0-dB LED to light occasionally, and the +3 dB LED will indicate more than 3% distortion. With metal particle tape, the +3-dB light may be allowed to light occasionally, as metal tape has a little more headroom with typical musical signals (and a lot more with treble-intensive signals that are found in live music). With poorer quality tapes, try to have the 0-dB LED light rarely. A



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CIRCLE NO. 3 ON FREE INFORMATION CARD

'Dithering' display expands bar graph's resolution

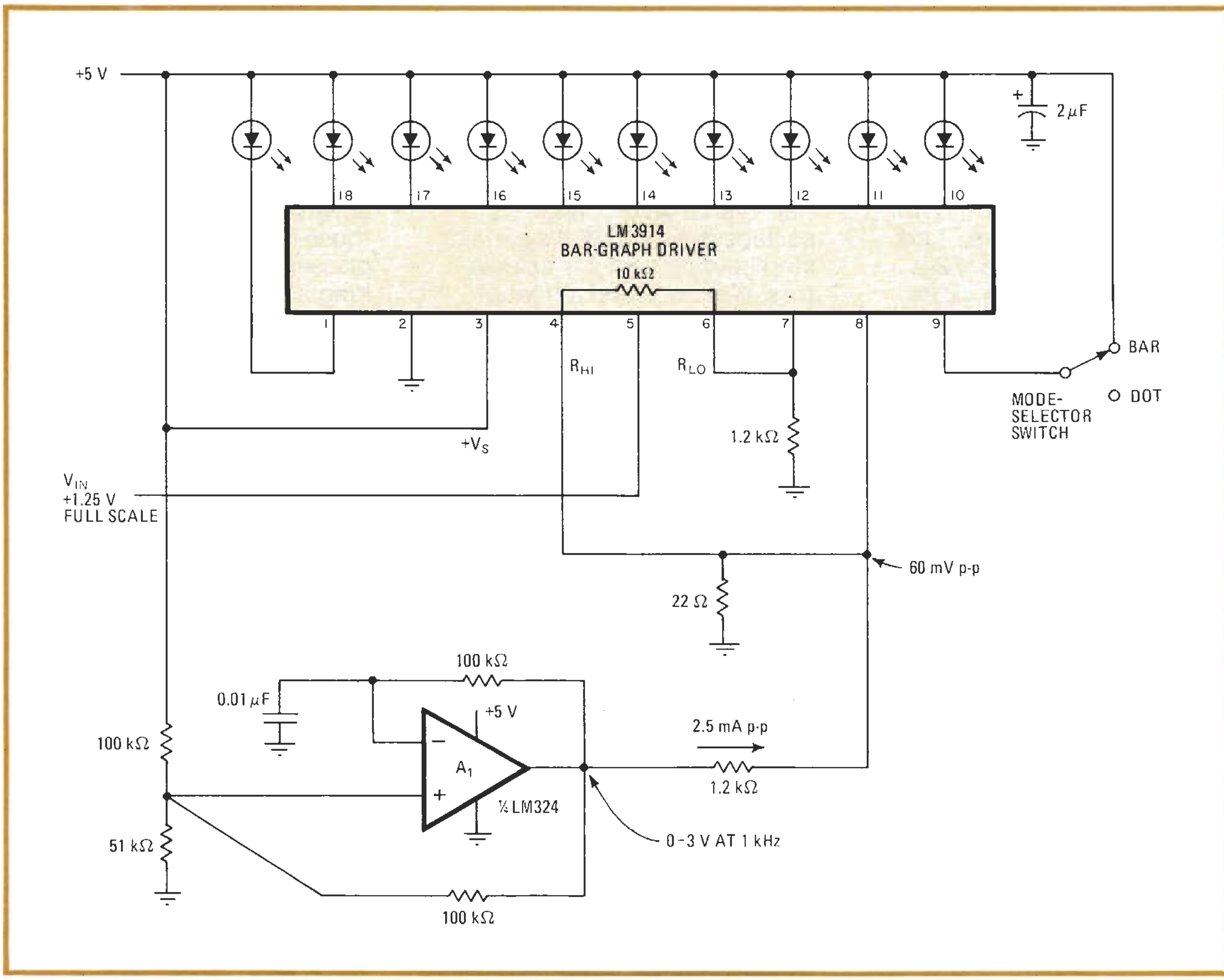
by Robert A. Pease
National Semiconductor Corp., Santa Clara, Calif.

Commercially available bar-graph chips such as National's LM3914 offer an inexpensive and generally attractive way of discerning 10 levels of signal. If 20, 30 or more steps of resolution are required, however, bar-graph displays must be stacked, and with that, the circuit's power drain, cost and complexity all rise. But the techniques used here for creating a scanning-type "dithering" or modulated display will expand the resolution to 20 levels with only one 3914 or, alternatively, make it possible to implement fine-tuning control so that performance approaching infinite resolution can be achieved.

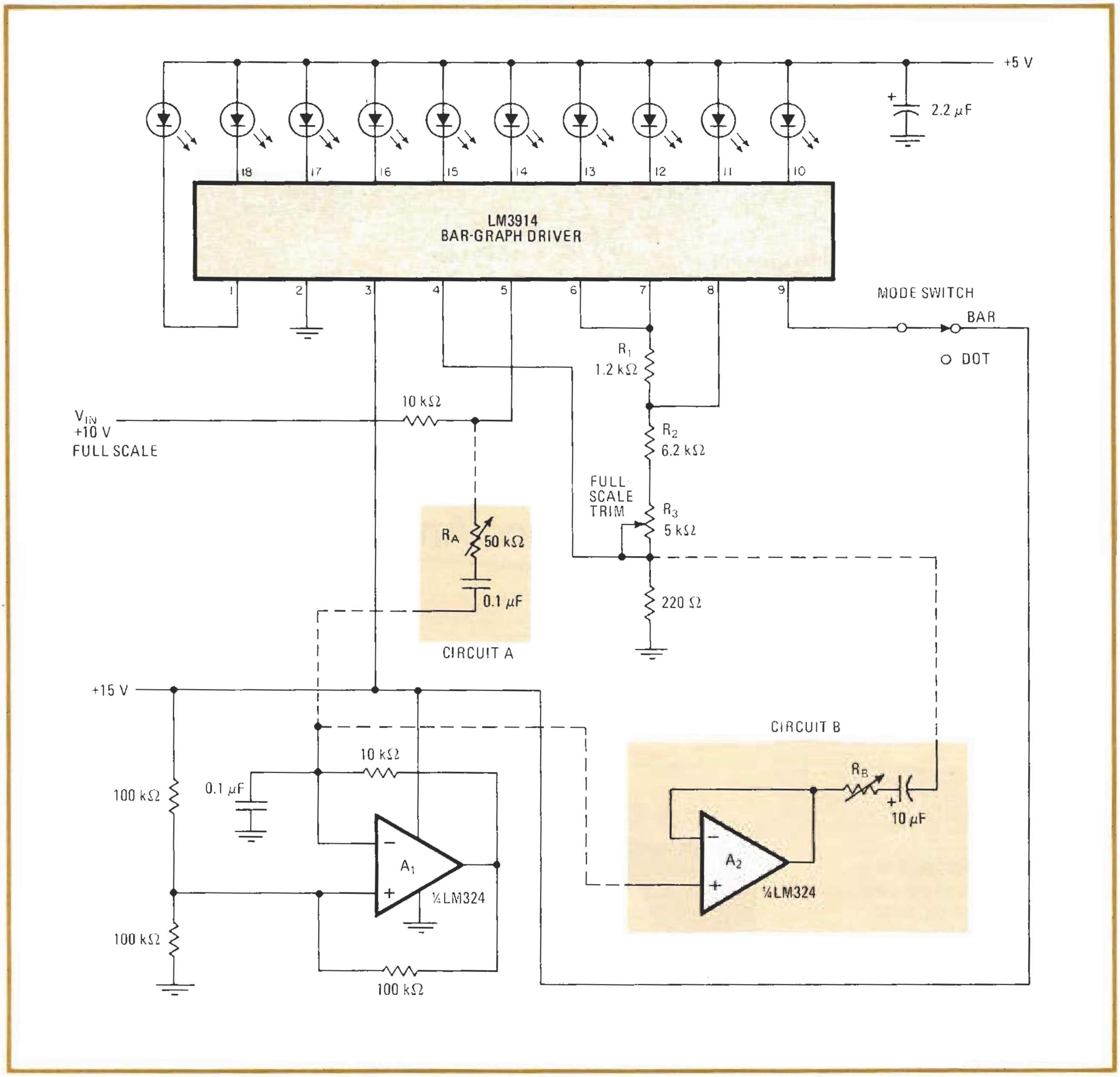
The light-emitting-diode display arrangement for simply distinguishing 20 levels is achieved with a rudimentary square-wave oscillator, as shown in Fig. 1. Here, the LM324 oscillator, running at 1 kilohertz, drives a 60-millivolt peak-to-peak signal into pin 8 of the 3914.

Now, the internal reference circuitry of the 3914 acts to force pin 7 to be 1.26 V above pin 8, so that pins 4 and 8 are at an instantaneous potential of 4.0 mV plus a 60-mV p-p square wave, while pins 6 and 7 will be at 1.264 V plus a 60-mV p-p square wave. Normally, the first LED at pin 1 would turn on when V_{in} exceeded 130 mV, but because of the dither caused by the ac component of the oscillator's output, the first LED now turns on at half intensity when V_{in} rises above the aforementioned value. Full intensity is achieved when V_{in} = 190 mV.

When V_{in} rises another 70 mV or so, the first LED will fall off to half brightness and the second one will begin



1. Half tones. Input-signal biasing on LM3914 bar-graph chip is set by the instantaneous output of a low-amplitude square-wave oscillator so that bar-graph resolution can be doubled. Each of 10 LEDs now has a fully-on and a partially-on mode, making 20 states discernible.



2. Spectrum. Greater resolution, limited only by the ability of the user to discern relative brightness, is achieved by employing a triangular-wave oscillator and more sensitive control circuitry to set the voltage levels and thus light levels of corresponding LEDs. Two RC networks, circuits A and B, provide required oscillator coupling and attenuation. B replaces A if oscillator cannot suffer heavy loading.

to glow. When V_{in} reaches 320 mV, the first LED will go off, and the second will turn on fully, and so on. Thus 20 levels of brightness are easily obtained.

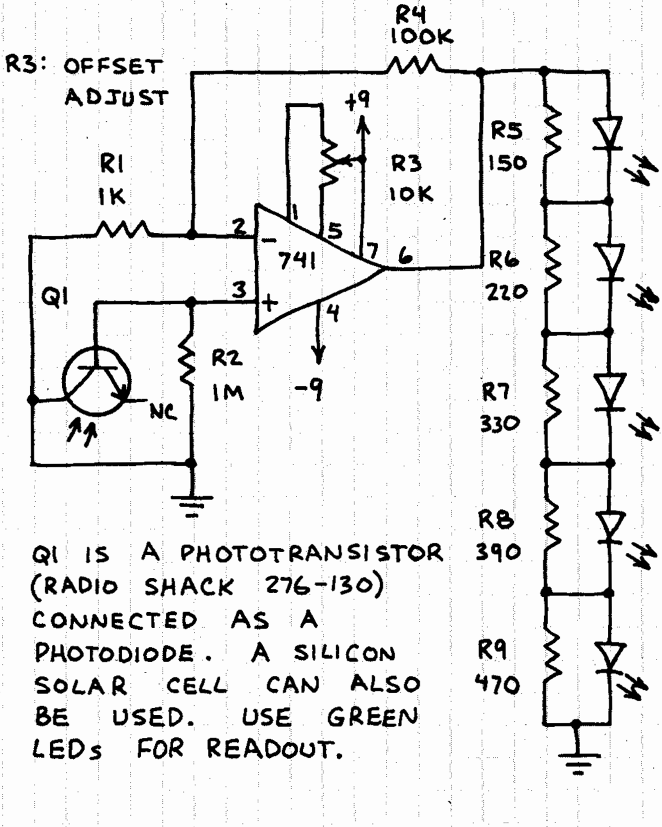
Similarly, greater resolution can be achieved by employing a triangular-wave oscillator and two simple RC networks as seen in Fig. 2. Here, by means of circuit A, this voltage is capacitively coupled, attenuated, and superimposed on the input voltage at pin 5 of the LM3914. With appropriate setting of the 50-kilohm potentiometer, each incremental change in V_{in} can be detected because the glow from each LED can be made to spread gradually from one device to the next.

Of course, if the signal-source impedance is not low or linear, the ac signals coupled into the input circuit can cause false readings at the output. In this case, the circuit in block B should be used to buffer the output of the triangular-wave oscillator.

The display is most effective in the dot mode, where supply voltages can be brought up to 15 V. If the circuit's bar mode is used, the potentials applied to the LEDs

(CONTINUED)

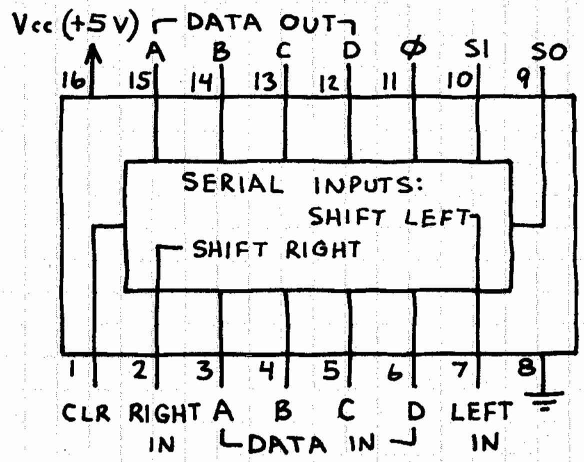
BARGRAPH LIGHT METER



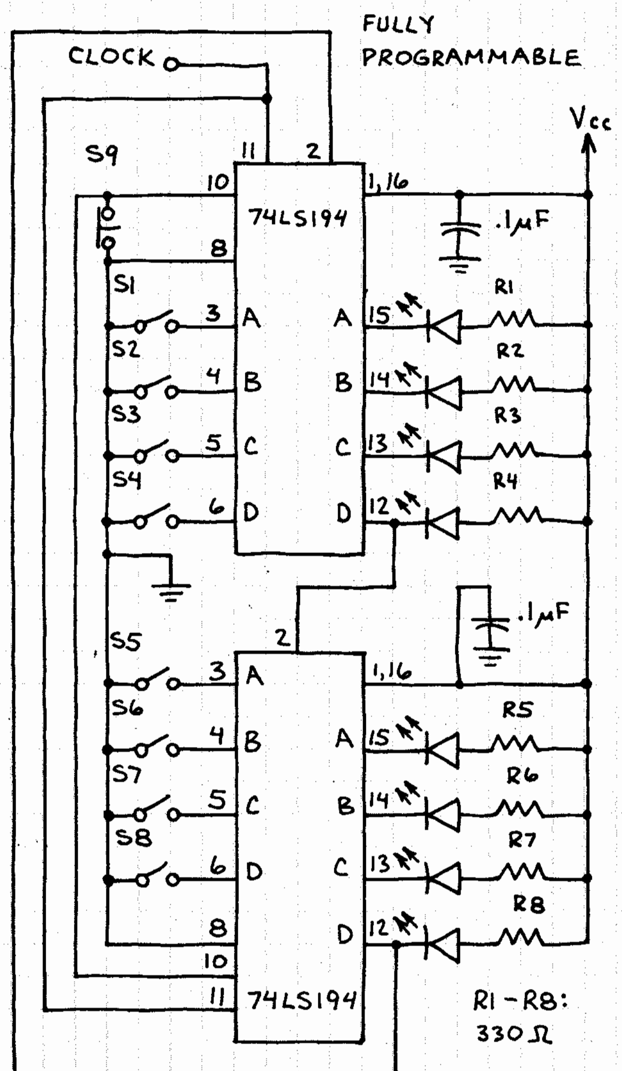
Q1 IS A PHOTOTRANSISTOR (RADIO SHACK 276-130) CONNECTED AS A PHOTODIODE. A SILICON SOLAR CELL CAN ALSO BE USED. USE GREEN LEDs FOR READOUT.

4-BIT SHIFT REGISTER
74LS194

BIDIRECTIONAL UNIVERSAL SHIFT REGISTER. SHIFTS RIGHT WHEN SO IS HIGH AND SI IS LOW. SHIFTS LEFT WHEN SO IS LOW AND SI IS HIGH. SHIFTS ONE POSITION PER CLOCK PULSE. LOADS DATA AT INPUTS WHEN SO AND SI ARE HIGH. IMPORTANT: BYPASS POWER SUPPLY PINS WITH 0.1μF CAPACITOR!



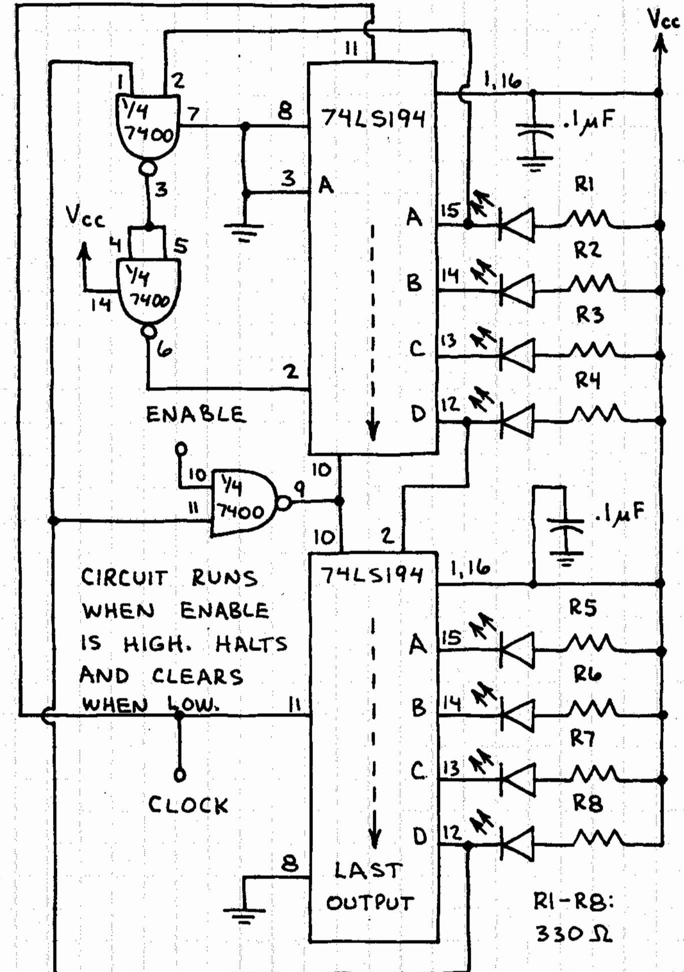
SEQUENCE GENERATOR



LOAD ANY DESIRED BIT PATTERN INTO S1-S8 (OPEN = HIGH AND CLOSED = LOW). PRESS S9 (NORMALLY CLOSED) TO LOAD. DATA WILL MOVE RIGHT ONE OUTPUT PER CLOCK PULSE. LEDS ARE OPTIONAL.

BARGRAPH GENERATOR

WHEN POWER IS FIRST APPLIED, MAKE ENABLE INPUT LOW TO START CIRCUIT.



OUTPUTS GO LOW AND STAY LOW ONE AT A TIME FROM LEFT TO RIGHT (A→D) IN SEQUENCE WITH CLOCK. WHEN FINAL OUTPUT GOES LOW, ALL OUTPUTS BUT THE FIRST GO HIGH AND RECYCLE.

LED Level Meter

PROJECT

The LED level meter described here, is ideal for any application requiring a wide dynamic range level display. Naturally, two are required for stereo applications.

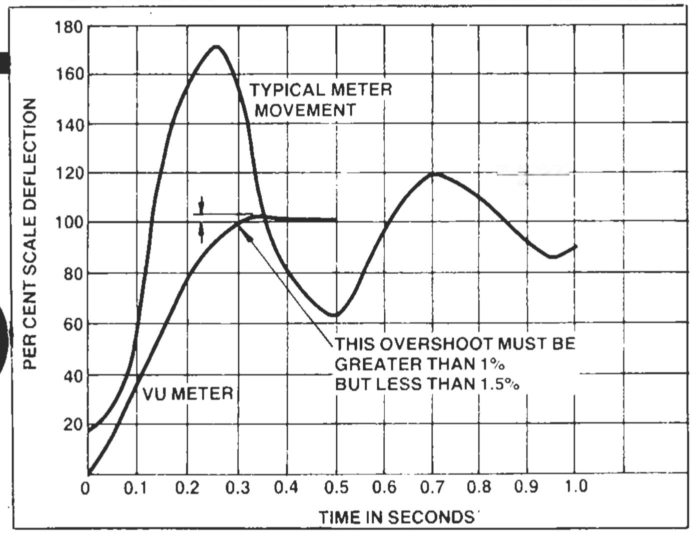
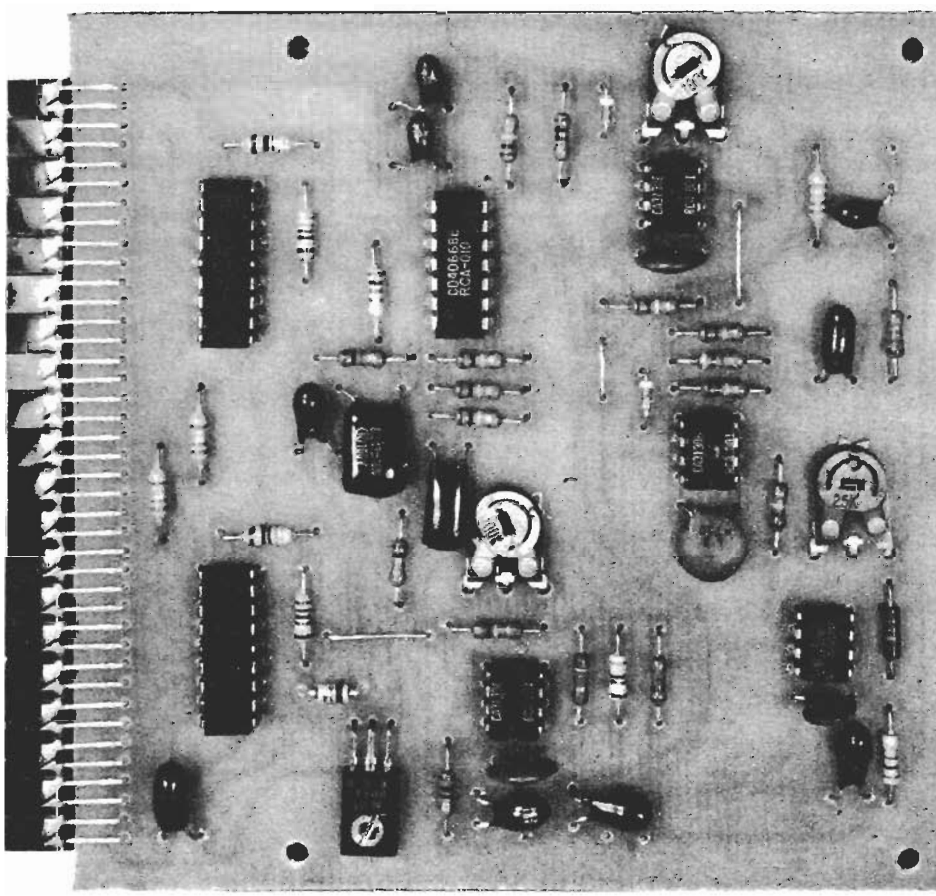


Fig. 1 'Ballistics' of a VU meter compared to conventional moving-coil meter.

THE ETI LED LEVEL meter overcomes a number of the drawbacks inherent in mechanical VU meters by replacing the meter movement with a row of light emitting diodes driven by a pair of dB LED display drivers. Twenty LEDs are used, with 3 dB between each LED, so the total dynamic range displayed is 60 dB. The circuit monitors both the true peak and the average signal level and displays both simultaneously. The difference between the peak and the average voltages of a sinewave is around 3 dB, so with a sinewave applied consecutive LEDs will light. With music applied however, the difference between the two LEDs will be substantially greater, depending on the transient nature of the signal applied.

Fig. 2 shows a complete circuit diagram for the LED level display. The input is fed first to a prescaling amplifier formed by an LM301 op-amp, IC1, and the associated passive components. This stage has adjustable gain, set by the preset RV1 that allows the 0 dB point to be set to the desired reference voltage. This will be covered in greater depth later, in the setting up procedure. The output of the prescaling stage is connected to the input of a full wave rectifier formed by IC2 and its associated components. The output of the full wave rectifier is fed to an averaging filter formed by R9 and C6, and to a peak follower formed by IC3 and associated components. The peak follower has a rapid attack/slow decay characteristic so that it responds quickly to any transients but decays slowly so the transient can be seen easily on the display. The outputs from the peak follower and the averaging filter are connected to the inputs of two CMOS analogue switches.

The outputs of these switches are connected together and go to the input of the LED display. Two more CMOS switches are used to form a square wave oscillator. This oscillator has out of phase outputs used to drive the signal-carrying analogue switches alternately off and on at a relatively high frequency. When the switch connected to the output of the averaging filter is on, the average signal voltage is connected to the input of the LED display. This switch is subsequently turned off by the oscillator and the other analogue switch turned on, connecting the output of the peak follower to the LED display. So, only one of the two LEDs is on at any ins-



Full-size reproduction of the completed project. Note the components are laid flat to permit close stacking of two boards for a stereo display.

tant, but the rapid switching speed between them and the persistence of vision make them both appear to be on.

Input signals to the LED display portion of the circuit are fed simultaneously to the LM3915 driving the upper 30 dB display and via a voltage amplifier to the lower 30 dB display.

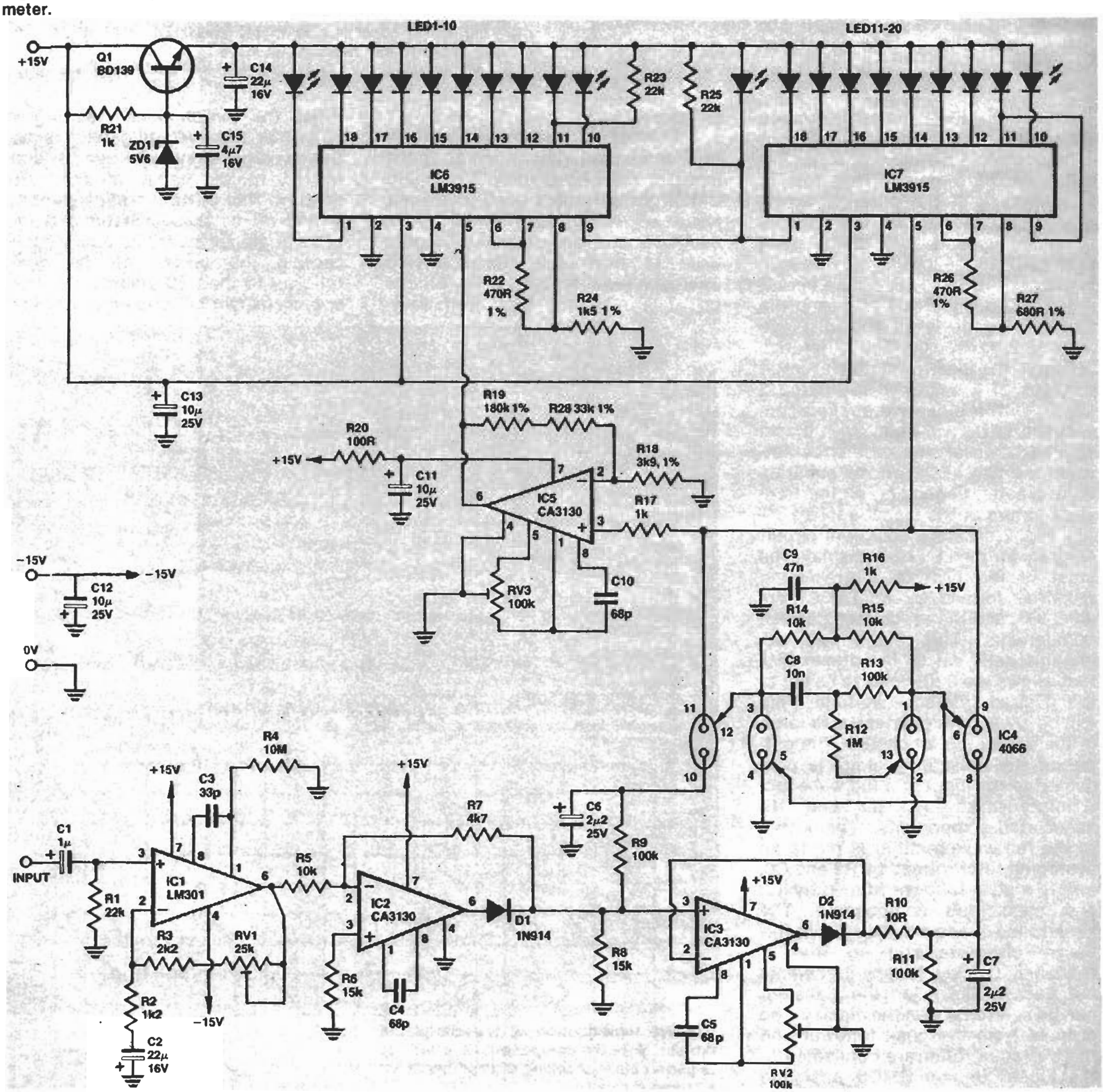
The resistors R26 and R27 set the reference voltage of IC7 at 3.1 V and 30 dB below this voltage is

$$\frac{-30}{20} = \log\frac{x}{3.1}, \text{ or } 98 \text{ mV}.$$

Now, the top LED driven by IC6 must correspond to this voltage, so the required gain around IC5 is 5.34/98 mV or 54.6. The values of the resistors R19 and R18 set this gain at (180 + 33 + 3.9)/3.9 or around 56 which is a good enough approximation, amounting to an error of less than 0.5 dB.

Internally, the LM3915 consists of a string of comparators; each one compares the input signal to a reference voltage it derives from a ten-way protential divider (see Fig. 3). The accuracy of the LM3915 is determined by these internal resistors and is therefore very good. To ensure the display is accurate over the entire 60 dB range it is only necessary to ensure that the changeover from one LM3915 to the other is accurate. Resistors R18, R19, R22, R24, R26, and R27 have been

Fig. 2 Circuit diagram of the LED Level meter.



specified as 1% tolerance types for this reason.

Transistor Q1 forms a simple voltage regulator delivering 5V to the LEDs. This decreases the power dissipation in the LM3915s. The current consumption from the positive rail is around 100 mA while the negative rail needs only several milliamps. If the display is to be used from an existing power supply in a preamplifier for example, care should be taken to ensure that the relatively high positive rail current does not upset the preamplifier performance.

Construction

Start construction by mounting the LEDs. This is by far the most difficult part of the project. The LEDs must be inserted evenly and with equal heights, and this is not easy. Furthermore, the LEDs must be inserted the right way around. The longer of the leads represents the anode of the LED. Check the orientation of each LED against the overlay, before soldering.

