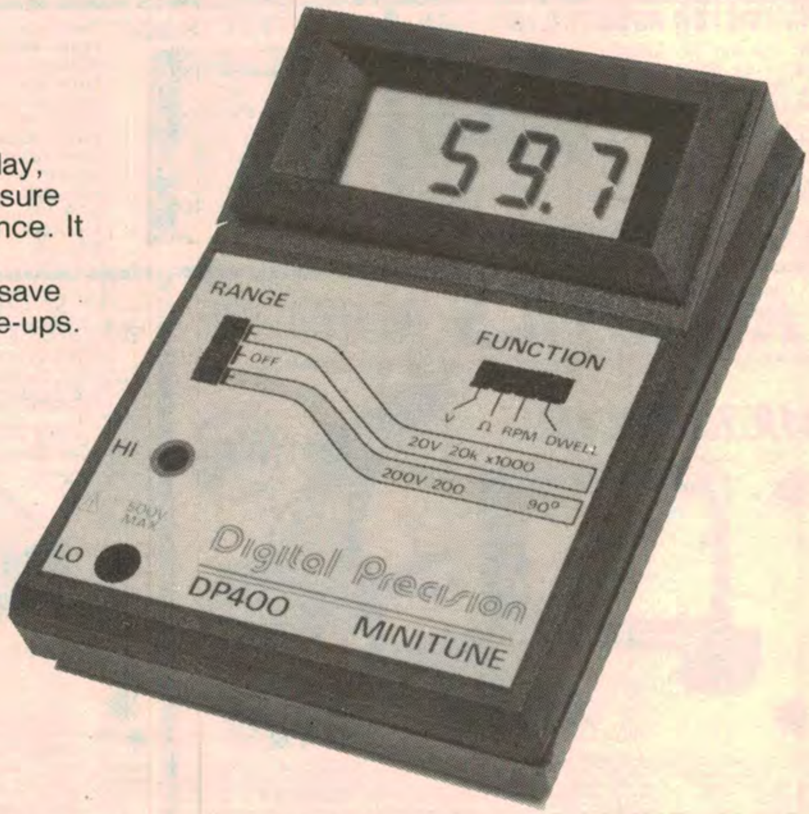
Measures rpm, dwell, volts & ohms

Tacho/dwell meter for engine tune-ups

by GREG SWAIN

Featuring a 3½-digit liquid crystal display, this compact engine analyser can measure engine rpm, dwell, voltage and resistance. It is compatible with both electronic and conventional ignition systems and will save you money on petrol and engine tune-ups.



The Minitune is built into a calculator-style plastic case.

The Minitune engine analyser is the latest in our series of projects based on the DPM05 LCD voltmeter module. As with the digital multimeter described in our March issue, it comes as a complete kit of parts, packaged by the English firm Lascar Electronics Ltd and distributed in Australia by Jaycar Pty Ltd. The cost of the kit from Jaycar is $42.95 plus $2.95 for a pair of test leads.

While we have described several engine analysers in the past, the Minitune must surely take the prize as the most compact. Overall dimensions are just 80 x 110 x 35mm (W x D x H). It can be easily held in the palm of one hand and yet will prove very useful for fault finding in automotive electrics and for accurate engine tuning.

Main specifications of the Minitune include two voltage ranges (0-20V DC and 0-200V DC); two resistance ranges (0-200Ω and 0-20kΩ); and the ability to measure engine rpm and dwell on most 4-stroke petrol engines. Readers should note, however, that the unit will not read dwell on many cars fitted with electronic ignition. This is of academic significance only as the dwell angle on cars with electronic ignition is fixed and can not be adjusted.

Note also that the display only has 3½ digits, so all readings on the rpm range must be multiplied by 10. For the same reason, resolution on the rpm range is limited to 10rpm. Resolution on the dwell range is 0.1°, while accuracy of the tacho and dwell ranges is quoted as 1% ± 3 digits and 2% ± 3 digits respectively.

The voltage and resistance ranges have a quoted accuracy of 0.5% ± 1 digit.

Only two leads are required to connect the Minitune for use. On the tacho and dwell ranges, the leads are simply connected across the points, or across the coil-switching transistor in the case of electronic ignition (ie, between the negative end of the coil and chassis). Connections for voltage and resistance measurements are made in the conventional way.

One disadvantage of the unit is that it is not switchable to suit different engine categories (either 4, 6 or 8 cylinder). The literature supplied with the kit skims over this point, suggesting that the unit be calibrated to suit 4-cylinder engines. Tacho and dwell readings are then multiplied by two-thirds for 6-cylinder engines and halved for 8-cylinder engines.

