Helps save petrol by keeping your car in tune

Transistor-assisted Ignition System

with dwell extension and full protection!

Electronic ignition is in but CDI systems are out. Our new transistor-assisted ignition system with dwell-extension has all the advantages of CDI without the disadvantages. Our new circuit results in a hotter spark at high engine speeds and is directly compatible with electronic tachometers.

by LEO SIMPSON and RON DE JONG

Some four and a half years ago in July 1975 we published the circuit of a Capacitor Discharge Ignition system which has proved extremely popular and with the recent surge in petrol prices is selling more strongly than ever in kit form. However, even back in 1975 and even prior to that we were unhappy about some aspects of CDI.

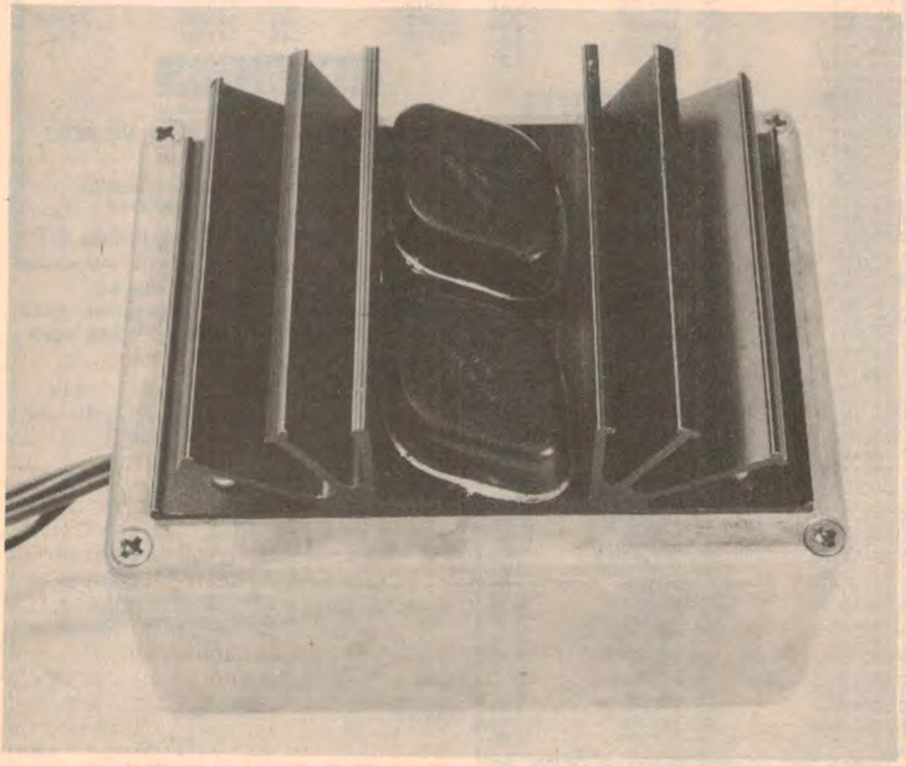
Now, in December 1979, the time has come to close the book on CDI systems and present a viable and appealing alternative — a transistor assisted ignition system with dwell extension. But let us state that while this new circuit is more satisfactory in every respect than CDI systems, it and other automotive add-ons are not the ultimate answer to obtaining best economy, performance and minimum pollution from car engines.

The ultimate answer, as far as the petrol engine is concerned, will undoubtedly involve some sort of microprocessor circuitry (which will have the high falutin' term of "on-board computer") controlling a breakerless electronic ignition system together with fuel injection. That answer is probably a few years off yet, so let us revert to the present.

