# LED TACHOMETER

**A unique two-range tach that gives an analogue RPM display on a bar of 21 LEDs. The display flashes to indicate an alarm condition when the RPM exceed a preset limit.**

THE ETI TACH/ALARM is an all solid-state project. It displays engine speed in analogue form (like a conventional tach) as an illuminated section of a line of 21 LEDs. The length of the illuminated section is proportional to the engine speed, so that half of the scale is illuminated at half of full-scale speed, and so on. In other words, the display is in bar rather than dot form.

The Tach/Alarm can be used with virtually any type of multi-cylinder gas engine. It has two speed ranges, each of which can be calibrated by a preset pot to give any full-scale speed range required by the individual owner. Our prototype is calibrated to give full scale readings of 10,000 RPM and 1,000 RPM on a four-cylinder, four-stroke engine. The lower range is of great value when adjusting the engine's ignition and carburator for recommended idle speeds. The upper range has adequate resolution (500 RPM per step in our case).

A unique feature of our product is the provision of a visual over-speed alarm facility, which causes the LED display to rapidly flash on and off when the RPM exceed a preset level; the tach continues to indicate the actual RPM under the alarm condition. Tachs are normally placed directly in front of the driver in sports/racing cars, so this visual alarm system is a highly effective 'attention getter' in such vehicles.

The unit is designed for use only on vehicles with 12V electrical systems. It can be used with conventional or capacitor-discharge (CD) ignition systems and is wired into the vehicle with three connecting leads. It can be used on vehicles with either negative or positive ground electrical systems.

## Construction

The complete unit, including the 21 LED display, is mounted on a single PCB. Take care over the construction, paying special attention to the following points:

(1) Our prototype uses a display comprising a linear row of 21 square LEDs, mounted horizontally on the PCB. You may prefer to use a semicircular display of LEDs, in which case you can mount the display on a separate board of your own design, with suitable connections to our board. In either case confirm the polarity and functioning of each of the 21 LEDs, by connecting in series with a 1K0 resistor and testing across a 12V supply, before wiring into place on the PCB. Note that the LED colours can be mixed, if required.

If you use the same display form as our prototype, bend and adjust the LED leads so that each LED slightly overhangs the edge of the PCB when soldered into place.

(2) Seven link connections are made on the PCB. Also note that the external connections to the unit (0V, + ve and points) are made via solder terminals (Veropins).

(3) Range-changing is achieved via a three-pole two-way switch. On our prototype we've used a slide switch for this purpose.

(4) Note that the values of C2 and C3 must be chosen to suit the engine type and full-scale RPM ranges required (see the conversion graph). Our prototype, calibrated to read 10,000 RPM and 1,000 RPM on a four-cylinder four-stroke engine, uses C2 and C3 values of 22nF and 220nF respectively.

When the construction is complete, connect the unit to a 12V supply and check that only LED1 illuminates. If all LEDs illuminate, suspect a fault in the wiring of IC1.

## Calibration

The unit can be calibrated against either a precision tachometer or against an accurate (2% better) audio generator that gives a square wave output of at least 3V peak-to-peak. The method of calibration against an audio generator is as follows.

Connect the tach to a 12V supply and connect the square wave output of the audio generator between the 0V and points terminals of the unit.

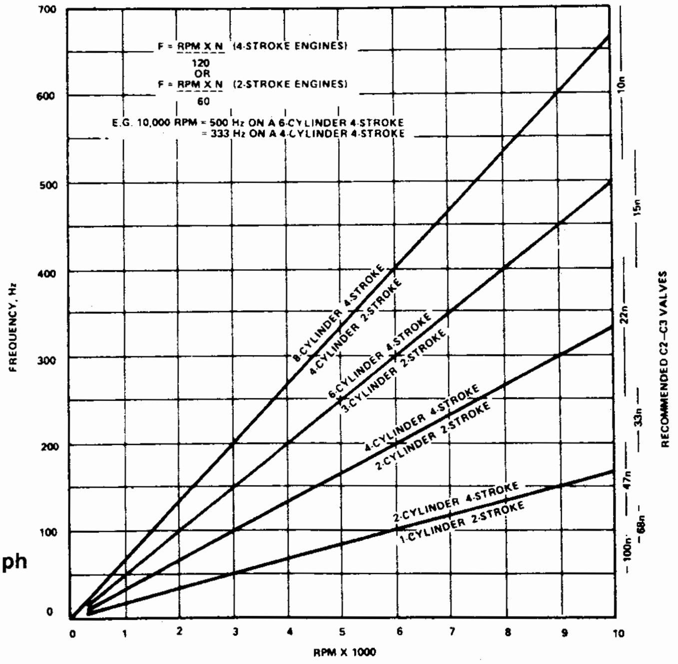
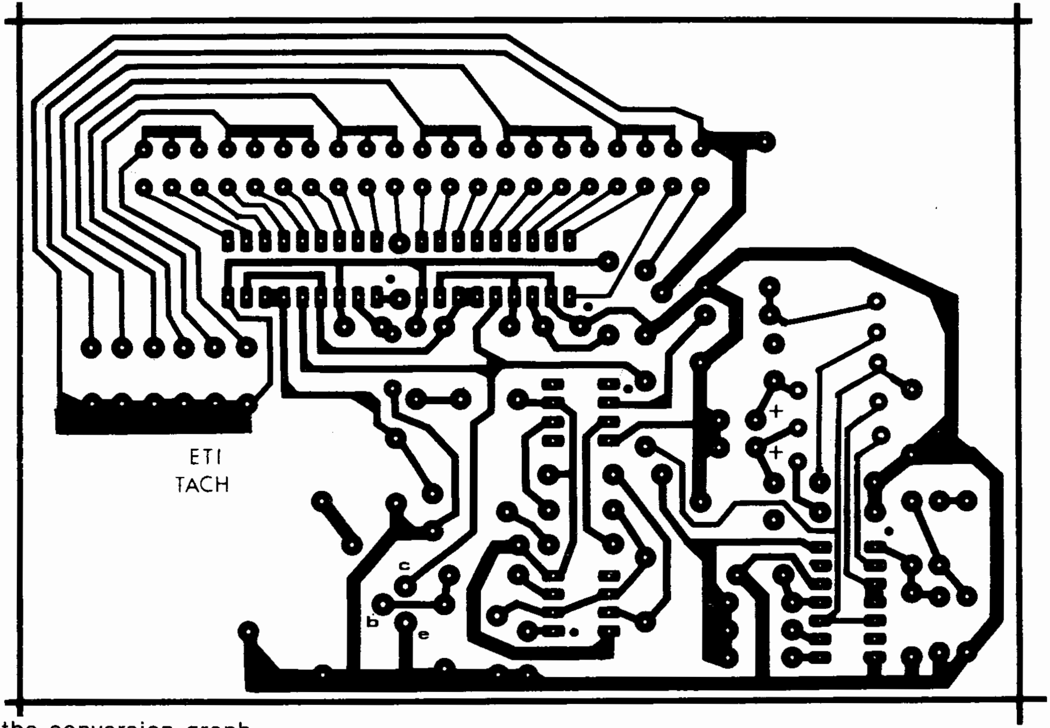