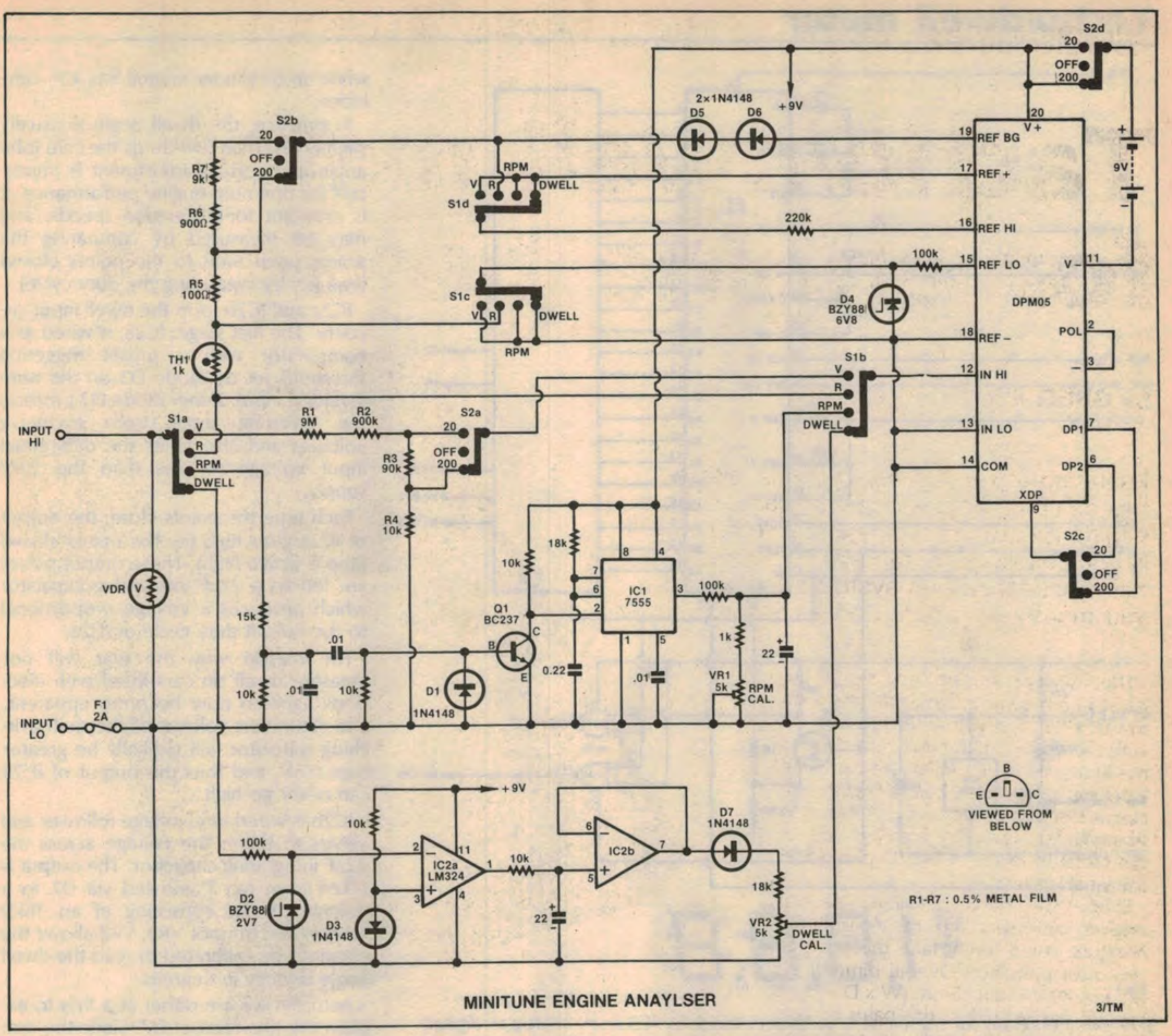
Our own experience with the Minitune, however, has shown that it is quite possible to calibrate the unit to suit 6-cylinder engines without any circuit changes. We'll have more to say about the subject of calibration a little later on.

The Minitune kit

The kit for the Minitune engine analyser includes two printed circuit boards (PCBs), a case, and all the parts necessary to make up two modules. These two modules are the DPM05 voltmeter module and a "conditioning" module branded DP401/2B. Also included is an instruction sheet giving brief details of the circuit operation and construction.

