LED Level Meter

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.

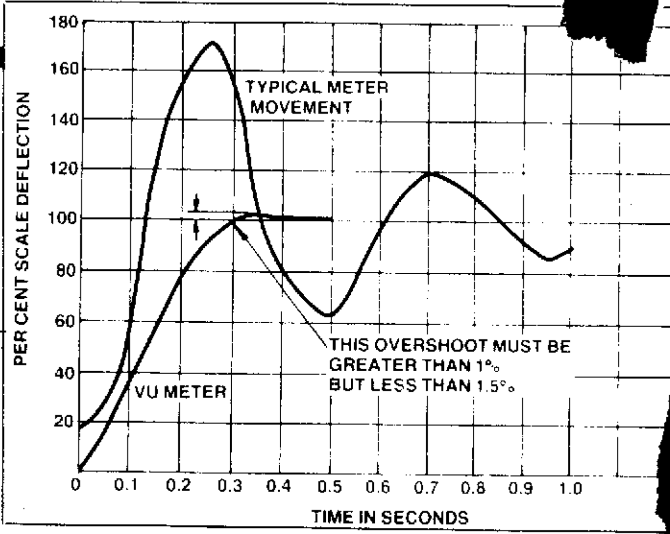
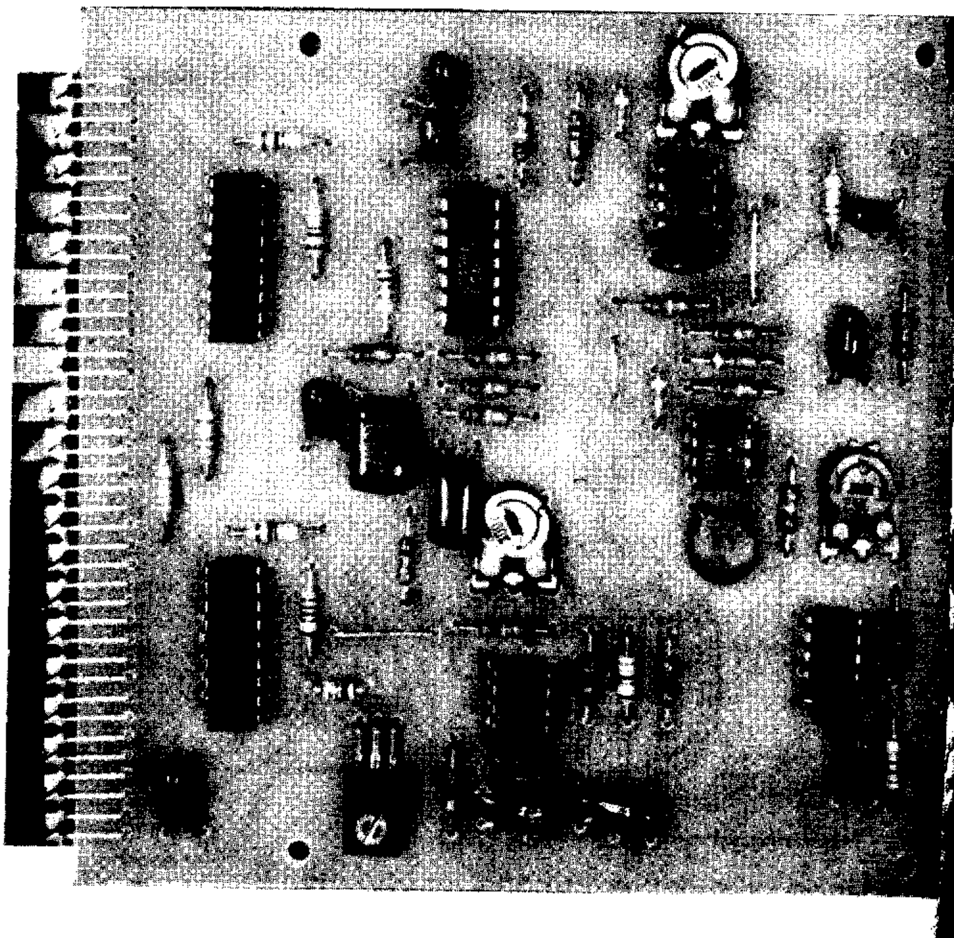


Fig. 1 'Ballistics' of a VU meter compared to conventional moving coil meter.