**Fig. 2 Conversion graph to determine the values of C2 and C3.**



Check against the conversion graph to find the frequency needed to give the required high range full-scale RPM reading on the type of engine in question and feed this frequency into the tach input. Switch SW1 to its high range (10,000 RPM on our prototype) and adjust PR1 for full-scale reading. Now set the generator to the alarm frequency and adjust PR3 so that the display flashes. Recheck both adjustments.

Now switch SW1 to its low range (1,000 RPM on our prototype), set the required full-scale frequency and adjust PR2 for a full-scale reading on the tach. Note that the alarm facility is inoperative on this range.

**Installation**

The completed unit can either be mounted in a special cut-out in the vehicle's instrument panel or (preferably) can be assembled in a home-made housing and clipped on top of the instrument panel. In either case try to fit some kind of light shield to the face of the unit, so that the LEDs are shielded from direct sunlight.

To wire the unit into place, connect the supply leads to the tach via the vehicle's ignition switch and connect the unit's points terminal to the points terminal on the vehicle's distributor.

The lower range of the tach is of great value when adjusting the engine for correct idle. It is thus advantageous to arrange the tach housing so that it can be easily dismounted from the instrument panel.

## PARTS LIST

| **Resistors all ¼W, 5%** | |
|---|---|
| R1,2,5 | 10k |
| R3,13 | 22k |
| R4 | 470R |
| R6,15 | 1k2 |
| R7,9,10,12 | 330R |
| R8,11 | 270R |
| R14 | 27k |
| R16,20 | 2k2 |
| R17 | 270k |
| R18,19 | 12k |
| R21 | 1M0 |
| R22 | 6k8 |
| R23 | 4k7 |
| **Potentiometers** | |
| PR1,2 | 100k miniature horizontal preset |
| PR3 | 47k minature horizontal preset |
| **Capacitors** | |
| C1,2 | 22n polycarbonate |
| C3,8 | 220n polycarbonate |
| C4 | 1u0 35V tantalum |
| C5 | 4u7 35V tantalum |
| C6,7 | 47u 16V tantalum |
| C9 | 100u 25V electrolytic |
| **Semiconductors** | |
| IC1 | LM2917N |
| IC2,3 | LM3914 |
| IC4 | CA3140 |
| IC5 | ICM7555 |
| Q1 | 2N3904 |
| ZD1 | 400mW 12V |
| D1,2 | 1N4148 |
| D3 | 1N4001 |
| LED1-21 | Red, square type. |
| **Miscellaneous** | |
| SW1 | 3-pole double throw switch |
| PCB, case. | |