As supplied, the kit is complete apart from the 9V battery which must be purchased separately. In fact, we found that two components (a resistor and a diode) were left over at the end of construction. All the parts appear to be of good quality, while the two PCBs are made of fibreglass.

Construction of the kit should present



The circuit is built around the DPM05 module. Q1 and IC1 form the tacho circuitry while IC2 forms the dwell circuit.

few problems, although readers should note that many of the pads on the PCBs are quite close together. A fine-tipped soldering iron is necessary to build this kit and even then care should be taken to guard against solder bridges between adjacent pads.

How it works

The Minitune circuit is built around the DPM05 module which is essentially a high input impedance voltmeter with a full-scale reading of 199.9mV (see Fig. 1). At the heart of this module is the Intersil 7126 dual slope integration analog-to-digital converter chip (IC3). This chip drives the liquid crystal display directly and yet draws only 50μA.

IC6 is a high stability bandgap voltage reference and drives a voltage divider consisting of a 220kΩ resistor and a 10kΩ trimpot (VR3). VR3 is adjusted during the calibration procedure to provide a REF+ of 100mV. This forms a reference voltage against which the input voltage is compared.

Clock signals are provided by an internal 48kHz oscillator which is also divided to give the 60Hz backplane signal necessary to drive the display. This backplane signal is made available at the BP pin (pin 21), and is a square wave with an amplitude of ±2.5V with respect to the common rail.

Note that the common (pin 14) is maintained by the module at Vcc – 2.8V, and is used as the "earth" return for the external circuit.

In addition to the 3½-digit readout, the LCD also features decimal point indicators and a low battery annunciator. A decimal point is enabled simply by connecting the appropriate display pin to the XDP pin on the output of exclusive-OR gate IC4b.

Transistor Q2 senses the low voltage condition. When the battery voltage drops below a critical level (6.8V approx), Q2 turns off and IC4a gates through the inverted backplane signal to drive the "low bat" input.

Refer now to the main circuit diagram. It can be divided into four parts: the DPM05 voltmeter module, the tachometer circuitry (Q1 and IC1), the dwell circuitry (IC2a, 2b), and the resistive divider networks for the voltage and resistance functions. Switch S1 provides the function switching, while S2 provides range switching for the voltage and resistance measurements.

Tachometer mode

In the tachometer mode, the signal from the points is fed to a voltage divider and filtered by a .01μF capacitor. From there, the signal is applied to a differentiating network (.01μF and 10kΩ) which produces large positive and negative