Now all the other components can be mounted. The order of mounting is not really important although it is good general practice to solder the passive components first (resistors and capacitors). And then solder the ICs and transistors. The presets are mounted against the circuit board and this is best done by bending their leads at right angles first, and then soldering. Similarly, many of the larger capacitors may have to be folded against the board. Be careful with the orientation of all polarised components, such as transistor Q1 and the electrolytic and tantalum capacitors. Tantalum capacitators are very intolerant of reverse biasing.

Setting Up Proceedure

Once all the components have been mounted on the pc board and checked, the unit can be switched on. Ensure that the power supply you are using has sufficient current capability for the positive rail and that it is correctly connected to the supply points on the circit board. If the input is touched with a finger two LEDs should light and move up the display. If all is well the dc offsets can now be adjusted. The preset RV2 adjusts the dc offset of the peak follower. This will be adjusted to equal the dc level of the average filter, i.e. that from the output of the full wave rectifier. The overall dc offset can be nulled by

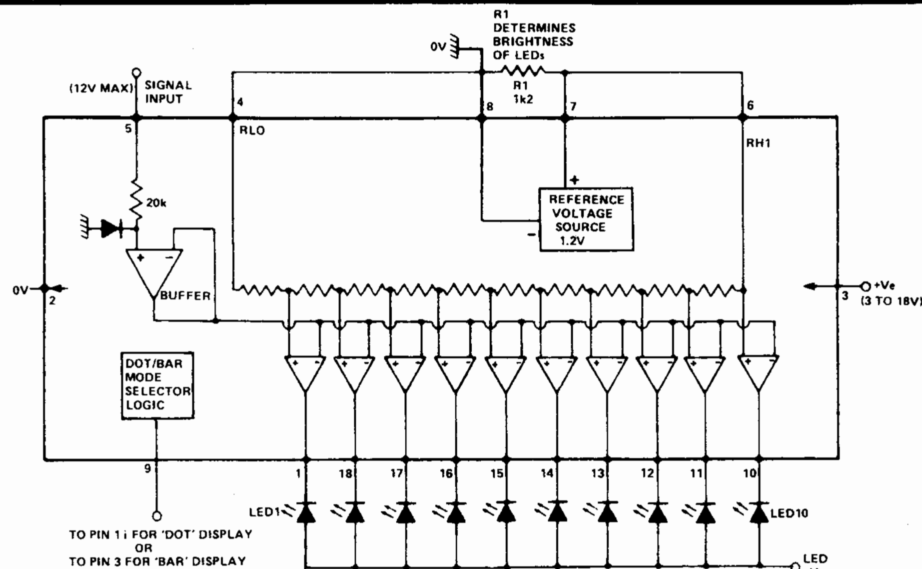
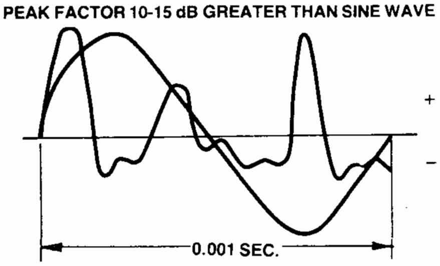


Fig. 3 Internal block diagram of the LM3915.



A typical 'music' signal may have a completely different peak-to-average ratio compared to a sinewave, and the peaks are often not symmetrical in amplitude about the zero axis. The duration of peaks may be as short as 50 microseconds.

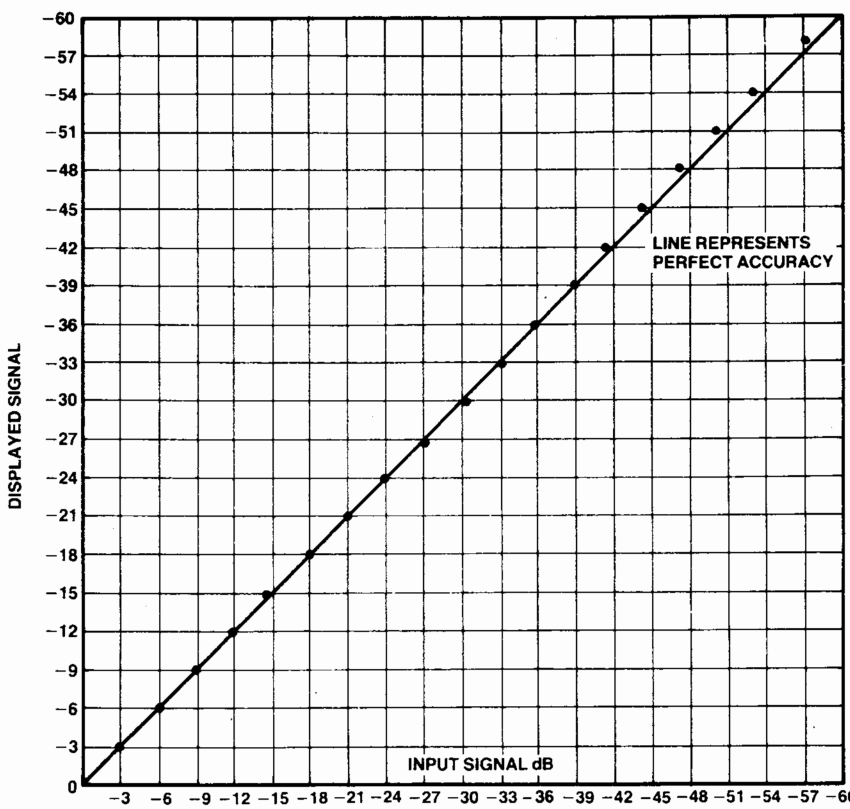
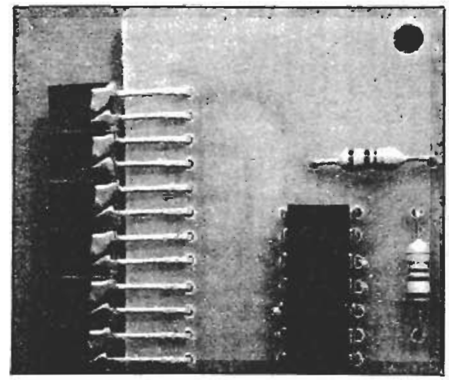


Fig. 4 Accuracy of the ETI LED level meter display (dots) compared to 'perfect accuracy' (line).

RV3.

First connect the input of the LED level meter to ground on the board. This ensures that no signal voltage will be present when the adjustments are made. Now turn both RV2 and RV3 fully clockwise; both LEDs should run off the bottom of the display. Turn RV3 slowly counterclockwise until the second LED from the bottom has just turned on. If RV2 is now turned counterclockwise also, a second LED will light on the display. This is the peak level LED. Adjust RV2 to superimpose this LED onto the second bottom LED. Now adjust RV3, turning it clockwise again until the LED has just run off the bottom of the display.

The final stage in the setting up procedure is to align the meter for the appropriate 0 dB level. Preset RV1 varies the gain of the prescaling amplifier stage formed by IC1. Adjustment of this preset will vary the input voltage required to light the top LED between 260 mV and 2.5 V. If your application requries 0 dB to be a higher voltage than 2.2 V, use a potential divider at the input to decrease the input signal voltage. If more gain is required increasing the value of the preset from 25k to 100k will decrease the necessary input voltage to around 70 mV, which should be sufficient for most applications.



Close-up of the pc board showing orientation of the LEDs. IC7 at lower right.

HOW IT WORKS

The input stage consists of a variable gain amplifier formed by IC1 and its associated components. This is a conventional IC amplifier circuit in which the gain is determined by the values of the components RV1, R3 and R2. Specifically:

$$A_V = \frac{R2 + R3 + RV1}{R2}$$

So the bigger the value set on RV1, the greater the gain. Capacitor C2 has the effect of decreasing this gain for very low frequencies, or dc, decreasing the dc offset on the output.

The second stage is the full wave rectifier or 'absolute value generator'. As mentioned in the text, most fully wave rectifiers requrie more than a single op-amp, so this stage will be of use in any application requiring a full wave rectifier with minimum component count. For negative-going signals the stage functions as an inverting amplifier with a gain of 0.5. This is determined by the values of R5 and R7. when the input signal goes positive the output is driven hard against its negative supply voltage, which in this case is 0 V. So the output stage is turned off, and has a relatively high output impedance. In this state the resistors R5, R7 and R8 form a potential divider and connect the input signal to the output directly. Again, the output voltage is one half of the input voltage. In order for this circuit to work, the output stage in the op-amp must be CMOS so that the output can go completely to 0V and have an output impedance high enough not to short out the signal voltage from the potential divider. This is the reason the CA3130 is used. Furthermore, this is a relatively fast device which ensures that the full wave rectifier will have a frequency response that covers the entire audio spectrum. The one disadvantage of the circuit is that it requires a high load impedance since the output signal for positive-going input signals is obtained from the potential divider and not from the op-amp itself. In this application the load is around 100k (R9) which causes negligible error.

The output of the full wave rectifier is fed simultaneously to an average filter formed by R9 and C6, and to the peak hold circuit formed by IC3 and its associated components. The peak hold circuit is really nothing more than a 'precision diode' that charges a capacitor to the peak voltage. The precision diode is formed by including a conventional signal diode in the feedback loop of a fast op-amp. If an input signal is applied which is less than the forward voltage drop of the diode, the stage is effectively in open loop gain (around 320,000 for the CA3130). The output voltage will rise very quickly, turning the diode on. Since the output of the diode is connected to the inverting input of the op-amp, the stage functions with unity gain once the diode has been turned on. Capacitor C5 ensures stability of the stage while preset RV2 allows adjustment of dc offsets due to this stage. The output of the peak hold circuit charges capacitor C7 through resistor R10. The combination of R10 and C7 defines the attack rate of the peak detector.

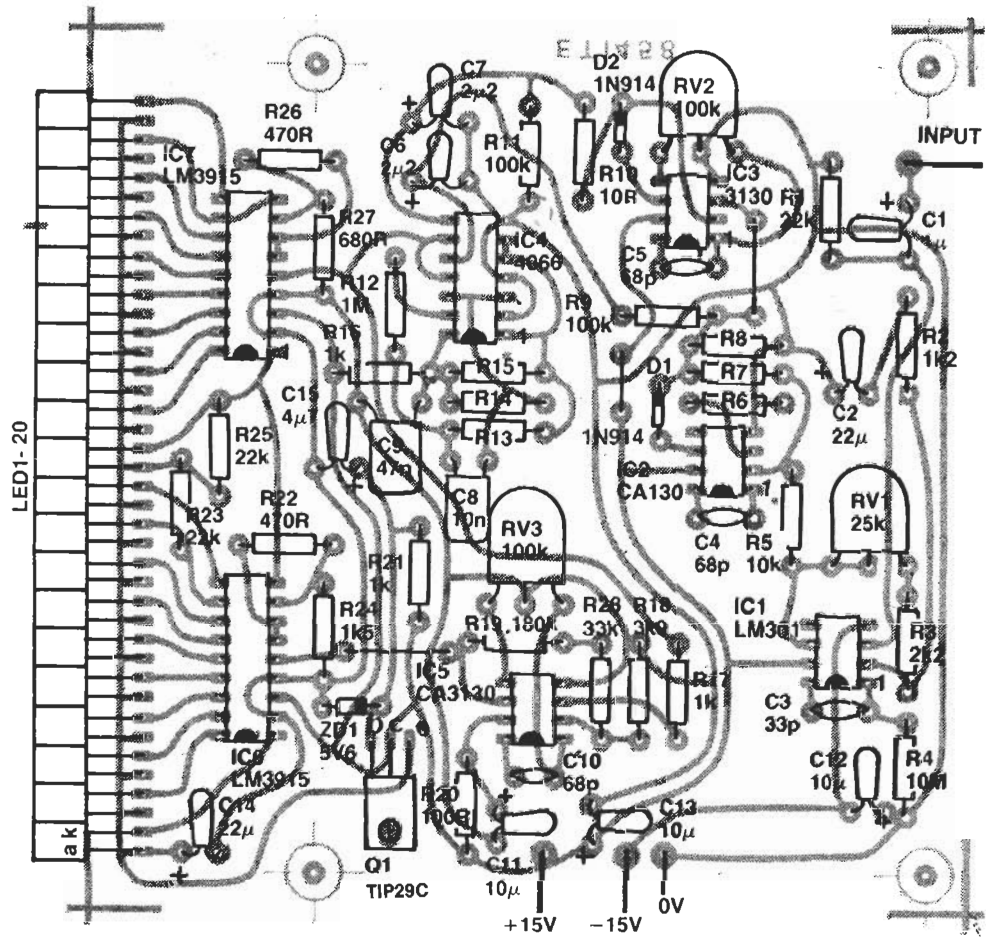
As shown, the value of R10 is 10 ohms and this is small in comparison to the output impedance of the CA3130, but is included in case some applications requrie the peak detector to have a slower attack rate. With the values shown, the LED level meter will display single 50 uS pulses accurately and this is entirely adequate for any audio application.

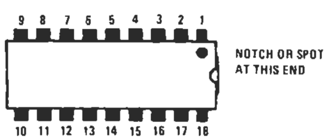
Resistor R11 discharges the capacitor and its value of 100k dictates a decay rate of around one second. This gives the level meter its rapid attack, slow decay characteristic and enables even short transients to be spotted.

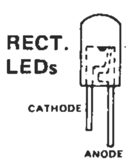
As explained in the text, both the average and the peak levels of the signal are displayed simultaneously. This is accomplished by multiplexing the outputs of the peak and average detectors. This is done by switching between the output of these two circuits at a relatively high frequency (say a few hundred Hertz). In the circuit, this is done with CMOS transmission gates. The 4066 was chosen mainly because its on resistance is a little lower than the older 4016 and this enables the remaining two gates in the package to be used as the driving oscillator. The oscillator is formed by resistors R12 to R15 and capacitor C8, with the associated two transmission gates. The frequency of the oscillator is determined by the values of R13 and C8 at around 150 Hz.

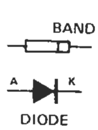
IC5 functions as an amplifier stage as discussed in the text. Once again dc offset adjustment is provided, this time by RV3. Capacitor C10 provides the necessary compensation to ensure stability. Details of the two LED drivers and the amplifier formed by IC5 are in the main text.

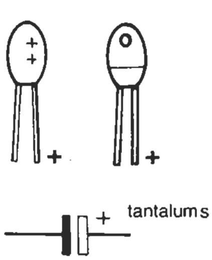
The transistor Q1 and the associated components R21, C15 and ZD1 form a simple 5V regulator to power the LM3915s. Capacitor C16 is essential for stability of the LED drivers and must be mounted close to the LEDs.











PARTS LIST

Resistors (all ½ W, 5% unless marked otherwise

R1,23,25	22k
R2	1k2
R3	2k2
R4	10M
R5,14,15	10k
R6,8	15k
R7	4k7
R9,11,13	100k
R10	10R
R12	1M
R16,17,21	1k
R18	3k9 1%
R19	180k 1%
R20	100R
R22,26	470R 1%
R24	1k5 1%
R27	680R 1%
R28	33k 1%
RV1	25k min trimpot
RV2, RV3	100k min trimpot

Capacitors

C1	1u/6V tant.
C2,14	22u/16V tant.
C3	33p ceramic
C4,5,10	68p ceramic
C6,7	2u2/25V tant.
C8	10n greencap
C9	47n greencap
C11,12,13	10u/25 V tant.
C15	4u7/16V tant.

Semiconductors

IC1	LM301, 8-pin DIL
IC2,3,5	CA3130, 8-pin DIL
IC4	4066
IC6,IC7	LM3915
D1,D2	1N914 or sim
ZD1	5V6 zener diode
Q1	TIP29C
LED1-20	Siemens LD80-2 or sim.

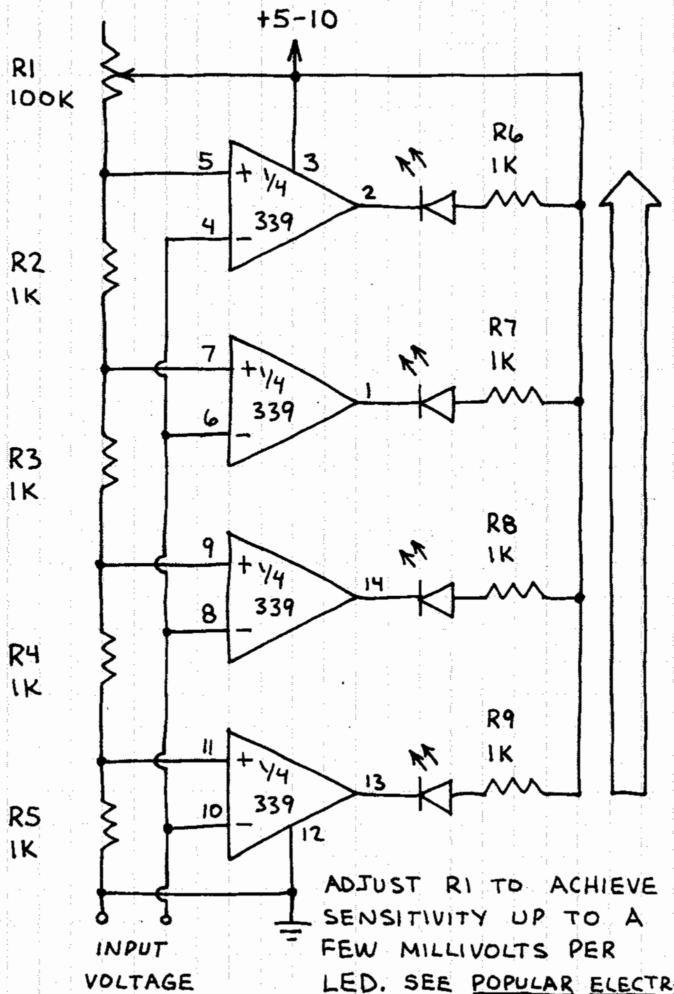
Miscellaneous

pc board (double-sided); one bolt and nut.

QUAD COMPARATOR (CONTINUE

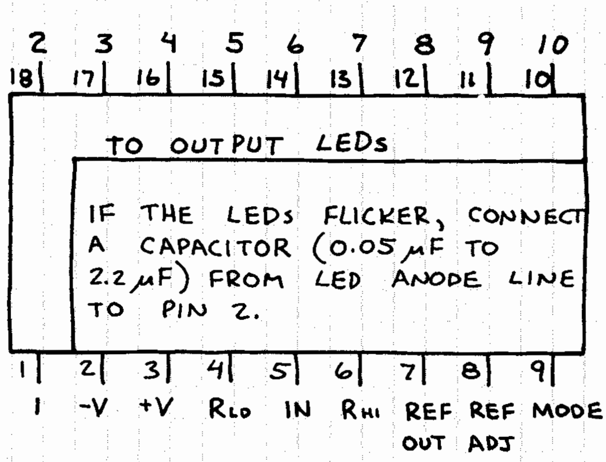
LM339

LED BARGRAPH READOUT

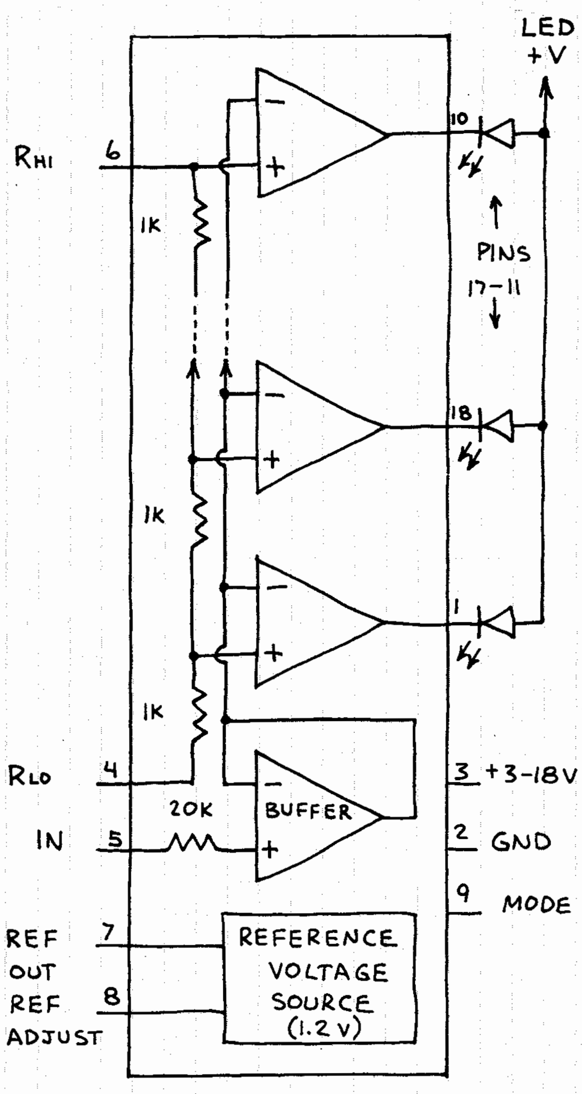


ADJUST R1 TO ACHIEVE SENSITIVITY UP TO A FEW MILLIVOLTS PER LED. SEE <u>POPULAR ELECTRONIC</u> (SEPT. 1978, pp. 92-97).

DOT/BAR DISPLAY DRIVER
LM3914N

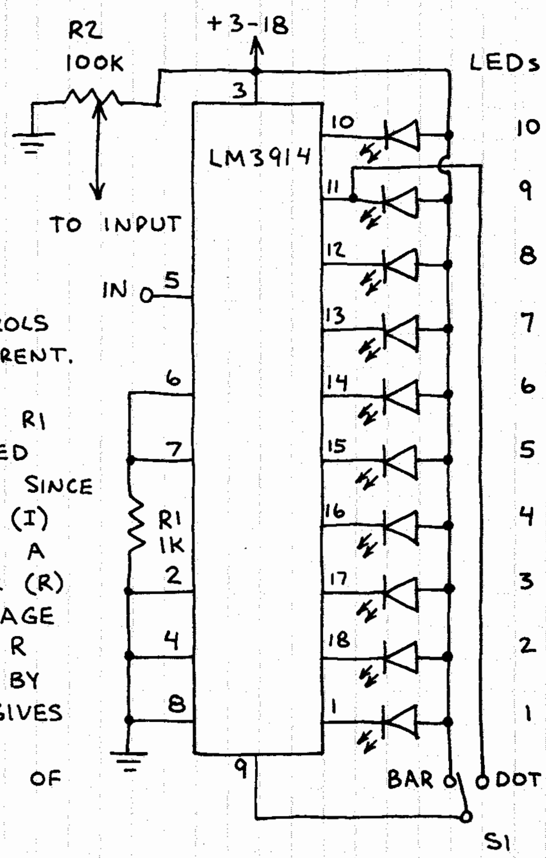


ONE OF THE MOST IMPORTANT CHIPS IN THIS NOTEBOOK. LIGHTS UP TO 10 LEDs (BAR MODE) OR 1-OF-10 LEDs (DOT MODE) IN RESPONSE TO AN INPUT VOLTAGE. CHIP CONTAINS A VOLTAGE DIVIDER AND 10 COMPARATORS THAT TURN ON IN SEQUENCE AS THE INPUT VOLTAGE RISES. HERE'S A SIMPLIFIED VERSION OF THE CIRCUIT:



RHI AND RLO ARE THE ENDS OF THE DIVIDER CHAIN. THE REFERENCE VOLTAGE OUTPUT (REF OUT) IS 1.2–1.3 VOLTS. CONNECT PIN 9 TO PIN 11 FOR DOT MODE OR +V FOR BAR MODE.

DOT/BAR DISPLAY

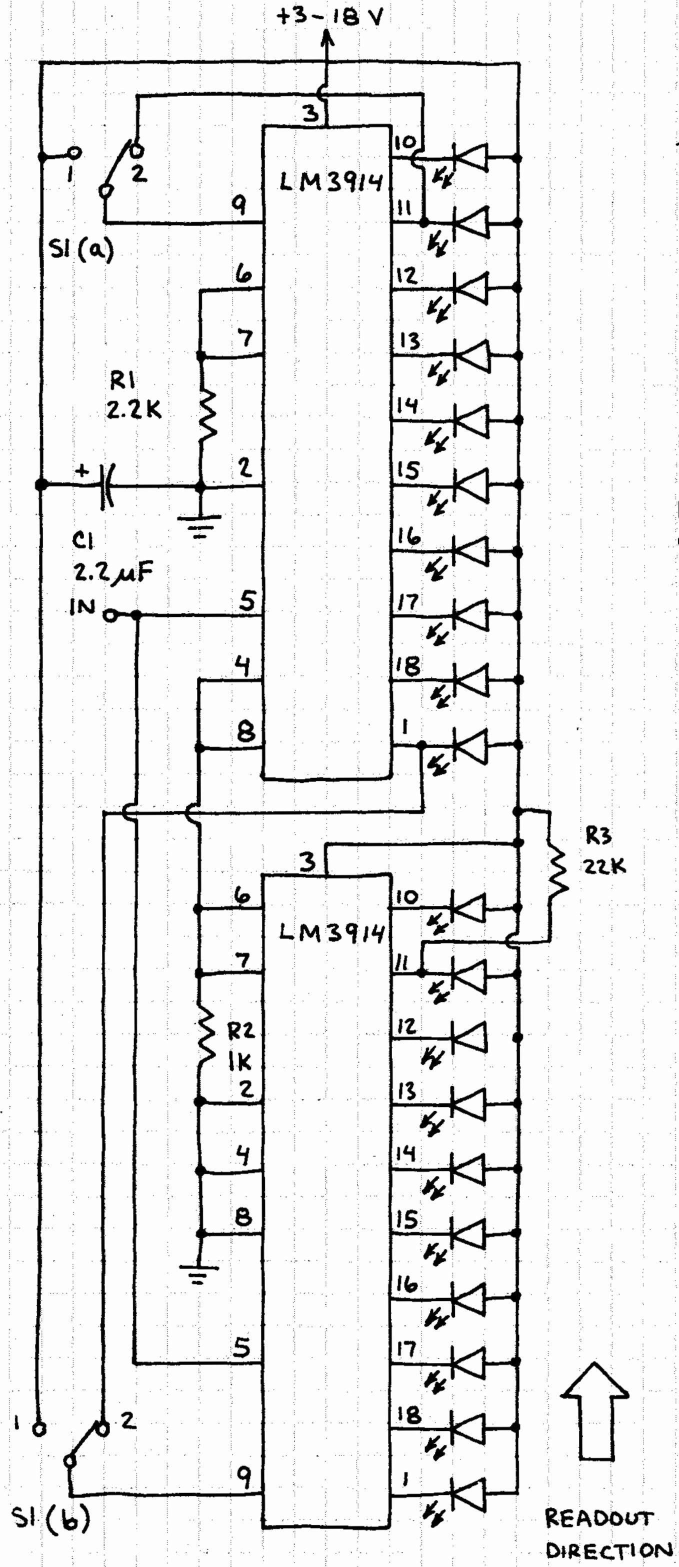


R1 CONTROLS LED CURRENT. CURRENT THROUGH R1 IS $\frac{1}{10}$ LED CURRENT. SINCE CURRENT (I) THROUGH A RESISTOR (R) IS VOLTAGE ACROSS R DIVIDED BY R, 1K GIVES AN LED CURRENT OF 10 mA.

WHEN +V = +3–18 VOLTS, THE READOUT RANGE IS 0.13 — 1.30 VOLTS. TO CHANGE RANGE TO 0.1–1.0 VOLT (0.1 VOLT PER LED), INSERT A 5K POTENTIOMETER BETWEEN PINS 6 AND 7. CONNECT VOLTMETER ACROSS PINS 5 AND 8 AND ADJUST R2 FOR 1 VOLT AT PIN 5. THEN ADJUST 1K POT UNTIL LED 10 GLOWS. REPEAT THIS PROCEDURE FOR 0.1 VOLT AT PIN 5 AND LED 1. OK TO REPLACE THE 1K POT WITH A FIXED RESISTOR OF THE PROPER VALUE.

DOT/BAR DISPLAY DRIVER (CONTINUED)
LM3914N

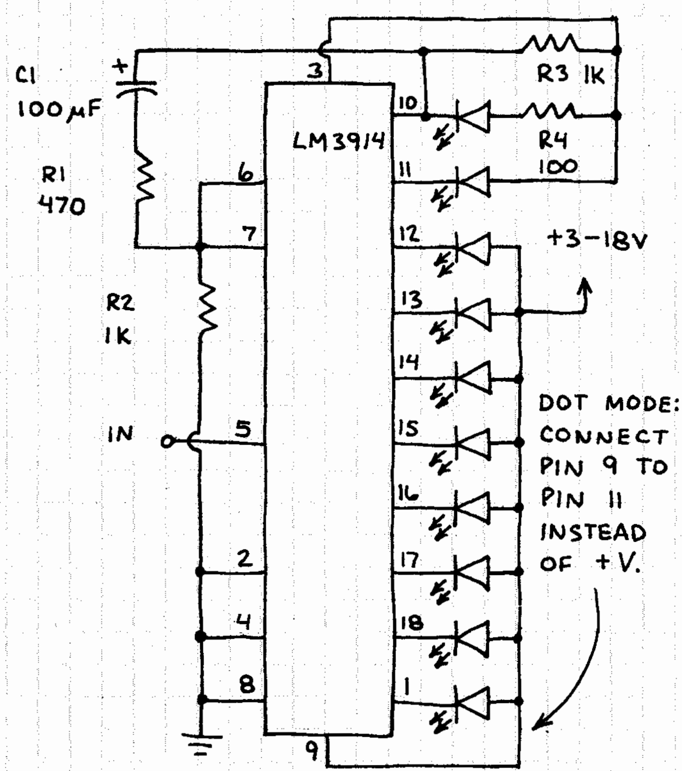
20-ELEMENT READOUT



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 <u>ON</u> 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.

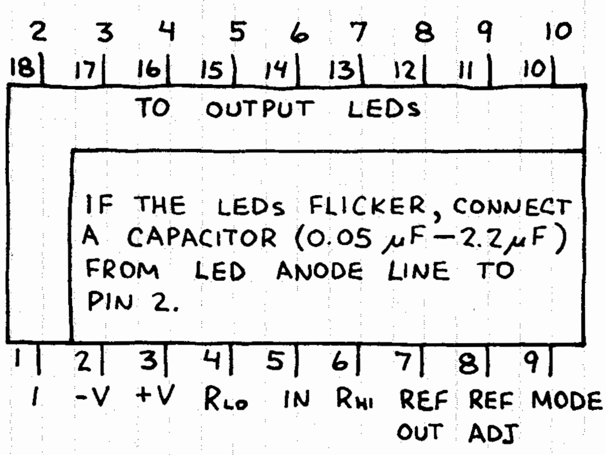
FLASHING BAR READOUT



'E CIRCUITS ON THIS PAGE
E ADAPTED FROM NATIONAL
MICONDUCTOR'S LM3914 LITERATURE.
I WORK WELL.