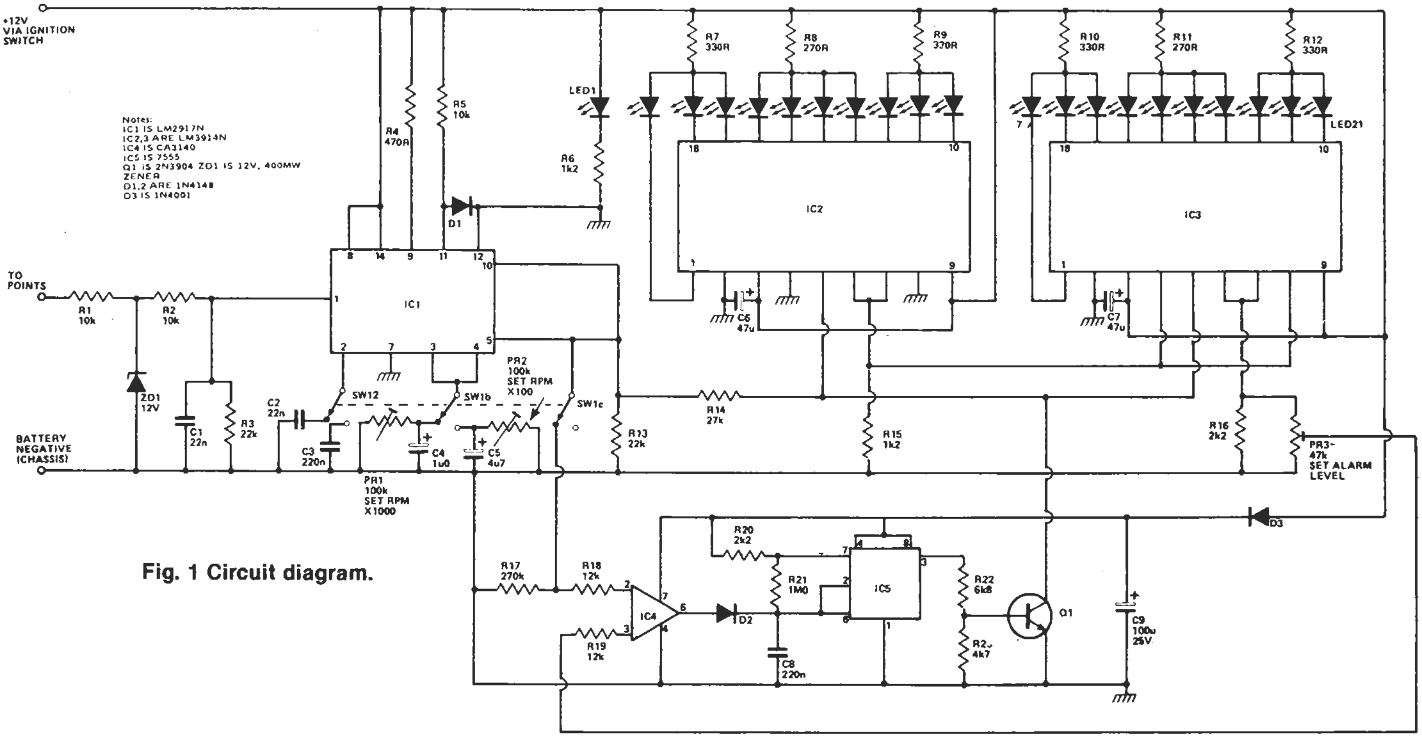


Fig. 1 Circuit diagram.

Cont. on p. 70

## HOW IT WORKS

The ignition signal appearing on a vehicle's points has a basic frequency that is directly proportional to the RPM of the engine. Our tach works by picking up the signal, extracting its basic frequency, converting the frequency to a linearly-related DC voltage and then displaying this voltage (and thus the RPM) on a line of 21 LEDs. The basic tach can thus be broken down, for descriptive purposes, into an input signal conditioner section, a frequency-to-voltage converter section and a LED voltmeter display section.

The input signal conditioner section comprises R1-R2-R3-ZD1-C1. The points signal of a conventional ignition system consists of a basic RPM-related rectangular waveform that switches alternately between zero and 12V, onto which various ringing waveforms with typical peak amplitudes of 250V and frequencies up to 10 kHz are superimposed. The purpose of the input signal conditioner is to cleanly filter out the basic rectangular waveform and pass it on to the F-to-V converter. It does this first by limiting the peak amplitude of the signal to 12V via R1 and ZD1 and then filtering out any remaining high frequency components via R2-R3-C1. The resulting clean signal is passed on to the input (pin 1) of IC1.

IC1 is a frequency-to-voltage converter chip with a built-in supply voltage regulator. The operating range of the IC is deterimined by the value of a capacitor connected to pin 2 and by a timing resistor and smoothing capacitor connected to pins 3-4. In our application, two switch-selected presettable ranges are provided. The DC output of the IC is made available across R13 and is passed on to the high-impedance input terminals of the IC2-IC3 LED voltmeter circuit via series resistor R14. R14 is essential to the operation of the alarm section of the tach.

IC2 and IC3 are LED display drivers. Each IC can drive a chain of 10 LEDs, the number of LEDs illuminated being proportional to the magnitude of the IC's input signal. Put simply, the ICs act as LED voltmeters.

In our application, the two LM3914 ICs are cascaded in such a way that they perform as a single 20-LED voltmeter with a full-scale range of 2V4. This full-scale value is determined by precision voltage references built into the ICs. The full-scale reference voltage (2V4) is generated across R16 and PR3. The configuration of our voltmeter is such that it gives a bar display, in which LEDs 1 to 11 are illuminated at half-scale or LEDs 1 to 21 are illuminated at full-scale. R7 to R12 are wired in series with the display LEDs to reduce the power dissipation of the two ICs. LED 1 is permanently illuminated so that the RPM display does not blank out completely when the engine is stationary with the ignition turned on.

The alarm section of the tach is fairly simple. IC4 is wired as a voltage comparator with a stable reference voltage fed to its non-inverting (pin 3) input from PR3 and with an RPM-related voltage fed to its inverting (pin 2) input from R13 via SW1c. The output of IC4 is used to enable or disable astable multivibrator IC5 and the output of IC5 is used to enable or disable the inputs to the IC2-IC3 voltmeter via Q1 and R14.

At low engine speeds (below the alarm level) the input of IC4 is driven high, thereby disabling the IC5 astable by preventing C8 from discharging. Under this condition the output of IC5 is driven low, cutting off Q1 and enabling the tach circuit to operate in the normal way.

At high engine speeds (at or above the alarm level) the output of IC4 is driven low, thereby enabling the IC5 astable to operate at a rate of roughly 2 Hz and alternately drive Q1 on and off. In the moments that Q1 is cut off, the tach operates in the normal way, but in the moments that Q1 is driven on its collector pulls the pin 5 input terminals of IC2 and IC3 to near-zero volts and thereby effectively blanks the LED displays. The LEDs flash rapidly under the alarm condition, but continue to indicate RPM vlaues.

