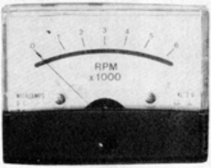
diesel tachometer

connected to the alternator measures r.p.m. in virtually any (12 V) diesel or petrol engined car

A tachometer is probably the single most important 'meter' in a car's dashboard (unless you're in the habit of running out of fuel). It informs the driver how hard the engine is working and, when used correctly, it is an aid to economy, performance and engine longevity (to name but a few). These things are, of course, no less important to the driver of a diesel car than to his petrol-powered counterpart, but most electronic tachometers cannot be used with diesel engines. The reason for this is that they take their 'timing' from the ignition circuit, which diesel cars do not have. The engine speed of a diesel car can, however, be measured by 'picking the brains' of another part of the electrical system, namely the alternator.



The difficulty with fitting a tachometer to a diesel engined car has not escaped the car manufacturers' notice. Many diesel cars sold today have an extra (so-called 'W') connection available on the outside of the alternator, and the purpose of this is to enable the engine speed to be measured without unnecessary complication or cost. Petrol cars are, of course, not a problem as the tachometer timing is conventionally taken from the ignition system (the contact breaker points). The diesel engine, however, does not use spark plugs to ignite the fuel/air mixture and this is the root of the problem with fitting a tachometer to a diesel car. Some different value must be found, therefore, that is directly proportional to the engine speed. This should preferably be an electrical value to make connection to the electronics easier. The ever-present alternator looks like a good possibility. Because it is driven from the crankshaft via the fan belt it turns at a speed which is directly proportional to the engine speed. The 'circuit' of an alternator is shown in figure 1b, and this is typical of the layout used in the vast majority of modern cars. The diagram shows that a 'pick-up' for the engine speed need only be connected to one of the points U, V or W. Most manufacturers select W and feed this to the outside of the alternator.

When a car is available with either petrol or diesel engine the alternator is generally the same for both versions, so even petrol cars often have the W connection available at the outside of the alternator. If your car lacks this W connection don't panic, under the section 'W connection' we will return to this problem to show how such a connection could, if needed, be made.

At the input of the circuit diagram of figure 1a we see roughly what the signal taken from the alternator looks like. The actual form of the signal is unimportant; what is of interest is that the frequency of the signal depends on the engine speed. This frequency is from about 125 Hz to 1250 Hz depending on the type of car but variations can be taken care of by our circuit. Having got a signal at the input, all that remains is to convert the frequency variations at the input into voltage variations, which brings us to the circuit of our tachometer.

The circuit

As the circuit diagram of figure 1a shows, this tachometer contains nothing complicated as regards electronics. The supply is taken from the car battery via R1 and protection diode D1. The input resistance and input current (1.5 mA maximum) are defined by resistors R2 and R3. The pulse signal coming from the W connection is limited to 12 V by means of zener diode D2. Any high frequency noise that might be present is shorted to earth by C2. The signal is then fed to the inverting input of op-amp IC1 which operates as a schmitt trigger. The hysteresis of this schmitt trigger is about 6 V, and the signal at its output (pin 6) is a rectangular waveform with an amplitude of 6 V_{pp} and a frequency corresponding to that of the input signal. The signal oscillates about the 6 V line.

Differentiating network C3/R8 converts the rectangular waveform into the 'peaked' signal shown at the junction of these two components. The positive peaks are limited to about 0.65 V by D3. The negative peaks, on the other hand, are used to trigger MMV IC2. The width of the output pulse from this 555 can be varied with P1 between 150 and 450 μs.

The output signal from IC2 is limited to 5.6 V by zener D4 and is then integrated by R11 and C6 before being fed to the moving coil meter M1. As a result of this integration, and also to a certain extent because of the inertia of the meter, M1 gives a stable read-out of the engine speed.

1a

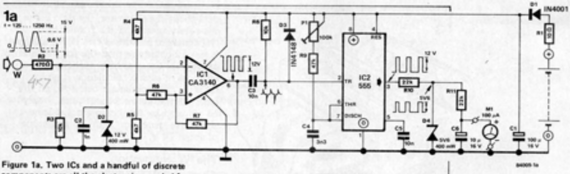
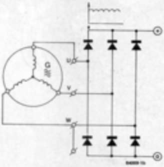


Figure 1a. Two ICs and a handful of discrete components are all the electronics needed for this circuit, as the diagram here shows.

Figure 1b. Most modern alternators have the configuration shown here, with a rectifier consisting of six diodes.

1b



Construction and calibration

The printed circuit board layout for this circuit is shown in figure 2. The connection points from the circuit have purposely been made big so that the normal automotive type connectors and push-on clips can be used.

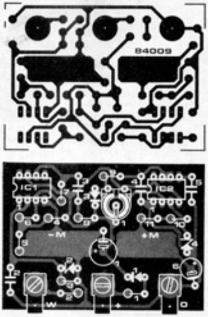
No holes have been drilled in the board for the meter connections, but large copper areas have been left for this purpose. Holes can be drilled to suit the type of meter used, and the board can then be fixed directly to the rear of the moving coil meter. It goes without saying that the meter must be connected with the right polarity. The meter needs a suitable scale, of course; this could be made by using one of the dry transfer systems available.

There are three possible methods of calibrating the circuit (no, we don't mean do-it-yourself, get somebody else to do it, or don't do it at all). The handiest method is to use a hand-held tachometer, which can probably be borrowed from a garage (if you grease the right palms). If you also enlist the help of an assistant things will be considerably speeded up. Run the engine at about 2/3 of its maximum speed. Your helper measures the engine speed at the crankshaft with the borrowed tachometer and tells you what the reading is. You then adjust the Elektor tachometer to this value with P1.