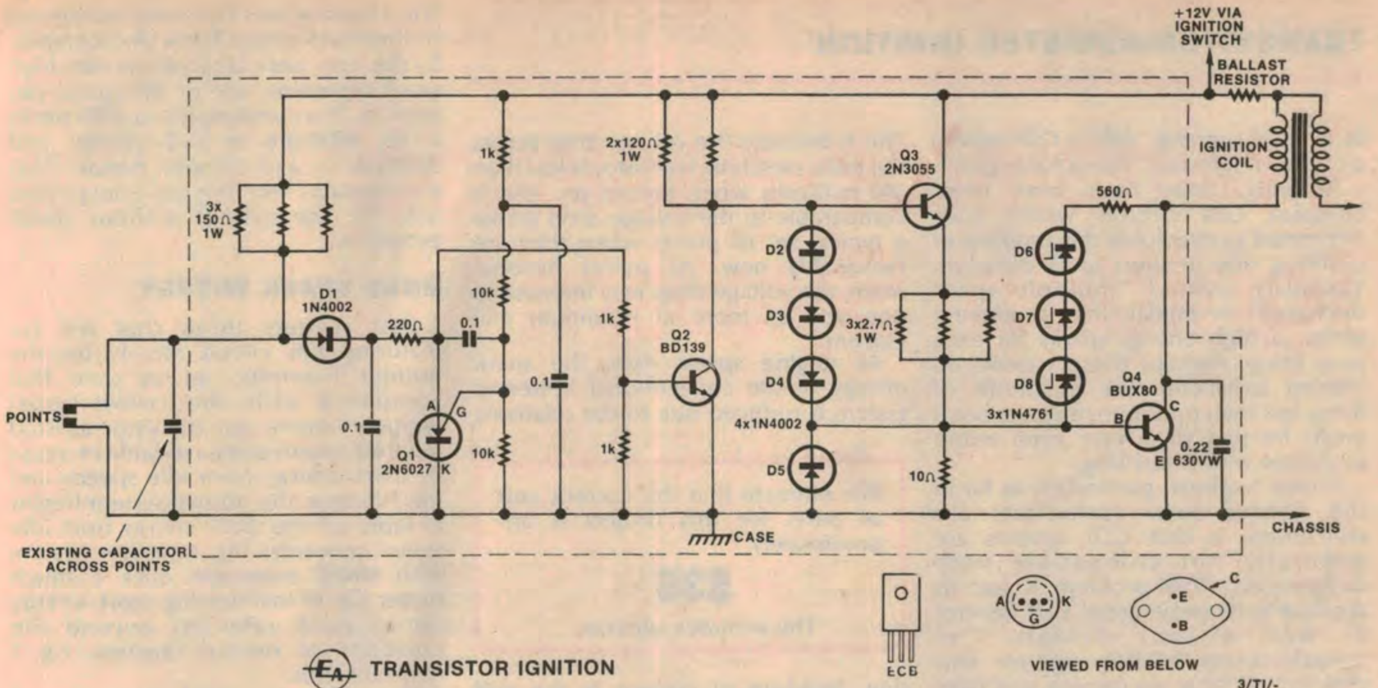
Well, why is Capacitor Discharge Ignition now "beyond the pale"? The first problem regards reliability of the circuit itself. It seems that, even now, some people are troubled with malfunction of the circuit we published back in July 1975 (File No 3/TI/12). It is not possible for us to judge whether these few cases are due to poor assembly, normal component failures or a fault in the original design. But, for the record, some constructors have had trouble.

Apart from reliability of the circuit itself, the most severe problem with CDI systems is " crossfire". For those not familiar with this phenomenon, crossfire is the result of the higher energy and very fast rise-time of CDI systems combined with the normal stray capacitance and leakage resistance across the distributor cap and between spark plug leads.

Every time a designated spark plug fires there is the possibility of a weak spark occuring in other cylinders due to the high energy available from the coil. The engine behaviour when crossfiring is occuring can range from slight "pinking" behaviour to very rough running, particularly when accelerating or lugging up hills.



Looks are unimportant, utility is the name of the game. That hefty heatsink helps dissipate the heat generated by the constant current source, Q3.



TRANSISTOR IGNITION

HOW THE CIRCUIT WORKS:

The heart of the circuit is the BUX80 which is a rugged transistor rated at 10 amps with a collector emitter voltage rating of 800 volts and maximum power dissipation of 100 watts. It is intended for use in converters, inverters, switching regulators and motor control systems. The BUX80, Q4, does the arduous job of switching the coil current. It is protected against excessive voltages by a 0.22uF capacitor and by a string of 75V zener diodes and a 560 ohm limiting resistor between base and collector. Q4 is switched on and off by Q3 which, together with a diode string D2,3 and 4 and its three paralleled 2.7 ohm emitter resistors, is set up as a constant-current source at 1.3 amps. The base of Q4 is driven at this relatively high current to ensure that its saturation voltage is 300 millivolts or less.

Constant-current source Q3 is turned on and off by Q2 which, in turn, is controlled by the points. Ignore Q1, for the moment, as it does not control the primary switching function but provides the dwell extension feature.