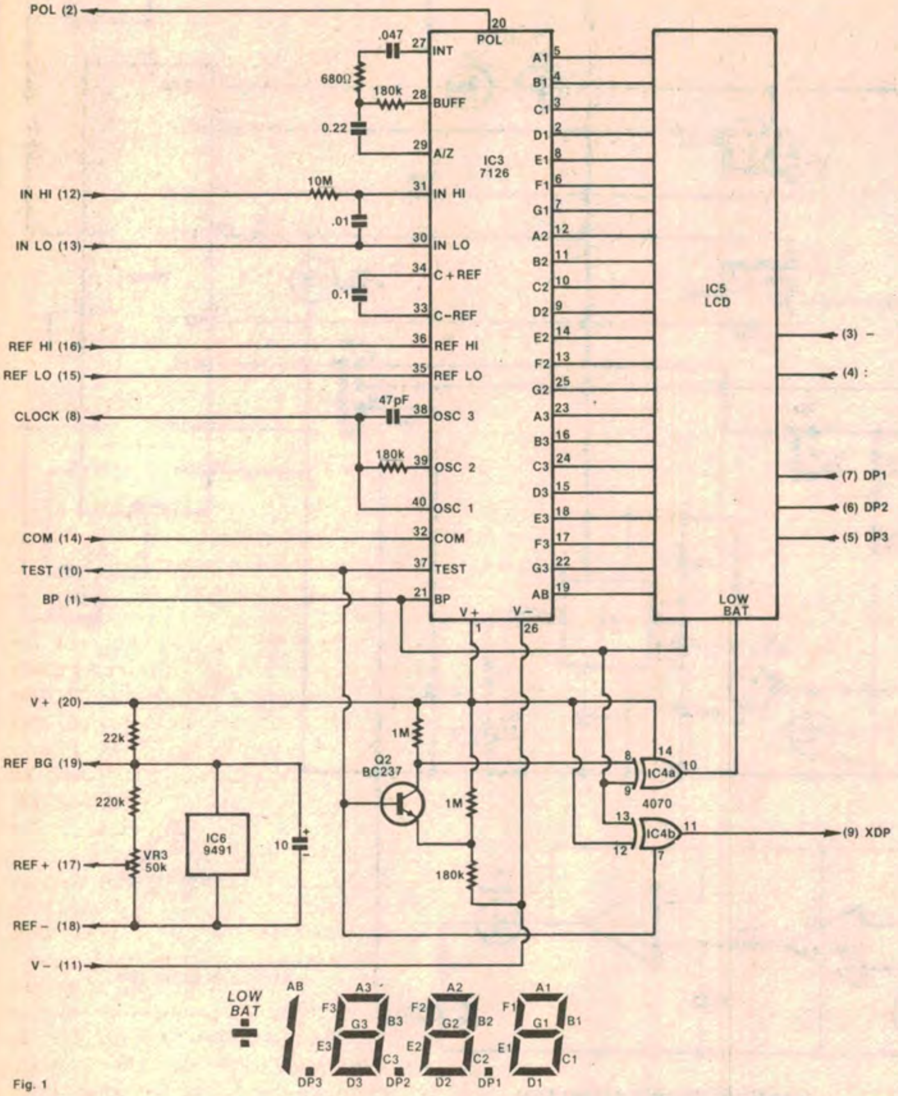


Fig. 1

Schematic diagram for the DPM05 voltmeter module. IC3 is an analog-to-digital converter chip that direct drives the liquid crystal display (IC5).

output spikes coinciding with the rising and falling edges of the input waveform. In this circuit, however, the large negative spikes are clipped by diode D1 to prevent damage to the base-emitter junction of transistor Q1.

Transistor Q1 is normally held off by its 10kΩ base-emitter resistor, and is briefly turned on each time a positive pulse is applied to its base. Q1 thus serves to invert the positive spikes, turning them into negative-going pulses with an amplitude approaching the 2.8V supply. These negative-going pulses are used to trigger IC1, a 7555 timer IC.

The 7555 is essentially a CMOS version of the familiar 555 timer. It is wired as a one-shot monostable and produces a short positive pulse on its pin 3 output whenever a negative pulse appears at its trigger input (ie, each time the points open). The monostable period is about 4.4ms, as set by the 18kΩ resistor and 0.22μF timing capacitor on pins 6 and 7.

IC1's output thus consists of a train of brief positive-going pulses of constant width and amplitude, the pulse rate depending upon the number of times the points open and close. These pulses are fed to a voltage divider and integrated by a 22μF capacitor to produce a steady DC voltage on the input of the DPM05 module. Trimpot VR1 allows the unit to be calibrated to read directly in rpm.

Dwell measurements

The dwell angle of a distributor is defined as the angle through which the distributor shaft rotates while the points are closed. A 4-cylinder engine, for example, has four distributor cam lobes spaced 90° apart and this represents the maximum possible dwell angle (ie, points permanently closed). Similarly, a 6-cylinder engine has 60° cam lobes, while an 8-cylinder engine has 45° cam lobes.

In practice, the dwell angle is usually slightly less than two-thirds the cam lobe angle and correct adjustment is important for optimum engine performance. It is constant for all engine speeds, and may be measured by comparing the points open time to the points closed time (ie, by measuring the duty cycle).

IC2a and IC2b form the dwell input circuitry. The first stage, IC2a, is wired as a comparator with a preset triggering threshold set by diode D3 on the non-inverting input. Zener diode D2 protects the inverting input from excessive voltages and also limits the differential input voltage to less than the 2.8V supply.

Each time the points close, the output of IC2a goes high (ie, the points closed time is active high). These output pulses are fed to a 22μF integrating capacitor which produces a voltage proportional to the output duty cycle of IC2a.

The reason why the unit will not measure dwell on cars fitted with electronic ignition now becomes apparent. The saturation voltage of the coil switching transistor will typically be greater than 0.6V, and thus the output of IC2a can never go high.

IC2b is wired as a voltage follower and serves to buffer the voltage across the 22μF integrating capacitor. The output is taken from pin 7 and fed via D7 to a voltage divider consisting of an 18kΩ resistor and trimpot VR2. VR2 allows the circuit to be calibrated to read the dwell angle directly in degrees.