The alarm point can be set in any position on the tach scale by PR3. SW1c is used to diable the alarm section when the tach is set to its low (1,000 RPM in our prototype) range. Note that the power supply to the alarm is decoupled from the main supply by D3 and C9.

*Cont from page 32.*

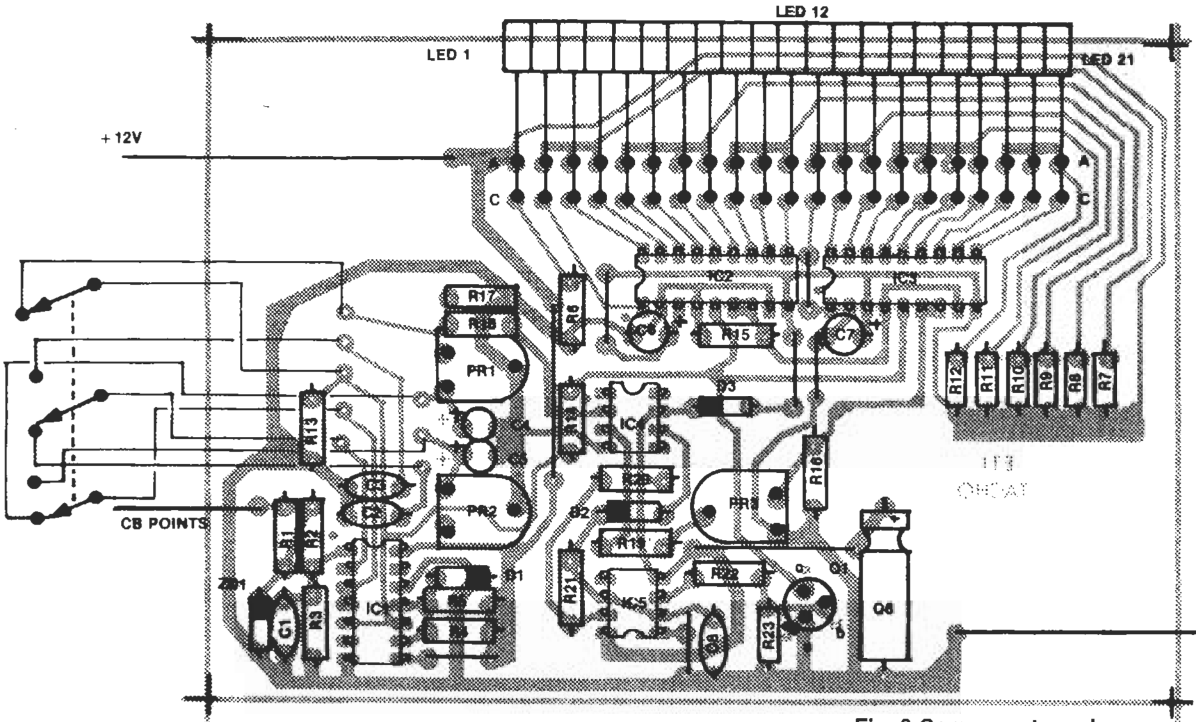


Fig. 3 Component overlay.

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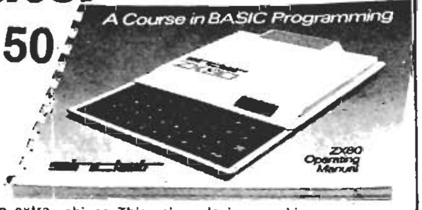

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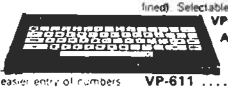

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**20** The pecularity of this rev. counter is that it responds to differences in luminous intensity. Consequently, if this circuit is to be used as a rev. counter, the motor shaft must be provided with a vane which periodically intercepts the light incident on the light sensor. Little can be said about the choice of light sensitive element, because they come in numerous types. Instead of a photo diode, photo transistors or photo darlingtons can be used. In practically all cases it will be necessary to experiment with the value of R1. A first setting can be obtained by applying half the supply voltage to point A by means of R1.

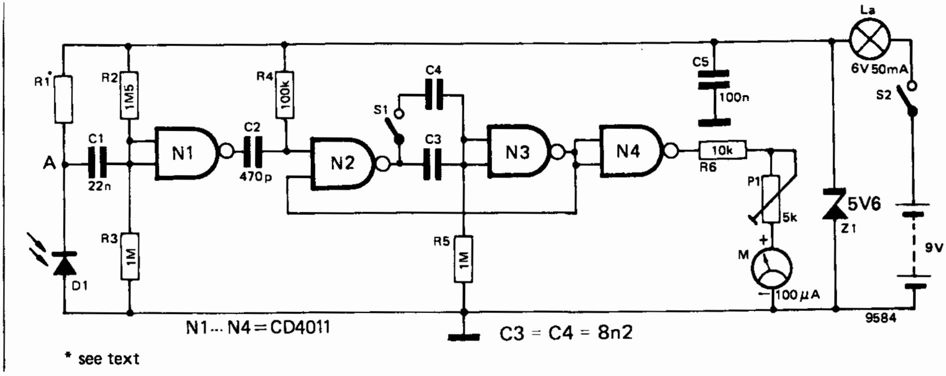
For slow-running machines, D1 can sometimes be replaced by an LDR. As soon as more light is incident on D1, the current through D1 will increase so that the voltage on point A drops. Via C1 and C2 this voltage drop is fed to the monostable multivibrator N2/N3.