Three 150 ohm resistors in parallel provide a current "wetting" through the points to keep them clean in the fume-laden atmosphere inside the distributor cap. Assume, at the beginning, that the points are closed. This means that Q2 is held "off" and so Q3 and Q4 are "on" and current is passing through the coil.

Now the points open and Q2 is turned on by base current via the three paralleled 150 ohm resistors, D1 and series 220 ohm and 1k resistors. Q2 then turns off Q3 and Q4 which interrupts the coil current and develops a high voltage across the coil primary. And so on. Diode D1 and associated 0.1uF capacitor form a "points debounce" circuit to prevent erratic triggering.

In the normal course of events, the points will eventually close again, so that D1 ceases to be forward-biased, turning Q2 off and Q3, Q4 on again to recommence the cycle. But Q1 modifies that cycle by turning Q2 off 0.6 milliseconds after the points open. Q1 is, in fact, a programmable unijunction transistor (or anode gate SCR) which works in the following way.

When the points are closed, the anode of the PUT (programmable unijunction transistor) is held close to zero while its gate is held at a little less than half the supply voltage. When the points open, the anode will be lifted up to almost the full battery voltage while the gate, by virtue of the 0.1uF capacitor tied between gate and anode, will be forced up to about 1.5 times the battery voltage.

This 0.1uF capacitor then discharges via the voltage divider made up of two 10k resistors and a 1k resistor. When the capacitor is discharged to the point where the gate voltage is 0.6 volts less than the anode voltage, the PUT triggers on and removes the forward bias from Q2. Q1 stays in the latched condition until the points close again.

So the PUT enables transistors Q3 and Q4 to turn on much sooner than they otherwise could if controlled directly by the points.

The only remaining components requiring comment are the diode D5 and the parallel 10 ohm resistor. The resistor effectively ties the base of Q4 to its emitter and thus improves its abilities to withstand high voltage. D5 protects the base-emitter junction against reverse biasing.

Excessive crossfiring can result in bearing damage and even the collapse of piston crowns. And contrary to what many CDI fans believe, crossfiring is not only a problem in V8 engines but can also effect six and even four-cylinder engines.

It is possible to minimise the effects of crossfiring by carefully spacing the spark plug leads but with many engines this may lead to only a modest improvement. After all, crossfiring can be a problem with V8 motors using just the standard ignition system. So CDI can really cause havoc with these motors.

Another problem with CDI is involved with erratic firing of lean mixtures. Later model cars which conform to ADR27A often have very lean fuel-to-air mixtures which are more likely to result in misfiring with CDI. This is because of the very short spark duration with CDI. If there is not an optimum fuel/air mixture swirling in the vicinity of the spark plug gap at the time of the spark then a misfire will occur.

This misfiring characteristic with lean mixtures can be enough of a problem in later model cars using just the conventional Kettering ignition system. They are often hard to start and rough in normal running. Add a CDI system and they might run "like a hairy goat".

Recently, there have been more complex CDI circuits which have attempted to overcome this problem of misfiring due to short spark duration. Variously termed "multiple spark discharge" or similar, they produce a series of high energy sparks for each plug firing. Perhaps these systems do indeed overcome the problems of firing less than optimum mixtures but it could be that they have even worse problems with crossfiring.

A final bugbear, particularly as far as the keener auto enthusiasts are concerned, is that CDI systems are generally not compatible with tachometers. This problem is just as applicable to commercial CDI systems as well as our design. The manufacturers blithely ignore this problem, as far as we can see, and have even referred dissatisfied customers to our magazine for a suitable preamplifier circuit to enable the tachometer to be used. For the record, we have not published such a circuit.

CDI does have a place but not with the four-stroke engine. They are more applicable to magneto-based ignition systems as used on two-stroke motors for lawnmowers, motorcycles and outboard motors. There, the ability of capacitor-discharge ignition to fire fouled plugs is a significant feature and crossfiring is not a problem.

Our new transistor-assisted ignition system offers significant advantages over the conventional Kettering system and our previous transistor system described in August 1975 (3/TI/13). For a start, as with other electronic systems, it relieves the points of the heavy burden of coil current switching while still passing enough current through them to keep them clean.

This means that once the system is initially set up it will not be necessary to readjust the system until wear of the rubbing block becomes significant. In practice, this means that every 15,000 kilometres or so, the points should be regapped and the timing readjusted. So, in essence, the car will stay at peak tune for much longer periods than would otherwise be the case and long term economy will be improved.