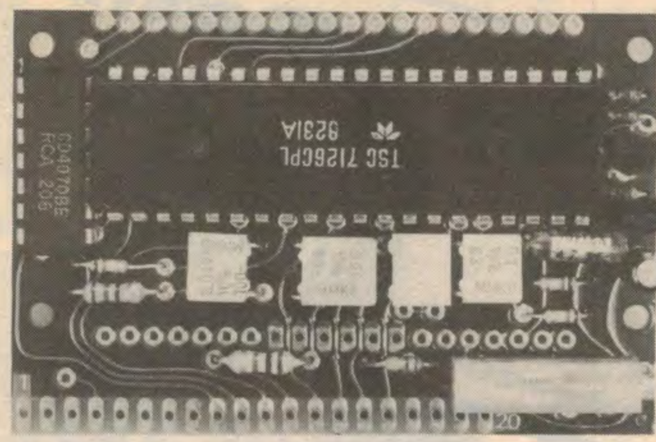
Actually, we are rather at a loss to explain the presence of D7. Since the output of IC2b can never swing negative, this component could presumably be replaced by a wire link with no change in circuit performance. We have included it in the circuit and overlay diagrams because that's the way it is presented in the kit. It does no harm by leaving it in circuit – it just seems unnecessary.

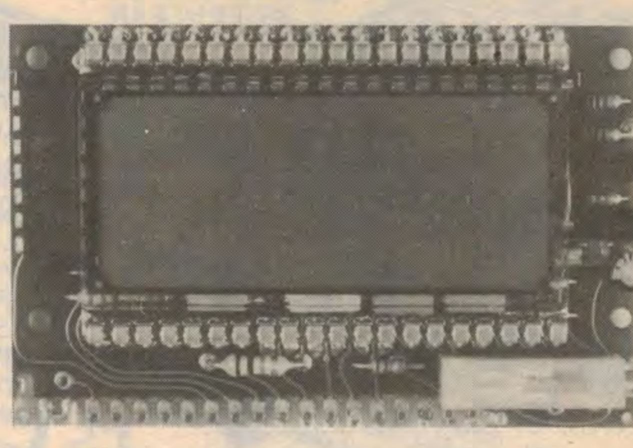
Voltage and resistance

The voltage and resistance measurement ranges are straightforward. For voltage measurements, resistors R1-R4 form a simple attenuator network with an input impedance of 10MΩ. S2a selects the appropriate attenuator setting and feeds the output via S1b to the IN HI input of the DPM05 module.

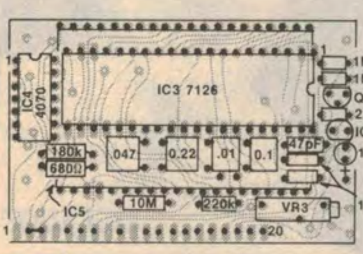
The voltage dependent resistor (VDR) is included to protect the meter circuitry against high-voltage transients.

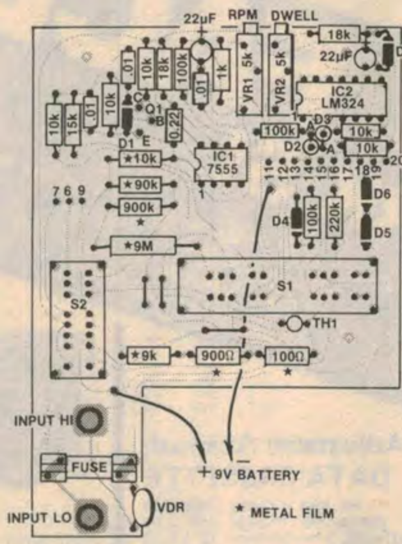
For resistance measurements, the bandgap reference (REF BG) from the DPM05 is applied via D5, D6, S2b and S1 to fixed resistors R5-R7. The resulting





At left is the DPM05 module prior to mounting the LCD while at right is the completed module.





Here are the parts layout diagrams for the DPM05 (above) and DP401/2B modules. Check component polarity before soldering.

current is then passed through the unknown resistor connected to the meter terminals and the voltage across it is the resistance reading. The 1kΩ thermistor protects against any external voltage which may be present when "in-circuit" resistance measurements are attempted.

If an "in-circuit" voltage is present, D4 will turn on at about 6.8V to shunt the applied voltage. The resulting current through the thermistor causes its resistance to increase markedly and thus limit the current to a safe value.

Construction

Construction can begin with the assembly of the DPM05 display module. Begin by installing the wire link between pads 2 and 3 of the edge connector, then mount the various components according to the parts layout diagram. Note that the PCB uses plated-through holes, so soldering is required only on the underside of the board.