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

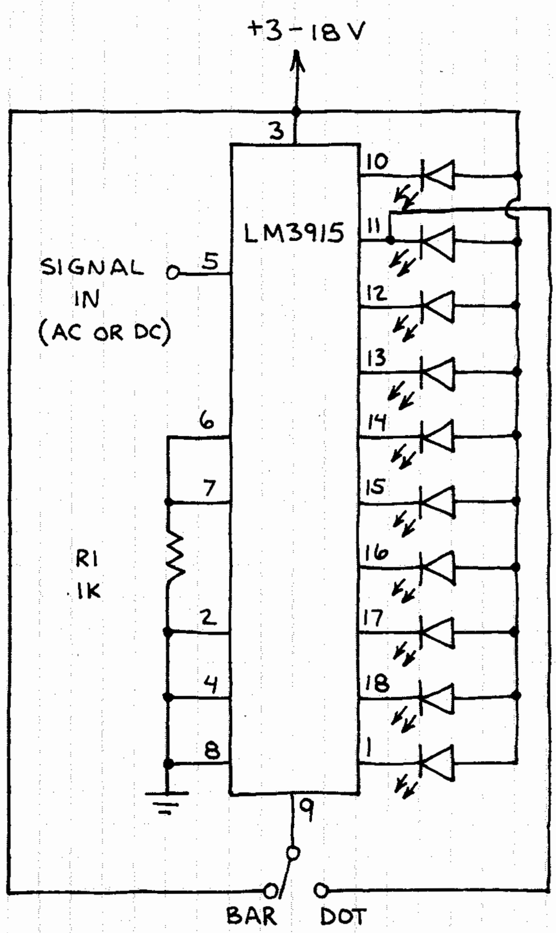
DOT/BAR DISPLAY DRIVER
LM3915N



LOGARITHMIC VERSION OF THE LM3914N. THE LM3914N USES A STRING OF 1K RESISTORS AS A VOLTAGE DIVIDER WITH LINEARILY SCALED DIVISIONS. THE VOLTAGE DIVIDER RESISTORS OF THE LM3915N ARE SCALED TO GIVE A −3dB INTERVAL FOR EACH OUTPUT. THIS CHIP IS IDEAL FOR VISUALLY MONITORING THE AMPLITUDE OF AUDIO SIGNALS.

SEE LM3914N FOR EXPLANATION OF PIN FUNCTIONS.

0 TO −27 dB DOT/BAR DISPLAY



LED DISPLAY

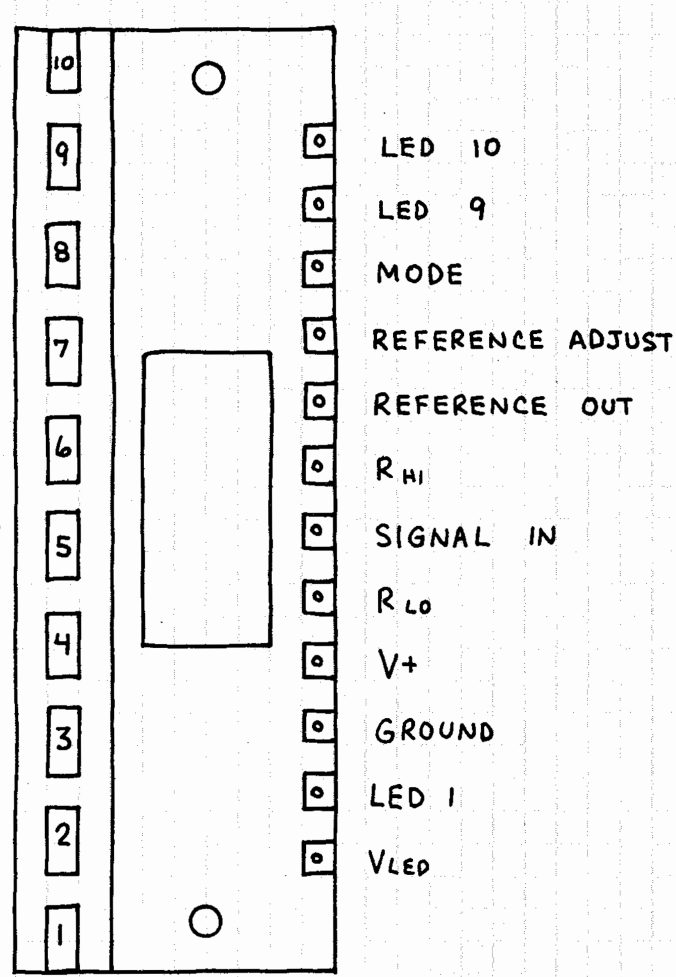
		BAR MODE*
0 dB	(FULLSCALE OR FS)	● ● ● ● ● ● ● ● ● ●
−3 dB	(.707 FS)	● ● ● ● ● ● ● ● ● ○
−6 dB	(.500 FS)	● ● ● ● ● ● ● ● ○ ○
−9 dB	(.354 FS)	● ● ● ● ● ● ● ○ ○ ○
−12 dB	(.250 FS)	● ● ● ● ● ● ○ ○ ○ ○
−15 dB	(.177 FS)	● ● ● ● ● ○ ○ ○ ○ ○
−18 dB	(.125 FS)	● ● ● ● ○ ○ ○ ○ ○ ○
−21 dB	(.088 FS)	● ● ● ○ ○ ○ ○ ○ ○ ○
−24 dB	(.062 FS)	● ● ○ ○ ○ ○ ○ ○ ○ ○
−27 dB	(.044 FS)	● ○ ○ ○ ○ ○ ○ ○ ○ ○

* OK TO USE DOT MODE.

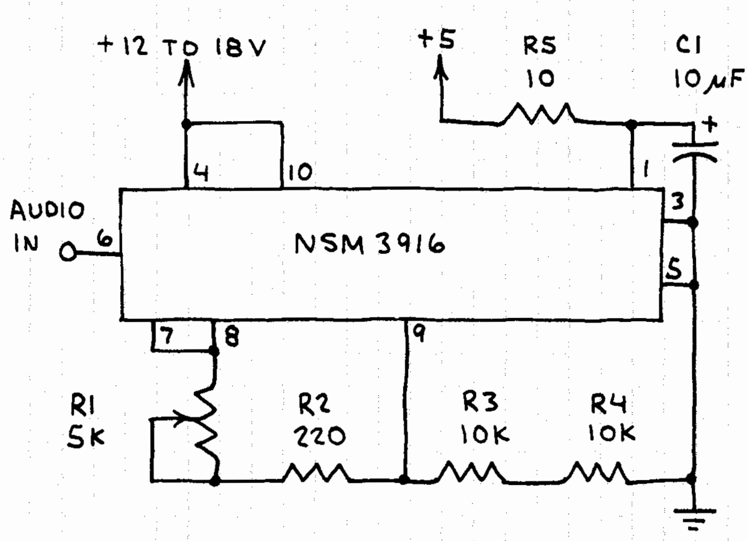
THE INPUT SIGNAL CAN BE CONNECTED DIRECTLY TO PIN 5 WITHOUT RECTIFICATION, LIMITING OR AC COUPLING. SEE THE LM3914N FOR MORE IDEAS AND TIPS.

LED VU METER MODULE
NSM3916

INCLUDES LED BARGRAPH DRIVER AND LEDs ON SAME SUBSTRATE. MAKE MODE PIN HIGH FOR BAR-GRAPH MODE. LEAVE OPEN FOR DOT MODE. SEE DATA SUPPLIED WITH MODULE FOR MORE INFORMATION. ALSO, SEE LM3914 AND LM3915.

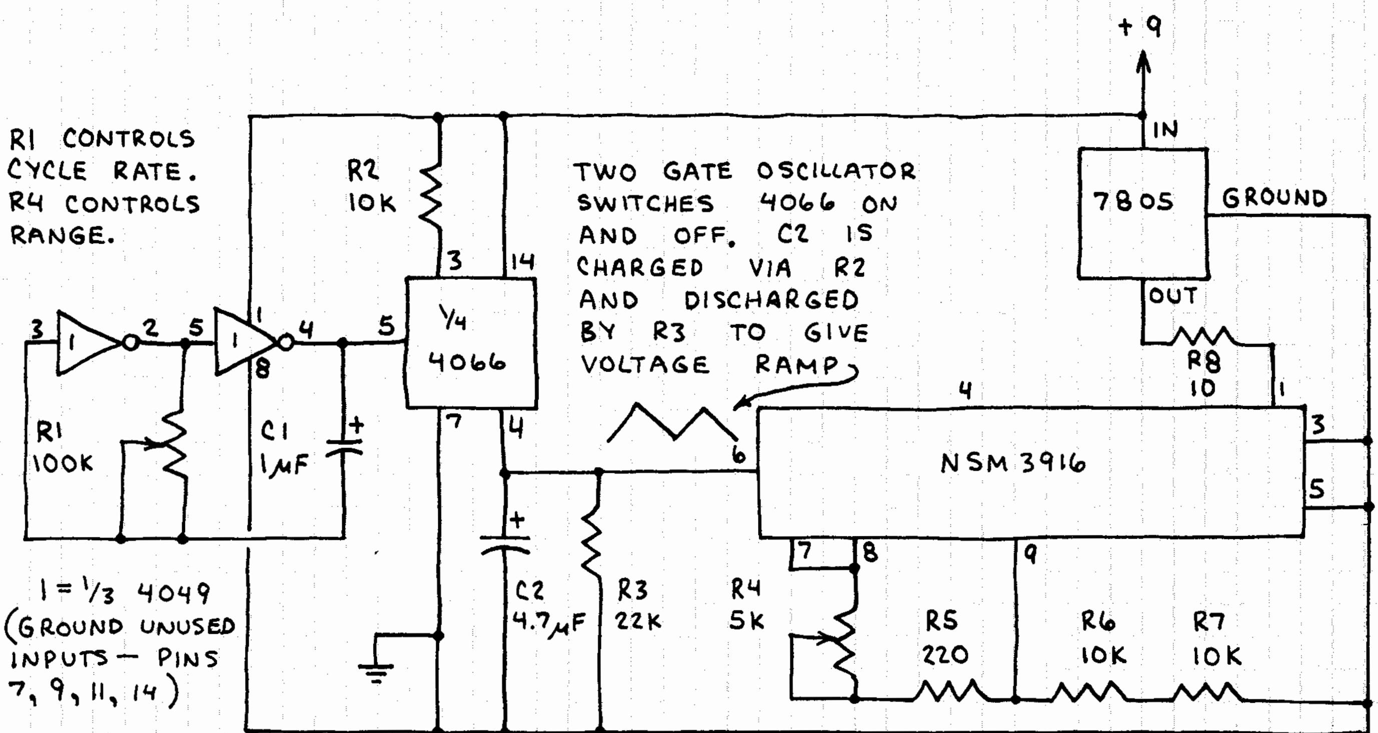


VU BAR GRAPH DISPLAY



BACK AND FORTH FLASHER

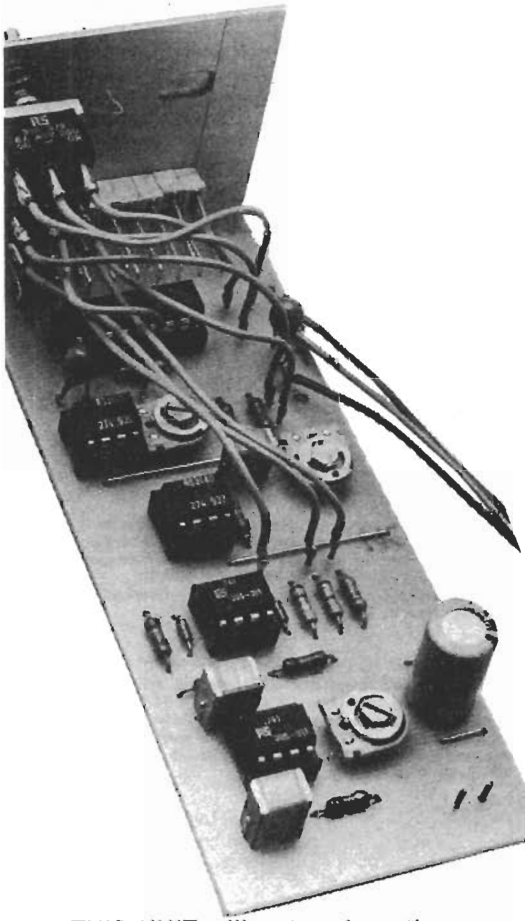
R1 CONTROLS CYCLE RATE. R4 CONTROLS RANGE.



1 = 1/3 4049 (GROUND UNUSED INPUTS — PINS 7, 9, 11, 14)

LED VU Meter

This meter can be adapted to various levels of operation and is an excellent way to watch what goes on in those secretive shielded cables.



THIS UNIT will not replace the conventional VU or PPM meter; no LED display could fulfill the spec. However, with an output in 3 dB steps and a choice of a dot or bar display, it will make a useful and attractive addition to any audio system.

5 Into 1 = 10

With the log function achieved directly inside IC5, the use of four separate op-amps to condition the signal may seem extravagant. However, the circuit design precludes the use of a conventional quad op amp package like the 324 and the final circuit exploits the good, all-round, economical performance of the 741s and the extremely high input impedance of the 3140s. The display consists of ten LEDs and these can be illuminated in a dot or bar format. Selection is by a SPDT switch, or a wire link may be permanently connected. Sensitivity of the unit is high. The gain of the first amplifier stage is adjustable and a full scale reading can be obtained with an output of just a few millivolts.

To keep down cost and avoid complex circuitry, a half-wave rectifier has been used. The meter has switchable resistors giving a peak programme response with fast attack and slow decay and a volume unit response with slower approximately equal response times. The response characteristics for each mode may easily be changed by selection of a few resistors and have little interacton with each other.

Construction And Setting Up

Use of our PCB makes construction simplicity itself and results in quite a compact and attractive unit. The PCB has been designed to accommodate stackable rectangular LEDs as shown in our photos. However, any type and colour of LEDs may be used. There are only four wire links to be inserted and the remaining components may be inserted as they come to hand. It is good practice to leave the semiconductors until last and use of sockets for the ICs makes substitution for fault-finding easy. Although ICs 3 and 4 feature FET input stages, these are well protected and no special handling precautions are required.

When completed, the unit may be set up by short-circuiting the input and, with a DC-coupled 'scope or sensitive voltmeter connected to the output (pin 6) of IC4, adjusting RV2 until the output reaches 0 V. Then apply the maximum signal you wish to indicate and with the unit set to VU adjust RV1 for a full scale reading. Now switch to PPM and adjust RV3 until a full scale reading is just obtained.

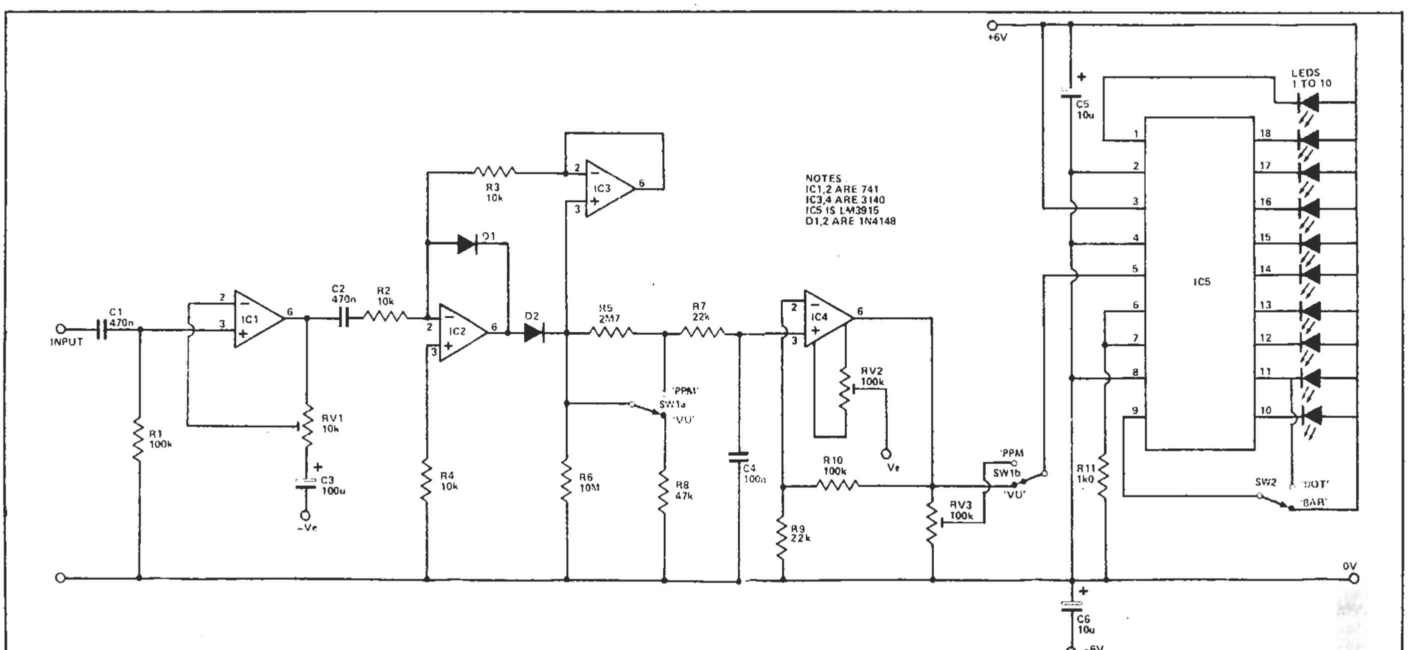


Fig. 1. The circuit diagram.

The unit will cover a wide range of input levels, though for very high input signal levels you may have to attenuate the driving signal. A simple resistive divider will easily accomplish this. Do yourself a favour and have a peak at better VU today.

Parts List

Resistors (all ¼ W, 5%)

R1,10	100K
R2,3,4	10K
R5	2M7
R6	10M
R7,9	22K
R8	47K
R11	1K0

Potentiometers

RV1	10K min horiz. preset
RV2,3	100K min horiz. preset

Capacitors

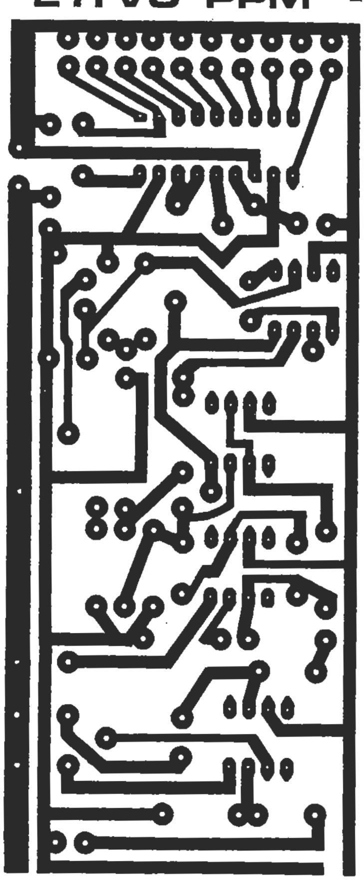
C1,2	470n polycarbonate
C3	100u electrolytic
C4	100n polycarbonate
C5,6	10u tantalum

Semiconductors

IC1,2	741
IC3,4	3140
IC5	LM3915
D1,2	1N4148
LEDs	any LED

Miscellaneous

PCB, DPDT switch, SPDT switch, connectors, etc.



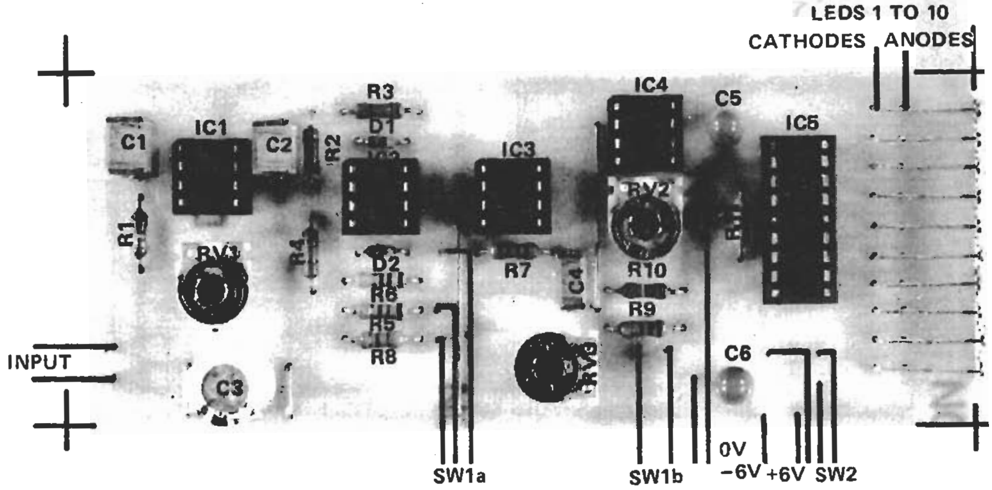


Fig. 2. Parts location.

How It Works

The circuit consists of an AC amplifier driving a half-wave rectifier whose output charges a capacitor via a switched resistor network. The charge on the capacitor is then amplified and drives the bargraph chip either directly or via a potentiometer.

The signal is input via C1 to the non-inverting input of IC1. Resistor R1 provides DC bias for IC1, which is connected as a variable gain AC-coupled amplifier. This arrangement avoids offset problems when the gain is increased which would severely limit the usefulness of the stage.

The output of IC1 drives the half-wave rectifier built around IC2. The circuitry here follows fairly conventional lines except for the inclusion of IC3 in the feedback loop. Use of this BIFET chip with its negligible input current enables high values of resistance and a low value (100n) of storage capacitance to be used with the consequent advantage of a relatively low current drive producing a high rate of voltage change. Without IC3 in circuit and with SW1a in the 'PPM' position, C4 would charge quickly via R7 but would discharge almost as fast through R7 and R3. In the final circuit, the charge path is via R7, but the discharge path is via R7 and R6, giving a fast attack and slow decay time. Diode D1 acts as a clamp for a positive input and prevents IC2 from going into saturation. In the 'VU' mode, C4 charges via R5 and R7 and discharges through R5, 7, 6, 8. The ratios of these resistors produce almost equal attack and decay times.

As any load on C4 would interfere with the time constant of the RC network, another BIFET op-amp is used as a non-inverting amplifier with a gain of about five. Offset adjustment is provided for this stage with RV2; enabling the output to be accurately zeroed. Owing to the greater insertion loss of the RC network in the 'VU' mode, RV3 is included so that a full scale reading can be obtained for the same overall input level in both modes.

The bargraph chip IC5 handles the display. The input signal from SW1b is applied to pin 5, about 1V2 gives a full scale reading. The internal resistor chain gives an output in 3 dB steps; the ten LEDs providing a 30 dB range, a ratio of 32:1. No attempt has been made to 'tailor' the response of this chip as the LM3916 with an internally set VU response should be available in the future. It will probably be a pin for pin, plug-in replacement. Current through the LEDs is set at about 10 mA by R11 and capacitors C5, 6 provide decoupling.

A power supply of plus and minus six volts is recommended. A lower voltage may restrict the output swing of IC4 making a full scale reading unobtainable in the 'PPM' mode. Too high a positive supply may result in destruction of IC5 through excessive dissipation. Absolute maximum dissipation for this chip is 660 mW. If you use a positive supply greater than 6 V then the LEDs should be returned to the positive supply via a dropper resistor or a zener diode. IC5 produces either a 'dot' or 'bar' display depending on the connection of pin 9 to pin 11 or to the positive supply. Although SW2 is shown on the circuit diagram, the connection may be made permanently with a wire link.

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ASSEMBLY (Cont'd)

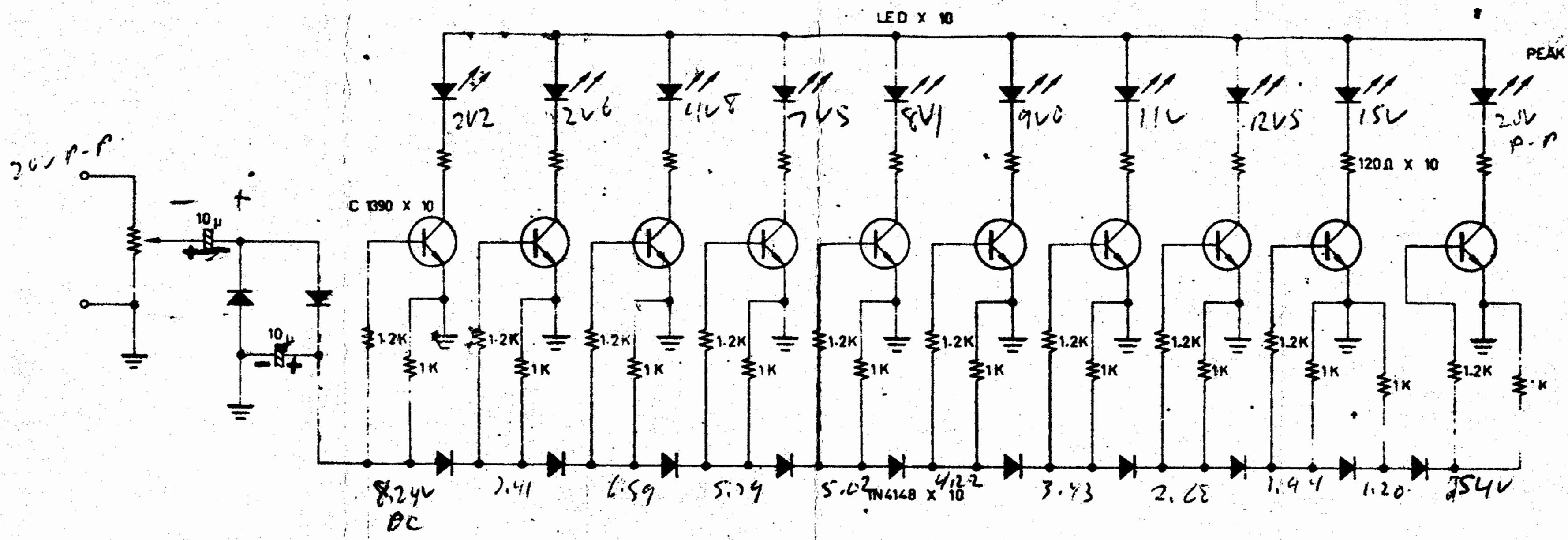
( ) Install 4 Capacitors at locations marked 10u. Match the positive (+) mark on the capacitor with the positive(+) mark on the circuit board. Solder the leads to the foil and cut off the excess lead lengths.

( ) Install 2 5K or 10K trimmers at locations marked VR.

( ) Install 6 circuit board pins at locations marked Rin + & -, Lin + & -, DC+ & DC-.

CALIBRATIONS

Turn the trimmer to fully counterclockwise.
Determine the maximum output power of your amplifier. By using the formula $V = \sqrt{PR}$, where V=A/C voltage, P=Power of amplifier, R= speaker impedance, apply an A/C source having an amplitude equals to V, to the Rin or Lin terminals. By adjusting the trimmer VR, you should see the LEDs light up one after another. Turn the trimmer slowly clockwise until the 100% LED has lit up. This will be the point where your amplifier is delivering maximum power. Then proceed with the other channel.



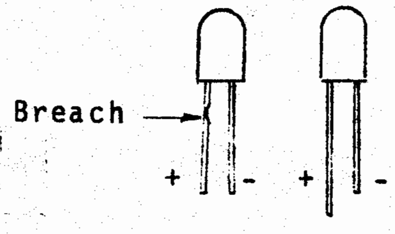


Fig. C

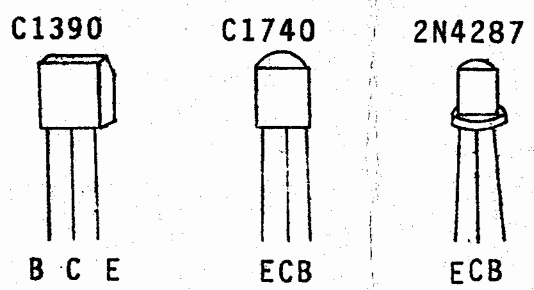


Fig. B

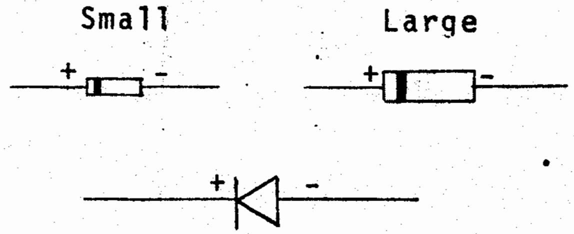


Fig. A

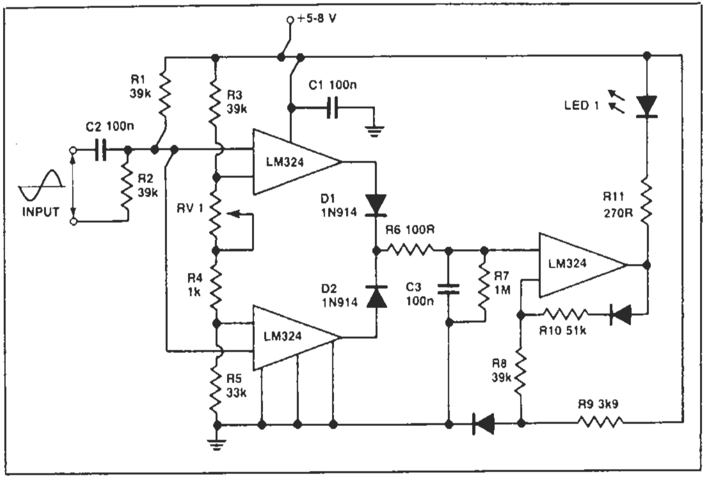
Peak Level Indicator

David Hamill

This peak level indicator is useful for recording when it is more important to know what the peak level of a signal is, rather than its average level.

VU meters are normally used for this purpose; however, you will find that the LED output of this circuit is easier to interpret and makes the recording more accurate as the distortion will be reduced.

IC1a gauges the positive peaks while IC1b does the same for the negative peaks. Both positive and negative are set by RV1. You can select any threshold from ±1 V. Whenever the input exceeds the positive of the negative level LED1 lights for about 0.1 second.