Starting performance of the new transistor assisted ignition system can be expected to be on a par with a freshly tuned Kettering system. However, in the conventional Kettering system starting performance normally deteriorates as the points become worn, so as time goes on, the transistor system is superior.

At low engine speeds, the spark energy of the transistor system will be comparable with a freshly tuned Kettering system with new points fitted. This is because the voltage drop across the main switching transistor is less than 300 millivolts when turned on. This is comparable to the voltage drop across a typical set of points when they are reasonably new. As points become worn, the voltage drop may increase to one volt or more at maximum coil current.

As engine speed rises, the spark energy of the conventional Kettering system is reduced due to the relatively slow build-up of current in the coil primary. Our transistor-assisted system maintains spark energy at a high level even up to very high engine speeds by using "dwell extension".

> We estimate that the current cost of parts for this project is approximately
>
> **$35**
>
> This includes sales tax.

DWELL EXTENSION

The term "dwell" refers to the time the points are closed and is measured in terms of degrees of distributor camshaft rotation. Our circuit provides for dwell extension by switching on the coil 0.6 milliseconds after the points open. This means that we have artificially determined spark duration at 0.6 milliseconds.

By comparison, the typical spark duration of a capacitor-discharge ignition system is about 0.2 milliseconds.

The photographs of the oscilloscope waveforms shows the performance of the system. The first photograph shows the coil waveform without dwell extension.

At the instant of points opening the coil voltage rises very quickly until the spark discharge occurs, at which the voltage falls to a relatively low level while the coil secondary resonates with its distributed capacitance at about 10 to 15kHz. When the spark is extinguished, the remaining coil energy is dissipated by resonance in the primary circuit at a much lower frequency.

In practice then, the spark lasts for less than one millisecond. Our circuit takes advantage of this fact by fixing the spark duration at 0.6 milliseconds. In the second oscilloscope photograph, the effect of the dwell extension can be seen. Since the main coil transistor is turned on again 0.6 milliseconds (approximately) after the points open, there is no time for the low frequency coil primary resonance to occur.

But notice that the amplitude of the coil primary voltage is much increased. This clearly shows the useful advantage of dwell extension. These photographs, by the way, were taken at the very high spark repetition rate of 300 sparks per second. This corresponds to 4500rpm in a V8, 6000rpm in a 6-cylinder and 9000rpm in a 4-cylinder motor! That also explains why the coil energy is so low for the system without dwell extension.

MORE SPARK ENERGY

Lest readers think that we are featuring this circuit merely for the hotfoot fraternity, let us state that compared with the conventional ignition system, our transistor assisted ignition system gives a useable increase in spark energy from idle speeds and up. Whereas the normal system begins to taper off the spark energy from idle speed upwards, the transistor system with dwell extension does a much better job of maintaining spark energy up to spark rates far beyond the capability of normal engines. Fig 1 illustrates this.

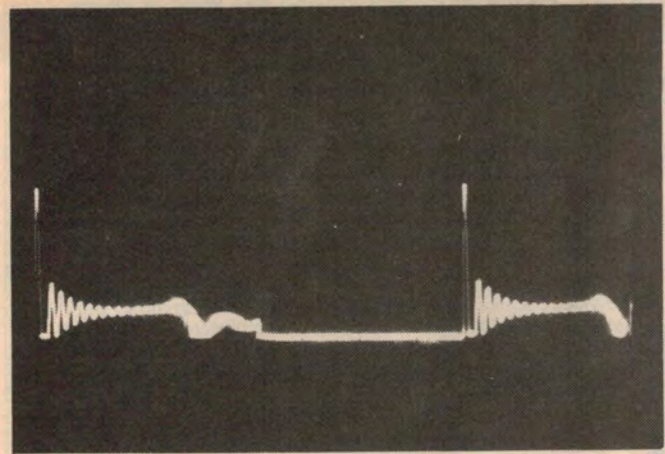
This great improvement in spark energy comes about in two ways. Consider the fact that a normal coil and ballast resistor system takes about 15 milliseconds for the current to rise to saturation (and thus provide maximum spark energy). Since in a 6-cylinder motor the points points provide an approximate 50% duty cycle, this means that if sparks are required less than 30 milliseconds apart, the coil current will not reach saturation level. And a 30 millisecond period coincides with a spark rate of only 33 sparks/second or only 667rpm for a 6-cylinder motor.