The accompanying photograph shows the module partially assembled, to the point where the LCD is ready to be fitted. This sits above the 7126 IC and most of the minor components, so it is essential that these be mounted as close to the PCB as possible. In particular, the two 1MΩ resistors in the top, right corner of the board must be kept well to the right, otherwise they will obstruct the 7126 IC.

Similarly, the four polyester capacitors beneath the 7126 must be mounted flat against the board. Bend the leads at right angles to the capacitor body before inserting them in the appropriate holes. The .047µF capacitor sits to the left of its mounting holes, while the other three sit to the right.

Note that there are a couple of plated-through holes near the .01µF capacitor which are not used (see photo and parts layout diagram). Similarly there is an unused hole under the 220kΩ resistor to the left of the 50kΩ trimpot. There are other unused holes but, provided the parts layout diagram is followed carefully, these should not cause any confusion.

Correct orientation of the LCD is important and is determined by either a blue bar or a small detent in the mask at one end of the display. This mounts to the left. Push the LCD down as far as it will go, so that it sits flat on the 7126 IC, then carefully solder the pins.

Finally, clean the flux off the back of the board using methylated spirits. It only takes a small leakage current between adjacent tracks or between the input terminals of the module to upset its operation.

The completed module can now be tested using the simple test circuit shown in Fig. 2. Temporarily connect the battery clip between pins 11 (negative) and 20 (positive), connect pins 13, 14, 15 and 18 together, and connect pins 16 and 17 together. Now short the two input terminals (pins 12 and 14) together – the display should read "000".

In some cases, however, the display may read "001" or "−001", or even cycle regularly between "−001", "000" and "001". This is quite normal.

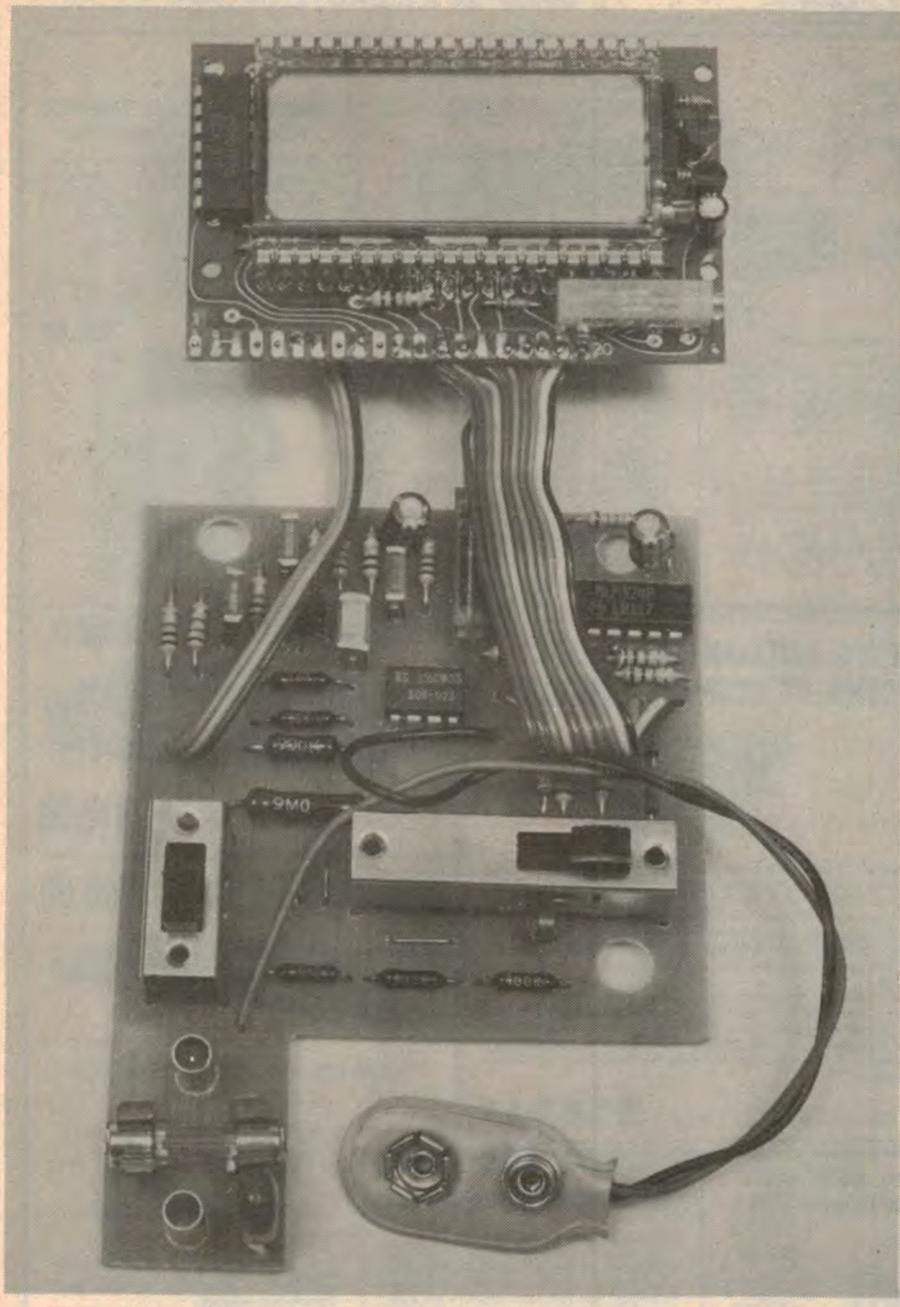
The DPM05 module can also be calibrated at this stage, assuming that a suitable 100mV reference voltage is available. We used the DC Voltage Reference described in the June 1976 issue. To calibrate the module, connect the reference voltage between pins 12 and 14 and adjust VR3 for a reading of "1000".