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 instant, but the rapid switching speed



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

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 potential 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

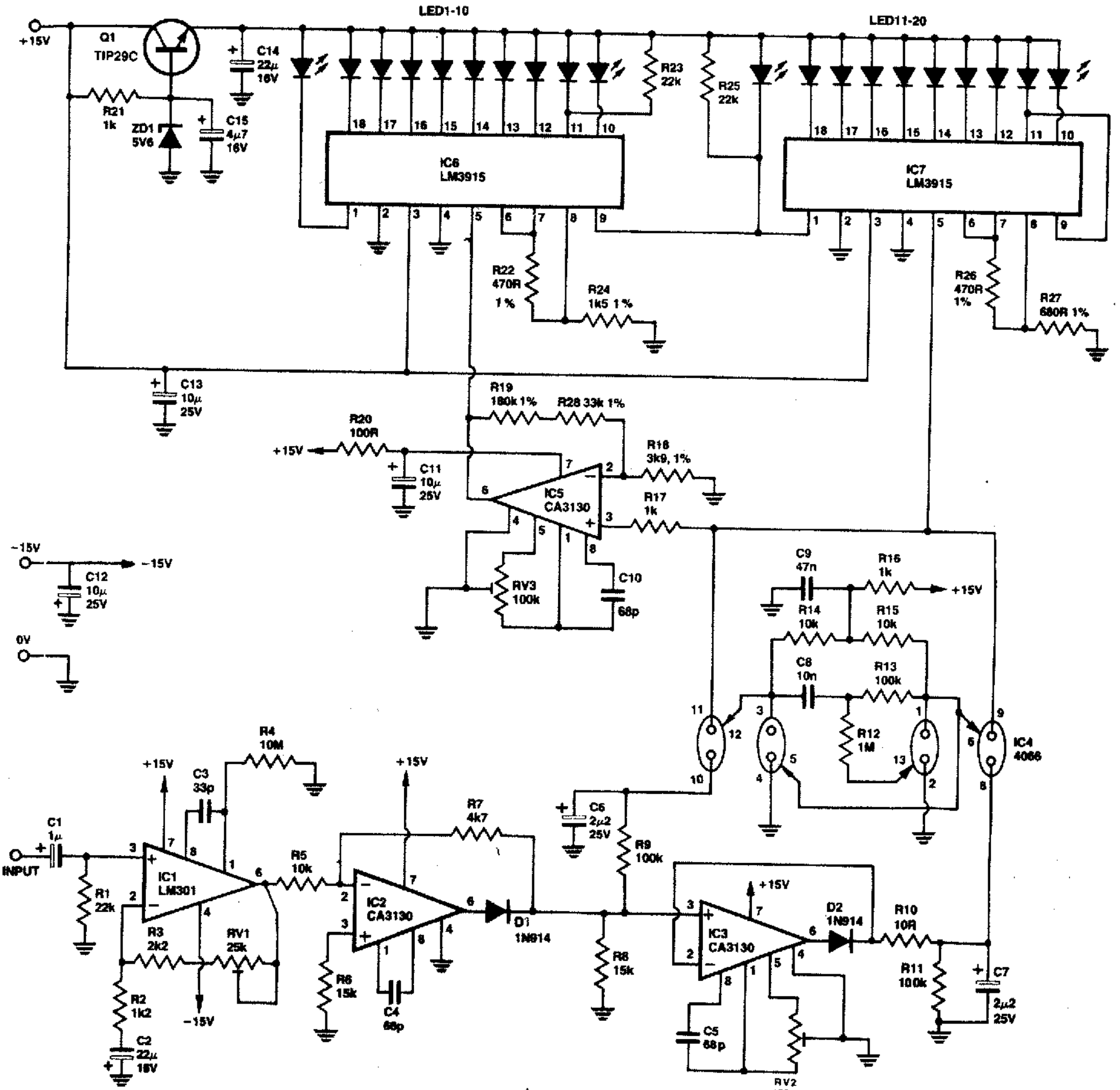


Fig. 2 Circuit diagram of the LED level meter.

other is accurate. Resistors R18, R19, R22, R24, R26, and R27 have been 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