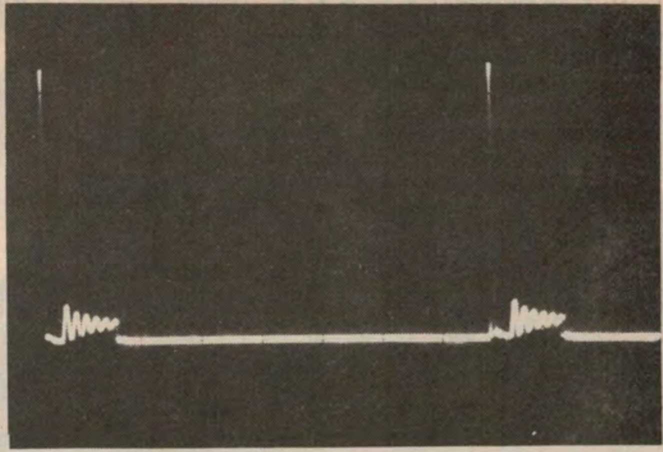
COIL NOT FULLY DISCHARGED

The main reason for the improvement is not so much the extra time for the coil current to build up but the fact that the coil transistor is turned on before the spark extinguishes naturally and primary coil resonance occurs. The fact is that when the coil transistor is turned on again the coil energy has not been fully dissipated. In fact, after the spark extinguishes there is considerable energy remaining in the coil which is usually dissipated in useless primary resonance.

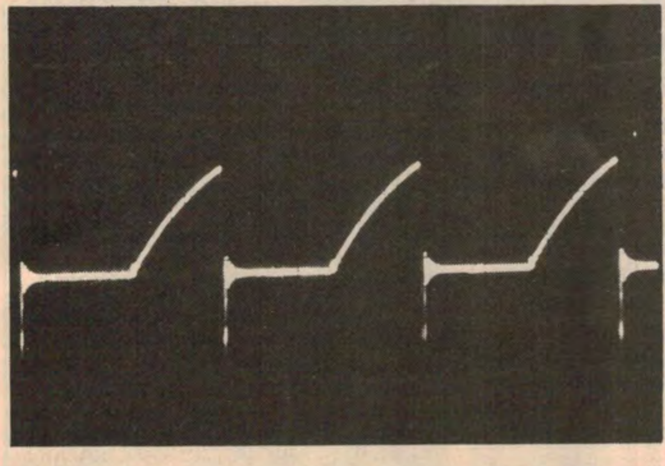
One benefit of a high energy transistor ignition system which has not so far been mentioned is its ability to refire a spark plug after the spark has been blown out by a turbulent mixture. So not only does this system have an advantage over CDI with longer spark duration but it is also able to re-ignite a spark that is blown out (provided it all happens within 0.6 milliseconds).

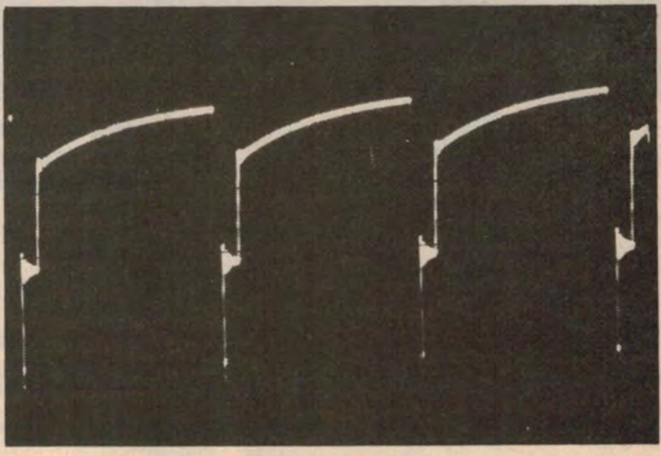
Other features of this transistor assisted circuit are comprehensive protection of both the ignition system components and the electronic circuitry itself and the ability to drive a standard tachometer without any modifications.





These two photos show the coil primary voltage from the circuit without (left) and with dwell extension. Cro settings: 50v/div and 0.5ms/div.





These two photos show the coil current without (left) and with dwell extension. Cro settings: 2 amps/div and 2ms/div.

