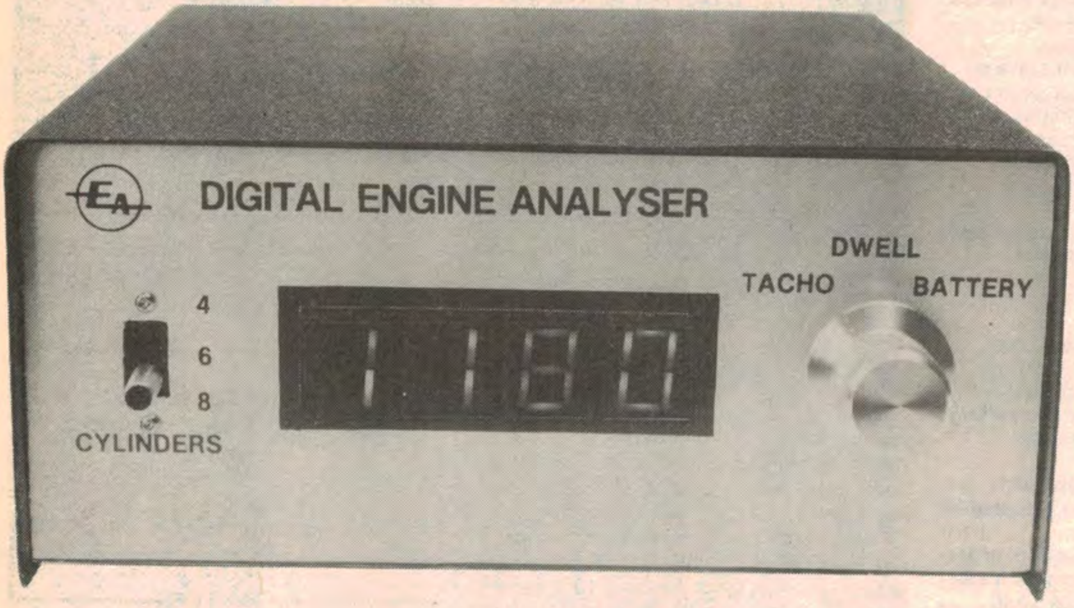
Tacho/dwell meter for engine tune-ups



☆ Easy to build

☆ 4 digits

☆ LED display

☆ Measures rpm, dwell & voltage

Featuring a bright, easy-to-read LED display, this new Digital Engine Analyser measures engine RPM, dwell and battery voltage on any 4, 6 or 8-cylinder petrol engine. It is compatible with both electronic or conventional ignition systems and will save you money on petrol and engine tune-ups.

circuit by RON DE JONG
article by GREG SWAIN

Once upon a time, when the world was not too much younger, you could buy petrol very cheaply. You could drive into Fred's Friendly Fill-up, have the windscreen cleaned, the oil and tyres checked, and the tank filled for a few measly dollars. Those were the "good old" days when the flow meter on the petrol pump spun faster than the dollar meter.

But that was once upon a time. Since then, petrol prices have risen dramatically and, at the current price of 33 or 34 cents per litre, filling up the family car is an expensive business. And it's going to get even more expensive – did someone say much more expensive? – in the near future.

Against this background, our new Digital Engine Analyser is bound to prove popular. In fact, we're rather proud of the instrument. Among the features it boasts are an easy-to-read, 4-digit LED display, and provision for measuring engine RPM, dwell and battery voltage on 4, 6 and 8-cylinder engines. Combined with an ignition timing light, it will enable you to accurately tune your car's engine for best performance and reduced fuel consumption.

At today's petrol prices, correct engine tune quickly translates into real on-road dollar savings (a badly tuned engine can have a devastating effect on fuel consumption). You'll save money by doing your own engine tune-ups too. In fact, our new Digital Engine Analyser will probably pay for itself in a very short time.

One important feature of the unit is that it is compatible with all current electronic ignition systems, including breakerless systems and transistor-assisted and capacitor discharge systems in which the points are retained. Only three leads are required to connect the unit for use: two to the battery and the third to the points or to the transistor side of the ignition coil in the case of a transistorised system.

To explain further, for conventional and CDI systems the lead is connected to the points; for a breakerless electronic system, the lead is connected to the coil (ie across the coil switching transistor); and for a transistor-assisted system the lead can be connected either to the points or to the ignition coil.

The tachometer and dwell ranges both use the same engine connections, except for TAI systems which have dwell extension. In one position, the dwell meter will give the duty cycle of the points; in the other (ie to the coil), it will give the extended dwell reading. The tachometer reading will be the same from either input.

ENGINE TUNING

Engine tuning usually involves little more than replacement of the points, followed by adjustments to the ignition system and engine idling speed. Once the points have been replaced, the first step is to set the dwell to the manufacturer's specifications. On Holden 6-cylinder engines, for example, this will be somewhere between 30° and 35°; for 4-cylinder engines the dwell angle will be somewhat higher, typically around 55°.

Dwell is simply the angle of rotation of the distributor shaft while the points are closed during each ignition cycle. All one has to do is adjust the points gap until the specified reading is indicated on the Analyser (or rather the reading falls within the manufacturer's recommended range).

Correct dwell adjustment is important. Too small a dwell angle, for example, will result in less current passing through the coil, with consequent poor ignition through loss of spark energy. This can cause misfiring at high RPM and can also make an engine hard to start, particularly in cold weather.