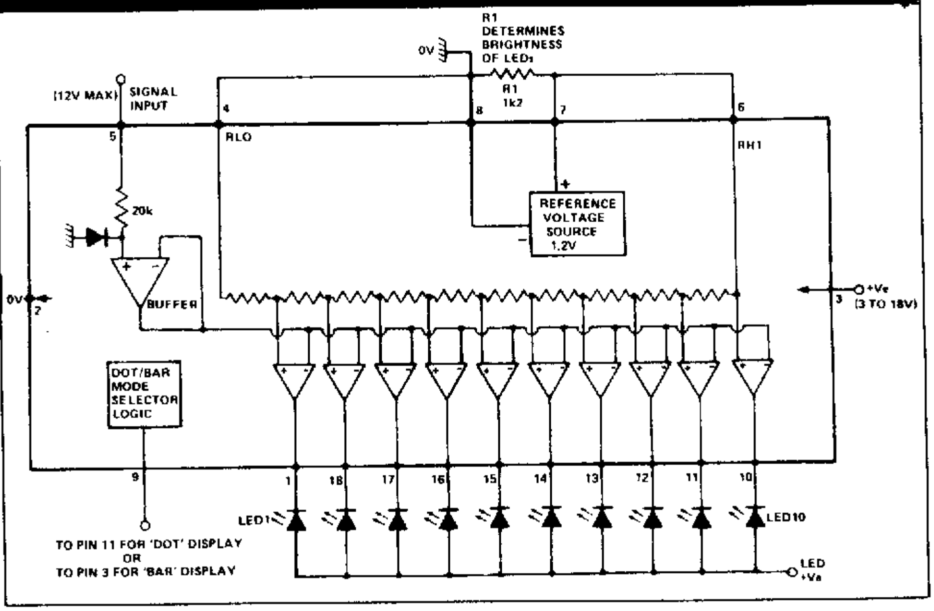


Fig. 3 Internal block diagram of the LM3915.

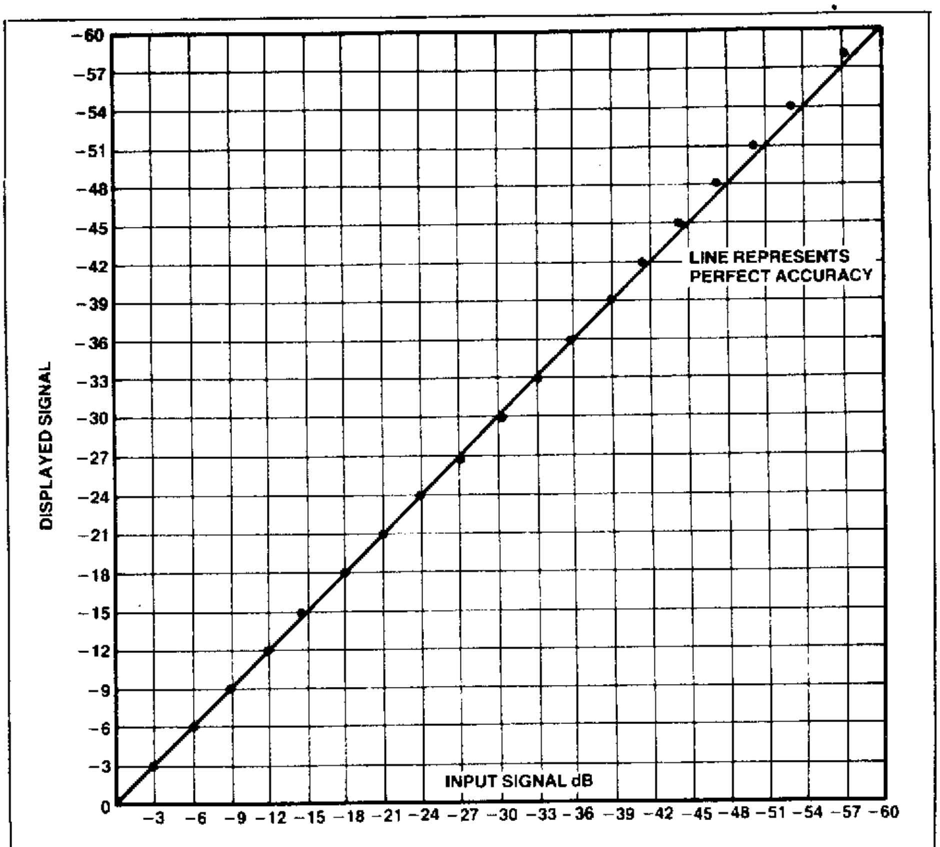
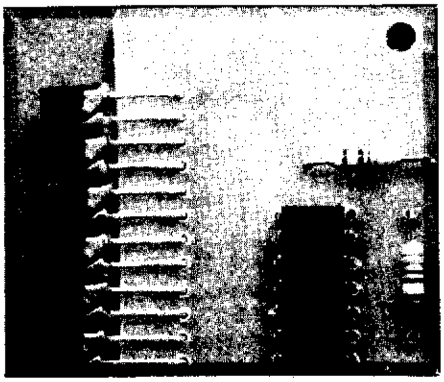