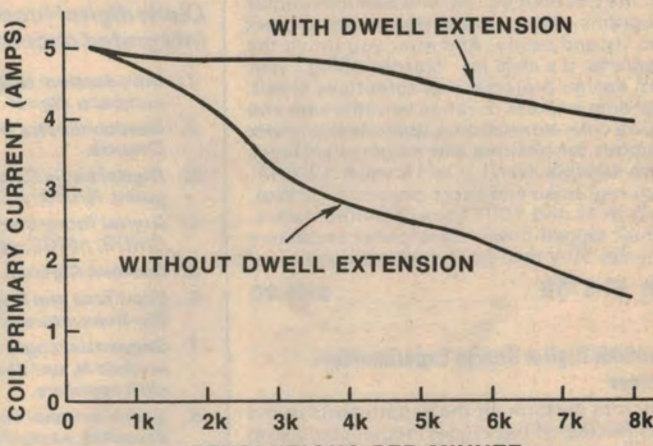


Fig 1 (left). This shows how the dwell extension feature maintains coil current and, therefore, spark energy up to very high engine speeds (in this case, for a 6-cylinder motor).

Is there a catch to all this? Are there no disadvantages of this new transistor ignition system compared with conventional or CDI systems? Well there are a few side-effects of the new system but you could hardly class them as major drawbacks.

For example, because of the dwell extension feature, the coil is maintained in saturation for a much higher proportion of its operating time. So the average current passing through the coil is about 80% higher. Or, to put it another way, the coil current is increased from about 2.5 to 4.5 amps.

In addition, the transistor drive circuitry draws about 1.5 amps so the total current drain of the transistor-assisted system is around six amps versus 2.5 amps for the conventional system.

The extra current drain is unlikely to pose much of a problem for the car electrical system but the extra coil current does mean that the coil runs hotter. This should not be a problem for the oil-filled coils on modern cars. Even so, the coil should ideally be placed so that it receives some of the cooling air from the fan.

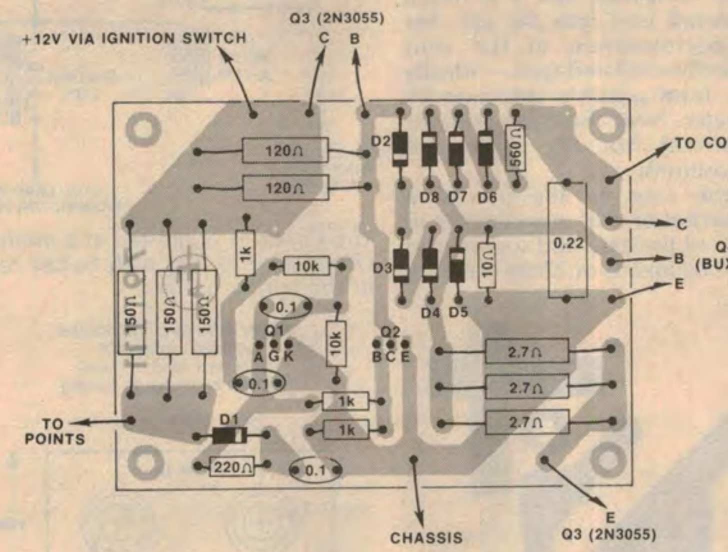
On the plus side, because of the comprehensive protection features of the circuit, the transistor assisted system is unlikely to cause catastrophic failure due to voltage breakdown which can occur with CDI systems.

As far as most enthusiasts are concerned, the only drawback of our new transistor-assisted ignition system is the necessity to gain access to the battery side of the ballast resistor. This can be difficult on cars which have the ballast resistor incorporated into the wiring harness, as on Holden cars, for example. More about this later.