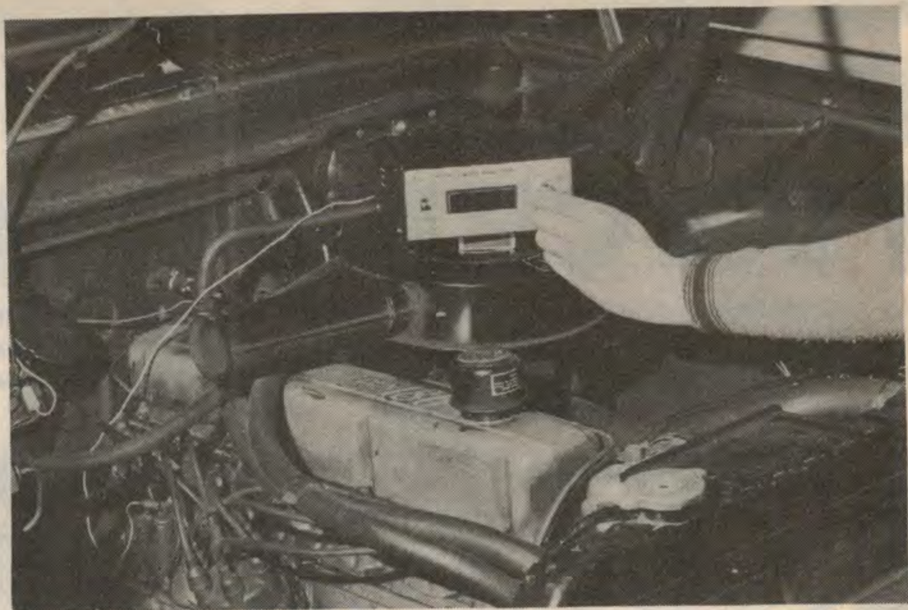
On the other hand, too large a dwell angle will result in higher currents which may lead to excessive arcing and pitting of the points at low engine speeds, again resulting in loss of spark energy.

This is where electronic ignition systems can offer superior performance. Our own Transistor-Assisted Ignition system (Dec, 79), for example, maintains spark energy at a very high level, even up to very high engine speeds, by using "dwell extension". Thus, with TAI and CDI systems, it will only be necessary to set the points dwell somewhere in the "ballpark".

The "tacho" range is essential for setting the engine idling speed, an adjustment which is particularly important for cars with automatic transmission. If the idling speed is too high, the car will tend to "creep" more than normal and waste petrol; if it is too low, the engine will run roughly, have a tendency to stall, and have higher than usual bearing wear.

Ignition timing adjustments also require the use of a tachometer, since timing is usually carried out at a specified engine speed. Make sure that you set the dwell before making ignition timing adjustments, as dwell affects timing (although the converse is not true). You should also make sure that all engine adjustments are carried out according to the manufacturer's specifications.

Invest in a workshop manual if you don't have one.



Three leads connect the unit for use – two to the battery and the third to the points side of the coil. The air cleaner is usually a convenient place to rest the instrument.

HOW IT WORKS

Fig. 1 shows a simplified block diagram of the tachometer circuit, and the various signal waveforms involved. Input to the tachometer is obtained from across the points (say), and the circuit counts the number of times the points open (ie the number of sparks) within a fixed "gating" interval. This gating interval is set so that, for a given spark rate, the meter will display RPM directly.

The gating signal and two other "housekeeping" signals – the latch enable and reset signals – are obtained from a master clock which drives a counter and associated gating circuitry. The sequence of these housekeeping signals is as follows: First the gating signal arrives and pulses from the input circuit clock the counter; then, as soon as the gating signal is finished, the latch enable goes high and the contents of the counter are transferred to latches and displayed (ie, the reading is updated); finally, the reset signal goes high, clearing the counter for the next cycle.

One problem with this scheme is that if we were to directly display RPM, the gating period (and hence the update time) would be quite long. In the case of a 6-cylinder engine, for example, 50 sparks per second corresponds to 1000 RPM. Thus, for the counter to read 1000, we would need a gating period of 1000/50 or 20 seconds!

This figure is much too long to be practical and must be reduced. Our circuit overcomes the problem in two ways.

Firstly, the first digit of the display has been set permanently to zero and the circuit arranged so that the first digit of the counter drives the second digit of the display (more on this later). This step not only reduces the required count (and hence the gating time) by a factor of 10, but also reduces display "bounce" due to small variations in engine idle speed.

Secondly, we introduced a phase locked loop (PLL) immediately after the input buffer. The PLL increases the apparent spark rate by multiplying the input frequency, and thus reduces the gating time even further.

Since the gating period is kept constant, a different multiplier factor must be used for each different engine category. For a 4-cylinder engine there are two sparks per engine revolution, three for a 6-cylinder, and four for an 8-cylinder.

We estimate that the current cost of parts for this project is about

$45

including sales tax

Fig. 1 (right): how the tachometer function works. The input frequency derived from across the points is buffered, multiplied by a PLL, and gated through to the display circuitry. Different multipliers are used for 4, 6 and 8-cylinder engines.

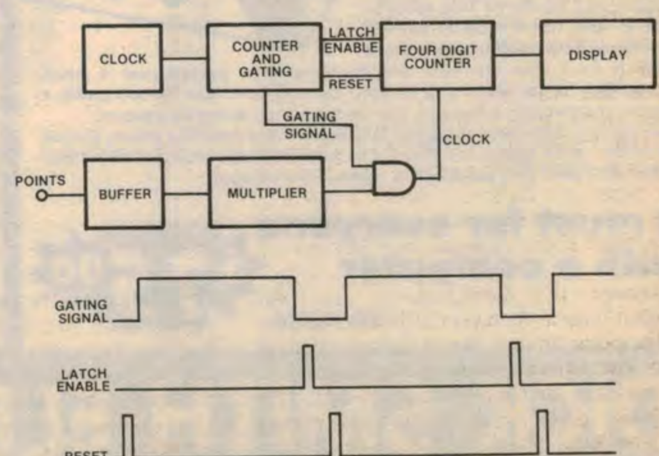


FIG. 1: TACHOMETER

These figures mean that for a given input frequency, engine RPM is obtained by multiplying by 30, 20 and 15 for 4, 6 and 8-cylinder engines respectively.