Fig. 4 Accuracy of the ETI LED level meter display (dots) compared to 'perfect accuracy' (line).

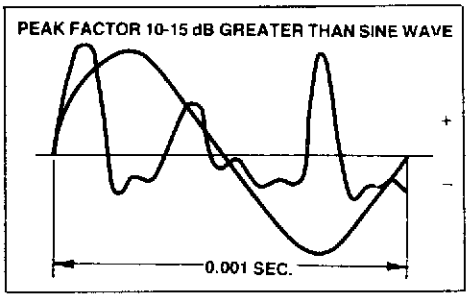
RV3.

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.



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.

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 full wave rectifiers require 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 require 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 C14 is essential for stability of the LED drivers and must be mounted close to the LEDs.

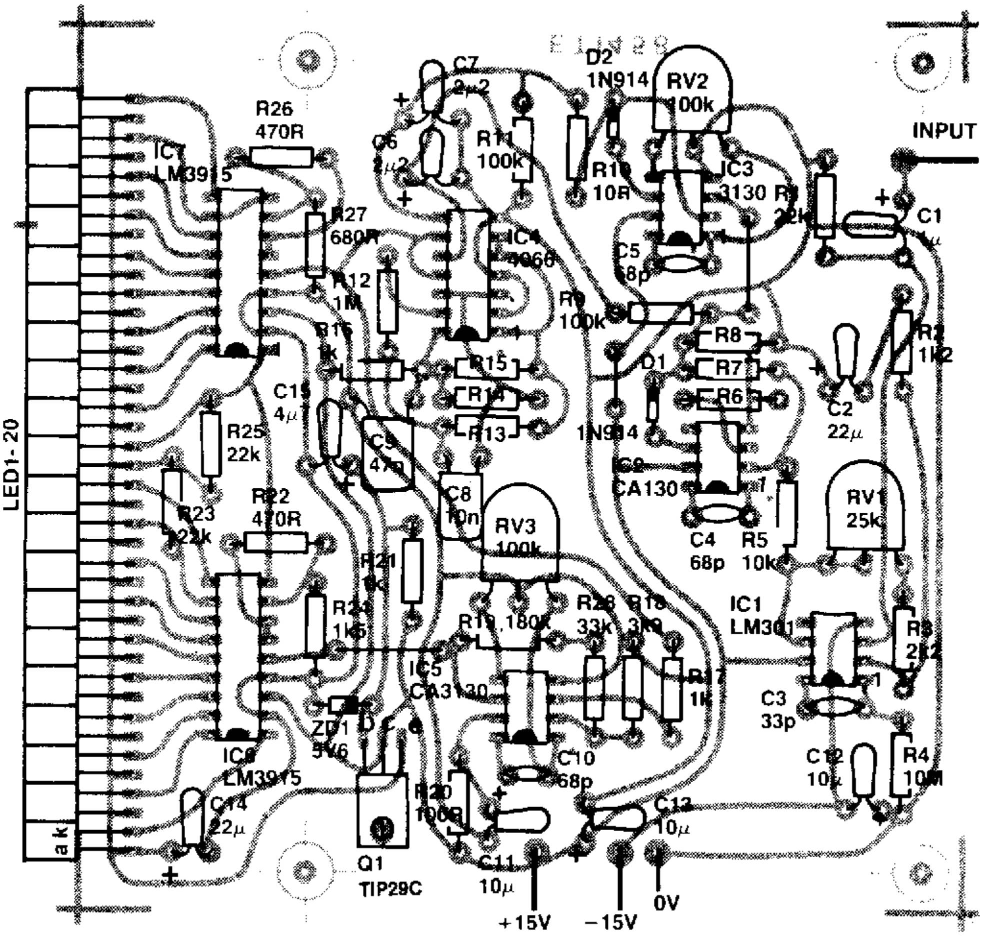
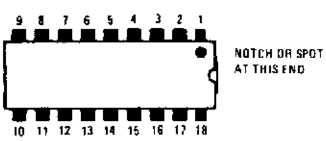
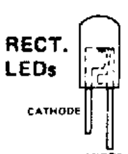
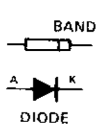
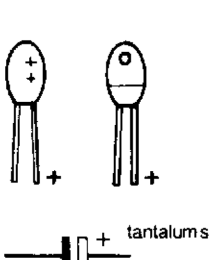