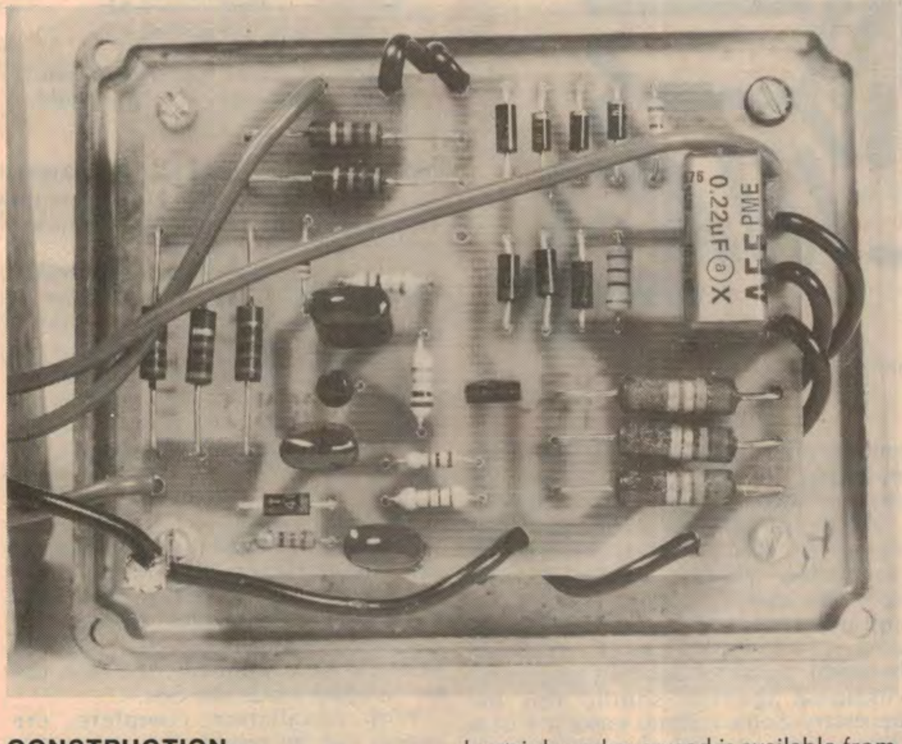
Well that explains some of the thinking behind this new transistor-assisted ignition system. You can refer to the section on circuit description to find out the details of operation. It is a fairly complicated circuit but it should be reliable as all components are operated well within their ratings and are able to sustain high temperatures.

MORE →

TRANSISTOR-ASSISTED IGNITION



The 150-ohm, 120-ohm and 2.7-ohm resistors are all 1W units; the 0.22uF capacitor across the BUX80 (Q4) should be rated at 630VDC or 250VAC.



CONSTRUCTION

The entire transistor ignition circuit is housed in a rugged diecast aluminium box. We used an Eddystone box measuring 93 x 56 x 119mm; but any diecast box which can comfortably accommodate the PC board and power transistor heatsink would be suitable. All the components except for the power transistors are mounted on a small PC board measuring 91mm x 68mm and coded 79TI11.

The two power transistors are mounted on the lid of the diecast box together with a suitable heatsink. The heatsink we have used is available from Dick Smith Electronics. Actually almost any heatsink which can accommodate two TO-3 devices is suitable provided it can fit comfortably on the lid of the diecast box and has a reasonable thermal resistance; ie a radiating area at least as large as that of the heatsink we have used.

If the heatsink does not come pre-drilled you should first drill it using a TO-3 mica washer as a template. After drilling, remove any burrs by using a large diameter drill. Next, position the heatsink on the lid of the diecast box in such a way that it does not interfere with the lid-securing screws and then punch suitable drill centres in the lid and drill and deburr the holes in the previous manner.

With the heatsink free of any metal shavings or other grit, a thin layer of thermal conducting compound or silicone grease can be applied in the area underneath the transistors and on the mica washer. Some heatsink compounds may contain beryllium, a highly toxic substance, so apply the compound carefully with a cotton bud and avoid skin contact with it. Mount the transistors with the mica insulating washers and plastic bushes in position and then check that the case of both transistors is insulated from the heatsink and lid using a multimeter or other continuity checker.

We used plastic TO-3 transistor covers on both transistors. These are essential both to eliminate the possibility of short circuits and also to isolate the rather high voltages which are present on the case of the BUX80 transistor.

Now the components can be soldered onto the PC board. The only problems which might be encountered here are with the orientation of the

PARTS LIST

1 PC board coded 79TI11, 91mm x 68mm
1 diecast aluminium box, 118 x 93 x 56mm, Eddystone 6908P or similar.
1 dual TO-3 heatsink (see text)
3 metres red 4mm auto cable
1 metre black 4mm auto cable
4 25mm brass standoffs
2 sets of TO-3 mounting hardware, ie. mica washers insulating bushes, screws and nuts.
2 TO-3 transistor insulating caps

SEMICONDUCTORS
1 BUX80 transistor
1 2N3055 transistor
1 BD139 transistor
1 2N6027 PUT
5 1N4002 diodes
3 1N4761 75V zener diodes

CAPACITORS
1 0.22uF 630VW or 250VAC
3 0.1uF metalised polyester (greencap)

RESISTORS (½W or ¼W)
2 x 10k, 3 x 1k, 1 x 560 ohm, 1 x 220 ohm, 1 x 10 ohm, 3 x 150 ohm (1W), 2 x 120 ohm (1W), 3 x 2.7 ohm (1W).