Don't worry if you haven't got a suitable reference voltage, though. The DPM05 can be easily calibrated after the Minitune has been fully assembled as we shall see later on.

DP401/2B module assembly

Construction of the DP401/2B module is straightforward. As before, take care with component orientation and don't forget the three wire links adjacent to switch S1. The thermistor (TH1) and the voltage dependent resistor (VDR) can be mounted either way round.

Note that seven of the resistors (R1-R7 on the circuit) are 0.25% metal film types. These are marked with asterisks on the parts overlay diagram, so be sure to use a metal film resistor wherever you see an asterisk. Do not substitute carbon film types, otherwise the accuracy of the voltage and resistance ranges will be degraded.



This view shows the Minitune all wired up and ready for testing. The rainbow cable connecting the two modules should be kept as short as possible.

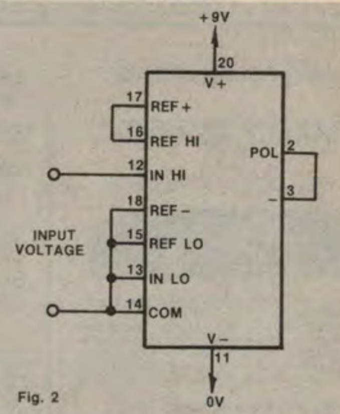


Fig. 2

Use this test circuit to check the DPM05 for correct operation.

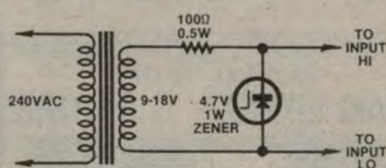


Fig. 3

This simple calibration circuit uses the mains as a frequency reference.

The two switches can only be mounted one way and should be pushed down on to the PCB as far as they will go. Check that they are perpendicular to the PCB before soldering the terminals – if crooked, they will not line up with the slots in the front panel. Similarly, make sure that the two input terminals are also perpendicular to the PCB.

When the main PCB is completed, it can be wired to the DPM05 module using rainbow cable. One 10-way 5cm length of cable is connected between the DPM05 and a group of holes below the LM324 IC, while a 3-way length of cable is connected to a second group of holes above switch S2. Finally, connect the battery clip leads to the main PCB.

To test the unit, connect the battery and switch to the 20V voltage range. The display should read "0.00" (or, more likely, "0.01" or "−0.01"). Now switch to the resistance ranges. With the input leads open circuit, the display should show a "1" at the leading digit with all other digits blanked. This indicates the over-range condition. The display should now read zero with the input leads shorted together (either "0.00" or "00.0", depending on the range selected).

One problem that may become evident at this stage is that the unwanted decimal point has a tendency to partly turn on. If this proves to be the case, the solution is to connect 1MΩ resistors between each decimal point annunciator (DP1 and DP2) and the backplane pin (pin 1). These resistors will prevent noise from turning on the decimal point annunciators, yet allow normal operation of each annunciator when it is connected to XPD.

Calibration

If you haven't already done so, the first step in the calibration procedure is to calibrate the DPM05 module. To do this, select the 20V range and connect a suitable voltage of around 12V to the input terminals and to your DVM. Trimpot VR3 on the DPM05 module should now be adjusted so that the reading on the Minitune matches the DVM reading.