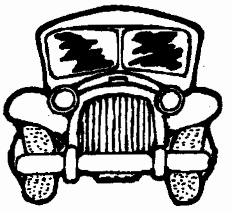
In the quiescent state both inputs of N3 are earthed via R5, so the output of N3 is 'high'. Consequently, the two inputs of N2 are 'high' so that its output is 'low'.

As soon as a negative pulse arrives at one of the inputs of N2, the output of N2 changes to 'high' and causes gate N3 to change state, so that the second input of N2 goes 'low'. Even when the trigger pulse on the input of N2 cuts out, the circuit remains in this condition. Only after C3 (+C4) is (are) charged to such an extent that the voltage on the inputs of N3 are 'low' again will the circuit return to the initial state. Thus the monostable multivibrator changes any input pulse on D1 into a pulse of constant width. These pulses are fed to the meter via buffer stage N4.

The lamp in the supply line provides a better stabilization than a resistor, at the same time giving an on/off indication for the meter.

The measuring range can be doubled with S1. When S1 is closed, the range is from 0 to 33 Hz (0 – 2000 r.p.m.); when S1 is open the range is from 0 to 66 Hz (0 – 4000 r.p.m.).





# tachometer

This Tachometer adapter was primarily designed to be used in conjunction with the UAA 170 LED meter (Elektor 12, April 1976, p. 441) and will give a clear 'analogue' indication of the number of revolutions made by the car engine. This article gives a short re-cap of part of the original article plus the additional information needed to make a full-fledged Tack.

For some time Siemens has been marketing two ICs suitable for driving analogue LED displays. One of these is the UAA170, a 16 pin IC with 8 encoded outputs capable of driving a column of 16 LEDs. Only one of these LEDs is lit at any time, which one is lit being dependent on the input voltage; as the voltage is increased a point of light will move up the column. The possible applications for LED meters are numerous, but they are particularly useful 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 not only an almost unlimited life, but also, the ability to follow very rapid input signal changes, since there is no inertia to overcome.

## 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 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. For input voltages equal to or less than the voltage at pin 12 the first LED in the column will be lit.

## 30 LED display

For applications requiring greater resolution than can be provided by 16 LEDs the circuit may be extended using two ICs as shown in figure 1. Both ICs 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 $0 - \frac{V}{2}$, and the second IC over the range $\frac{V}{2} - V$, 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

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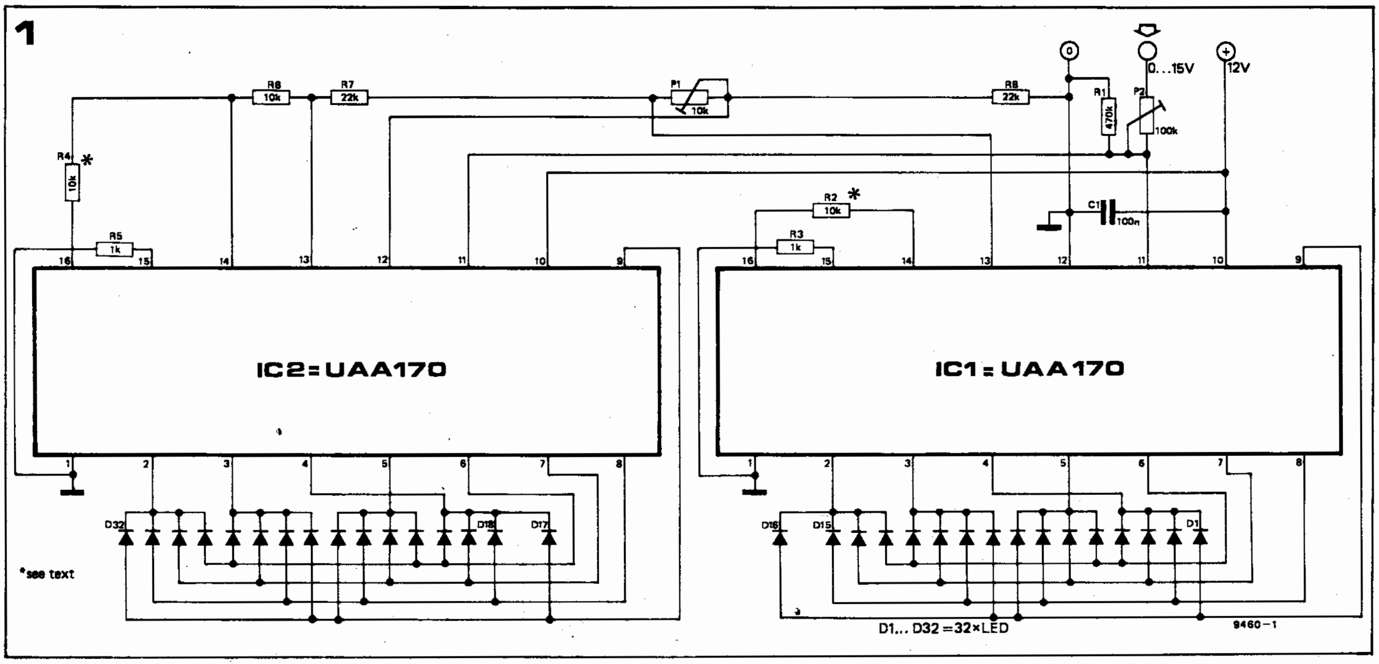


first LED from the display of the second IC, otherwise for voltages in the lower half of the range the first LED of the second IC would always be lit, and for voltages in the upper range the last LED of the first IC would always be lit. For this reason only 30 LEDs may be used, not 32. This means that D16 and D17 should not be part of the scale, although they must be included in the circuit.