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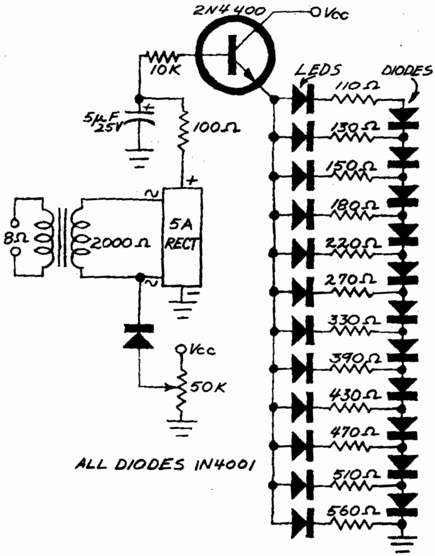
INEXPENSIVE ALTERNATIVE

Congratulations on presenting "A LED-Readout Audio Power Meter" (March 1976). I have been using a similar device for almost a year. While it may not be as accurate as the one presented in POPULAR ELECTRONICS, it costs only about $12 to build. The schematic for my "poor man's" LED VU meter is shown below. The trimmer



potentiometer and diode between the transformer and rectifier assembly are optional. If used, however, they will compensate for the initial forward drop of the diode junctions.

—*Bertram A. Thiel, Frostburg, MD.*

LED
Anode

LED
node±1

7 LED
nmon
Digits
CH

1 LED
nmon
Digits
H

ED
Anode

357
mon
ACH

LED DISPLAYS

A NEW LED ARRAY AND DRIVER FOR LEVEL METERS FROM SHARP

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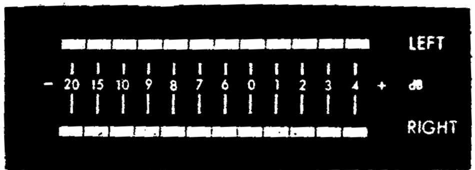
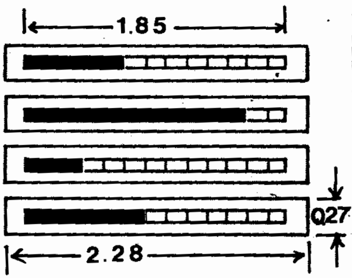
12 steps in red or tri color!

GL112M-3



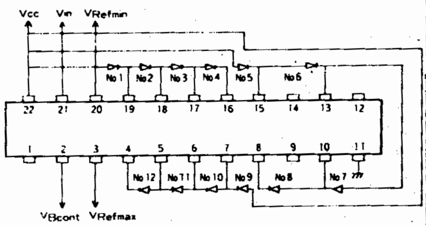
(TIPICAL USE EXAMPLE)



(DIMENSION INCH)

DRIVER

IR 2406G APPLIED CIRCUIT EXAMPLE



LED ARRAY

GL-112R3	Red, Red, Red	$5.50
GL-112N3	Green, Yellow, Red	$6.50
GL-112M2	Green, Green, Red	$6.50
GL-112G3	Green, Green, Green	$6.50

DRIVERS

IR 2406G is an I.C. specially designed to drive 12 LED. The number

LM3914 CIRCUITS

This month Ray Marston takes an in-depth look at the LM3914 IC and shows a variety of ways of using it as an indicating instrument in the car and the workshop.

IF YOU LOOK at this month's 'Car Voltmeter' project you'll notice that it is based on the LM3914 Dot/Bar Display Driver IC from National Semiconductors. We've used this IC in several projects in ETI over the last few months and are greatly impressed with the device. We regard it as a very important new tool in the field of amateur and professional electronics.

The LM3914 is a highly versatile IC that is designed to sense an analogue input voltage and drive a line of 10 LEDs to give a visual analogue display of that voltage. The unit can give either a 'Dot' or 'Bar' display of the voltage. Figure 1 illustrates the appearance of the two alternative display modes when used to indicate 5 volts on a 10 volt scale. The unit acts as an inexpensive and superior alternative to the conventional analogue-indicating moving-coil meter. It does not suffer from 'sticking' problems, is unaffected by vibration and can be used in any attitude.

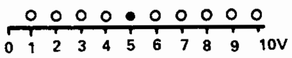


Fig. 1a. 'Dot' indication of 5 volts on a 10 volt LED scale.

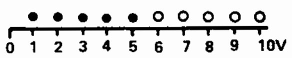


Fig. 1b. 'Bar' indication of 5 volts on a 10 volt LED scale.

The LM3914 can readily be used as the basis of a wide variety of 'indicator' and instrumentation projects in the home, the car, the workshop and in miscellaneous audio and musical projects. One of the great attractions of the device is that it is very easy to understand and use. You don't need to be a BA or MSc to be able to fully comprehend its operating principle and learn to adapt it to suit your own particular circuit requirement. We explain the essential details of the device and show several practical ways of using it in the next few pages.

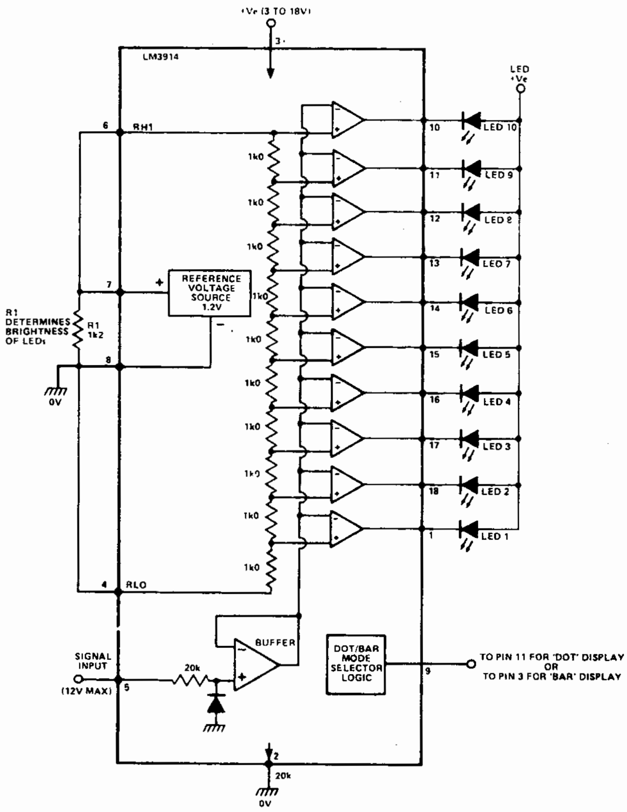


Fig. 2. Equivalent internal circuit of the LM3914 with connections for making a 0-12 volt dot or bar meter.

The LM3914: Basic Principles

Figure 2 shows the equivalent internal circuit of the LM3914 IC, together with the connections for making it act as a 10-LED voltmeter with a full-scale sensitivity of 1.2 volts.

The first point to note about the IC is that it contains a 10-resistor potential divider, wired between pins 4 and 6. The IC also contains ten voltage comparator circuits, each with its non-inverting (+) terminal taken to its own particular tap on the potential divider, but with all inverting (-) terminals of the comparators joined together and taken to the output of an input buffer amplifier. This buffer amplifier gives an output that is, for all practical purposes, identical to the voltage applied to input terminal 5 of the IC. The output of each one of the ten voltage comparators is individually available on one of the pins of the IC (pin 1 and pins 10 to 18) and is capable of 'sinking' a current of up to 30 mA.

The next point to notice is that the IC contains a built-in reference voltage source that provides a highly stable potential of 1.2 volts between pins 7 and 8. This source is of the 'floating' type, so that 1.2 volts is developed between pins 7 and 8 irrespective of whether pin 8 is tied to ground or is held at some voltage above ground. In the diagram of Fig 2 we've shown pins 7 and 8 externally connected to potential divider pins 6 and 4 respectively, so in this particular case 1.2 volts is developed across the 10-resistor potential divider network of the IC.

The final point to notice about the IC is that it contains an internal logic network that can be externally programmed to give either a 'dot' or a 'bar' display or action from the outputs of the ten voltage comparators. In the 'dot' mode, only one of the ten outputs is enabled at any one time. In the 'bar' mode all outputs below and including the highest 'energised' output are enabled at any one time.

At this point, let's put together the basic information that we have already learned about the LM3914 and the circuit of Fig 2, and see how the entire circuit functions. Let's assume that the logic is set for 'bar' mode operation.

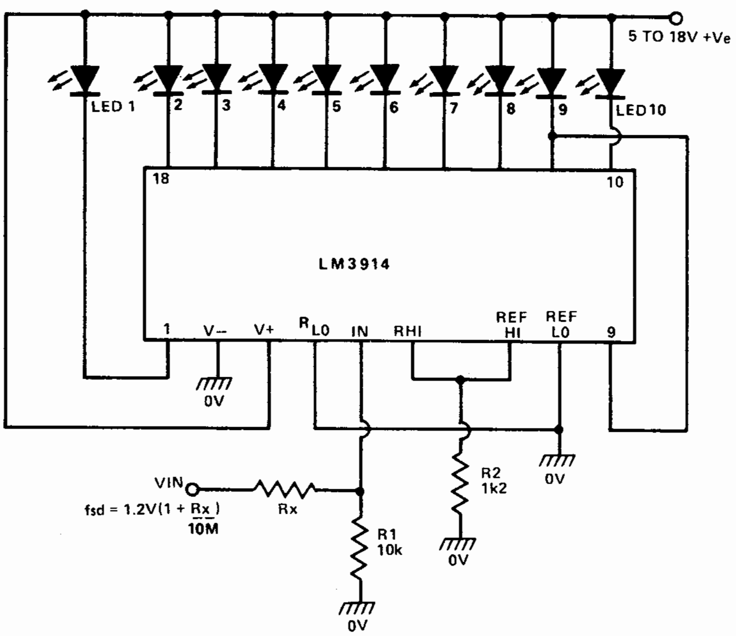


Fig. 3. 1.2 V to 1000 V FSD 'Dot' mode voltmeter.

We already know that a reference of 1.2 volts has been set up across the 10-resistor divider, with the low (pin 4) end of the divider tied to ground (zero) volts. Consequently, 0.12 V is applied to the '+' input of the lowest voltage comparator, 0.24 V to the next, 0.36 V to the next and so on. If we now apply a slowly rising voltage to input pin 5 of the IC, the following sequence of events takes place:

When the input voltage is zero, the outputs of all ten voltage comparators are high and none of the external LEDs are turned on. As the input voltage is slowly increased it eventually reaches and then rises above the 'reference' 0.12 volts value of the first comparator, which then turns on (it's output conducts) and energises LED 1. As the input is further increased it eventually reaches the 0.24 V of the second comparator, which then also turns on and energises LED 2. At this stage both LED 1 and LED 2 are on. As the input voltage is further increased progressively more and more comparators and LEDs are turned on, until eventually, when the input rises to and then exceeds 1.2 volts, the last comparator and LED 10 turn on, at which stage all ten LEDs are illuminated.

A similar kind of action is obtained when the LM3914 logic is set for 'dot' mode operation, except that only one LED turns on at any given time. At zero volts, none of the LEDs are on. At voltages above 1.2 (or whatever reference value is applied to the last comparator) only LED 10 is turned on.

At this stage, then, you can see that the LM3914 is a reasonably easy device to understand. Let's move on, then, and look at some of the finer details of its operation.

The LM3914: A Closer Look

There is one component in Fig 2 that we have not yet mentioned and that is R1. This resistor is wired between the pin 7 and pin 8 output terminals of the reference voltage source and determines or 'programmes' the ON currents of the LEDs. The on current of each LED in fact approximates ten times the output current of the reference voltage source. The reference can supply up to 3 mA of current, so the LEDs can be programmed to pass currents up to 30 mA.

Remembering that the reference develops 1.2 V, you can see that if a total resistance of 1k2 is placed across the pin 7 — pin 8 terminals the reference will pass 1 mA and each LED will pass 10 mA in the ON mode. In Fig 2 the total resistance across the reference terminals is equal to the 1k2 of R1 shunted by the 10k of the ICs internal potential divider, so the reference actually passes about 1.1 mA and the LEDs conduct 11 mA. If R1 were removed from the circuit the LEDs would still pass 1.2 mA due to the resistance loading of the internal potential divider on pins 7 and 8.

You'll notice from the above description that the IC can pass total currents up to 300 mA when it is used in the 'bar' mode with all ten LEDs on. The IC has a maximum power rating of only 660 mW, so there is a danger of exceeding this rating when the IC is used in the 'bar' mode. We'll return to this point later.

The LM3914 IC can be powered from any d.c. supply in the range 3 to 25 volts. The LEDs can use the same supply as the IC or can be independently powered from supplies with voltages up to a maximum of 25 V. The voltage across the internal potential divider can have any value up to 25 volts maximum.

The internal reference amplifier produces a basic nominal output of 1.28 volts (limits are 1.2 V to 1.32 V), but can be externally 'programmed' to produce effective reference values up to 12 V (we'll show how later).

The input buffer of the IC has integral overload protection and can withstand inputs of up to plus or minus 35 V without damage.

The IC can be made to give either a 'dot' display by wiring pin 9 to pin 11, or a 'bar' display by wiring pin 9 to positive-supply pin 3.

Practical Circuits: Simple 'DOT' Mode Voltmeters

The basic circuit of Fig 2 acts as a voltmeter that reads full-scale at an input of 1.2 volts. The range of the circuit can be changed in a variety of ways. The sensitivity can be increased, for example, by either interposing a d.c. amplifier between the input signal and pin 5 of the IC, or by reducing the reference voltage that is applied to the pin 4 — pin 6 terminals of the IC: in this latter case the IC will operate quite well with a reference voltage down to a couple of hundred mV.

The easiest and best way to reduce the sensitivity of the meter is to use the connections shown in Fig 3. Here, the basic circuit is that of a 1.2 V meter, but the input signal is applied to the IC via a potential divider formed by Rx and R1. Thus, the circuit can be made to read 12 volts full scale by giving Rx a value of 90k, so that Rx-R1 act as a 10:1 divider. This circuit can be used to read full scale voltages from 1.2 V up to about 1000V.

An alternative connection is shown in Fig 4. In this case the input voltage is applied directly to pin 5 of the IC, but the reference voltage on the internal devider is made variable from 1.2 V to 10 V via RV1. You'll remember that the 'reference voltage' develops 1.2V between pins 7 and 8, but this voltage is fully floating. By wiring RV1 between pin 8 and ground we can ensure that the output current of the reference flows to ground via RV1, thus providing a voltage that raises the pin 8 (and also pin 7) value considerably above zero volts. This increased voltage is applied to the top (pin 6) end of the internal potential divider, which has its low end (pin 4) grounded, and determines the full scale sensitivity of the circuit. This circuit has a useful voltage range of only 1.2 V to 10V. The IC supply voltage must be greater than the required full scale voltage.

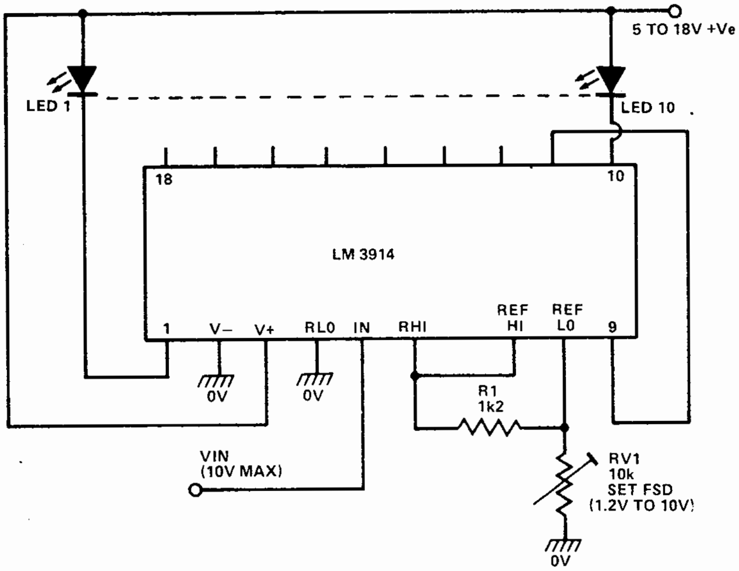


Fig. 4. An alternative 1.2 to 10 V FSD 'Dot' mode voltmeter.

Figure 5 shows how the LM3914 can be used as an expanded scale voltmeter that reads (say) 10V at minimum scale but 15 V at full scale. The secret of this circuit is that both the top and bottom ends of the internal potential divider (pins 6 and 4) of the IC are externally available, so the top and bottom limits of the scale can be individually set. In the diagram the top of the divider is fed from the 1.2 V reference, but the bottom is fed from

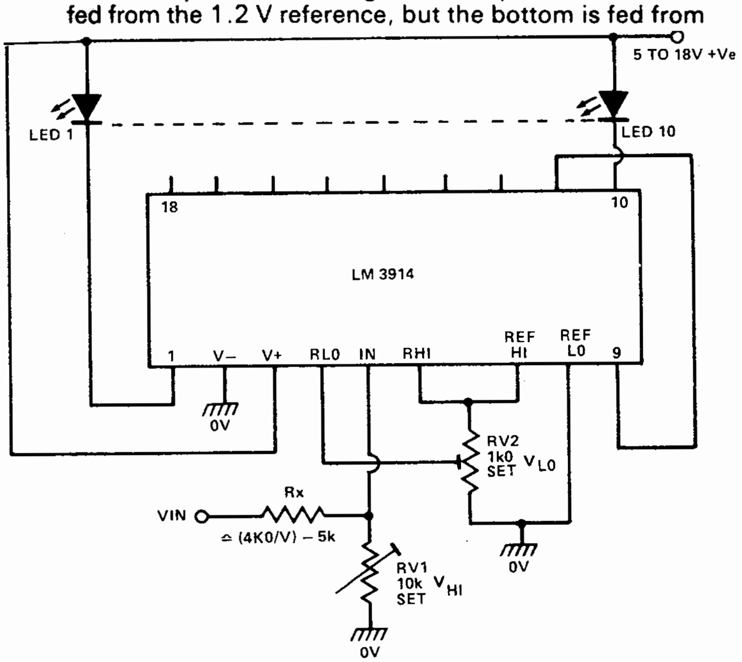


Fig. 5. Expanded scale (10 V - 15 V etc) 'Dot mode voltmeter.

the slider of RV2. The external input signal is applied to the IC via the Rx-RV1 potential divider. Thus, if 1.2V is set to the top of the divider and 0.8 V is set to the bottom and the input divider has a ratio of 20:1, the circuit will read 24 V at full scale and 16 V at minimum scale.

Practical Circuits: 'BAR' Mode Operation

The three basic voltmeter circuits of Figs 3 to 5 can be used with the IC connected in either the 'dot' or the 'bar' mode. When using the bar mode, however, it must be remembered that the power rating of the IC can easily be exceeded when all ten LEDs are on if an excessive voltage is allowed to develop across the output terminals

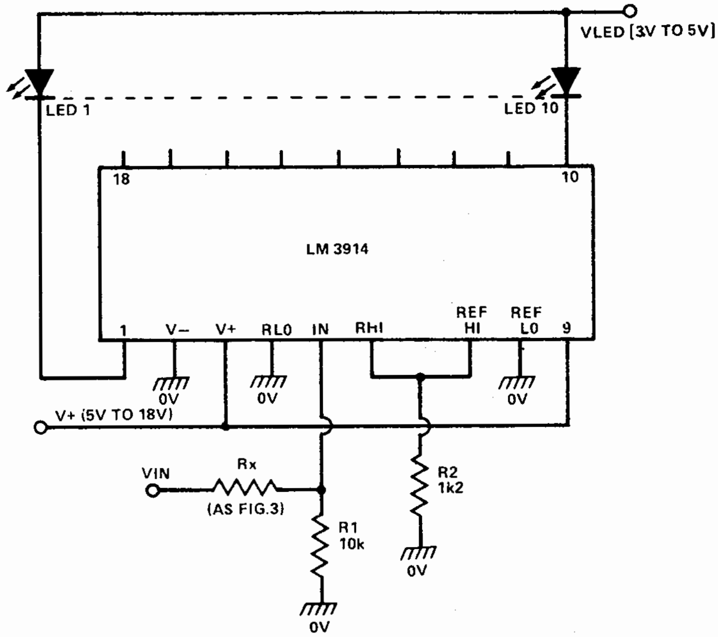


Fig. 6. Bar-display voltmeter with separate LED supply.

of the IC. LEDs normally drop about 2 volts when they are conducting, so one way around this problem is to power the LEDs from their own low-voltage (3 to 5 V) supply, as shown in Fig 6.

An alternative solution is to power the IC and the LEDs from the same source but to wire a current-limiting resistor in series with each LED, as shown in Fig 7, so that the output terminals of the IC saturate when the LEDs are on.

Practical Circuits: 20-LED Voltmeters

Figure 8 shows how two LM3914s can be interconnected to make a 20-LED dot mode voltmeter. Here, the input terminals of the two ICs are wired in parallel, but IC1 is configured so that it reads 0 to 1.2 volts and IC2 is configured so that it reads 1.2 volts to 2.4 volts. In the latter case, the low end of the IC2 internal potential divider is coupled to the 1.2 V reference of IC1 and the top of the divider is taken to the 'top' of the 1.2 V reference of IC2, which is raised 1.2 V above that of IC1.

The Fig 8 circuit is wired for 'dot' mode operation. In this case pin 9 of IC1 is wired to pin 1 of IC2 and pin 9 of IC2 is wired to pin 11 of IC2. Note that a 22k resistor is wired in parallel with LED 9 of IC1 in this mode.

Fig 9 shows the connections for making a 20-LED 'bar' mode voltmeter. The connections are similar to those of Fig 8, except that pin 9 is taken to pin 3 on each IC, and a 470R current limiting resistor is wired in series with each LED to reduce the power dissipation of the ICs.

Practical Circuits: A 20-LED Car Tachometer

The LM3914 can be made to act as a car tachometer by simply wiring a frequency-to-voltage converter between the vehicles contact breaker points and the input pin of the IC. Fig 10 shows the practical circuit of such a converter, designed to interface with either of the

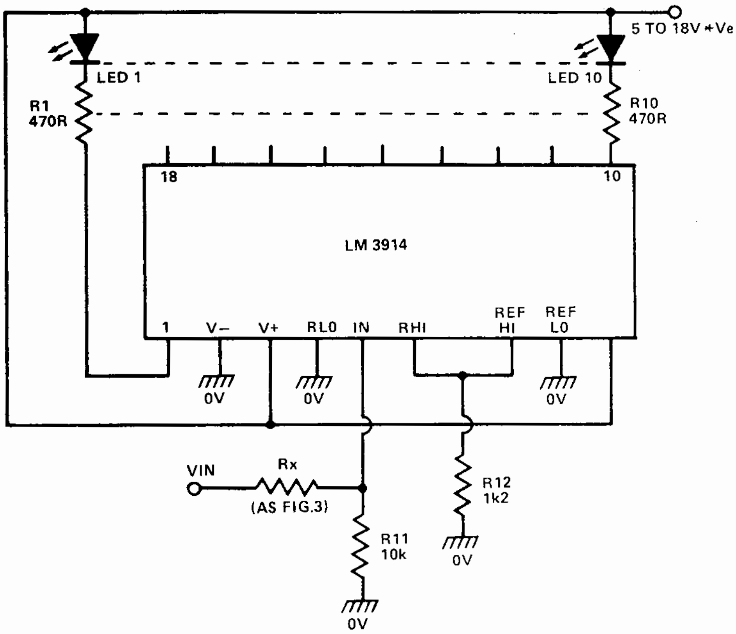


Fig. 7. Bar-display voltmeter with common LED supply.

20-LED voltmeter circuits of Figs 8 or 9. Note the LM2917 IC used in this circuit is a 14-pin device. The C2 value of 22n is the 'optimum' value for a full scale range of approximately 10 000 RPM on a 4-cylinder 4-stroke engine. For substantially lower full scale RPM values, the value of C2 may have to be increased. The value may have to be reduced on vehicles with 6 or more cylinders.●

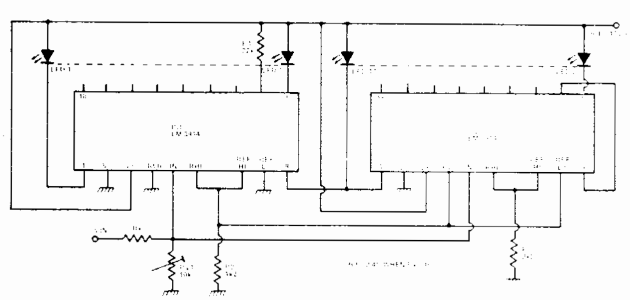


Fig. 8. Dot-mode 20 LED voltmeter. (FSD = 2.4V when Rx=1)

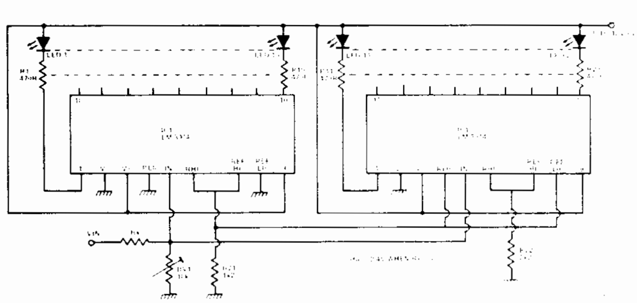


Fig. 9. Bar-mode 20-LED voltmeter. (FSD=2.4 V when R_x=0).

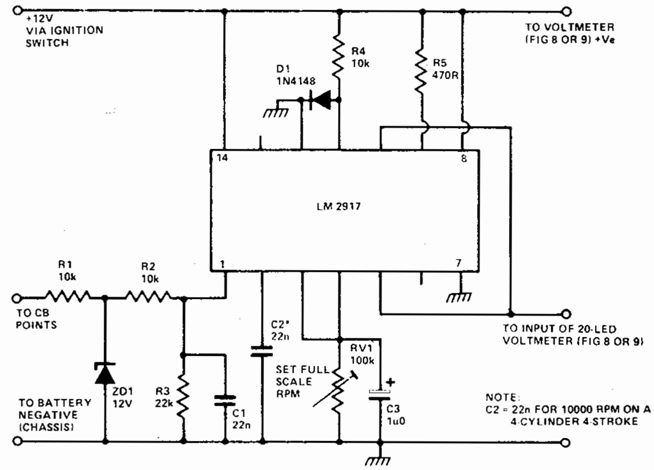


Fig. 10. Car tachometer conversion circuit for use with a 20 LED voltmeter. (Fig. 8 or 9).

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USING BARGRAPH DISPLAYS

LED Bar-graph displays are now being used to replace moving-coil meters. This month we take a look at how they can be used.

RAY MARSTON

BAR-GRAPH DISPLAYS ARE INEXPENSIVE and often superior alternatives to analog moving-coil meters. They are immune to inertia and sticking problems, so they are fast-acting, and unaffected by vibration or position. Their scales can easily be given any desired shape, such as a vertical or horizontal line, an arc, or a circle. In a given display, individual LED colors can be mixed to emphasize particular sections of the display. Over-range detectors can be activated from the driver IC's to sound an alarm and/or flash the entire display.

Bar-graph displays have better linearity than conventional moving-coil meters, with typical linear accuracies of 0.5%. Scale definition depends on the number of LED's used, although a 10-LED display provides adequate resolution for just about any practical purpose.

LM3914 Dot/bar-driver IC's

The LM3914 family of dot/bar-graph driver IC's are manufactured by National Semiconductors. Each type is capable of directly driving up to 10 LED's, or several IC's can be cascaded to drive as many as 100 LED's in either the dot or bar mode. The family comprises three devices: the linear scaled LM3914, the log-scaled LM3915, and the semi-log LM3916.

All three device types use the same basic internal circuitry. Fig. 1 shows the internal circuit of the linear-scaled LM3914, together with its connections for operating as a 10-LED voltmeter, having a 0–1.2-volt scale. The IC contains ten voltage comparators, each with its non-inverting terminal connected to a specific tap on a precision voltage divider. All inverting terminals are wired in parallel and driven by a unity-gain buffer. The buffer's input (pin 5), is protected against overload voltages to ± 35 volts. The output of each comparator can sink up to 30 mA. The sink currents are internally limited; the limit can be externally pre-set by resistor (R1).

The IC also contains a floating 1.2-volt reference source connected between pins 7 and 8. In Fig. 1, the voltage reference is shown externally connected via pins 6,7,8, and 4 to the internal voltage divider. The IC also contains a dot/bar se-

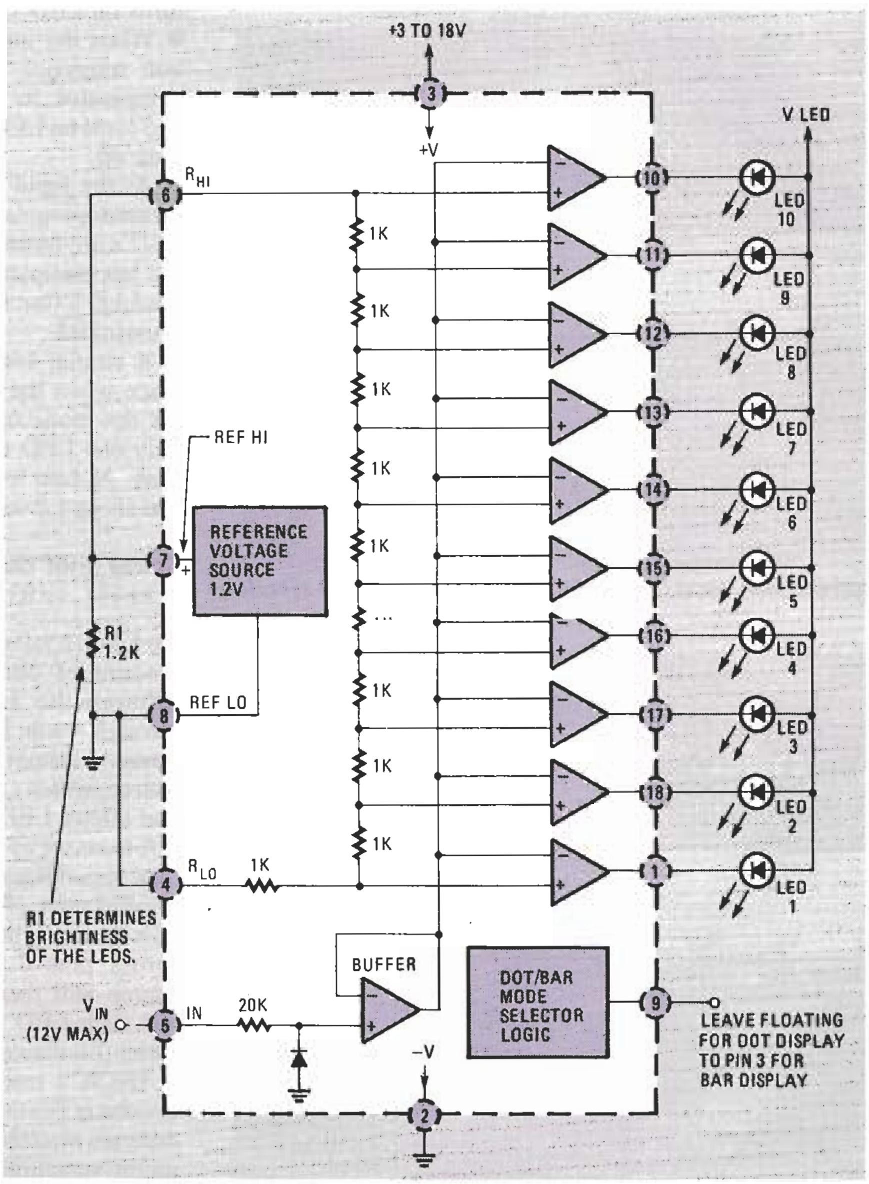


FIG. 1—INTERNAL CIRCUITRY OF THE LM3914, with connections for making a 10-LED 0–1.2-volt linear meter having a dot or bar display.