By choosing a gating period of 0.5s, these figures translate into required PLL multiplication factors of 6, 4 and 3.

In essence then, the tachometer is a frequency meter, but with the addition of a frequency multiplier in the input stage.

DWELL METER

Fig. 2 shows the basic scheme for the dwell meter section of the engine analyser.

Dwell is actually a measure of the duty cycle of the points and is measured in degrees of distributor camshaft rotation. Our circuit measures dwell by simply filtering the waveform across the points to give a DC voltage proportional to the duty cycle and then measuring this voltage to give a reading in degrees. In fact, the dwell meter section of the circuit functions in exactly the same manner as a digital voltmeter.

The dwell meter uses the same basic housekeeping circuit as the tachometer but, in addition, includes a ramp generator, comparator, divider and a low pass filter (LPF). Gating is derived from the comparator, which has one input connected to the LPF and the other connected to the ramp generator.

At the heart of the dwell meter circuit is an analog-to-digital converter (ADC) which functions as follows: After the counter has been reset to zero, the ramp voltage at the inverting input of the comparator increases linearly with time. During this time, the gating signal is high and the counter is clocked. The ramp voltage continues to rise until it equals the DC voltage from the LPF, at which point the gating signal goes low and stops the counter.

The point behind all this is that the length of the gating period will be proportional to the voltage output of the LPF, which in turn is proportional to the dwell — the very thing that we wish to measure.

So that the circuit will give a direct reading in degrees for 4, 6 and 8-cylinder engines, we have included a divider which divides down the clock signal before passing it to the gate. The appropriate division factors can be worked out by simply noting that for a 100% duty cycle — ie points permanently closed — the dwell angles would be 90° for a 4-cylinder engine, 60° for a 6-cylinder engine and 45° for an 8-cylinder engine. After setting the counter and gating circuit to divide by 512, the division factors used were 4, 6 and 8 for 4, 6 and 8-cylinders respectively.

While developing the dwell meter circuit we realised that, since it includes a fairly accurate A-to-D converter, we might as well take advantage of the situation and add a battery voltage range. This range works in exactly the same way as the dwell meter, except that the clock signal passed to the gate does not come from the "Cylinder preset" divider but from the counter following the clock.

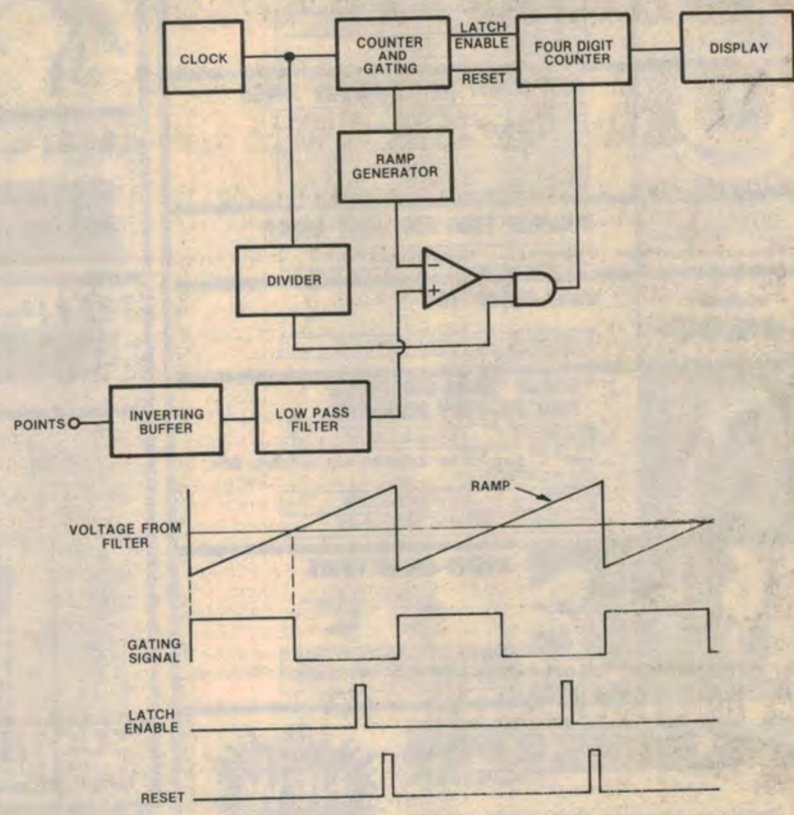


FIG. 2: DWELL METER

THE CIRCUIT

To see how we have implemented the various functions refer now to the circuit diagram. The clock, which provides timing for the whole unit, consists of a 555 timer IC wired as an astable multivibrator. Calibration of the tachometer is performed by adjusting the frequency of the oscillator using trimpot VR1. Note that this adjustment does not affect the dwell or battery voltage ranges, because the ramp signal is also derived from the clock.

The counter and gating section of the circuit consists of a 4040 binary ripple counter (IC1), a 4001 quad NOR gate (IC5), and a 4011 quad NAND gate (IC4). The NAND and NOR gates decode the outputs of the ripple counter to obtain the gating, latch and reset signals for IC2, the 4-digit counter. IC4a provides the

SPECIFICATIONS

MEASURING FUNCTIONS:

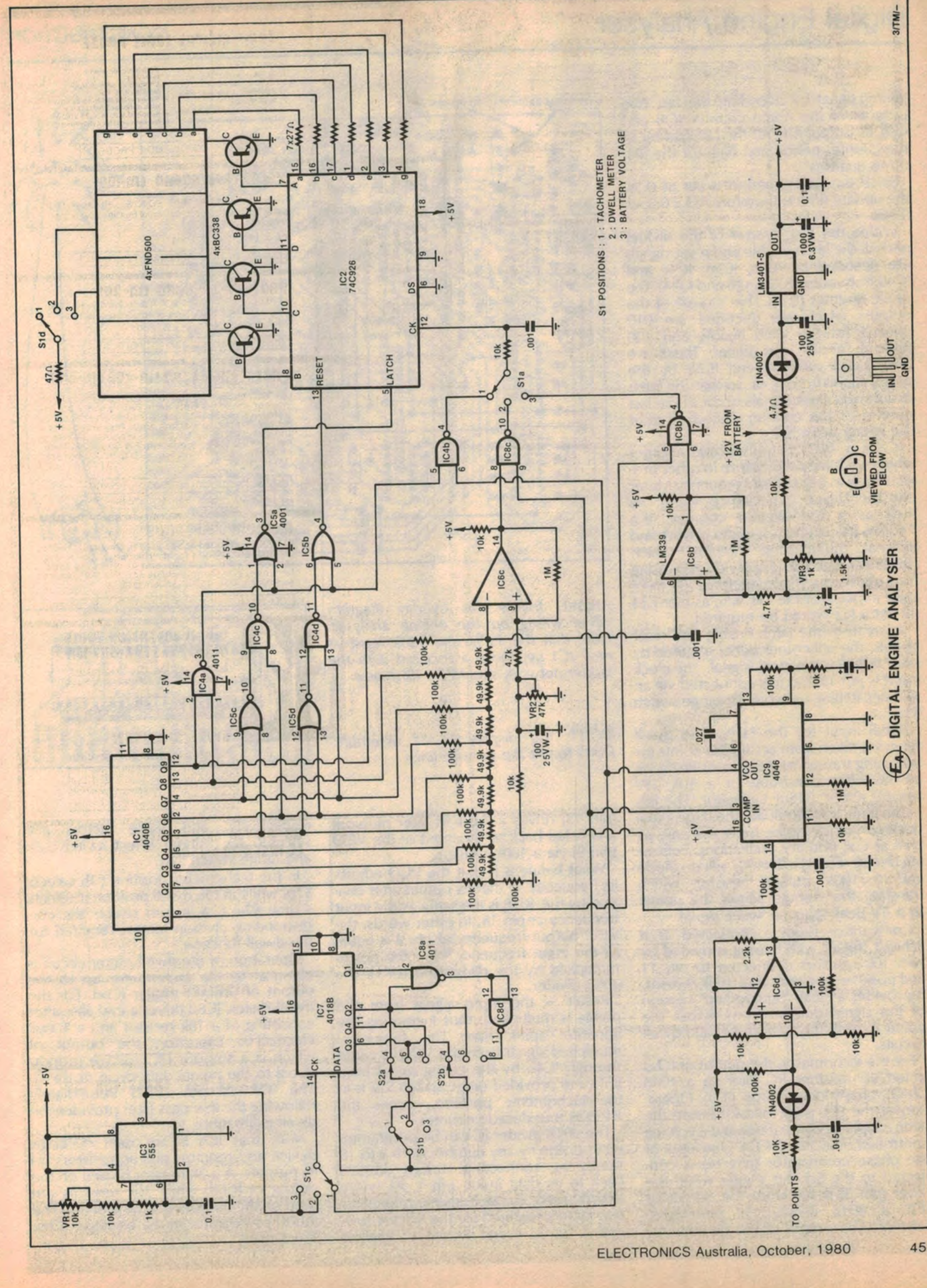
Tachometer — 360-9,990RPM on 4, 6 or 8-cylinder engines.
Dwell Meter — 0-90° (4-cylinder); 0-60° (6-cylinder); 0-45° (8-cylinder).
Battery Voltage — 9-20V; 0.1V resolution

COMPATIBILITY:

Compatible with 4, 6 and 8-cylinder petrol engines; Kettering and electronic ignition systems (includes breakerless ignition); and both negative and positive earth vehicles.

ACCURACY:

Tachometer: ± 10RPM — Dwell Meter: ± 1° — Battery Voltage: ± 0.1V.


DIGITAL ENGINE ANALYSER
S1 POSITIONS : 1 : TACHOMETER
2 : DWELL METER
3 : BATTERY VOLTAGE
3/TM/-
4xFND500
4xBC338
IC2 74C926
IC1 4040B
IC3 555
IC7 4018B
IC9 4046
LM339
LM340T-5
+12V FROM BATTERY
TO POINTS
VIEWED FROM BELOW

gating signal by decoding the last two outputs of the ripple counter (Q8 and Q9), its output low for the last quarter of the counter period and high for the first three quarters.

Since the gating period is set at 0.5s, the update time is therefore 4/3 x 0.5, or 0.66s.

Within this last quarter of the divider period, the latch enable and reset signals are decoded by IC5c, IC5d, IC4c and IC4d from outputs Q5, Q6 and Q7 of the ripple counter (IC1). The "states" of the outputs which are decoded are 010 (binary) for the latch enable and 100 (binary) for the rest signal. These are then gated via IC5a and IC5b by the gating signal from IC4a, so that the latch enable and reset signals occur in the last quarter of the counter period (ie after the gating period).