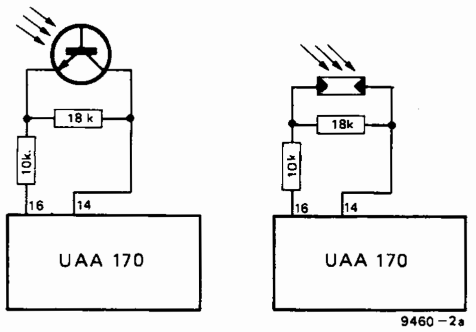
So that the omission of these two LEDs does not cause a 'blind spot' in the middle of the display it is necessary to arrange that the second LED of the second IC lights as the 15th LED of the first IC extinguishes. This is accomplished by having the reference voltage on pin 12 of the second IC lower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

## Brightness Control

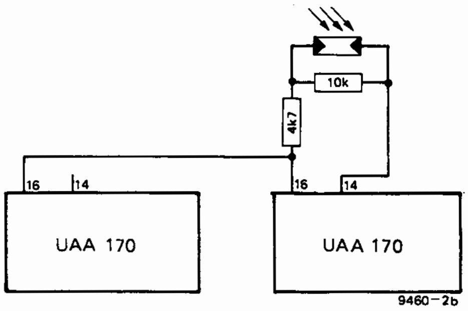
The output current delivered to the LED display, and hence the brightness, can be altered by a brightness control connected between pins 14 and 16 of the IC. This may take the form of an LDR or phototransistor to adjust the display brightness to suit ambient lighting conditions, or it may be a manual control such as a potentiometer. The control is connected in place of the two fixed resistors R2 and R4. A fixed resistor between pin 15 and ground adjusts the control characteristics of the brightness control.

Figure 2a shows two methods using a photo-transistor, and a LDR. Since there are two ICs in the circuit they would both require a photo-transistor. These transistors must then be mounted in close proximity to each other, otherwise differences in lighting could cause uneven scale brightness. However, it has also proved possible to interconnect the pins 16 of the two ICs, and use one photo-transistor or LDR between these pins and either of the pins 14. This is shown in figure 2b.

2a



2b



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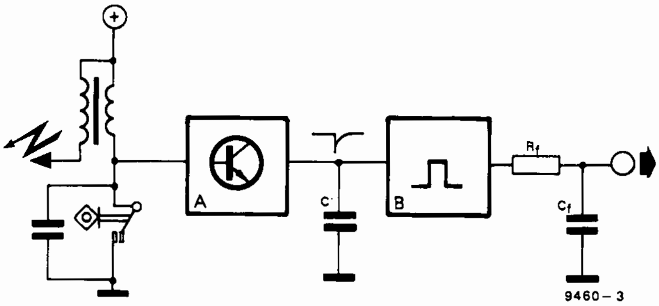


**Figure 1. The original LED meter circuit diagram. D16 and D17 must be included in the circuit, although they can not be used as part of the scale.**

**Figure 2. Two methods for obtaining automatic display brightness control.**

**Figure 3. Block diagram of the tachometer.**

**Parts list for figure 1**

Resistors:
R1 = 470 k
R2,R4,R6 = 10 k
R3,R5 = 1 k
R7,R8 = 22 k
P1 = 10 k preset
P2 = 100 k preset

Capacitors:
C1 = 100 n

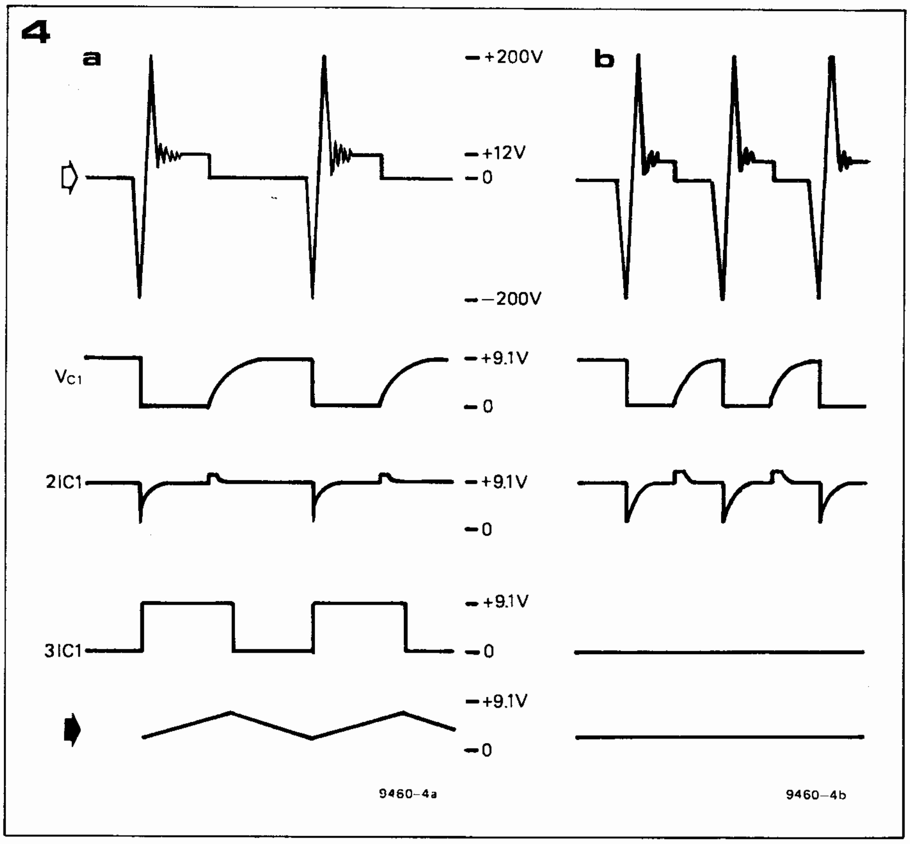
Semiconductors:
IC1,IC2 = UAA170
D1 . . . D32 = LED

## Tachometer converter

The circuit to adapt the LED meter to a full-fledged tachometer need not be complex, a simple monostable multivibrator will do. At the Elektor Labs a simple but effective design was developed using only one 555 IC. This design uses an input stage with one transistor and a filter in the output.