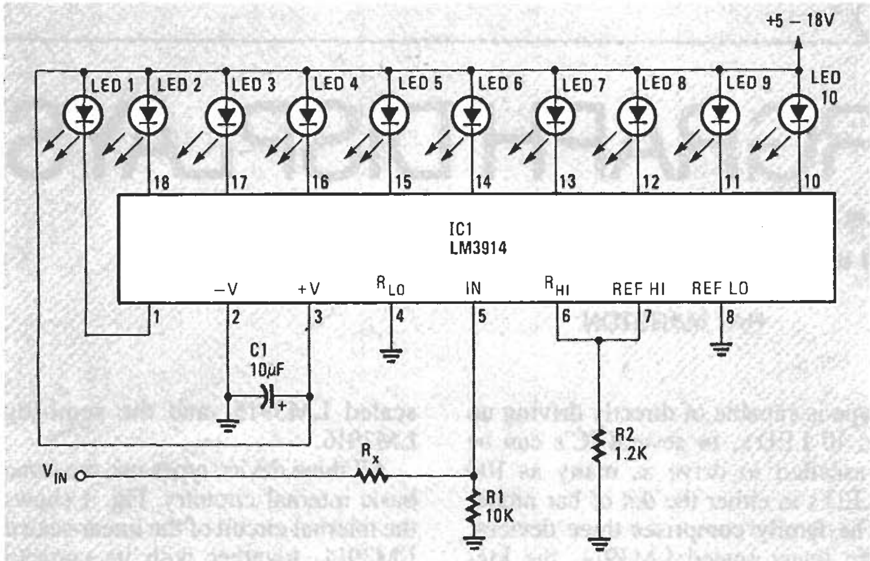


FIG. 2—THE FULL-SCALE DISPLAY CAN BE ADJUSTED from 1.2–to 1000 volt.

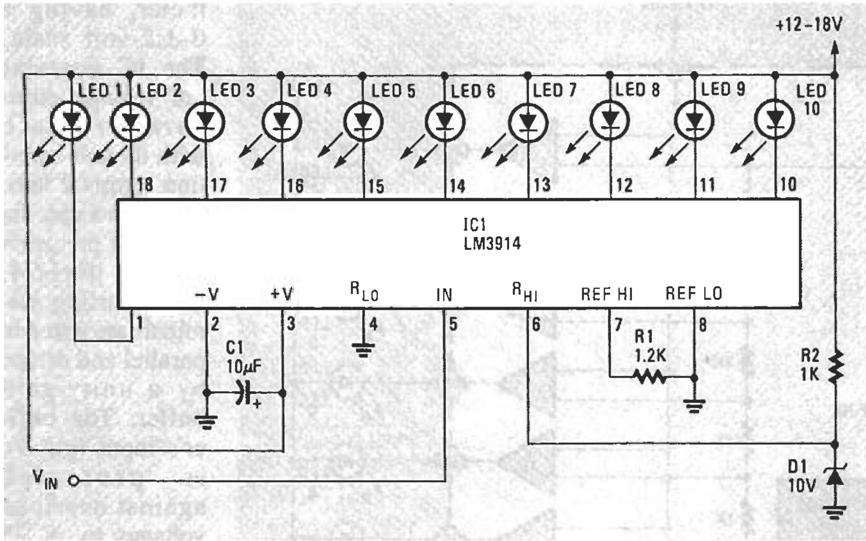


FIG. 3—AN EXTERNAL REFERENCE VOLTAGE CAN BE USED to make a 10 volt full-scale-display meter.

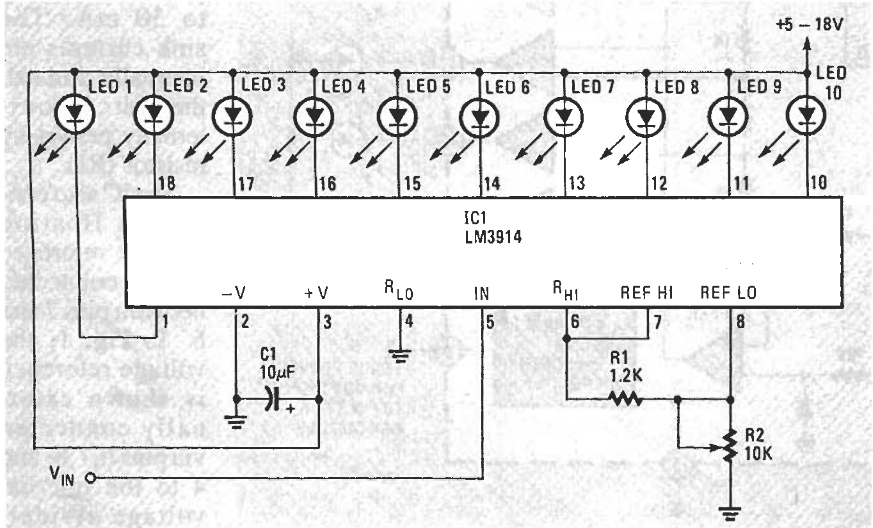


FIG. 4—A VARIABLE-RANGE DOT-MODE VOLTMETER can be made by using a 10K potentiometer to set the full-scale display.

lector (pin 9) network so that the dot or bar mode can be set externally.

How it works

Assume that the device is set for bar-mode operation and that, as already shown, the 1.2-volt reference is applied across the internal resistive voltage divider. Thus, 0.12 volt is applied to the inverting or reference input of the first comparator, 0.24 volt to the next, 0.36 volt to the next, and so on. If a slowly rising input voltage is applied to pin 5, the following sequence of actions then take place:

- When the input voltage is zero, the outputs of all ten comparators are disabled and all LED's are off.
- When the input voltage reaches the 0.12-volt reference value of the first comparator, its output conducts and turns on LED 1.
- When the input reaches the 0.24-volt reference value of the second comparator, its output also conducts and turns on LED 2; LED's 1 and 2 are both on.
- As the input voltage is further increased, progressively more and more LED's are turned on, until eventually the last comparator conducts and all ten LED's (the full-scale display) are illuminated.

A similar kind of operation takes place when the LM3914 logic is set for dot-mode operation, except that only one LED turns on at any given time. At zero volts, no LED's are on, and above 1.2 volts only LED 10 is on.

Some finer details

In Fig. 1, R1, which is connected between pins 7 and 8 (the output of the 1.2-volt reference), determines the amount of current that will flow through the LED's. The current through each LED is roughly ten times the output current of the 1.2-volt source, which can supply up to 3 mA; that allows LED currents of up to 30 mA to be set by R1. If, for example, a total resistance of 1.2K, (equal to the parallel value of R1 and the 10K of the IC's internal voltage divider) is placed across pins 7 and 8, the 1.2-volt source will therefore conduct 1 mA and each LED will conduct 10 mA, when illuminated.

The IC's internal 10-stage voltage divider is floating, meaning that both ends are available externally for maximum versatility. It can be powered from either the internal reference voltage, or from an external source. If, for

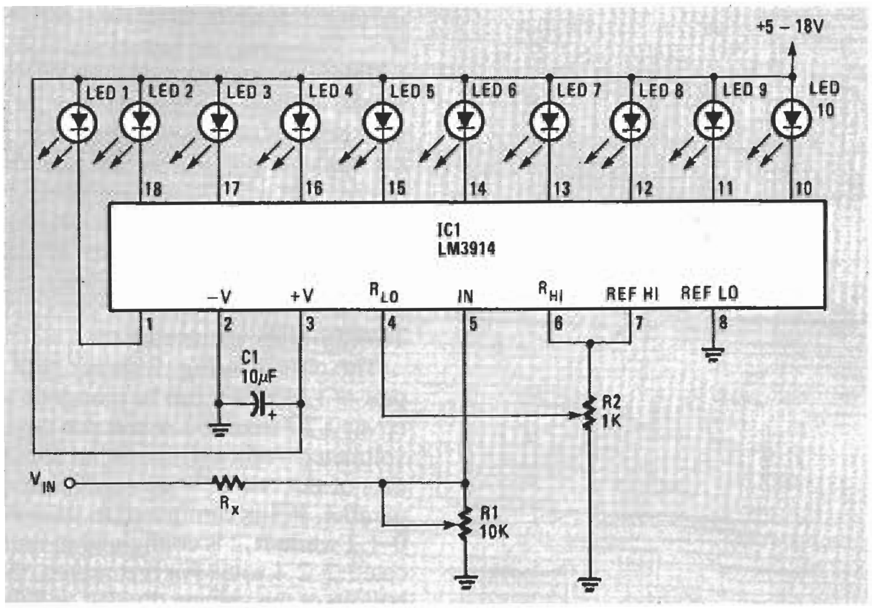


FIG. 5—THIS EXPANDED-SCALE DOT-MODE voltmeter will only display inputs between 10–15 volts.

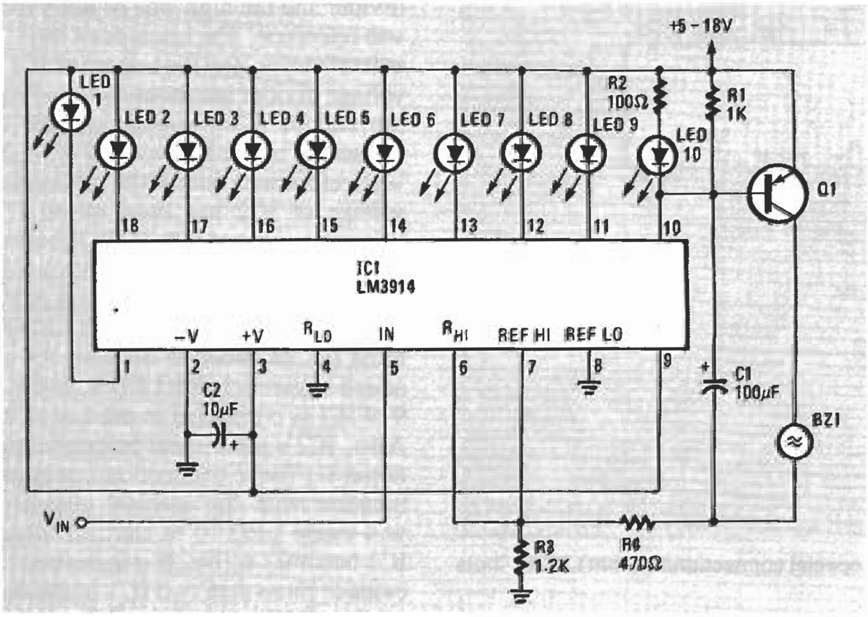


FIG. 6—AN OVER-RANGE ALARM CAN BE ADDED to sound a buzzer and flash the entire display when the full scale display is illuminated.

example, the top of the network is connected to a 10-volt source and the low end is connected to ground, the IC will function as a voltmeter, having a 0–10-volt scale. However, if the low end of the network is connected to a 5-volt source, the IC will function as a restricted-range voltmeter, having a 5–10-volt scale. The only constraint on using the internal divider is that its supply voltage must not exceed a voltage that is 2 volts less than the IC's supply voltage (which is limited to 25-volts maximum).

The IC's internal reference voltage produces a nominal output of 1.28 volts (its limits are 1.2 to 1.34 volts), but as we'll show later, it can be externally programmed to produce effective reference values up to 12 volts. Also, by wiring pin 9 to pin 3, the IC will operate in the bar mode. (If pin 9 is left floating, it will operate in the dot mode.)

The major difference between the three members of the LM3914 family of IC's is in the resistance values used for the internal 10-stage voltage divider. In the LM3914, all resistors in the divider have equal values, so the device has a linear display of ten equal steps, which makes the LM3914 well-suited for most applications. In the LM3915, the resistors are logarithmically weighted, which results in a log display that spans 30 dB in ten steps of 3 dB, making it suitable for signals having a wide dynamic range. In the LM3916, the resistors are weighted in a semi-log fashion which produces a display that is specifically suited to VU-meter applications.

Practical applications

Let's move on now and take a look at some practical applications, paying particular attention to the linear LM3914.

Figures 2 through 5 show various ways of using the LM3914 IC to make 10-LED dot-mode voltmeters. Note that pin 9 in all of the circuits is left floating to provide dot-mode operation, and a 10µF capacitor is wired directly between pins 2 and 3 to ensure circuit stability.

Figure 2 shows the connections for making a variable-range (1.2- to 1000-volt full-scale) voltmeter. The low ends of the internal reference (pin 8) and the divider (pin 4) are grounded, and their top ends (pins 7 and 6) are joined together, so the meter has a basic full-scale sensitivity of 1.2 volts. However, variable ranging is provided by the Rx-R1 voltage divider at the input (V_{in}). For example, when Rx is zero, the full-scale display is 1.2 volts, but when Rx is 90K the full-scale display is 12 volts. Resistor R2 is wired across the internal reference voltage, and sets the *on* current of all LED's to about 10 mA.

Figure 3 shows how to make a fixed-range 0- to 10-volt meter. An external 10-volt Zener, D1, connected to the top of the internal divider provides the reference voltage. The supply voltage to that circuit must be at least two volts greater than the Zener diode's reference voltage.

Figure 4 shows how the internal reference of the IC can be made to effectively provide a variable voltage, thereby allowing the meter's full-scale-display value to be set anywhere in the range of 1.2–10 volts. The 1-mA current (determined by R1) of the floating 1.2-volt internal reference flows to ground via R2, and the resulting R2 voltage raises the reference voltage (pins 7 and 8) above zero. If, for example, R2 is set to 2.4K, pin 8 will be at 2.4 volts, while pin 7 is 3.6 volts. R2 thus enables the voltage at pin 7, which is connected to the top of

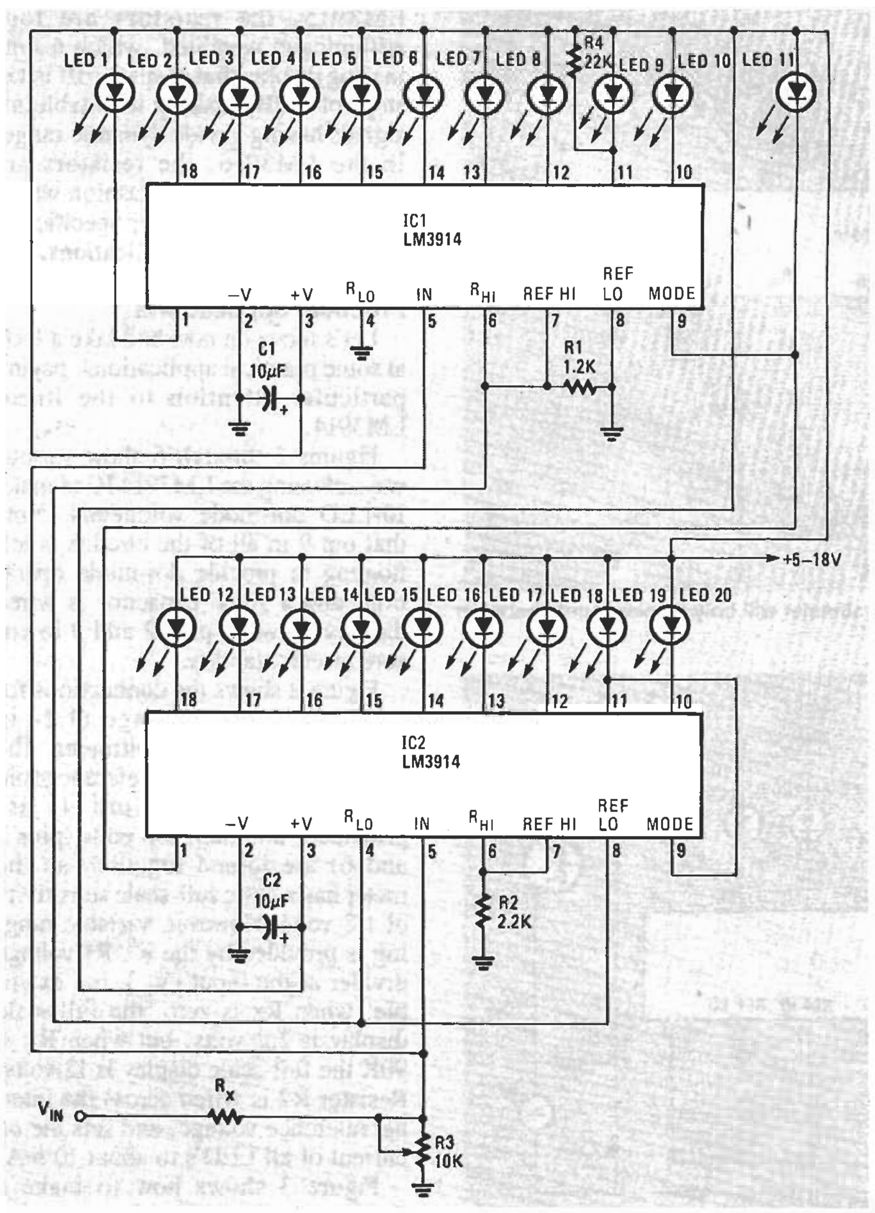


FIG. 7—A DOT-MODE 20-LED VOLTMETER has special connections so that LED 10 shuts off when LED 11 turns on.

the internal divider, to be varied from 1.2 volts to approximately 10 volts, so the full-scale-display value of the meter is determined by those values.

The circuit of Fig. 5 shows the connections for making an expanded-scale meter that, for example, reads voltages in the range 10–15 volts. Potentiometer R2 sets the LED current at about 12 mA, and also enables a reference value in the range from 0 to 1 volt to be set on the low end of the internal divider. Thus, if R2 is set to apply 0.8 volt to pin 4, the basic meter will read voltages only in the range of 0.8–1.2 volts. By adding the voltage divider Rx-R1 to the input of the circuit, that range can be amplified to between 10 and 15 volts, or whatever range is desired. Note that the dot-mode circuits of Figs. 2 to 5 can be programmed to operate in the bar mode by simply connecting pin 9 to pin 3. If the IC should become warm from power dissipation when operating in bar mode, try adding a 7.5-ohm resistor in series with the LED supply voltage.

Figure 6 shows how the basic LM3914 circuit can be fitted with an over-range alarm that powers a buzzer and flashes the entire display when the full-scale display is illuminated. If the comparator's output for LED 10 goes low, Q1 is turned on, which sounds the buzzer BZ1. At the same time, C1 starts to discharge and momentarily brings pin 7 low. That sets the comparator's outputs to approximately V +. Therefore, the voltage across the LED's is not enough to keep them on, so the display briefly shuts off. C1 then begins to charge up again, due to the high at pin 10, so Q1 and the buzzer shut off. The voltage at pin 7, and subsequently the LED's, are then restored, and if the full-scale display is still present, the cycle repeats.

Twenty-step voltmeter

The circuit in Fig. 7 shows how a pair of LM3914's can be cascaded to create a 20-step, 0–2.4-volt dot-mode voltmeter. Although the input terminals of the two IC's are connected in parallel, IC1 is configured to indicate 0–1.2 while IC2 is configured to indicate 1.2–2.4 volts. For that reason, the bottom of the voltage divider, and the low side of IC2's 1.2-volt reference are coupled to the top of the voltage divider and the high side of IC1's 1.2-volt reference. The low side of the 1.2 volt reference, and the bottom of IC1's voltage divider are grounded, and the top end of IC2's voltage divider is connected to the high side of it's 1.2-volt reference. Since the reference voltage of IC2 has been raised 1.2 volts above that of IC1, IC2's R3 must be raised to 2.2K. Because the circuit is set up for dot mode, we want IC1's LED 10 to shut off when IC2's LED 11 turns on. In order to do that, R4 is added in parallel with LED 9, and pin 9 of IC1 is connected to pin 1 of IC2. Also, IC2's pin 9 must be connected to pin 11. Those connections, in combination with the internal circuitry, will cause LED 10 to shut off when IC2 becomes active. If it is desired to cascade more than two IC's in the dot mode, all IC's must have R4 added in parallel with LED 9, and pin 9 connected to pin 1 of the next IC, with the exception of the last IC, whose pin 9 must be connected to pin 11.

The circuit in Fig. 7 can be wired for bar-mode operation. The connections would be similar except that pin 9 must be connected to pin 3 of each IC, and the resistor (R4) that had been connected across IC1's LED 9 must be eliminated.

Although the practical circuits have been devoted to the LM3914 IC, the log-type LM3915 and semi-log LM3916 can be directly substituted in most of the circuits. Depending on the transducer you use, a bar-graph display can represent any quantity, such as light, heat, or vibration. **R-E**

Moving-dot indicator tracks bipolar signals

by Ted Davis
Riverton, Ill.

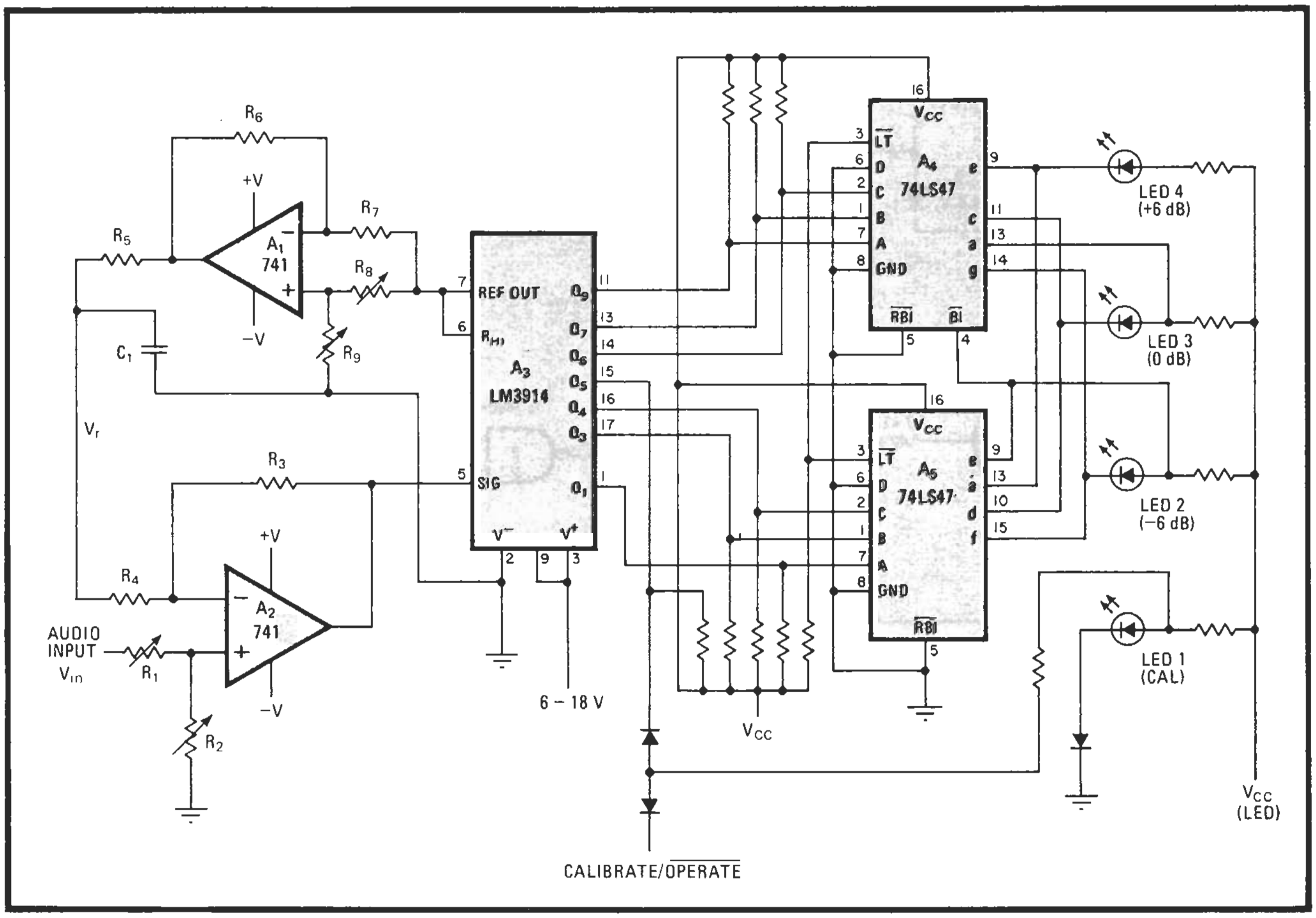
Although bar- or dot-display chips are a simple means of indicating the instantaneous value of a signal, they respond only to unipolar levels, a definite drawback in processing audio-frequency signals with asymmetrical (bipolar) inputs. If reduced resolution is acceptable, one solution is to offset the 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)

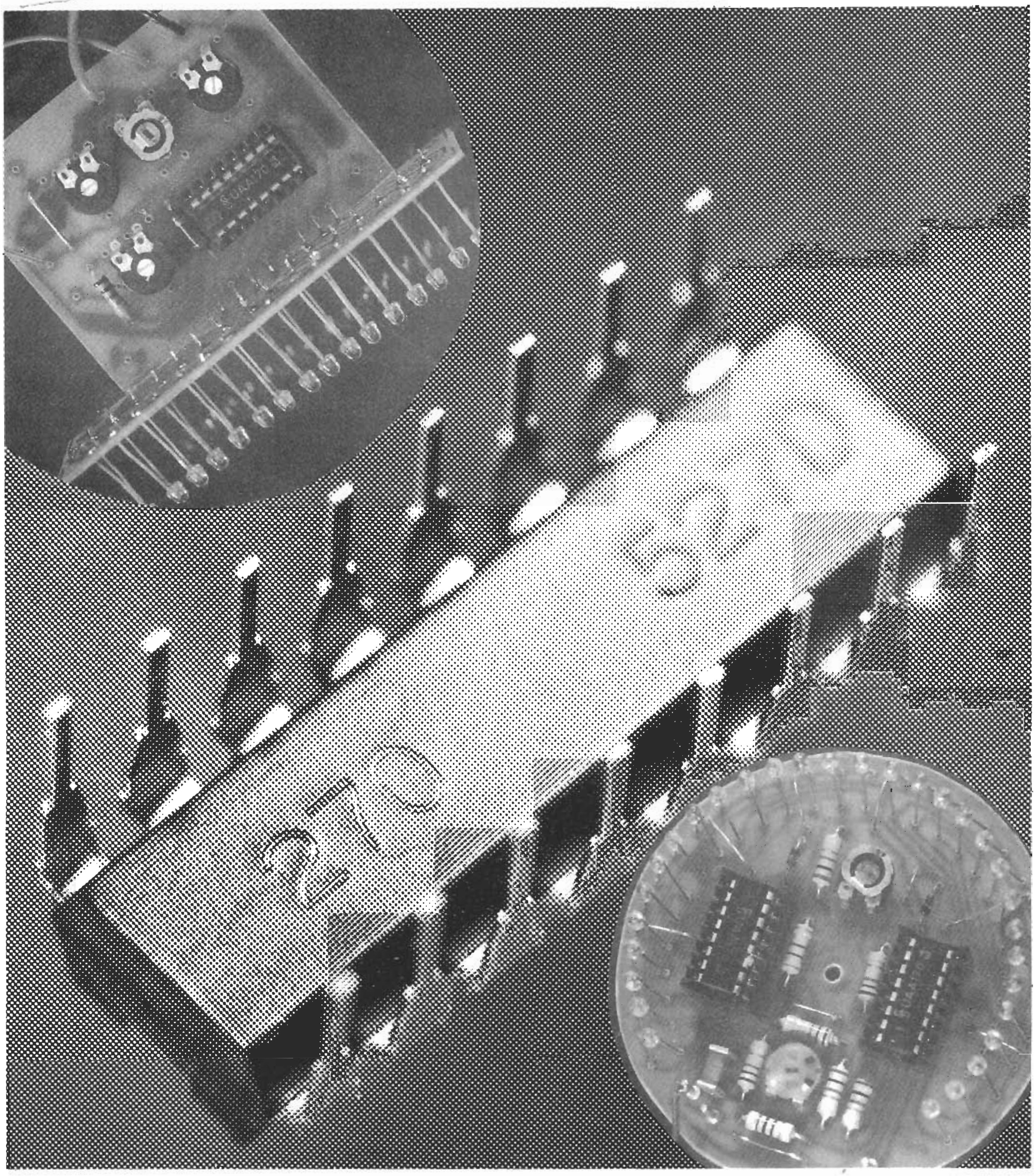
X = don't care   Input voltage V_{in} normalized to full scale at pin 5 of LM3914

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}. □



P.C.M. Verhoosel

LED meters

Analogue indicators that make use of columns of LED's to measure voltage or other parameters provide a robust alternative to the conventional moving coil meter in many applications. Using one of the special IC's currently available for this purpose, such as the Siemens UAA 170, such indicators can easily be constructed.

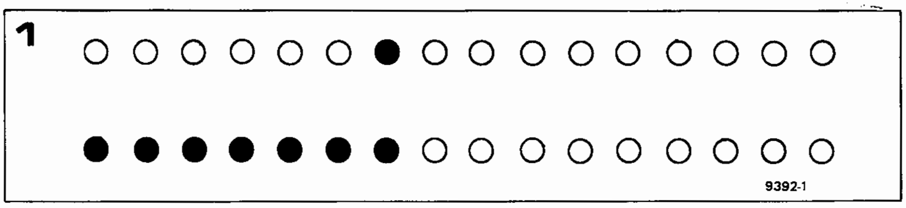
For some time Siemens has been marketing two IC's suitable for driving analogue LED displays. One of these is the UAA 170, a 16-pin IC with 8 encoded outputs capable of driving a column of 16 LED's. Only one of these LED's is lit at any time, which one is lit being dependent on the input voltage in such a way that as the voltage is increased a point of light will move up the column. A companion IC, the UAA 180, provides a 'thermometer' type of indication, i.e. as the input voltage increases, successive LED's light and stay lit, producing a column of light whose length is proportional to the input voltage.
The choice of IC depends on the taste of the individual user, but it must be remembered that the thermometer type of indicator consumes more current than the moving dot type, as more than one LED is lit.
Figure 1 clearly shows the difference between the two types of display.

The possible applications for LED meters are numerous, but they are particularly useful in two types of application. The first is where the response time of the meter must have special characteristics such as audio modulation meters. The attack and decay time can be tailored electrically, and are not dependent on the mechanical inertia of a conventional meter movement. The second is in applications requiring mechanical robustness, such as use in the presence of mechanical vibrations, which could damage moving coil instruments. Here the absence of moving parts gives the LED indicator almost unlimited life.