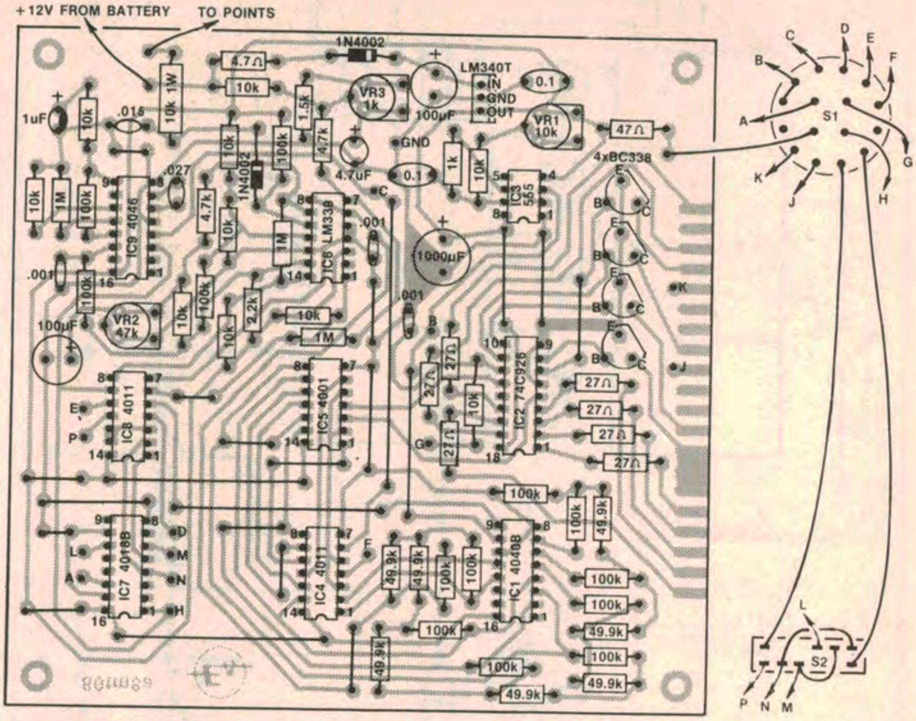
IC2 is a 74C926 four-decade counter which we have used before in other projects such as our Digital Frequency Meter and the Digital Capacitance Meter. As well as a four-decade counter, the 74C926 has latches, decoder drivers and internal multiplexing circuitry which drives a 4-digit LED display directly using four transistors. If conventional ICs were used in place of the 74C926, as many as 12 extra ICs would be required.

Apart from the latch enable and reset signals, the only other signal required by the 74C926 is the clock signal. The clock input is pin 12 and it is connected via an RC "deglitching network" to range switch S1a.

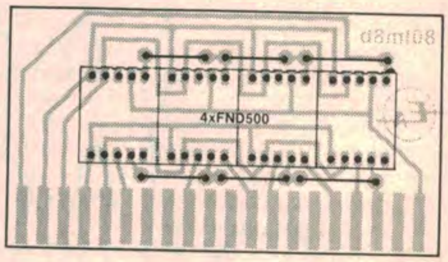
Signal input for the tacho and dwell ranges is taken from across the points (or switching transistor) and passes firstly via an RC filter consisting of a 10k 1W resistor and a .015uF capacitor. The job of the filter is to attenuate the large initial positive voltage spike from the coil, as well as coil primary oscillations. Following the RC filter is a 1N4002 silicon diode and a 100k pull-up resistor which translate the voltage across the points to a 5V peak "square" wave signal.

Comparator IC6d is connected as a Schmitt trigger with biasing provided by two 10k resistors connected to pin 11 and positive feedback via a 100k resistor. It provides a clean "squared-up" version of the signal derived from across the points to both the tachometer and dwell circuits.

For the tachometer, the output of IC6d is fed via another RC filter to a 4046 CMOS phase locked loop (IC9). Operation of the PLL is as follows: Inside the 4046 is a phase comparator and a voltage controlled oscillator (VCO). One input of the phase comparator (pin 14) is connected to the Schmitt trigger while the other (pin 3) is fed from the output of IC7, a 4018 divide-by-N presettable counter. The output of the comparator



ABOVE: follow this overlay diagram when wiring up the engine analyser. Note that the 49.9k and 100k resistors near IC1 (ie, those associated with the ladder network should be 1% types).



RIGHT: the display board assembly. Don't forget the six wire links.

(pin 13) drives a lag-lead filter network and is fed back to the input of the VCO (pin 9) via a 100k resistor.

What happens is that the VCO adjusts its frequency so that its output after division by the 4018 is the same as the input frequency at pin 14. In other words, the VCO output frequency at pin 4 is equal to the input frequency from the points multiplied by the division factor of the 4018 divider.

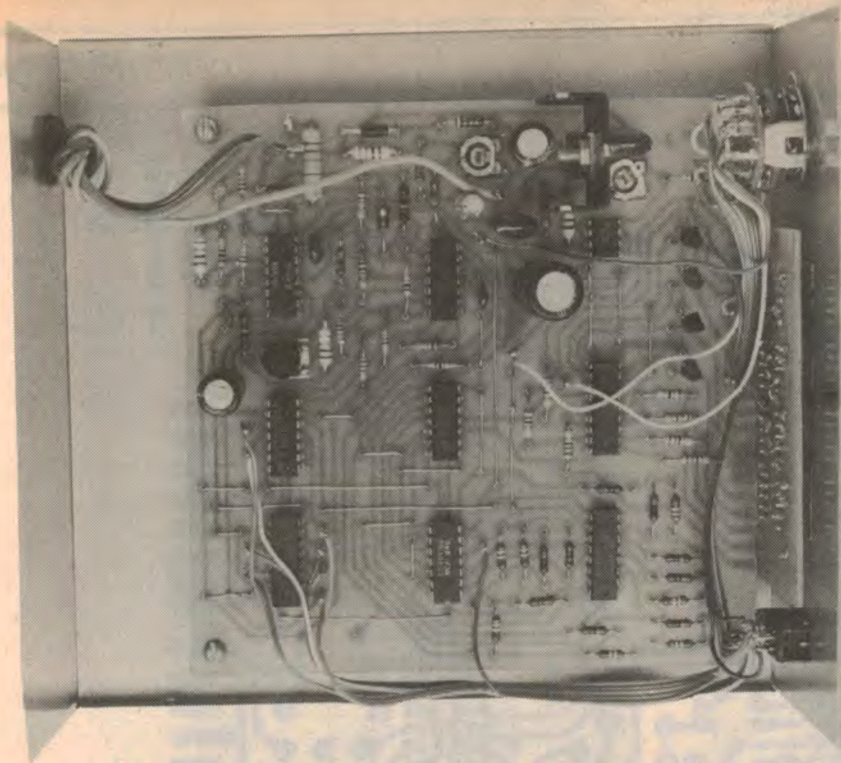
Result – the input signal from the points is multiplied, thus increasing the apparent spark rate. This frequency multiplied signal from the VCO is gated through IC4b by the gating signal from IC4a and provided range switch S1a is in the tachometer position, clocks the 74C926 four-decade counter.