The tachometer range is calibrated by using the mains as a frequency reference. Fig. 3 shows the calibration circuit. This uses a 4.7V zener diode to clip the secondary output of a mains transformer to provide a suitable input waveform. Most readers will have a suitable transformer on hand.

Connect the output of the calibration circuit to the Minitune and temporarily connect a 0.1μF polyester capacitor in parallel with the .01μF capacitor connected to the base of Q1. Trimpot VR1 should now be adjusted so that the display reads 1500rpm (1.50) for a 4-cylinder car, or 1000rpm for a 6-cylinder car. Remove the 0.1μF capacitor when you have finished this step.

The dwell calibration is even easier. All you have to do is leave the input leads open circuit and adjust VR2 for a full-scale reading of 90° (90.0) for a 4-cylinder car or 60° for a 6-cylinder car. You should get the same reading when the input leads are shorted together.

Owners of 8-cylinder cars should calibrate the tacho and dwell ranges as for a 4-cylinder car. The tacho and dwell readings are then halved to get the correct readings.

The case

Construction can now be completed by mounting the two modules in the case. As supplied, the case consists of two sections which press together and are held by two long self-tapping screws. There is also a small bezel which mounts on the outside of the case and supports the display module, the latter being held by four small self-tapping screws.

The DP401/2B module is retained by three locating studs which fit three holes in the board. It will be necessary to fold the rainbow cable to allow everything to fit when the two sections of the case are pressed together. Having said that, the case is really too small and a great deal of patience is required to achieve a neat result (it helps if the wiring between the two modules is kept as short as possible).

Despite our best efforts, we were unable to get the case to close neatly although admittedly our wiring was longer than necessary to allow the case to be opened for photography. The display bezel also had a tendency to lift at one corner, as it is only held in place by an interference fit between the bezel, case and components.

Because of this, some constructors may wish to consider mounting the electronics in a plastic zippy box. It should then be a simple matter to add switching so that the unit can be used with different engine categories. This would involve switching in different voltage divider networks across the outputs of the tacho and dwell circuits.

We should also point out that the "multimeter-style" test leads sold with the kit are unsuitable for connecting the Minitune to an automotive ignition system, although they are suitable for voltage and resistance measurements. Readers are therefore advised to make up a second pair of test leads fitted with alligator clips. In addition to the alligator clips, you will need two 4mm banana sockets (1 red, 1 black) and suitable lengths of red and black hook-up wire.

That's it — project completed and ready for engine tuning! Drive safely.

PARTS LIST

DP401/2B Module

1 plastic case
1 bezel
2 fuse clips
1 2A fuse
2 4mm PCB-mounting terminals
1 printed circuit board, DP401/2B
1 9V battery, Eveready 216 or equivalent
1 battery snap connector (216)

SWITCHES
1 4-pole, 4-position slide switch
1 3-pole, 3-position slide switch

SEMICONDUCTORS
5 1N4148 dodes
1 BZY88 2V7 zener diode
1 BZY88 6V8 zener diode
1 7555 CMOS timer IC
1 LM324 quad op amp IC
1 BC237 NPN transistor

CAPACITORS
2 22μF 10VW electrolytic
1 0.22μF polyester
3 .01μF polyester

RESISTORS (0.25% metal film)
1 x 9MΩ, 1 x 900kΩ, 1 x 90kΩ, 1 x 10kΩ, 1 x 9kΩ, 1 x 900Ω, 1 x 100Ω

RESISTORS (carbon film, 5%)
1 x 220kΩ, 3 x 100kΩ, 2 x 18kΩ, 1 x 15kΩ, 5 x 10kΩ, 1 x 1 kΩ, 2 x 5kΩ multiturn trimpots, 1 x 1kΩ thermistor, 1 VDR.

DMP05 Module

1 printed circuit board, DPM05/3B

SEMICONDUCTORS
1 7126 A/D converter
1 4070 exclusive-OR gate
1 9491 voltage reference
1 BC237 transistor
1 3½-digit LCD

CAPACITORS
1 10μF 10VW electrolytic
1 0.22μF polyester
1 0.1μF polyester
1 .047μF polyester
1 .01μF polyester
1 47pF polystyrene

RESISTORS (½W, 5%)
1 x 10MΩ, 2 x 1MΩ, 1 x 220kΩ, 3 x 180kΩ, 1 x 22kΩ, 1 x 680Ω, 1 x 50kΩ multiturn trimpot.

Calibration Circuit

1 100Ω 0.5W resistor
1 4.7V 1W zener diode