Of course it might be argued that in some of these applications instruments with a digital readout could be used, since they possess the same advantages of fast response and mechanical robustness, and additionally have greater resolution. However, an additional advantage of the analogue LED indicator lies in its ability to show trends. It is much easier to tell if a rapidly changing quantity is increasing or decreasing when using an analogue indicator than from the blur of figures on a digital display.

Principle of operation

Figure 2 shows a simplified internal circuit of the UAA 170. The input circuitry consists of a series of high-gain differential amplifiers. One input of each of these is commoned and connected to the input terminal via an emitter-follower buffer stage T1. The other input of each differential amplifier is connected to a point in a potential divider chain consisting of equal resistors R, which is fed from a reference voltage applied to T2. The differential amplifiers thus operate as analogue voltage comparators. Whenever the input voltage exceeds the reference voltage on a particular comparator the output of the comparator will change state. The UAA 170 contains 16 such comparators, so the input range from zero to full-scale is divided into 16 steps.
To avoid the necessity for 16 output pins the 16 LED's in the display are not driven individually but are arranged in a 4 x 4 matrix controlled by row and column outputs A to D and E to H. By enabling the appropriate row and column output one LED at a time can be lit. This is controlled by logic circuits represented by the box in the centre of the diagram. The logic circuitry is not shown in detail as it is rather complicated, and anyway it has little bearing



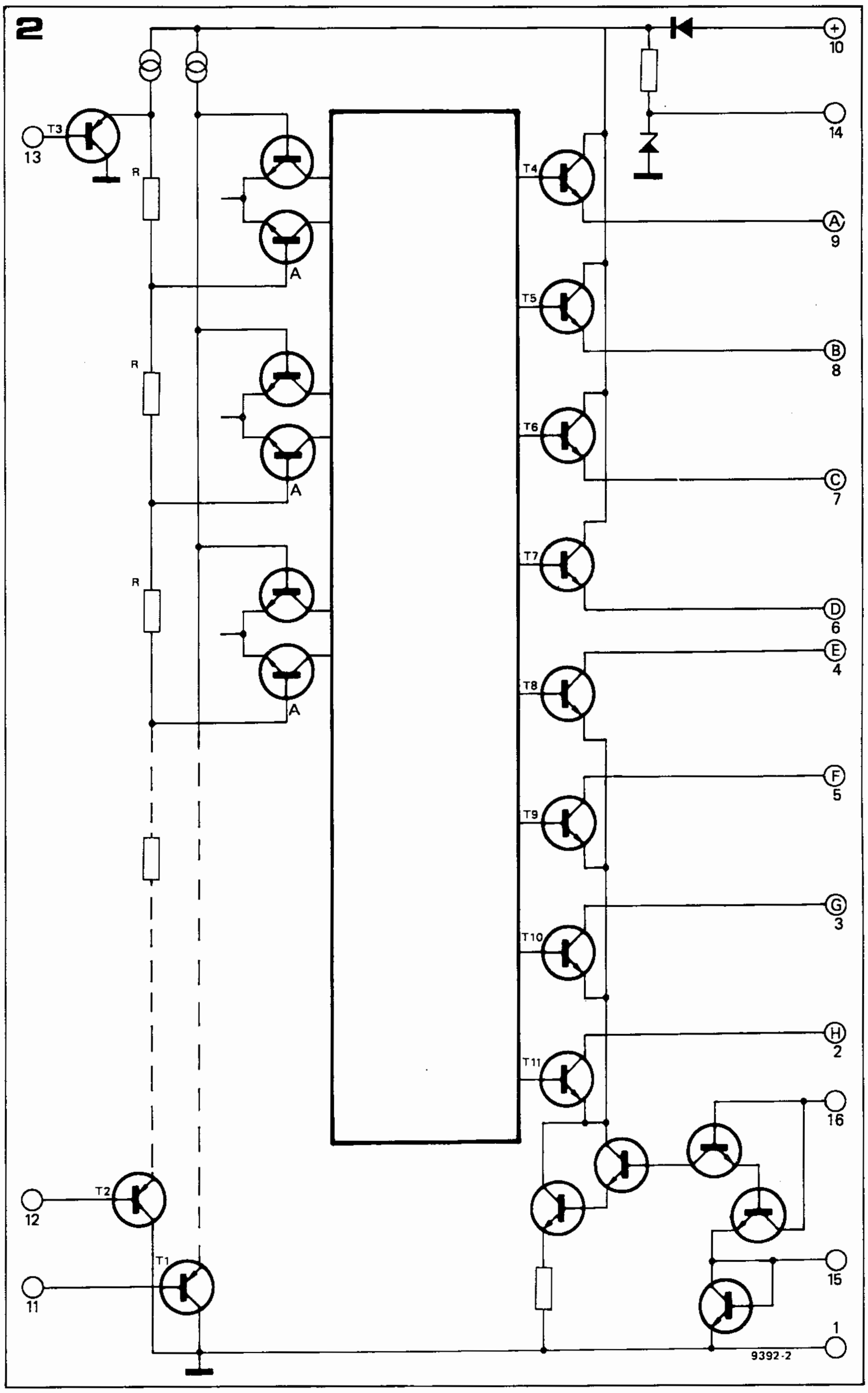
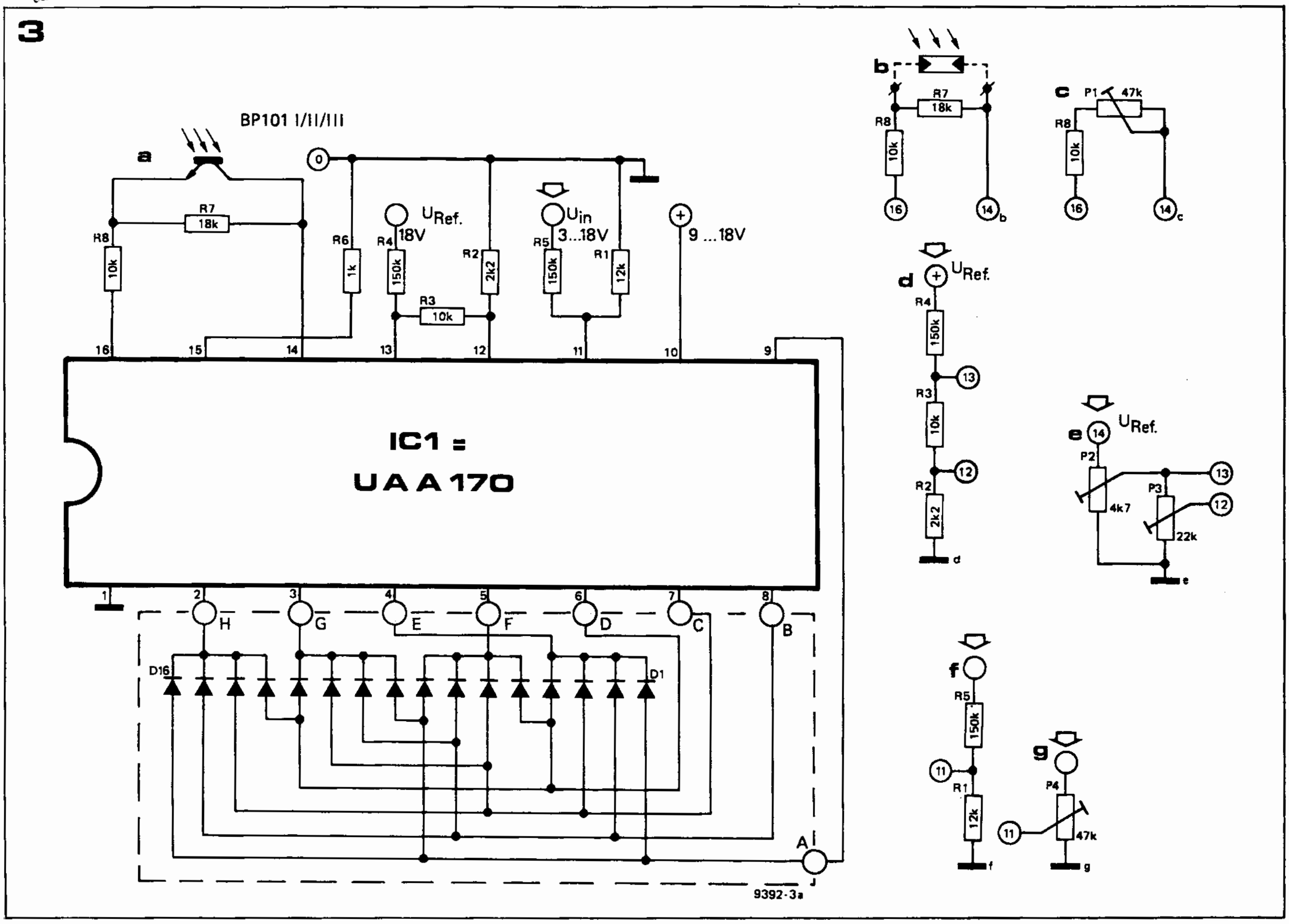
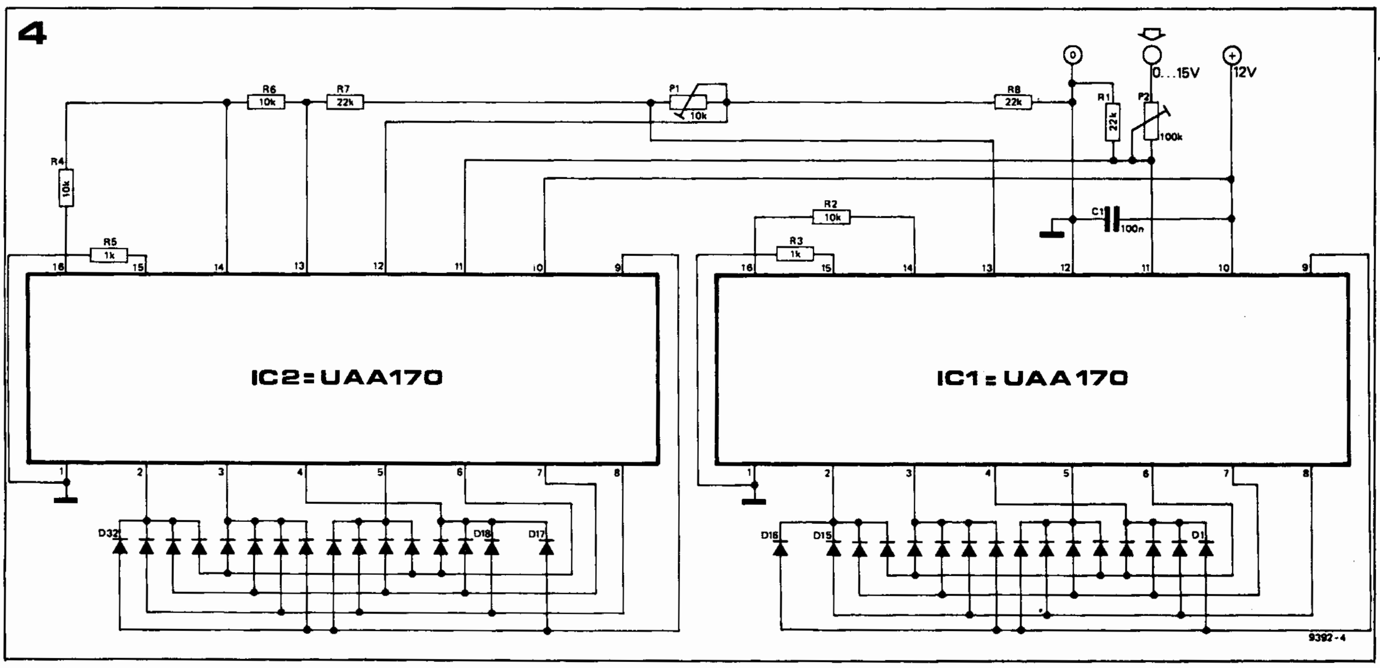


Figure 1. Showing the difference between a single point and thermometer type indication.

Figure 2. Simplified internal circuit of the UAA170, showing the input circuitry and output drive circuitry.





on the input and output parameters of the IC.

Reference voltage inputs

To establish the input voltage range over which the circuit operates a reference voltage must be applied between pins 12 and 13 of the IC, with pin 13 being the more positive of the two. The input voltage range is set by the voltage difference between these two points. The voltage at pin 13 sets the full-scale reading of the meter. For input voltages in excess of the voltage at this point the last LED in the column will light and stay lit.

The voltage at pin 12 establishes the lowest reading of the meter. While the input voltage is below the voltage at pin 12 the first LED in the column will always be lit, and will not extinguish until the input voltage exceeds the voltage at pin 12, when the second LED will light. This feature is particularly useful in situations where the voltage

Figure 3. Practical circuit of a LED voltmeter using one UAA170 IC.

Figure 4. The scale length can be extended to 30 LED's using two IC's each covering a different portion of the input voltage range. D16 and D17 must be included in the circuit, although they can not be used as part of the scale.

to be measured is above a particular value, and voltages below that value are of no interest. A typical example is a 'suppressed zero' voltmeter for use in cars. Here only voltages between about 11 and 18 volts are of interest, since the battery voltage normally never falls below 11 V, and the generator cuts out above about 17 V. If voltages below 11 V were included on the voltmeter scale then more than half the scale would never be used. This can be avoided by making the UAA 170 operate from 11 to 18 volts. Below 11 volts the first LED would remain alight, which could be used as a low battery voltage indication.

Different reference voltages produce unusual effects on the display. With reference voltages above 4 V the changeover from one LED to another is instantaneous, i.e. as one LED extinguishes the next one lights up to maximum brightness immediately. As the reference voltage is reduced the changeover becomes more gradual, and with a reference voltage of about 1.2 V it is possible to have two LED's alight simultaneously at reduced brightness. The emitter followers T1-T3 provide a high input impedance, input current being of the order of 2 μA, so for many applications the UAA 170 and 180 can be connected direct to the voltage to be measured without any intermediate buffering.

For use in situations where a stable reference voltage is not available, the IC is provided with a reference voltage output (pin 14). A 5 V reference is available at this point, with an output current capability of up to 3 mA. If voltages in excess of 6 V are to be measured then an input attenuator must be used to scale down the input voltage at pin 11.

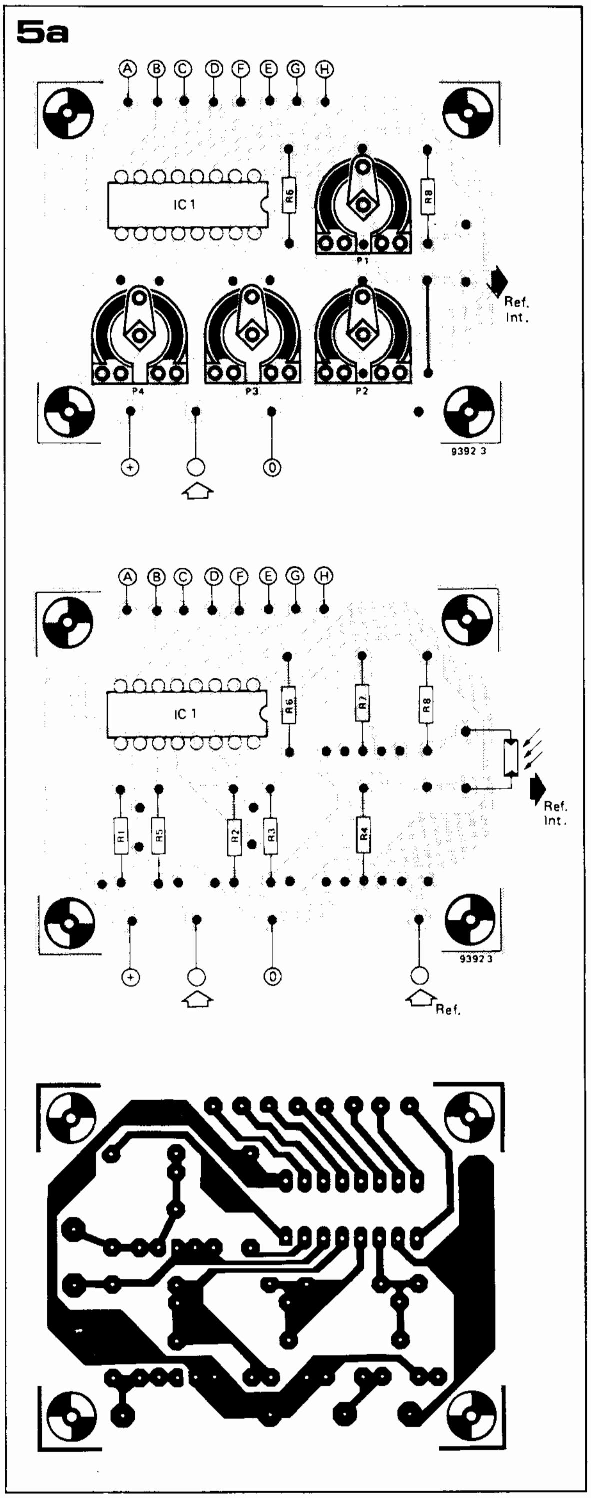
Brightness Control

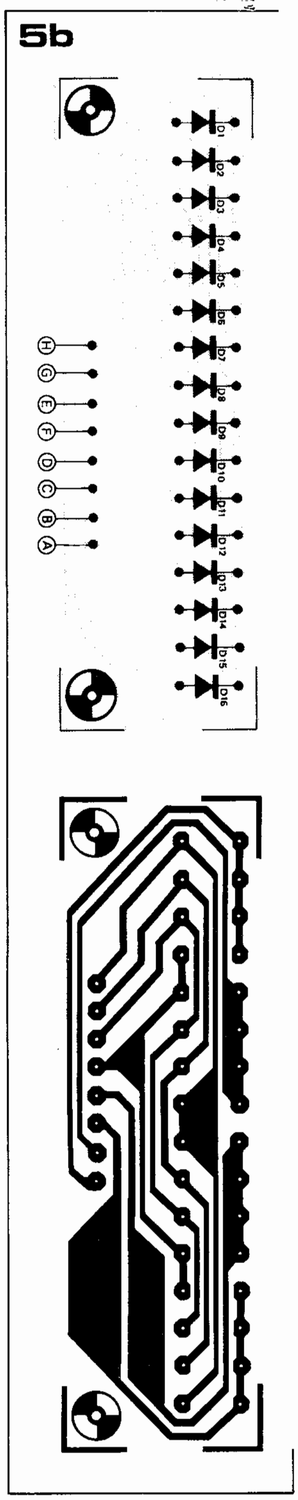
The output current delivered to the LED display, and hence the brightness, can be altered by a brightness control connected between pins 14 and 16 of the IC. This may take the form of an LDR or phototransistor to adjust the display brightness to suit ambient lighting conditions, or it may be a manual control such as a potentiometer. A fixed resistor between pin 15 and ground adjusts the control characteristics of the brightness control.

Practical Applications

The complete circuit of a LED voltmeter is given in figure 3. This has phototransistor brightness control and, with the component values shown is intended for an input voltage range of 3 - 18 V.

Various alternative possibilities are shown accompanying the main figure. b) and c) show brightness control using LDR and manual brightness control with a potentiometer respectively. d) and e) show a fixed voltage divider for the reference voltage and an adjustable one using presets respectively. f) shows a fixed input attenuator, while g) shows a preset input attenuator.





For correct operation of the display all four LED's connected to one of the pins 2, 3, 4 or 5 should have the same electrical characteristics.

If the UAA 180 with its thermometer-type scale is used then the LED's should also be chosen for similar brightness, as otherwise the appearance of the display will be degraded.

Extension to 30 LED's

For applications requiring greater resolution than can be provided by 16 LED's the circuit may be extended using two IC's as shown in figure 4. Both IC's receive the same input voltage at pin 11, but the reference voltages are arranged so that the first IC operates over the input voltage range of say 0 - V/2, and

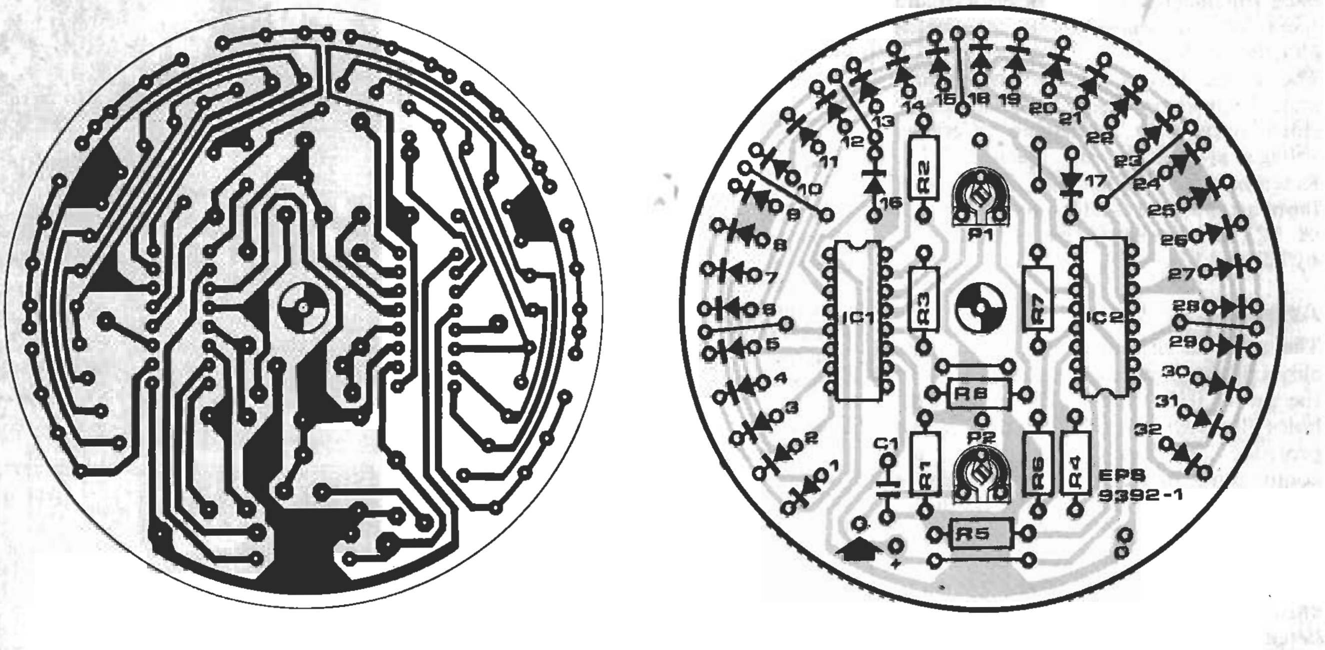
Figure 5a. Board layout for figure 3, with provision for automatic or manual brightness control and fixed or variable input and reference voltage attenuators (EPS 9392-3).

Figure 5b. p.c. board layout for LED display of figure 3 (EPS 9392-4).

Figure 6. p.c. board and component layout for a '270° meter' suitable for use with a rev counter circuit (EPS 9392-1).

Note that the UAA170 and the UAA180 are not pin-compatible! The circuits and p.c.boards given here are only suitable for the UAA170.

6



Parts list for figure 3.

Resistors, figure 3a:
R1 = 12k
R2 = 2k2
R3,R8 = 10k
R4,R5 = 150k
R6 = 1k
R7 = 18k

Resistors, figures 3c, 3e, 3g:
R6 = 1k
R8 = 10k
P1,P4 = 47k preset
P2 = 4k7 preset
P3 = 22k preset

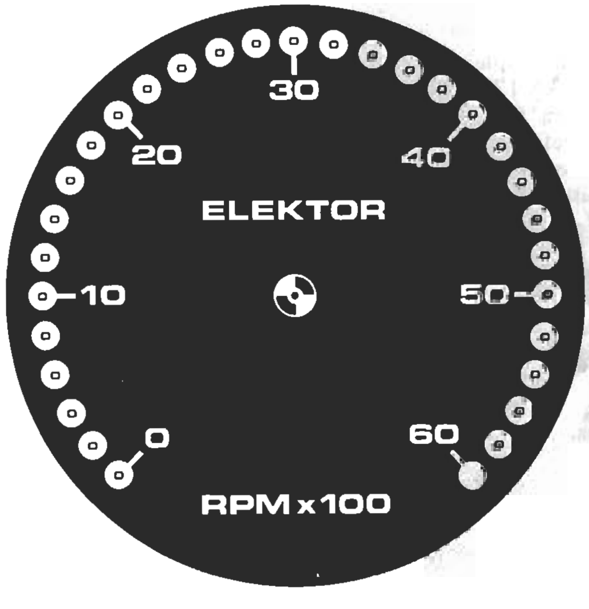
Semiconductors:
IC1 = UAA170
D1 . . . D16 = LED
Phototransistor
(e.g. BP101) or LDR

Parts list for figure 4.

Resistors:
R1 = 22k
R2,R4,R6 = 10k
R3,R5 = 1k
R7,R8 = 22k
P1 = 10k preset
P2 = 100k preset

Capacitors:
C1 = 100n

Semiconductors:
IC1,IC2 = UAA170
D1 . . . D32 = LED



(EPS 9392-2)

the second IC over the range V/2 - V, where V is the full-scale input voltage.
It is necessary to omit the last LED from the display of the first IC and the first LED from the display of the second IC, otherwise for voltages below V/2 the first LED of the second IC would always be lit, and for voltages above V/2 the last LED of the first IC would always be lit. For this reason only 30 LED's may be used, not 32. This means that D16 and D17 should not be part of the scale, although they must be included in the circuit.

So that the omission of these two LED's does not cause a 'blind spot' in the middle of the display it is necessary to arrange that the second LED of the second IC lights as the 15th LED of the first IC extinguishes. This is accomplished by having the reference voltage on pin 12 of the second IC lower than the voltage on pin 13 of the first IC.
The voltage difference between these two points can be adjusted by P1. P1 should be adjusted so that D18 begins to light as D15 extinguishes. There should be no blind-spot where both LED's are extinguished, nor should two or more LED's be fully lit at the same time.

Practical construction

The construction employed depends upon the intended application of the LED meter. Two board layouts are given here, a linear scale suitable for use as an FM tuning scale (see Elektor 9 page 134) and a scale in a 270° arc, intended specifically for use as part of a car rev counter. *(Note that this circuit is not a complete rev counter! It is merely a replacement for the original analogue pointer instrument – Ed).*

The printed circuit boards and component layouts for the linear scale meter are given in figures 5a and 5b. The IC and its associated passive components are mounted on a separate board from the LED display. The output terminals of this board match up with the input terminals on the display board, so the display board may be mounted on the main board at right angles to it, or the two may be linked by ribbon cable.
Provision is made on the main board

for either LDR or manual brightness control (P1) fixed or adjustable reference voltage (R2, R3, R4 or P2, P3) and fixed or adjustable input attenuator (R1, R5 or P4).
The board layout of the rev counter scale is given in figure 6. This is provided only with adjustable reference voltage at pin 13 by means of P1. Reference voltage at pin 12 is zero. Input attenuation is adjustable by means of P2, and display brightness is fixed by R2 and R4.

Assembly

The scale of the instrument will probably consist of a faceplate marked with the actual scale values and pierced with holes through which the LED's can protrude. An example is given accompanying figure 6. To ensure proper alignment of the LED's with the holes in the faceplate the LED's should first be mounted on the p.c. board and secured by soldering one lead only, ensuring that all LED's are the same height above the board. The faceplate can then be placed over the LED's and having positioned each LED in its hole the second lead of each LED can be soldered.

Practical hints

The principle electrical parameters of the UAA 170 are given in table 1. It will be seen that the voltage on the signal and reference inputs, pins 11, 12 and 13, must never exceed 6 V. When measuring input voltages greater than 6 V an input attenuator must therefore be used, as in figures 3f and 3g. This may take the form of a fixed attenuator or a preset potentiometer. The same applies to the reference voltage inputs. It is evident that the input voltage to pin 11 at full-scale reading must be the same as the reference voltage at pin 13, thus:

$$V_{ref.} \cdot \frac{R_2 + R_3}{R_2 + R_3 + R_4} =$$

$$= V_{in\ max} \frac{R_1}{R_1 + R_5}$$

If V_{ref} and the maximum input voltage are known then the ratios of the resistors can easily be calculated. If V_{ref} can be the same as V_{max} then the resistors can be chosen such that R4 = R5 and R2 + R3 = R1. The ratio of R2:R3 is chosen such that the voltage at pin 12 is equal to the minimum input voltage at pin 11, so:

$$V_{ref} \cdot \frac{R_2}{R_2 + R_3 + R_4} =$$

$$= V_{in\ min} \cdot \frac{R_1}{R_1 + R_5}$$

but with R4 = R5 and R1 = R2 + R3 then

$$V_{ref} \cdot R_2 = V_{in\ min} \cdot R_1$$

therefore

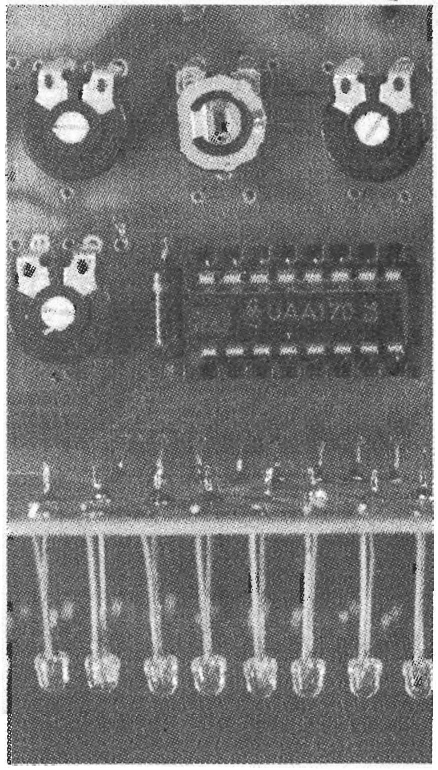
$$R_2 = \frac{R_1\ V_{in\ min}}{V_{ref}}$$

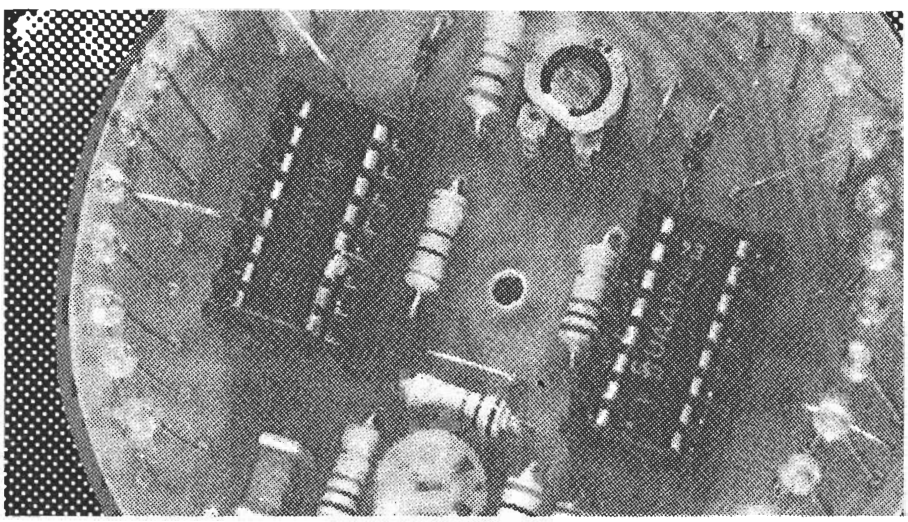
When choosing the actual resistor values the input current of the IC should be taken into account. If the total resistance is chosen so that the current through the potential divider chain is about 100 µA then the 2 µA input current of the IC can be neglected.
As mentioned earlier the current through the LED's, and hence the brightness, is controlled by what is connected between pins 14 and 16, and between pin 15 and ground. For example, with R6 in figure 3a chosen as 1 k, then with a resistance of 10 k between pins 14 and 16 the current through the display will be 50 mA. This corresponds to the phototransistor or LDR being fully illuminated and having minimum resistance. If the resistance between pins 14 and 16 is increased to 40 k then the display current falls to zero. The 18 k resistor across the phototransistor ensures that this can never occur in practice, even in total darkness, as the resistance is still only 28 k total.