The 4018 divider IC can be programmed to divide by any number from 2 to 10 simply by connecting various outputs back to its data input, pin 1. As we've already seen, the tachometer multiplication factors required for the PLL are 6, 4 and 3 for 4, 6 and 8-cylinder engines respectively, and these factors are selected by cylinder select switch S2b and range switch S1b.

In the tachometer position S1b selects S2b, while in the dwell position it selects switch S2a. S2a in turn selects the corresponding division factors required for the dwell function.

Operation of the dwell meter circuit is identical to the tachometer up to the output of Schmitt trigger IC6d. For the dwell meter, IC6d drives a low pass filter consisting of a 10k resistor and a 100uF electrolytic capacitor, the output of which is a smooth DC voltage proportional to the points duty cycle or dwell. The 47k trimpot (VR2) immediately following the low pass filter provides the dwell calibration.

Note that IC6 is an open collector device and requires pull-up resistors on its outputs. A 2.2k resistor is used on the output of IC6d, while 10k resistors are used on the outputs of IC6b and ICc. The fourth comparator in the package, IC6a, is not used.



Rainbow cable can be used to complete the internal wiring, while the points lead should be rated at 240V. The PCB assembly is mounted using 25mm brass spacers.

PARTS LIST

1 metal case, 184 x 160 x 70mm
1 PCB, 80tm8a, 136 x 133mm
1 PCB, 80tm8b, 82 x 46mm
1 4-pole, 3-position rotary switch
1 2-pole, 3-position slide switch
1 Scotchcal front panel
1 47k miniature horizontal trimpot
1 10k miniature horizontal trimpot
1 1k miniature horizontal trimpot
4 12mm brass spacers
2 car battery clips
1 alligator clip
1 heatsink for voltage regulator
1 rubber grommet

SEMICONDUCTORS
1 74C926 CMOS counter latch multiplexer
1 4040B CMOS binary ripple counter
1 4018B CMOS divide by N counter
1 4046 CMOS phase locked loop
2 4011 CMOS quad NAND gates
1 4001 CMOS quad NOR gate
1 LM339 quad comparator
1 555 timer IC
4 FND500 common cathode displays
1 LM340T-5 5V three-terminal regulator
4 BC337 or BC338 transistors
2 1N4002 rectifier diodes

CAPACITORS
1 1000uF/6.3VW PC electrolytic
2 100uF/25VW PC electrolytic
1 4.7uF/25VW PC electrolytic
1 1uF/25VW tantalum
2 0.1uF greencap (metallised polyester)
1 0.037uF greencap
1 0.015uF greencap
3 .001uF greencap

RESISTORS (¼W, 5% unless stated)
3 x 1M, 4 x 100k, 9 x 100k 1%, 7 x 49.9k 1%, 10 x 10k, 1 x 10k 1W, 2 x 4.7k, 1 x 2.2k, 1 x 1.5k, 1 x 1k, 1 x 47 ohm, 7 x 27 ohm, 1 x 4.7 ohm

MISCELLANEOUS
PC stakes, ½-metre of rainbow cable, machine screws, hoop-up leads, etc.

NOTE: Where specified, the "B" suffix on a CMOS IC part number indicates that only a buffered device should be used.

Output from the low pass filter passes to the non-inverting input of IC6c, which is the comparator depicted in the dwell meter block diagram (Fig. 2). The other input to the comparator is the ramp voltage which is obtained from a network of resistors connected to the outputs of the 4040 ripple counter (IC1). This resistor configuration is called an R:2R ladder network and is commonly used as an analog to digital (A to D) converter. Note that the resistors in this network require 1% tolerance.

IC6c provides the gating signal to NAND gate IC8c. When the gating signal is high, the signal from the 4018 divider is gated through IC8c to clock the 74C926 counter. The counter is stopped when the output of IC6c goes low, ie when the ramp voltage is equal to the voltage from the low pass filter.

The battery voltage measuring circuit works in exactly the same manner as the dwell meter, but uses comparator IC6b and a low pass filter consisting of a 10k resistor and 4.7uF electrolytic capacitor. Trimpot VR3 provides calibration, while clock signals are derived from the Q1 output of the 4040 binary counter rather than directly from the clock. This last step is to make maximum use of the voltage range of the ramp.

The power supply is straightforward and consists of a LM340 three-terminal regulator which provides the regulated 5V supply for the CMOS circuitry. Filtering is provided by the 100uF and 1000uF capacitors, while a 1N4002 silicon diode provides protection against reverse polarity battery connection.

Before leaving the circuit description, we should mention two points. The first concerns the phase-lock loop IC (4046). When no signal is present from the points, ie, when the motor is not running, the VCO "free runs". This produces a reading on the display of about 310 to 360 RPM. However, immediately the engine is started the PLL will lock to the input signal and produce a valid reading.