The block diagram of figure 3 gives an impression of how the circuit functions. Due to the fact that the crank shaft and the breaker contacts are coupled the pulse train produced by the breaker contacts is some multiple of the engine's rev's. These pulses are fed to the input stage (block A in figure 3) which, in conjunction with capacitor C, gives them a better shape. After shaping they are used to trigger the monostable multivibrator (block B). For each pulse applied to the input of the monoflop, a positive going pulse appears at the output. These positive pulses all have the same width and amplitude irrespective of the input pulse train. As the input frequency goes up, the duty cycle of the output also goes up. These pulses are fed through an integrating filter (Rf and Cf) which changes the pulsed output into a DC voltage with very little ripple. The ripple should be as low as possible because the LED meter responds so quickly that severe ripple on the DC will cause several LEDs to light up 'simultaneously'.

Depending on the number of revolutions made by the engine, the monostable multivibrator will produce many or few pulses per unit time. A low number of pulses will give a low output voltage and a high number of pulses will produce a higher voltage at the filter output. This voltage is displayed by the LED meter.



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## The input stage

The input resistor R1 (figure 5) is connected to the junction of the contact breakers and the ignition coil. R1 and R2 and the zener diode D1 protect the input transistor against high voltages. The moment the contacts open and the plugs spark, an oscillation occurs involving negative and positive peaks of a few hundred volts (see figure 4a, upper voltage form).

During the time that there is a positive voltage across the breaker contact, T1 is driven and the collector voltage drops. IC1 is triggered by this negative edge. Capacitor C1 serves to prevent the 555 from being triggered by short pulses.

The frequency at which the contact breaker feeds pulses to the input stage depends on the type of engine: the 'stroke' number of the engine (two-stroke or four-stroke), and the number of cylinders. The frequency f at which the contact breaker opens and closes is:

$$f = \frac{N}{30} \times \frac{C}{S},$$

where N is the number of revs per min. C is the number of cylinders, and S is the number of strokes in one complete cycle.

So for a four-stroke four-cylinder engine we have:

$$f = \frac{N}{30} \times \frac{4}{4} = \frac{N}{30}$$

At an engine speed of 6000 r.p.m. the corresponding frequency is 200 Hz. By using this formula it is possible to calculate the frequency of breaker pulses for other types of engines. This can be useful when calibrating the instrument.

## The monostable multivibrator

The monostable multivibrator is built around the 555 (IC1 in figure 5), an old acquaintance whom we need not introduce again. The IC requires only a few external components for reliable operation. P1, R6, and C3 determine the duration of the output pulses; P1 is variable, so that the circuit can be adjusted to maximum output voltage at a given number of revs. The IC is triggered via pin 2 by means of a short negative pulse (<5 V). Capacitor C2 has been added to ensure that the trigger pulses are of short duration. Otherwise at low engine r.p.m.'s the collector of T1 could remain low longer than the monostable time, and the 555 might then be triggered again. As a result, a multiple of the actual number of revolutions would be indicated. This is prevented by the combination of C2 and R5.

The diodes D2 and D3 ensure that the input voltage at point 2 does not exceed or drop below the supply voltage, as this would damage the IC.

If the output pulses last too long, i.e. longer than the period of the input frequency, but shorter than twice that period, the IC will not yet have returned to the initial position when the next trigger pulse arrives. This will mean that every second pulse has no effect. (The 555 is not re-triggerable). If alternate pulses are lost, it will seem as if the engine is running at only half its actual speed. To prevent this P1 must be adjusted so that the mono-time is shorter than the shortest period (corresponding to the highest input frequency).

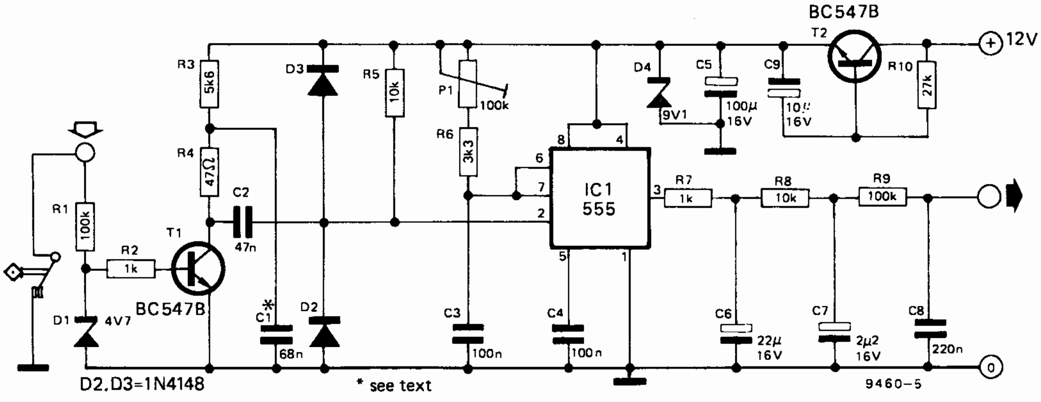
5

**Parts list for figure 5**

Resistors:
R1,R9 = 100 k
R2,R7 = 1 k
R3 = 5k6
R4 = 47 Ω
R5,R8 = 10 k
R6 = 3k3
R10 = 27 k
P1 = 100 k preset