Table 1

	absolute maximum	typical
Supply voltage	+ 18 V	–
Input voltage at pins 11, 12 and 13	+ 6 V	–
Output voltage pin 14	–	5 V
Output current pin 14	3 mA	–
Current consumption without LEDs	–	4 mA
LED drive current	50 mA	–
Input current at pins 11, 12 and 13	–	1-2 µA
Reference voltage between pins 12 and 13 for gradual display transition	–	1.2 V
Reference voltage between pins 12 and 13 for abrupt display transition	–	4 V

Table 1. Principle electrical specifications of the UAA170.





led vu/ppm

VU (Volume Unit) meters and PPMs (Peak Programme Meters) are used widely in the recording industry and by the amateur to monitor audio signal levels. Meters using conventional moving coil indicators have, however, several disadvantages. The ballistics of the meter movement are quite critical, which makes the meters expensive. They are also relatively bulky, which means that in a multichannel recording system the meters occupy a great deal of space and are difficult to read simultaneously.

Recording studios are increasingly turning to instruments in which the moving pointer is replaced by a column of LEDs that indicate the signal level. These have the advantage of occupying very little panel width. The characteristics of the meter are determined purely by the electronic circuitry, so a VU or PPM type of response can be achieved with very little modification. The design given in this article is for a two-channel meter, but this can easily be duplicated to give any desired number of channels.

To avoid the possibility of letters and telephone calls from irate recording engineers and enthusiasts, it should be stated at the outset that, although the meters described in this article will be referred to as 'VU' or 'PPM', these terms are used somewhat loosely to describe the type of response of the instruments. The meters do not and cannot conform to either VU nor BBC or IEC PPM standards since, among other things, the size, scale arc, scale markings and colour of the meter scale are specified. These specifications clearly cannot be duplicated by LED indicators.

Why and Wherefore?

Before looking at the details of the design it may be instructive, especially for the less experienced reader, to look at the why's and wherefores of signal level meters. In a perfect world signal level meters would be superfluous for many applications. Sound from any source could be recorded on to tape or disc with no reference to the signal level. The only adjustment necessary would occur during playback, when the volume control of our (perfect) amplifier would be adjusted to give a sound level acceptable to our ears.

Regrettably the real world is very imperfect. To begin with, the lowest signal level that can usefully be recorded is determined by the noise generated by the recording and/or transmitting medium itself in the absence of a signal. In the case of disc this is caused by the surface texture of the disc material, in the case of tape, by random orientation of the magnetic domains. At the other extreme, the maximum signal level is determined for tape by the level at which the tape 'saturates', i.e. when the signal level versus magnetisation graph becomes non-linear, thus distorting the signal. In the case of disc the upper limit is determined by the tracking ability of the cartridge and, to a lesser extent, that of the cutting lathe.

The electronic circuits used to process the signal also have upper and lower signal limits due to noise on the one hand and distortion due to clipping on the other. In a recording/reproducing situation however, the limits imposed by the recording medium are much narrower than those imposed by the electronics.

This brings us to the concept of dynamic range, which is simply the ratio between the highest usable signal level and the lowest. This may be expressed as a ratio, e.g. 1000:1, but is more usually expressed in dB (decibels). There is nothing mystical or magical about the use of decibels, a voltage ratio expressed in dB is simply $20 \log_{10} V_1/V_2$. Thus the dynamic range of 1000:1 expressed in dB would be 20 log 1000. Log 1000 = 3 so the dynamic range = 60 dB. It is most important to note that this tells nothing about the magnitude of the quantities involved, merely their ratio. If some absolute quantity such as a voltage is to be expressed in dB then a reference voltage must first be chosen against which tc express it. Thus, for example, the main voltage (250 V) could be quoted a: 60 dB (reference 0 dB = 250 mV).

There are many reasons for using d rather than simple ratios. Firstly, hum: sense organs tend to respond to stim in a logarithmic fashion, so if electror instruments such as signal level mete are scaled in dB then their response w be similar to that of the human e (disregarding frequency response Secondly, when dealing with dynam ranges of many thousands of times, i would be impossible to construct ar instrument with a linear scale that coula read both the lowest and highest signal levels without changing ranges. Thirdly, since ratios expressed in dB are simply logarithms, to express the product of several quantities such as the overall gain of a number of amplifiers and/or

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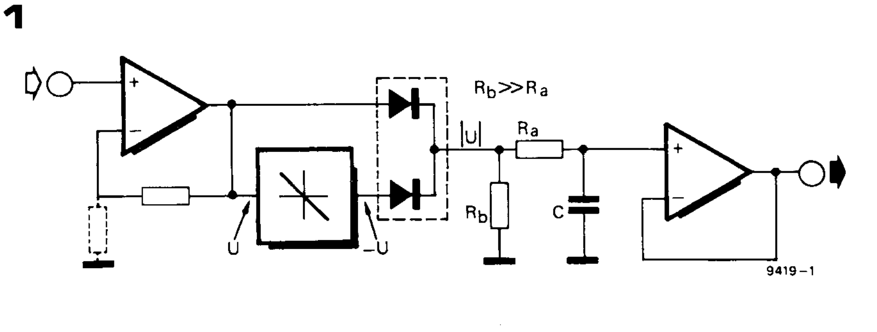

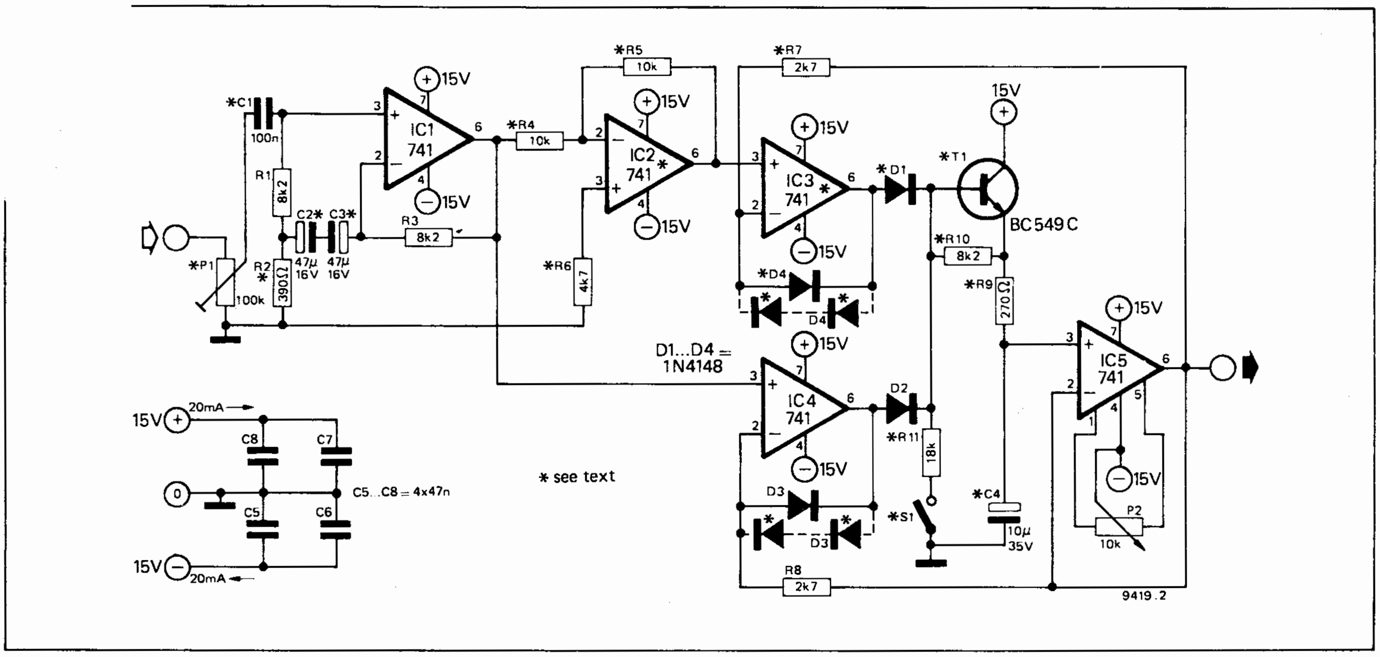

attenuators in cascade it is necessary merely to add up the dB gain/attenuation of each stage rather than multiplying the straight ratios. This makes life much simpler.

Meter Characteristics

This may seem something of a digression from the why's and wherefores of signal level meters, however, from the foregoing it is possible to make the following conclusions.

1. Signal level meters are required for the following reasons:

a. To set the limits of the signal within the dynamic range of the recording/reproducing chain.

b. When making multichannel recordings (including plain stereo) to set the balance between the different channels. This is particularly important in recordings studios using multi-mike techniques and umpteen-channel mixing desks.

c. The dynamic range of live sound is much greater than can be accomodated by the recording medium. It is around 120 dB, determined on the one hand by the softest sound that can be heard, and on the other by the threshold of pain. Since a tape or disc might have a dynamic range of only 50 to 60 dB it is necessary to turn up the recording level during quiet passages so that the signal is not masked by the noise, and to turn the level down during loud passages, so that the equipment is not overloaded. Of course automatic compressors can be used in this situation, but manual adjustment by a skilled engineer is frequently less noticeable.

2. From the earlier discussion it is evident that a signal level meter should have a logarithmic (dB) scale.

PPM or VU?

Since the average value of a symmetrical AC waveform is zero, before the signal level can be measured with any sort of DC meter it must first be rectified. If the rectified waveform is fed to a DC voltmeter then, due to the mechanical inertia of the meter movement, the meter will tend to indicate the average voltage of the waveform. So that the meter needle does not tend to follow the waveform at low signal frequencies (which would make it difficult to read) the inertia of the meter must be fairly high. This is the basic principle of the VU meter.

However, a meter that is sufficiently well damped for the needle not to jitter at low frequencies will also be unable to repond quickly to short transients. This means that the meter will tend to underestimate peaks,

Figure 1. Showing the principle of full-wave rectification of the audio signal, and the attack and decay time constants.

Figure 2. Complete circuit of the rectifier section of the meter.

Figure 3. Showing how, in a VU meter the voltage on C4 builds up until equilibrium is reached between charge and discharge.

Figure 4. For half-wave 'VU' measurement the inverting half of the rectifier section may be omitted.

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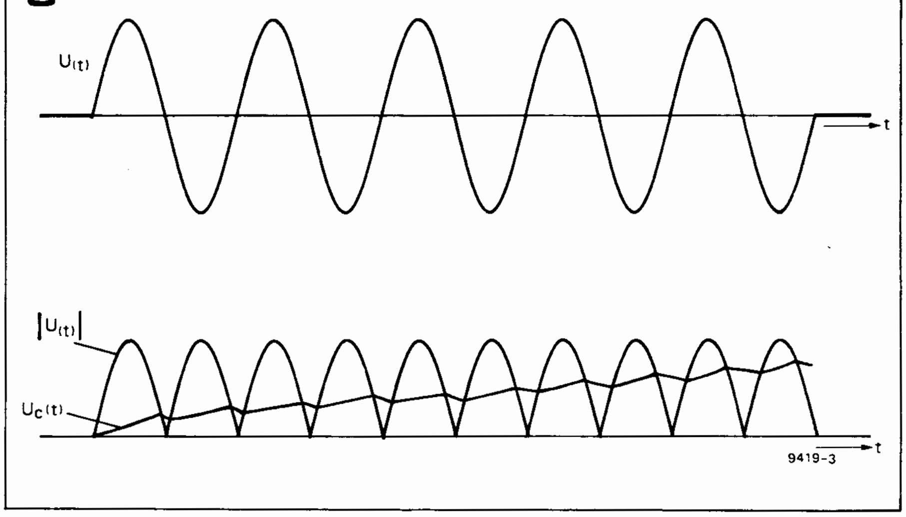

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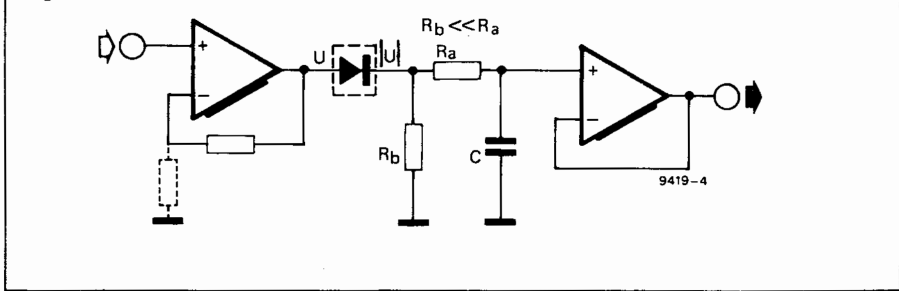


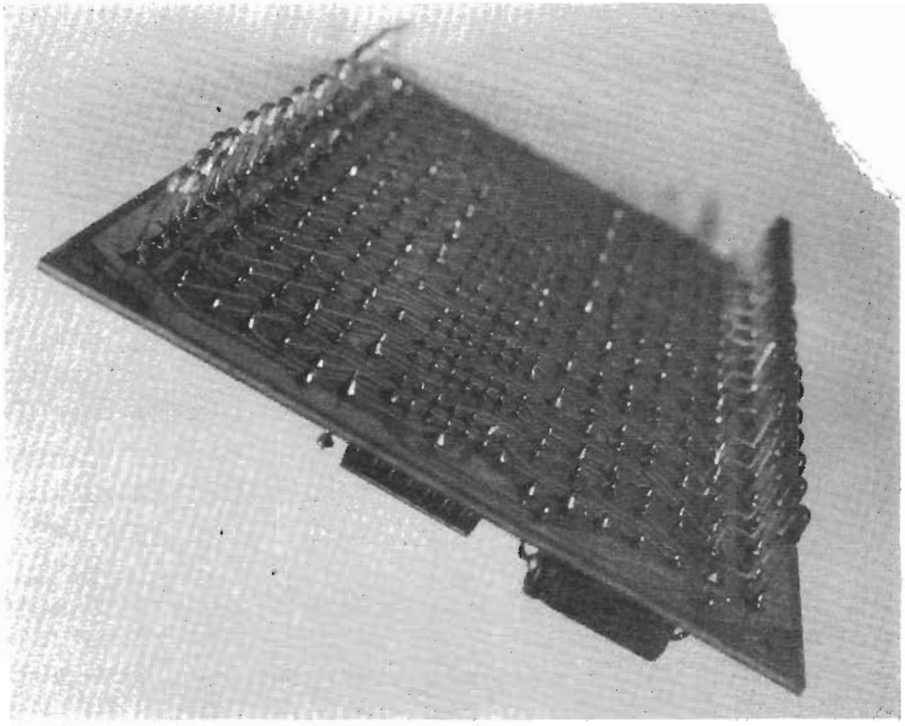
leading to overrecording, and this has been a criticism of the VU meter. That this criticism is to some extent justified is verified by the fact that cassette tape recorders, which almost invariably use VU-like meters, have lately begun to sport peak indicator lamps that light when the maximum safe recording level is exceeded by a few dB, even on short transients. Anyone possessing one of these cassette decks will have noted that when making live recordings, especially of speech, the peak indicator lamps can be made to flash merrily on and off with the VU meters barely leaving their end stops.

This simple experiment indicates that 'live' sound frequently has only a low average level, but a much higher peak level i.e. a very large peak to mean ratio. To give a truer indication of the peak signal level the BBC (and other) PPMs (Peak Programme Meters) were developed. These instruments were designed to respond very quickly to increase in signal level, but for ease of reading the meter reading was made to die away at a much slower rate. To put it another way, the PPM has a short attack time constant and a long decay time constant. The original PPMs had an extremely fast attack. However, later experiments in psycho-acoustics showed that the ear is unable to perceive distortion caused by short duration clipping (e.g. less than 10 ms). This means that overrecording of short transients is allowable, provided no undesirable effects occur such as blocking of amplifiers or r.f. bursting, and in this situation the original PPM tended to overestimate the effect of peaks.

Accordingly the attack time constant was modified, and the present (BBC) standard is an attack time constant of 2.4 ms and a decay time constant of 1 s.

Meter Drive Circuits

In the conventional VU meter and PPM



the ballistics of the meter movement play a great part in determining the time constants and are very tightly specified. However, the present design is to use a line of LEDs instead of a moving coil instrument, so the meter characteristics are determined entirely by the electronics.

Figure 1 shows a block diagram of the drive circuitry for the PPM. The signal is first buffered and if necessary amplified before being fed to two rectifiers. The signal to one rectifier is inverted so that this rectifier operates on negative half-cycles of the waveform, and a full-wave rectified version of the waveform appears at the junction of the outputs of the two rectifiers. This output is used to charge a capacitor C through resistor R_a, the time constant $R_a \cdot C$ being the attack time constant. C can

Figure 5. Complete circuit of the LED display with logarithmic divider chain. This gives a DIN-type PPM scale (Table 4) but can be adapted to give a BBC-type PPM (Table 3) or VU scale (Table 2).

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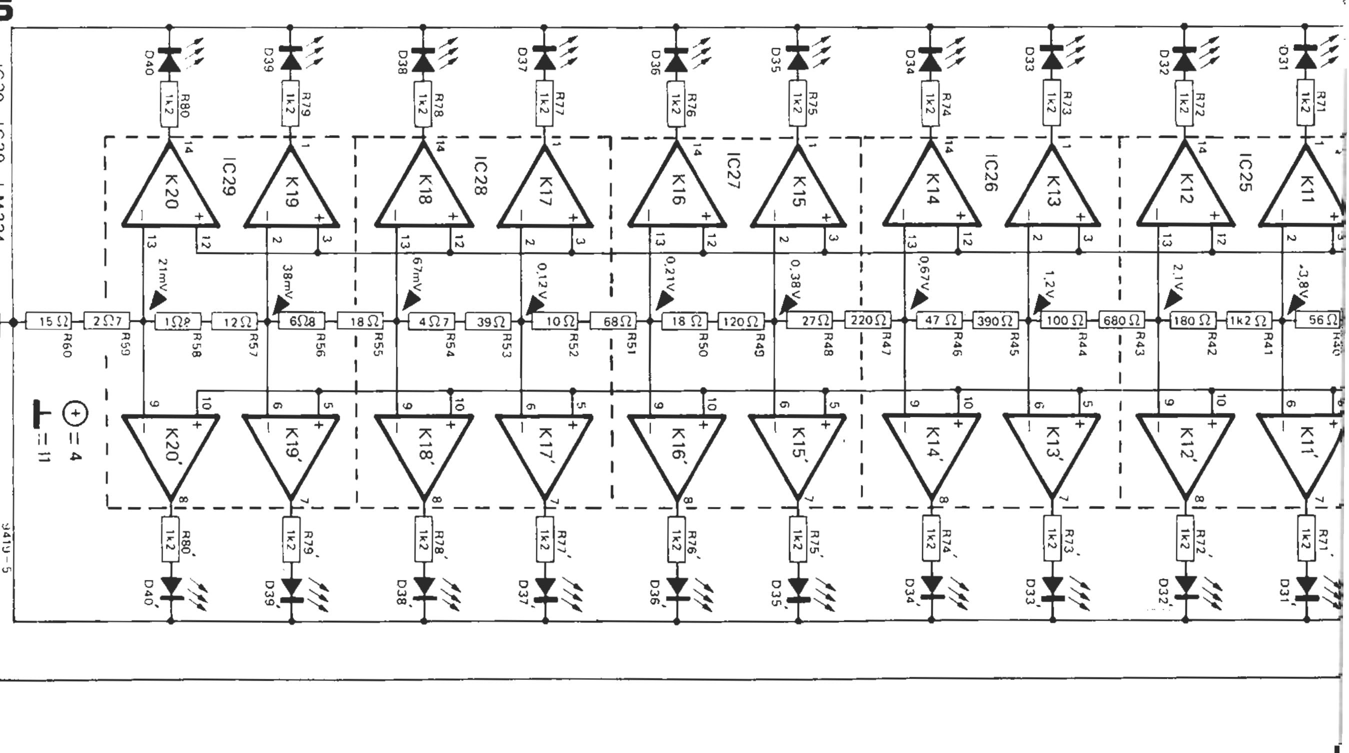

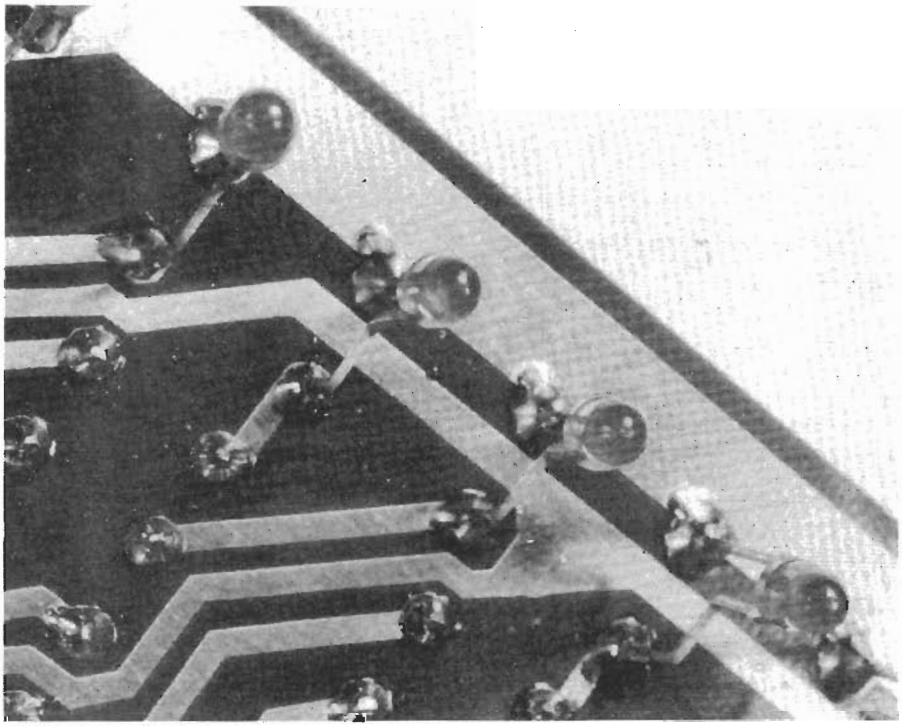

discharge through R_a and R_b. R_a, R_b and C are chosen to give the time constants mentioned earlier. To avoid the output from C being loaded by the following circuits a high input impedance buffer is provided.

Operation of the VU meter drive circuit is very similar. The only difference is that R_b is very small compared to R_a, so the attack and decay time constants are virtually identical.

Figure 2 shows the complete circuit of the meter drive. IC1 functions as a non-inverting amplifier with a gain of $\frac{R_2 + R_3}{R_2}$. Bootstrapping of R1 at the junction of R2 and C2 increases the input impedance. The reverse series connection of C2 and C3 is necessary since the DC voltage on pin 2 of IC1 can be either slightly positive or slightly negative. A 22 μ reversible electrolytic could also be used here.

IC2 functions as a unity gain inverter, and the inverted and non-inverted signals are fed to IC3 and IC4 respectively, which form the two halves of the rectifier circuit. The rectifier circuit is of the active type, and eliminates the effect of the forward voltage drop of the diodes, which could otherwise cause gross errors in the measurement of low signal levels.

The rectifier configuration shown offers some interesting possibilities, depending on how diodes D3 and D4 are connected. With the diodes connected as shown the circuit operates as follows: assuming that the circuit is in the quiescent condition the outputs of IC3 and IC4 are at zero volts. Since there is no bias voltage across D3 or D4 IC3 and IC4 have no feedback and are thus operating open-loop. On positive half-cycles of the input signal the output of IC4 will swing rapidly positive until it clips. D2 will conduct, T1 will conduct and C4 will charge rapidly from T1 via R9. IC5 is connected as a voltage follower, so its output will be equal to the voltage on C4. This provides negative feedback to the inverting input of IC4. The voltage on C4 will thus stabilise at a level equal to the peak value of the input voltage.

During this time the output of IC3 will swing negative, forward biasing D4 so that IC3 simply operates as a voltage follower following the (negative) output of IC2. D1 is thus reverse-biased, so no negative voltage appears on the base of T1.

On negative half-cycles of the waveform the situation is reversed. The output of IC3 swings positive and causes D1 and T1 to conduct, while the output of IC4 goes negative, reverse-biasing D2. The discharge path for C4 is through R9, R10 and R11, since IC5 presents a very high input impedance and thus has little effect on the discharge time. The ratio of R10 to R11 is chosen so that the voltage on C4 cannot cause reverse emitter base breakdown of T1 in the absence of a signal.

S1 can be opened to remove the discharge path and provide a 'peak memory', which can be useful when making 'dry-runs' of recording sessions to find the maximum level of the signal.

This 'Elektor Standard' system provides a peak rectifier with an extremely fast rise time. However, to make a rectifier with characteristics corresponding to that of a BBC or DIN PPM or VU meter, several changes must be made.

If the circuit is to be used as a VU meter then T1 is not required since the attack and decay times are relatively long (300 ms). The charging current of the

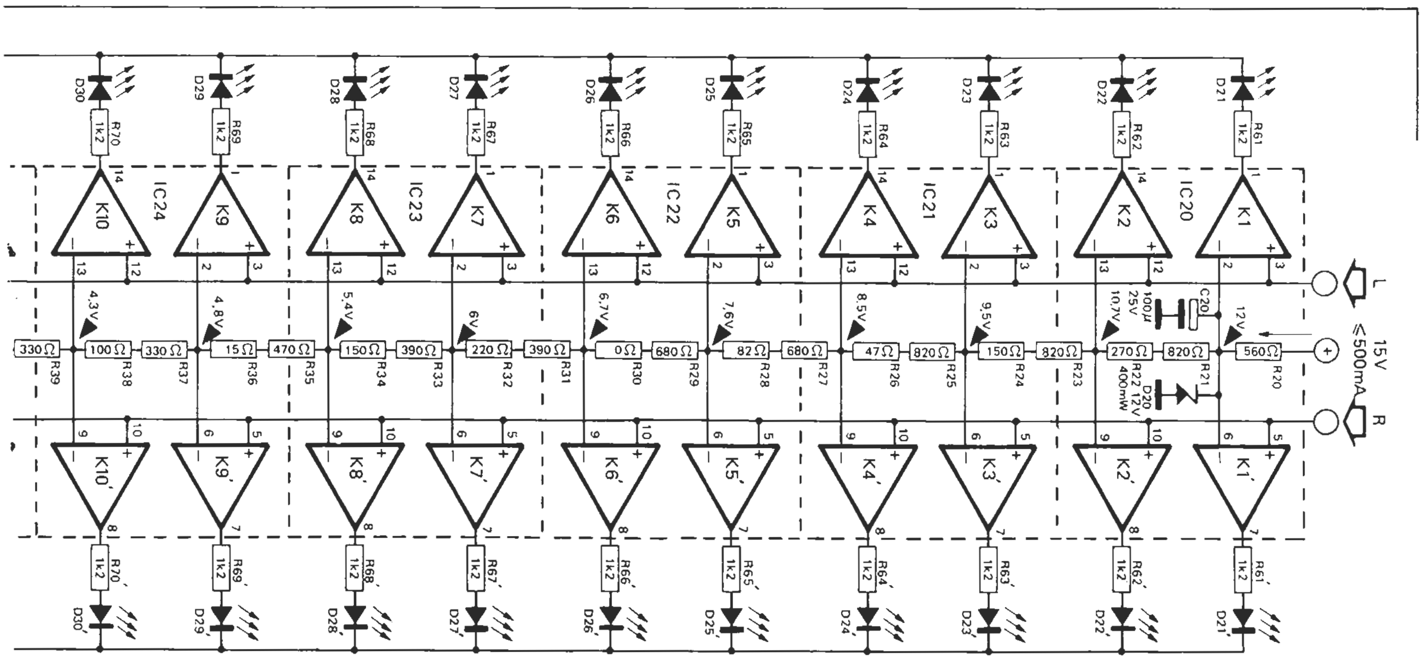

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Table 1.

Component values for different response characteristics.

	Elektor PPM	DIN PPM	BBC PPM	VU METER
R9	270 Ω	68 Ω	100 Ω	100 k
R10	8k2	10 k	12 k	0 Ω
R11	18 k	18 k	33 k	10 k
C4	10 μ(1)	22 μ(1)	22 μ(1)	330 n
D3	1N4148	2 x 1N4148 reversed		1 x 1N4148 reversed
D4	1N4148	2 x 1N4148 reversed		1 x 1N4148 reversed
T1	BC549C or equivalent			omitted

(1) Tantalum 20% tol. 16 V.

capacitor is smaller and can easily be provided by the outputs of IC3 and IC4 direct. R10 is replaced by a wire link, R9 becomes 100 k, R11 - 10 k and C4 - 330 n.

Diodes D3 and D4 are reversed. This may seem a little strange, but the circuit now operates as follows: on positive half cycles the output of IC4 will swing positive in an open-loop mode until D3 begins to conduct, after which IC4 will operate as a voltage follower. The voltage at the output of IC4 is thus equal to the input voltage plus the forward voltage of D3. D2 is forward biased and its voltage drop cancels that of D3, so the voltage at its cathode is equal to the input voltage to IC4. C4 will charge from IC4 through D2 and R9. On negative half-cycles the output of IC3 will swing positive and C4 will charge via D1 and R9. D4 discharges through R9 and R11, but since R11 is small compared to R9 the attack and decay time constants are similar.

The problem now arises as to how to calculate the required time constants. The specification for a VU meter states that if a 1 kHz sinewave, whose amplitude is such as to give a steady state reading of 100, is suddenly applied, the reading on the VU meter shall reach 99 within 300 ms. If it was a simple step function that was applied to the meter then the time constant would be simple to calculate. Unfortunately, since the meter is dealing with a full-wave rectified sinewave C4 does not charge continuously, but only when the rectified voltage is present. In the 'gaps' between it actually discharges, as shown in figure 3. The steady state reading is reached when the capacitor is discharging at the same rate as it charges.