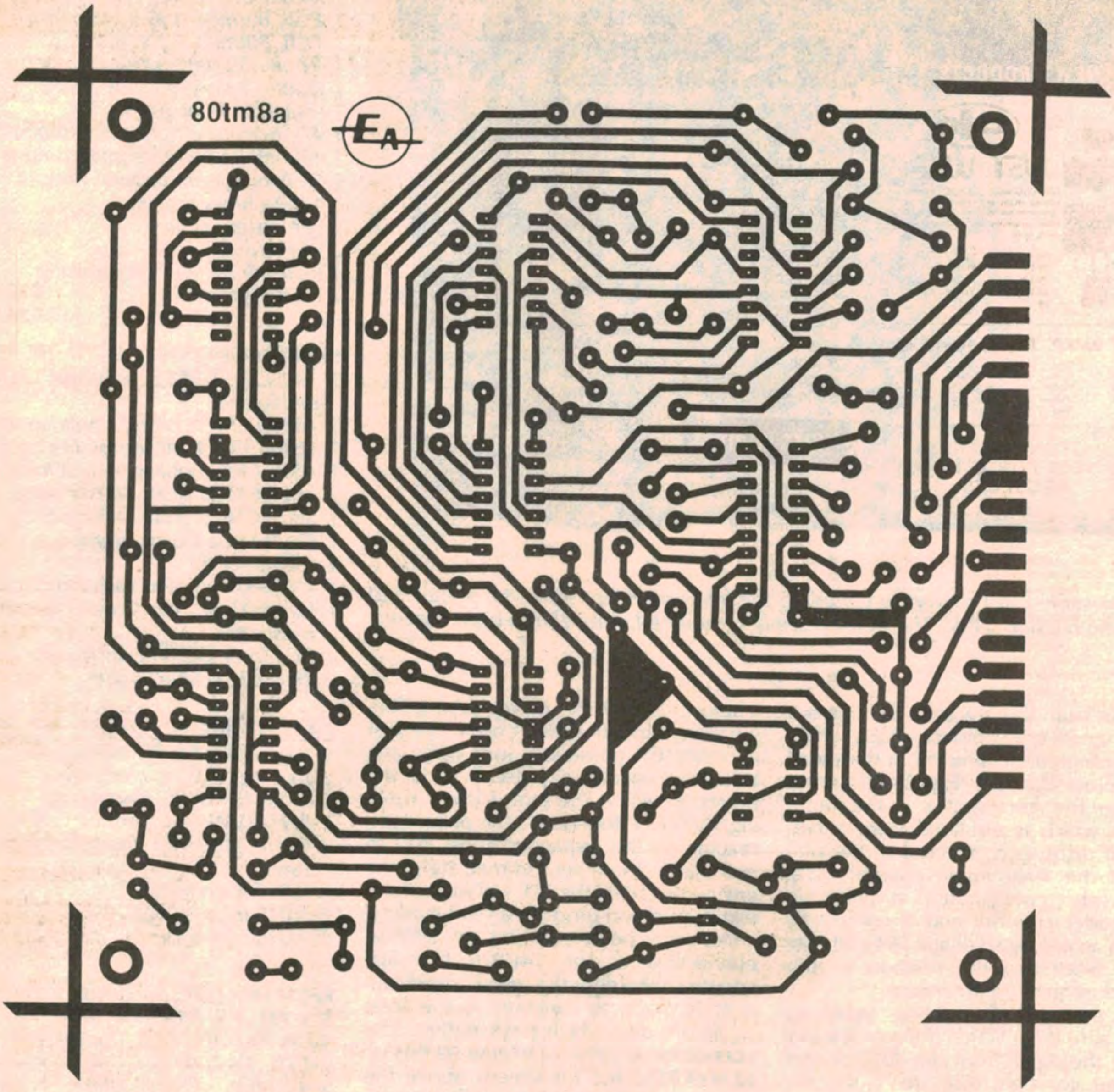
The other point concerns the unusual connection of the 74C926 four-digit counter whereby the most significant digit is made to function as the least significant digit which stays at zero. This connection is valid for engine speeds up to 9990RPM but for speeds above this range, the 74C926 counter will overange onto what in this circuit is the first digit. This means that an engine speed of 10,000RPM will produce a reading of "0001".

While some readers may regard this as a disadvantage we do not think it is serious. Few motors are capable of this speed and in any case, this instrument is really intended for stationary testing, where these engine speeds could not be used without serious danger of damage to the engine.

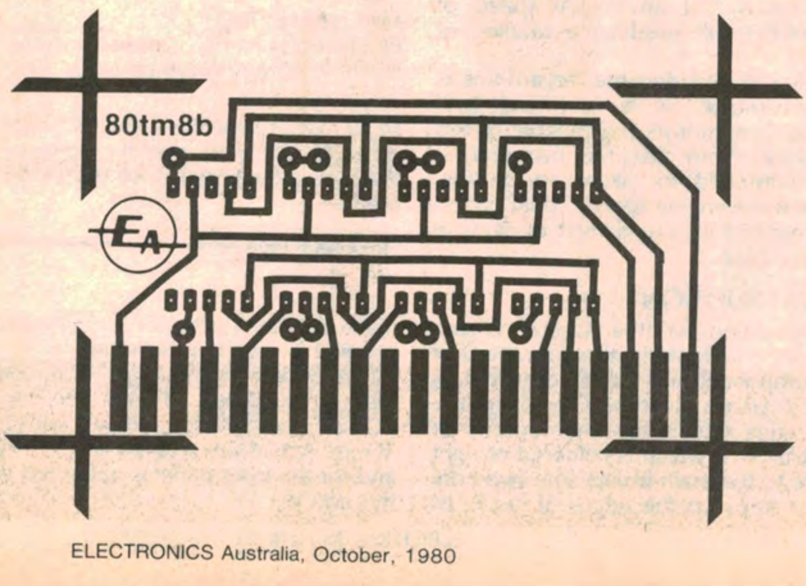
CONSTRUCTION

Construction of the Digital Engine Analyser is fairly straightforward. Most of the components are mounted on a main printed circuit board (PCB) while the seven-segment displays are mounted on a display PCB which is soldered at right angles to the main board. The two connector strips on the edges of the PCBs make all the necessary connections, keeping wiring to a minimum.