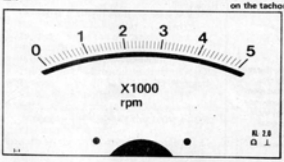
The second method of calibration involves a bit of arithmetic but in this case no reference tachometer is needed. Knowing the rpm/mph ratios of the car in various gears enables you to calculate the engine speed corresponding to a certain road speed in a certain gear. Then find a straight level road and drive at a steady speed for which you have calculated the engine speed. Your (indispensible) helper now adjusts the tachometer to the appropriate reading. The disadvantage of this method is that you are using the car's speedometer as a reference so the reading is almost certainly going to be a few percent incorrect.

The third calibration method involves measuring the diameters of the pulleys on crankshaft and alternator carefully and thereby calculating the ratio of engine speed to alternator speed. An example of this is given in figure 3. From the technical

2a



2b



Parts list

Resistors:

R1 = 10 Ω
R2 = 470 Ω
R3, R8 = 10 k
R4, R5 = 4k7
R6, R7, R9 = 47 k
R10, R11 = 22 k
P1 = 100 k preset

Capacitors:

C1 = 100 µ/16 V
C2 = 1 n
C3, C5 = 10 n
C4 = 3n3
C6 = 10 µ/16 V

Semiconductors:

D1 = 1N4001
D2 = 12 V, 400 mW zener
D3 = 1N4148
D4 = 5V6, 400 mW zener
IC1 = CA 3140
IC2 = 555

Miscellaneous:

M1 = moving coil meter, 100 µA f.s.d.

Figure 2a. The large copper areas on the printed circuit board shown here are to facilitate fixing the board directly on the back of a moving coil meter.

Figure 2b. This is a suitable scale to use for the meter on the tachometer.

data about the alternator, the ratio between the rotary speed and the frequency of the 'W' signal can be worked out. If, for example, it is a 12-pole type then the frequency is exactly six times as high as the speed. An example of such a calculation is given in table 1. The tachometer can now, on the basis of this information, quite simply be adjusted by feeding in a signal from a sine wave generator with an amplitude of about 14 V.

The 'W' connection

Alternators that do not have a W connection as standard can often be modified using special adapter sets. (Bosch, for instance, market a kit, no. ET-1 127 011 062, for VW and Audi diesels.) The best thing to do is look at the make and type of alternator and then ask at the appropriate garage if an adapter kit exists. An adapter kit is not, however, strictly necessary. The rectifier in the alternator generally consists of a six-diode bridge as shown in figure 1b. Points U, V and W are all located at the anode-cathode junction of two diodes. For our purposes there is no difference between the points and you can feed any one of them to the outside.

Using the tachometer

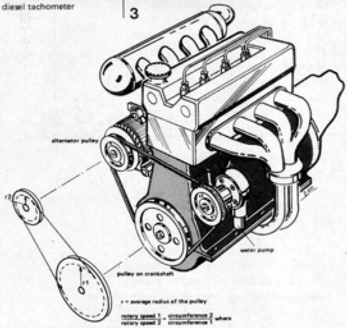
We are not, of course, going to tell you how you should drive, but nonetheless it may be no harm to see how a tachometer (any tachometer) can be put to its best use.

A lot of information about a car's engine can be gleaned by looking at graphs such as those shown in figure 4. These show the relationship between engine speed and both power and torque for a common diesel car, the Volkswagen Golf. The engine speed ranges from about 1000 to 5000 rpm. As one of the curves shows, the power rises almost linearly with (engine) speed up to about 4000 rpm. After this the power does not rise at the same rate so acceleration will be less. This is very important to know for overtaking, for example.

Torque is also dependent upon engine speed, but in this case maximum torque does not correspond to maximum engine speed. The engine is at its most efficient, and most economical, at maximum torque. This fact is used every day by people who wish to drive economically.

It is a common fallacy that only racing drivers need a tachometer. Certainly those for whom high speed driving is a profession do place a great importance on the information they get from the tachometer, but so can every driver on the road. Mechanical suffering is becoming more and more difficult to hear in today's well sound proofed cars, or at least that is the plea of the (obviously cloth-eared) driver who has his car ticking over at much too high a level and insists on thrashing it before it is fully warmed up. If you see him give him the message – don't put the pedal to the metal when the car is still cold. After all, can you work properly before you're well awake in the morning? ◆

3



r = average radius of the pulley

$$\frac{\text{rotary speed 1}}{\text{rotary speed 2}} = \frac{\text{circumference 2}}{\text{circumference 1}} \text{ where}$$

circumference = 2πr

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Figure 3. The ratio between the radii (radiuses?) of crankshaft and alternator pulleys can be used to determine the ratio of engine speed to alternator rotary speed.

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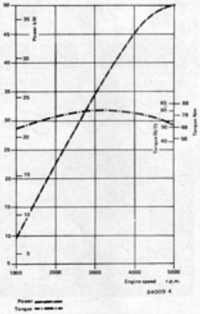

Figure 4. The power/rpm and torque/rpm curves shown here tell a lot about the way an engine works. Studying them briefly can help a driver make the most intelligent use of a tachometer.

Table 1

Data: r1 = 15 cm
r2 = 12 cm
number of poles, p = 12
engine speed, n = 3000 rpm

Calculation: $f = \frac{r2}{r1} \cdot \frac{p}{2} \cdot \frac{1}{60} \cdot n$

$$f = \frac{15}{12} \cdot \frac{12}{2} \cdot \frac{1}{60} \cdot 3000$$

f = 375 Hz

Table 1. Knowing the radii of the pulleys on the crankshaft (r1) and alternator (r2), the frequency of the signal given by the alternator at a certain engine speed (here 3000 rpm) can be calculated.