This makes the calculation of the required time constant rather complicated and by far the easiest way to find it is empirically.

Alternative drive circuits

Many cheap so-called VU meters use only half wave rectification (figure 4) and assume that the signal waveform will be symmetrical. The circuit of figure 2 may be so modified by omitting IC2, IC3 and their associated components. This does result in a slight saving in cost, but the meter does not have a true VU characteristic.

Since a conventional VU meter is simply a rectifier instrument relying on the meter ballistics for its attack and decay times it is fairly easy to simulate electronically. However, the attack time of a conventional PPM is determined by two factors, the meter ballistics and the electrical time constant of the rectifier circuit. This makes it more difficult to simulate accurately without using a more complex double time constant circuit. Some compromise must thus be found.

The standard for a BBC type PPM (BS 4297;1968) states that if a 5 kHz signal (whose steady state value would give a reading of mark 6 on the PPM scale) is applied in a 5 ms burst the reading will be 4 dB below mark 6. To obtain this reading the attack time constant must be about 2.5 ms. Since the attack of a genuine PPM is more complex this necessarily results in small errors at other scale points. The decay time constant of the BBC PPM is 1 s, and the decay time is largely independent of the meter ballistics, since these are swamped by the long time constant.

The specification for a PPM to DIN 45406 states that a 5 ms tone burst shall give a reading 2 dB below the steady state reading. Here an attack time constant of 1.5 ms is a reasonable compromise. The decay time of the DIN PPM is 650 ms.

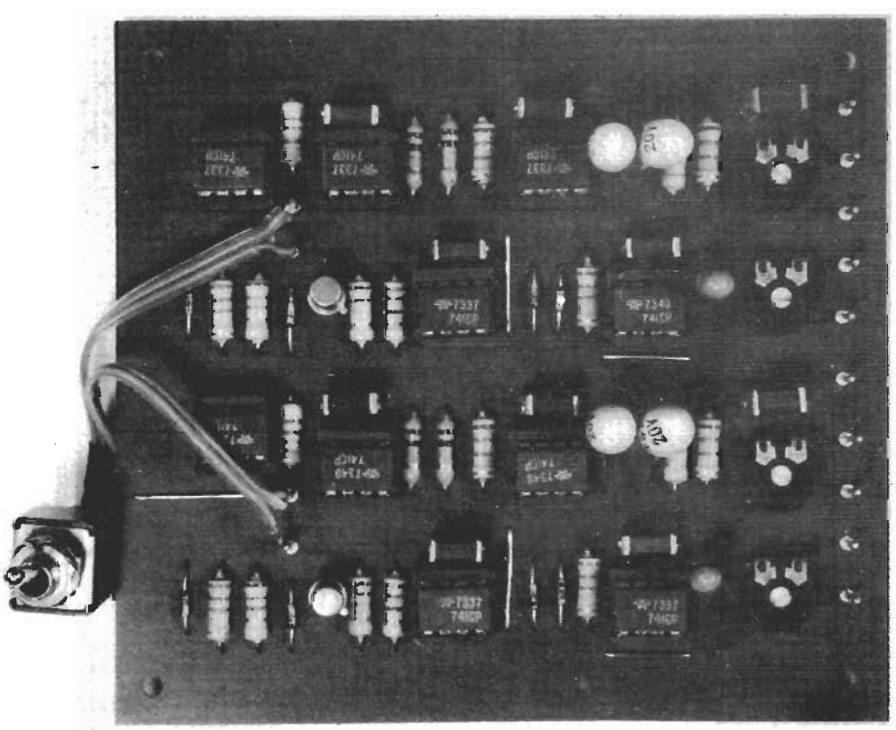
Since the attack time constants of PPMs are much shorter than that of a VU meter the value of R9 and/or C4 must be reduced. To obtain a value of R9 that could be driven direct from the 741 outputs C4 would need to be less than 1 μ, which means that R11 would be greater than 1 M. This is unacceptable as the input currents of IC5 would then have a significant effect on the decay time. To overcome this T1 must be reinstated so that smaller values of R9 and R11 and a larger value of C4 can be used. However, the base emitter junction of T1 then introduces an extra voltage drop, which must be eliminated. The solution is an extra diode in series with both D3 and D4.

To clarify matters the component values for the 'Elektor Standard' PPM, BBC and DIN PPMs and VU meter are given in Table 1. These values may of course be altered to suit personal taste and/or any other standards.

Display

Having obtained a voltage which increases and decreases with the appropriate time constants in response to a signal, the question now is how to convert it to a suitable display. Established readers of Elektor will be familiar with the ICs manufactured for this purpose by Siemens. These consist of a chain of analogue voltage comparators each having one input tied to a reference voltage from a potential divider, the other input being connected to the signal voltage and the output to a LED. When the input voltage exceeds the reference voltage the comparator output goes low and lights the LED. The higher the input voltage the more LEDs in the chain there are lit.

Unfortunately the response of these LED voltmeters is linear, whereas a logarithmic response is required for a signal level meter. One possibility would be to precede one of the Siemens ICs by



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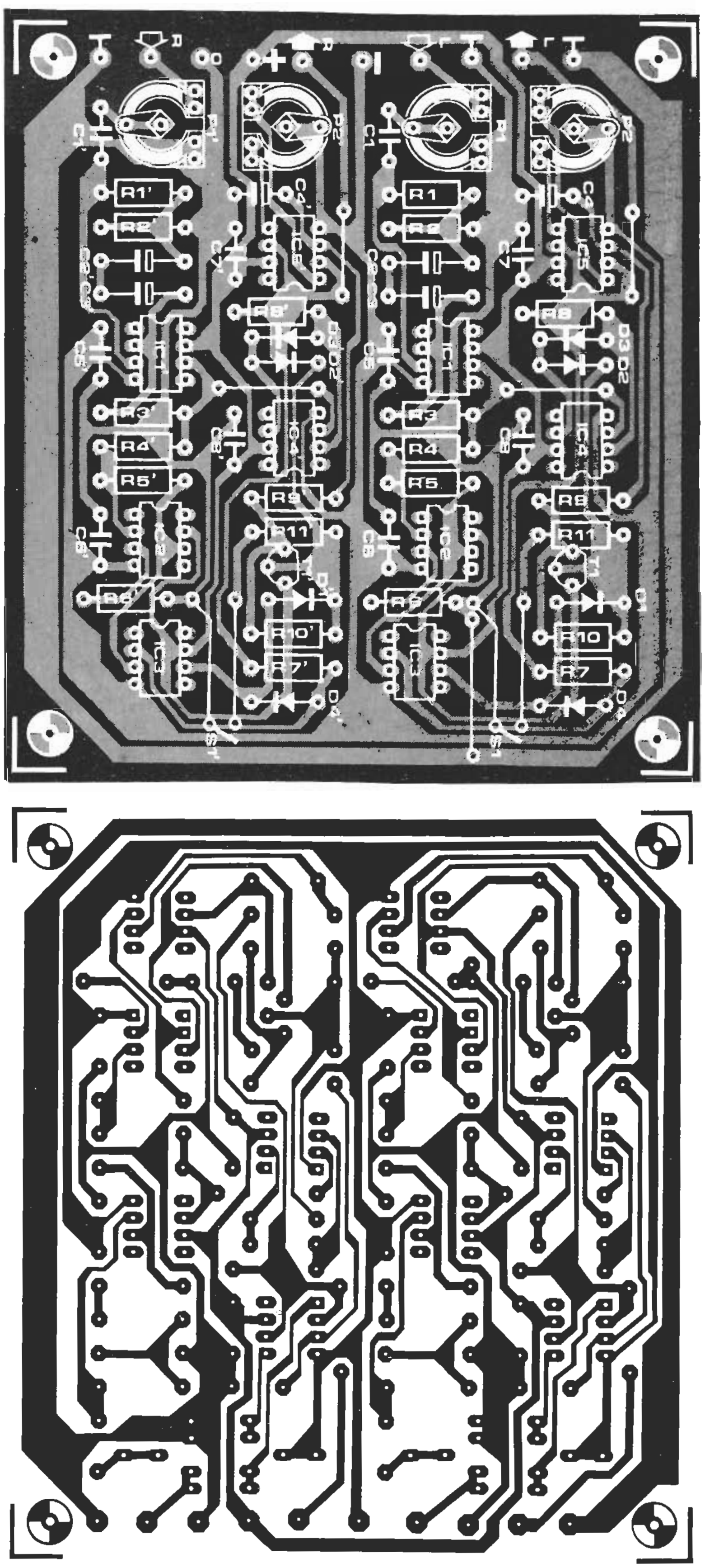

Parts list for figures 2 and 6:

Resistors:
R1,R3 = 8k2
R2 (1) = 390 Ω
R4 (2),R5 (2) = 10 k
R6 (2) = 4k7
R7 (2),R8 = 2k7
R9 = see text and Table 1
R10 = see text and Table 1
R11 = see text and Table 1
P1 (1) = 100 k
P2 = 10 k

Capacitors:
C1 (1) = 100 n
C2 (1),C3 (1) = 47 µ/16 V
C4 = see text and Table 1
C5,C6,C7,C8 = 47 n

Semiconductors:
IC1,IC2 (2),IC3 (2),IC4,IC5 = 741
D1 (2),D2 = 1N4148 or 1N914
D3,D4 (2) = see text and Table 1
T1 (3) = BC109C, BC549C or equivalent

Miscellaneous:
S1 (3) = DPST switch

Notes:
1: See 'Calibration'.
2: Omitted for half-wave VU measurement.
3: Omitted for VU measurement.

Table 1. Component values to modify figure 2 for different response characteristics.

Figure 6. Printed circuit board and component layout for the rectifier section (EPS 9419-1).

a logarithmic amplifier. However, these can be somewhat critical in operation, and a much simpler solution is to design a LED voltmeter using discrete comparators but, unlike the IC versions, having a logarithmic potential divider network.
The complete circuit for a stereo version of the indicator is given in figure 5. The 'law' of the logarithmic potential divider is shown in the second column of Table 4. It will be seen that around the 0 dB level the steps are 1 dB, but at lower levels the steps are made much coarser (5 dB). This means that the meter has the best resolution in the most useful part of its range. This corresponds to the scaling of a DIN PPM, but can easily be altered to give BBC PPM and VU type scales as will be explained later.

Construction

A printed circuit board and component layout for a two-channel version of the rectifier circuit are given in figure 6, and for the display unit in figure 7. The

2

Table 2.

Components for VU type display scale.

Resistors:
R21 – R28 = 0 Ω (wire links)
R29,R31,R33,R55 = 1 k
R30,R53 = 270 Ω
R32 = 100 Ω
R34,R48,R60 = 0 Ω
R35 = 820 Ω
R36,R44,R50 = 68 Ω
R37,R43,R45,R47 = 470 Ω
R38,R49,R51 = 330 Ω
R40 = 390 Ω
R41,R57 = 560 Ω
R42,R58 = 56 Ω
R46 = 33 Ω
R52 = 22 Ω
R54 = 47 Ω
R56 = 120 Ω
R57 = 18 Ω
R59 = 820 Ω
R61 – R64 and R61' – R64' = omitted

Semiconductors:
IC20,IC21 (K1 – K4 and K1' – K4') = omitted
D21 – D24 and D21' – D24' = omitted

All other components as per figure 5.

3

Table 3.

Components for 'BBC PPM' type display scale.

Resistors:
R21 – R30 = 0 Ω (wire links)
R31 = 3k3
R32 = 2k7
R33 = 1k2
R34,R37 = 560 Ω
R35 = 1 k
R36,R40,R43 = 270 Ω
R38 = 39 Ω
R39,R41 = 330 Ω
R42 = 68 Ω
R44,R46 = 33 Ω
R45 = 220 Ω
R47 = 180 Ω
R48,R54 = 22 Ω
R49 = 150 Ω
R50,R52,R56,R58,R60 = 0 Ω
R51,R53,R57,R59 = 120 Ω
R55 = 100 Ω
R61 – R65 and R61' – R65' = omitted

Semiconductors:
IC20,IC21 (K1 – K4 and K1' – K4') = omitted
D21 – D25 and D21' – D25' = omitted

All other components as per figure 5.

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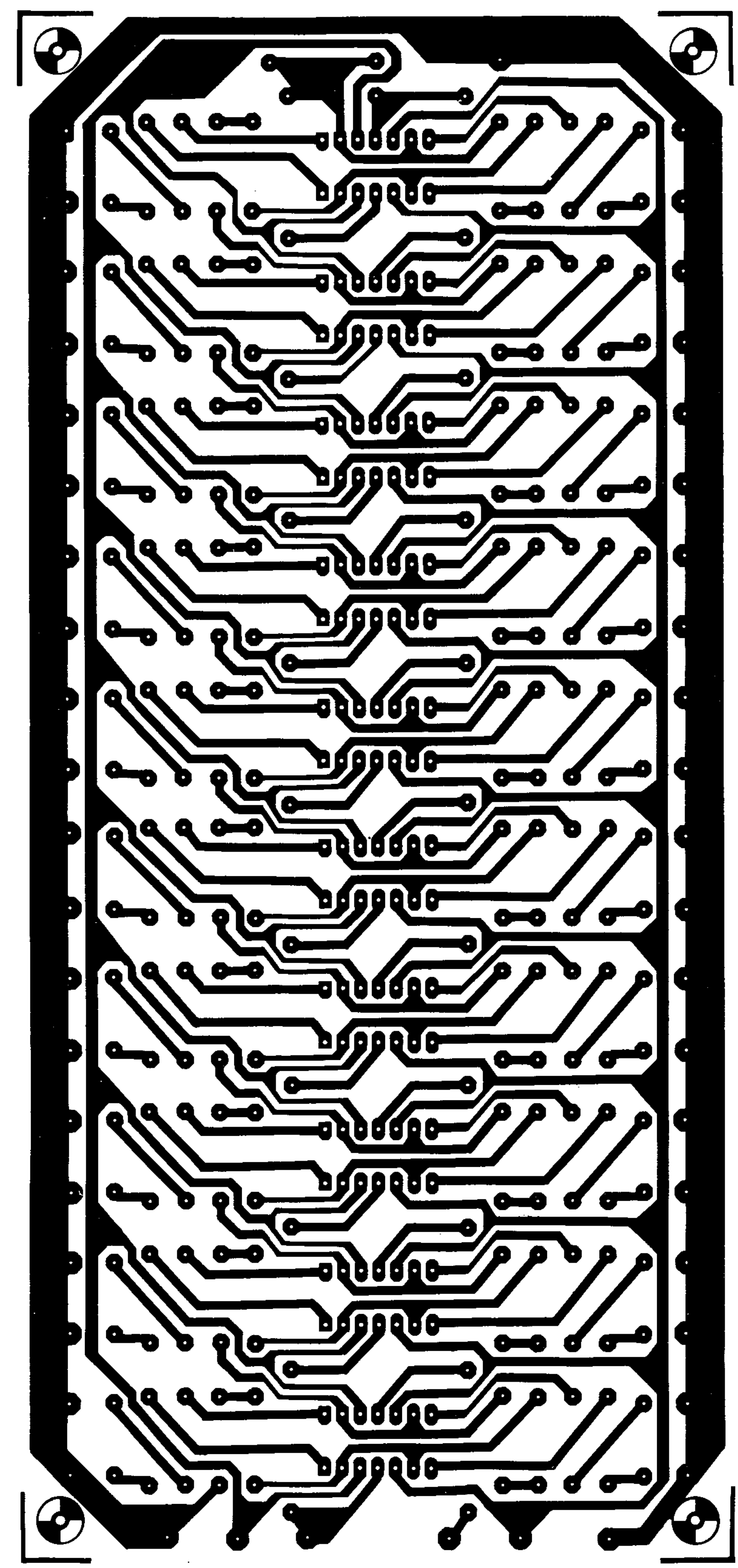
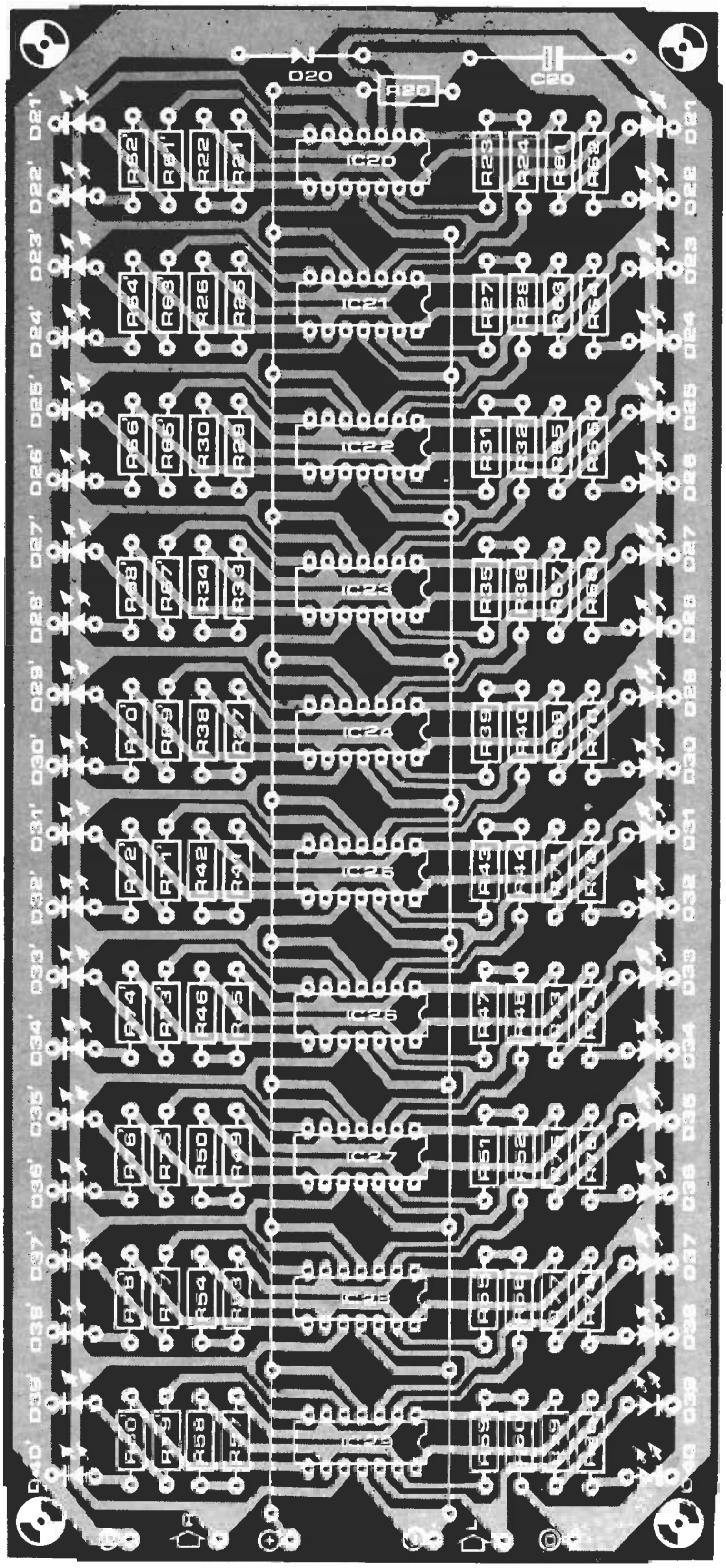


accompanying photographs show the construction of the complete unit. Of course it is not mandatory to mount the LEDs on the back of the p.c. board as shown. If panel width is at a premium the LEDs can be mounted separately on a piece of veroboard and the p.c. board can then be mounted edge on to the front panel.

Calibration

Having checked for any wiring errors, before connecting the rectifier and display boards a few simple checks can be carried out. Firstly, apply power to the display board and check that, with the input grounded, no LEDs are lit, and with the input connected to +15 V all LEDs are lit.
Secondly, with power applied to the rectifier board, adjust P2 in both channels to give a null (zero volts) at the output of IC5. It may be necessary to swap around the 741s to find the one with the best offset characteristics, so it is a good idea to mount them in sockets.
Having carried out these checks the two boards may be linked together and the whole system tested by applying a sine wave signal to the inputs and varying the input level. Calibration of the meter



Parts list for figures 5 and 7.

Resistors:
R20 = 560 Ω
R21,R23,R25 = 820 Ω
R22 = 270 Ω
R24,R34 = 150 Ω
R26,R46 = 47 Ω
R27,R29,R43 = 680 Ω
R28 = 82 Ω
R30 = 0 Ω (link)
R31,R33,R45 = 390 Ω
R32,R47 = 220 Ω
R35 = 470 Ω
R36,R60 = 15 Ω
R37,R39 = 330 Ω
R38,R44 = 100 Ω
R40 = 56 Ω
R41,R61(1) – R80(1) = 1k2
R42 = 180 Ω
R48 = 27 Ω
R49 = 120 Ω
R50,R55 = 18 Ω
R51 = 68 Ω
R52 = 10 Ω
R53 = 39 Ω
R54 = 4Ω7
R56 = 6Ω8
R57 = 12 Ω
R58 = 1Ω8
R59 = 2Ω7

Capacitors:
C20 = 100 μ/25 V

Semiconductors:
IC20 – IC29 (K1 – K20') = LM324
D20 = 12 V 400 mW zener
D21 – D25 = red LED(1)
D26 = yellow LED(1)
D27 – D40 = green LED(1)

Notes:
1: See 'Adaptions' and Tables 2 and 3.
Note that, for the stereo display, R61 to R80 and D21 to D40 are duplicated.
IC20 to IC29, R20 to R60, C20 and D20 serve both channels.

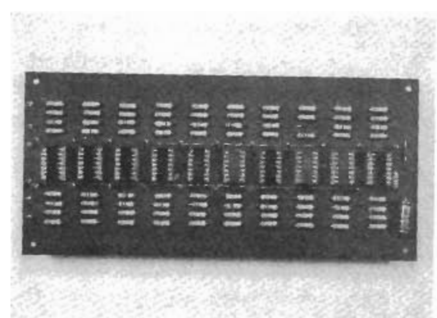


Figure 7. Printed circuit board and component layout for the display (EPS 9419-2).

Table 2. Component modifications for VU-type display.

Table 3. Component modifications for BBC PPM-type display.

depends on the maximum signal level likely to be encountered in the system. In any event, to calibrate the PPM version the unit must be fed with a sine wave signal having a peak value equal to the maximum peak signal level. P1 is then adjusted until all LEDs up to the 0 dB LED are lit.

To calibrate the VU meter it must be remembered that the average value of the signal is being measured, so the peak value of the input signal must be $\pi/2$ or 1.57 times higher. If the half-wave 'VU' circuit is used then, since only half the waveform is utilised the peak value of the input signal must be π times greater. To put it another way, if the same signal level is to give a 0 dB reading on both PPM and VU measurements then P1 will need to be turned up further in the VU meter.

If the meter is to be used to monitor the output of a high signal circuit such as a power amplifier then there is no need for IC1 to have any gain and it can simply be used as a voltage follower. In that case C2 and C3 are omitted, R2 is replaced by a wire link, P1 becomes 10 k and C1 becomes 1 μ.

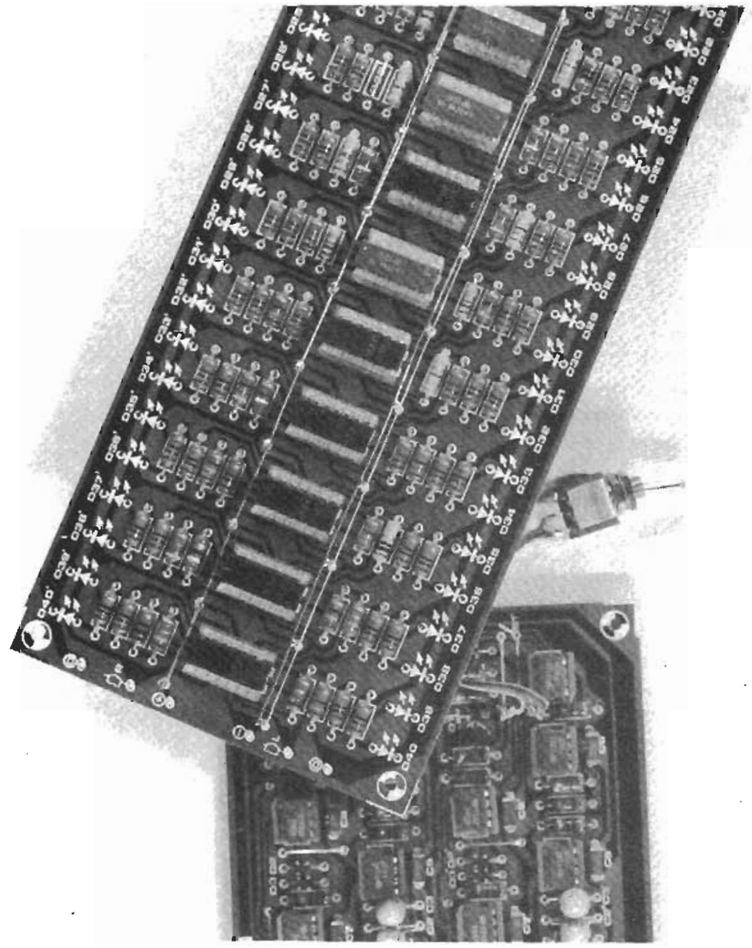
Adaptations

1. The scaling of the meter is −50 dB to +5 dB in accordance with DIN 45406 and the IEC proposal of September 1970. However, the display p.c. board is almost universal in scope and can be altered to give virtually any desired scale. This is achieved simply by altering the resistors in the potential divider chain and/or the number of comparators and LEDs. The modifications required to give a VU-type scale (−20 to +3 dB) are given in Table 2. Modifications to give a BBC PPM-type scale are given in Table 3.

2. The time constants of the rectifier circuit can be adjusted to suit personal taste. There are various 'standards' for peak reading meters, none of which agree with one another. If one wishes to stick to a particular standard, however, then the appropriate time constants should be used. The appropriate display scaling should also be used.

3. The current through the LEDs (and hence their brightness) can be varied by choosing different values for the series resistors. However the resistors should not be chosen so low that the current rating of the LEDs is exceeded.

4. The +15 volt supply must be well decoupled by a 100 μ/35 V capacitor to avoid transients appearing on the supply line due to the large current drawn by T1 and the LEDs on transient signal peaks. The +15 V supply should be capable of delivering 500 mA. The −15 V consumption, however is only about 20 mA.



5. Since 741s have a limited slew rate the h.f. response of the rectifiers may be somewhat limited, since for the first part of their output swing the 741s are operating open loop. Perfectionists may like to experiment with faster op-amps such as the 748 or 531. Such ICs, of course, require external frequency compensation, so would-be experimenters are advised to consult the manufacturer's data.

6. The LED colours may be changed to suit personal taste, but it is a good idea to arrange that the display colour changes to indicate an overload e.g. green below 0 dB, yellow at 0 dB and red above 0 dB. ◾

Table 4. Scale layout of the three types of display.

4

Table 4.

'DIN PPM' type scale parameters.

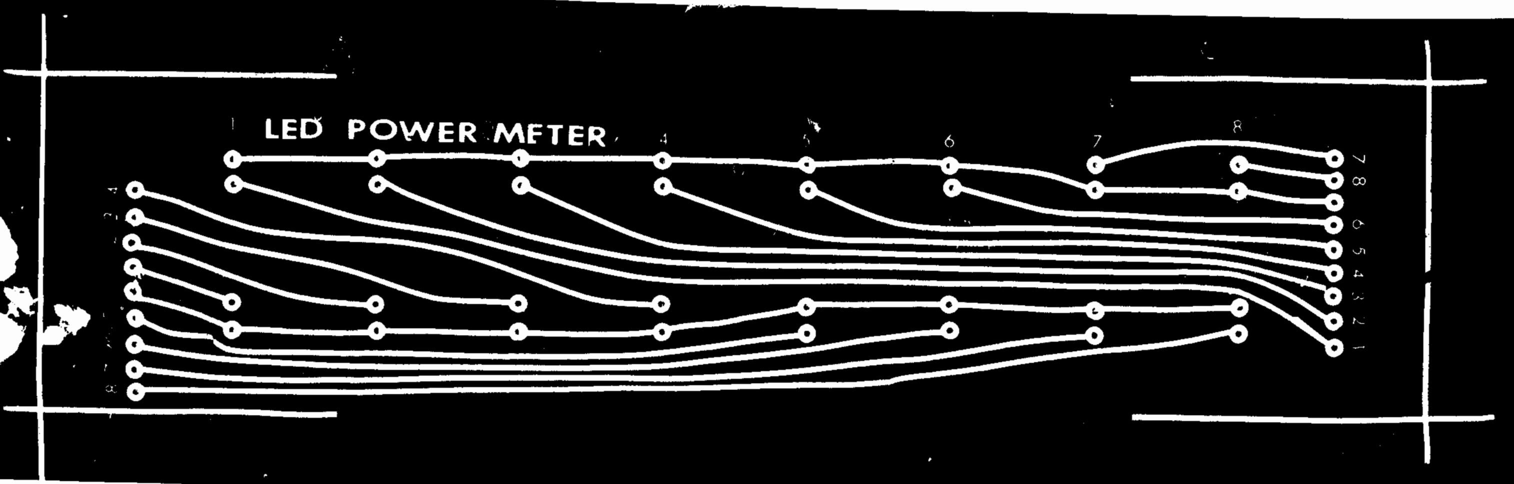
LED	PPM Level (dB)	Absolute voltage applied to display input (volts)
D40	−50	.021
D39	−45	.038
D38	−40	.067
D37	−35	.12
D36	−30	.21
D35	−25	.38
D34	−20	.67
D33	−15	1.2
D32	−10	2.1
D31	−5	3.8
D30	−4	4.3
D29	−3	4.8
D28	−2	5.4
D27	−1	6
D26	0	6.7
D25	+1	7.6
D24	+2	8.5
D23	+3	9.5
D22	+4	10.7
D21	+5	12

'BBC PPM' type scale parameters.

LED	dB Level	PPM reading	Absolute level at display input (volts)
D40	−20	unspecified	0.12
D39	−14	1	0.24
D38	−11	1.5	0.34
D37	−8	2	0.48
D36	−6	2.5	0.6
D35	−4	3	0.75
D34	−2	3.5	0.95
D33	0	4	1.2
D32	+2	4.5	1.5
D31	+4	5	1.9
D30	+6	5.5	2.5
D29	+8	6	3
D28	+11	6.5	4.26
D27	+14	7	6.01
D26	+20	unspecified	12

VU type scale parameters.

LED	VU Level	Absolute level at display input (volts)
D40	−20	0.85
D39	−15	1.51
D38	−10	2.68
D37	−9	3.01
D36	−8	3.38
D35	−7	3.79
D34	−6	4.28
D33	−5	4.77
D32	−4	5.36
D31	−3	6.02
D30	−2	6.75
D29	−1	7.57
D28	0	8.5
D27	+1	9.53
D26	+2	10.7
D25	+3	12


LED POWER METER