Capacitors:
C1 = 68 n
C2 = 47 n
C3,C4 = 100 n
C5 = 100 μ/16 V
C6 = 22 μ/16 V
C7 = 2μ2/16 V
C8 = 220 n
C9 = 10 μ/16 V

Semiconductors:
T1,T2 = BC 547 B, BC 107 B, 2N3904
IC1 = 555
D1 = zener 4V7/400 mW
D2,D3 = 1N4148
D4 = zener 9V1/400 mW



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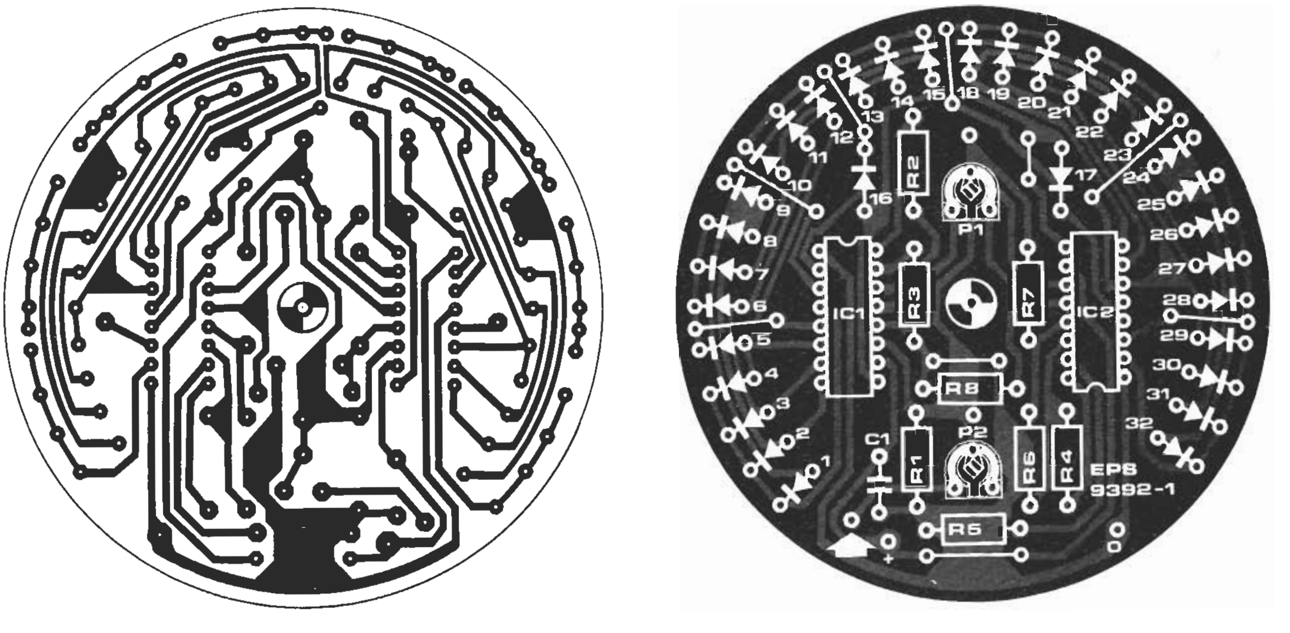

**Figure 4.** Some waveforms as they occur in the circuit of figure 5. In 4a the trigger pulses on point 2 of IC1 are large enough; in 4b the pulses are insufficient owing to the influence of C1. For the sake of clarity, the ripple voltage at the output is shown exaggerated.

**Figure 5.** The diagram of the tachometer. The input is connected to the breaker contacts of the car engine; the output drives the LED meter.

**Figure 6.** The p.c.b. and component layout for the LED meter (EPS 9392-1).

**Figure 7.** The p.c.b. and component layout of the tachometer (EPS 9460).

## The output filter and display

An output filter is not needed in normal rev counters because of the type of readout employed. A moving coil meter cannot possibly follow the pulses of the monostable because of its mass and self inductance.

When using a high-speed electronic read-out however, it is necessary to carefully filter the output to avoid having several LEDs light up simultaneously. This filtering is achieved by a series connection of three RC networks. Consequently, the output impedance is fairly high. This is no problem when it is used with the LED meter, but it is not suitable for a moving coil instrument! The output from the adapter is connected direct to the input of the LED meter (figure 1). Note the value of R1 (470 k); in the original article a different value was shown to obtain a wider input voltage range.

## Supply and construction

Although the pulse duration of the square waves at the output of the 555 is practically independent of the supply voltage, it is still necessary to stabilize the supply voltage because the amplitude of the square wave voltage is equal to the supply voltage, thus directly influencing the output voltage of the circuit. Stabilization is provided by means of a zener diode. However, here the usual series resistor for the zener has been replaced by a simulated self inductance (see Elektor nr. 2, page 253) consisting of one transistor. The total current consumption of the circuit remains below 10 mA.

The three p.c.b.s. can be mounted by using a long bolt pushed through the central hole in each board. Spacers are used between the boards.

The whole assembly can now be accommodated in a suitable housing. For this, even a round VIM tin, or something

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