Fig. 5 Component overlay.









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

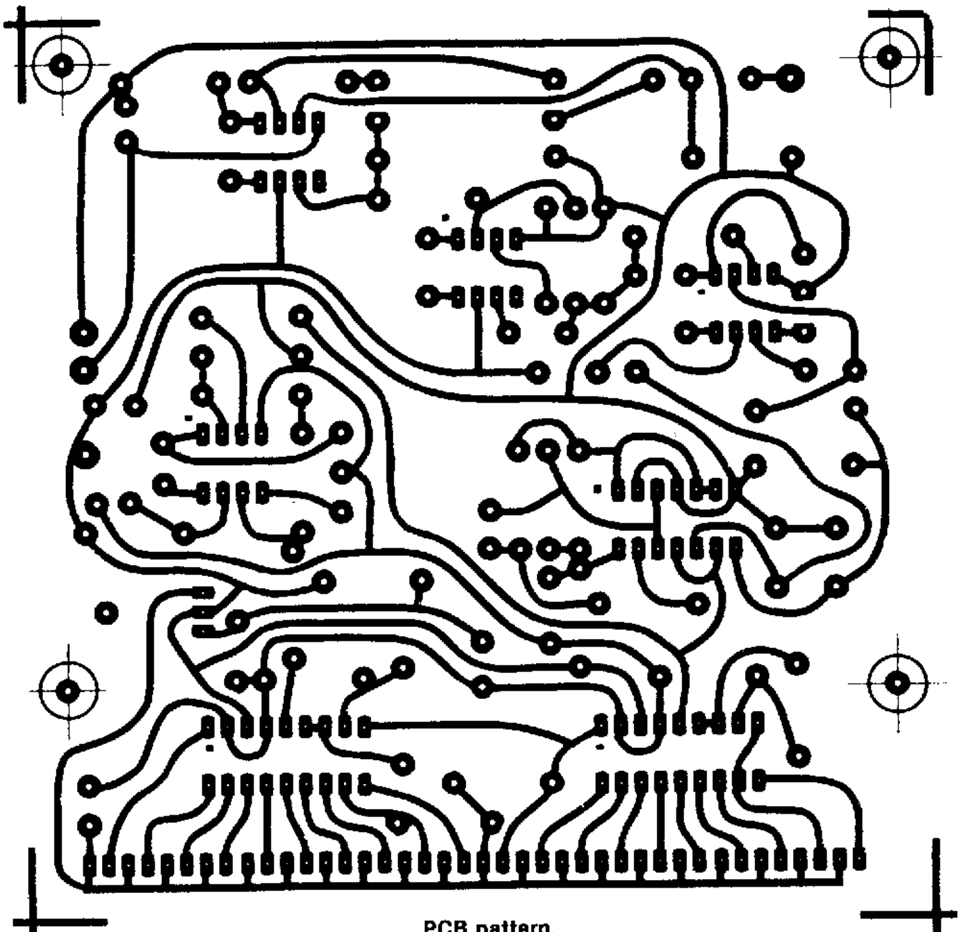
C1	1u/6V tant.
C2,14	22u/16V tant.
C3	33p ceramic
C4,5,10	68p ceramic
C6,7	2u2/25V tant.
C8	10n
C9	47n
C11,12,13	10u/25 V tant.
C15	4u7/16V tant.

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 one bolt and nut.



PCB pattern.