Dimensions of the main PCB coded 80tm8a, are 136 x 133mm. The display PCB is coded 80tm8b and measures 82 x 46mm. Actual size artwork for both PCBs and for the front panel is published with this article.

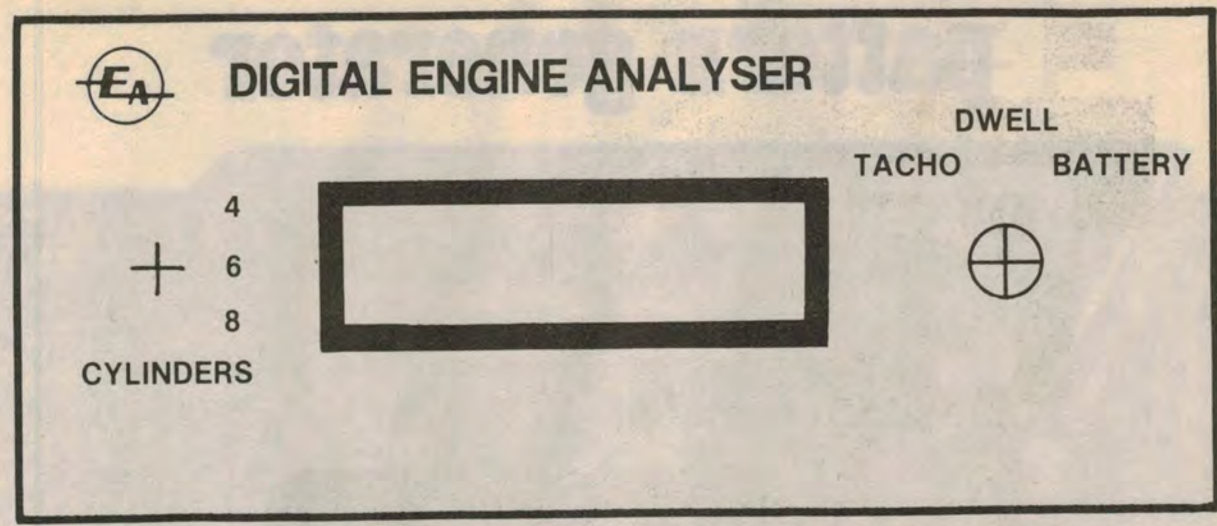


Here are actual size artworks for the main PCB (top) and the display PCB (below).



Commence construction by assembling the display PCB. Install the six wire links first, followed by the FND500 displays. Make sure that the displays are soldered and mounted flush against the PCB so that they will line up correctly with each other.

Mount all the components on the main PCB next, leaving the CMOS ICs till last. The LM340T regulator requires a heatsink and this can be made from a small piece of aluminium bent in a U-shape. Take the usual precautions when soldering the CMOS ICs: avoid handling the pins; earth the barrel of your soldering iron to the earth track on the PCB using a clip lead; and solder the supply pins (see circuit) first. Make sure that all polarised components (electrolytic capacitors, transistors, ICs) are correctly oriented or damage may result.



Actual size artwork for the front panel. Finished "Scotchcal" panels should be available from retail outlets.

The use of PC stakes is recommended and any type may be used provided they are a tight fit in the board. These greatly facilitate external wiring connections to the PCB.

Once the two PCBs are complete, they can be soldered together. Let the lower edge of the display PCB overlap the lower surface of the main PCB by about 6mm and make sure that the two are exactly at right angles to each other. First, solder "tack" one strip at either end of the boards together and then temporarily mount the assembly in the chassis to check that the display mates with the front panel cutout. Adjust the two boards as necessary and then solder the remaining connections.

The circuitry is housed in a metal case measuring 184 x 160 x 70mm (D x W x H). Use the front panel artwork to obtain drill centres for the switches, as well as the dimensions of the cutout for the display. With the metalwork complete, mount the PCB assembly using 12mm spacers and then mount the switches and complete the wiring.

Connections to the points and to the battery can be made using alligator clips. Note that the points lead should be rated at 240V in order to achieve acceptable insulation rating. The 10k input resistor should be rated at 1W.

An attractive finish to the engine analyser can be provided by using a "Scotchcal" photosensitive aluminium front panel. Use the artwork provided to make your own panel, or you can purchase a finished panel from the usual retail outlets.

CALIBRATION

Once construction is complete, "fire" up the engine analyser and proceed with the calibration. The tachometer is calibrated by feeding in a half-wave rectified signal from a 6-12V AC transformer (an AC plugpack or soldering iron transformer will do nicely). Simply select the 4-cylinder position, feed in the signal (see Fig. 3), and adjust VR1 for a reading of 1500RPM. Now check the 6 and 8-cylinder ranges – you should get readings of 1000RPM and 750RPM respectively.

The dwell calibration is just as easy. Select the 4-cylinder position once again, short the points lead to 0V, and adjust trimpot VR2 for a reading of 90°. The corresponding readings for the 6-cylinder and 8-cylinder positions are 60° and 45°.

Finally, the battery voltage function

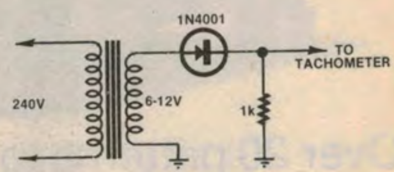


FIG. 3

Use this simple circuit to calibrate the tachometer ranges of the analyser.

should be calibrated against a multimeter or DVM of known accuracy. Hook both instruments up to your car battery and adjust trimpot VR3 to give the correct reading.

That's it – project completed and ready for engine tuning. Drive carefully!

Synertek

TICK ITEMS OF INTEREST
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☐ µP Computer Module, Super-Jolt
☐ 6500 Micro's & peripheral IC's
☐ Low cost/low quantity custom LSI's
☐ Industrial systems engineering

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