NOTE: Resistor wattage ratings and capacitor voltage ratings are those used for our prototype. Components with higher ratings may generally be used provided they are physically compatible.

diodes, the PUT and BD140 transistor, so pay special attention to the wiring diagram. Note that parallel combinations of 1 watt resistors have been used in some cases. This was done because they are cheaper than equivalent 5 watt wirewound resistors and their surface temperature rise is not as great. Even so the 1 watt types can still become quite hot so mount them slightly off the board to avoid the possibility of charring the PCB.

Wires to the transistors and to the various external connections are heavy gauge 4mm auto cable. This won't fit easily into a standard PC hole so we suggest that you could either redrill the holes to an appropriate size or use PC stakes. If PC stakes are used make sure they fit tightly into the PC hole so they can't fall out when a wire is soldered onto them.

Mounting holes for the PC board should now be drilled. The PC board is mounted on the lid using brass or plated standoffs, screws, nuts and shake-proof washers. The holes will pass through both the lid and the heatsink, so ensure that the mounting screws don't interfere with the fins on the heatsink first. Before installing the PCB, wire up the leads to the power transistors. Use one-metre lengths of wire to provide the chassis, points, coil and battery connections to the PCB.

When the unit is actually installed these lengths can be trimmed down and suitable lugs or connectors attached. The earth cable is also connected to a lug on one of the standoffs so that the circuit will be earthed via the case as well.

Clamp the cables before they exit from the box using a cable clamp; if necessary build up the cable thickness with insulation tape to give a tight fit. The cable should exit via a grommeted hole at the side of the box.

The only remaining task is to install the completed unit into the car. For reliable performance of the unit choose a well-ventilated spot — ideally well away from possible splashing by mud or water. Near the front grille or on the wheel housing would be suitable positions.

Install the case by the use of a suitable bracket or drill several holes in the bottom of the case and secure it to the vehicle by means of 12mm x No. 10 self-tapping screws. With the unit mounted, the various connections to the car electrical system can be made.

For this purpose we recommend that you use two eyelet/solder-lug assemblies, attached to the ignition coil. This allows the connection of the coil and points leads to be readily made and it allows quick changeover between transistor ignition and conventional ignition should this be necessary. Some systems make use of a slide switch or octal plug to facilitate changeover but poor reliability of these methods led us to opt in favour of the lug assemblies.

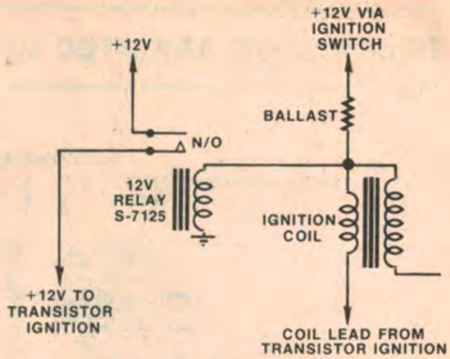
We understand that Watkin Wynne Pty Ltd will be able to make these eyelet assemblies available to parts suppliers. Alternatively, they are available from Dick Smith Electronics.

Apart from the connections to the ignition coil and points it is also necessary to connect the +12 volt lead to the battery via the ignition switch. Some circuit designs actually obtain power via the ballast resistor, which means that the circuit would probably be easier to install but it also has the disadvantage of reducing coil current and so reducing spark energy.

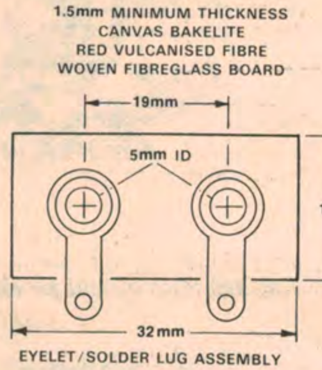
If your car has a separate ballast resistor then it is a simple matter to connect to the ignition switch side of the resistor. Some cars though, use a ballast wire, which complicates the situation because it is then necessary to guide the +12 volt lead from the transistor ignition through an appropriate hold in the firewall to the actual ignition switch itself. Alternatively, if you do not wish to drill through the firewall then you can use the circuit shown elsewhere in this article. It consists simply of a relay connected to the coil side of the ballast resistor which switches the +12 volt from the battery directly. The relay can be installed inside the box.

With installation complete, the system can be tested. The points gap should be set exactly as specified by the car manufacturer. Note that if a "dwell meter" is used to set the points gap, then it is probably best to do this adjustment when the vehicle is running with conventional ignition.

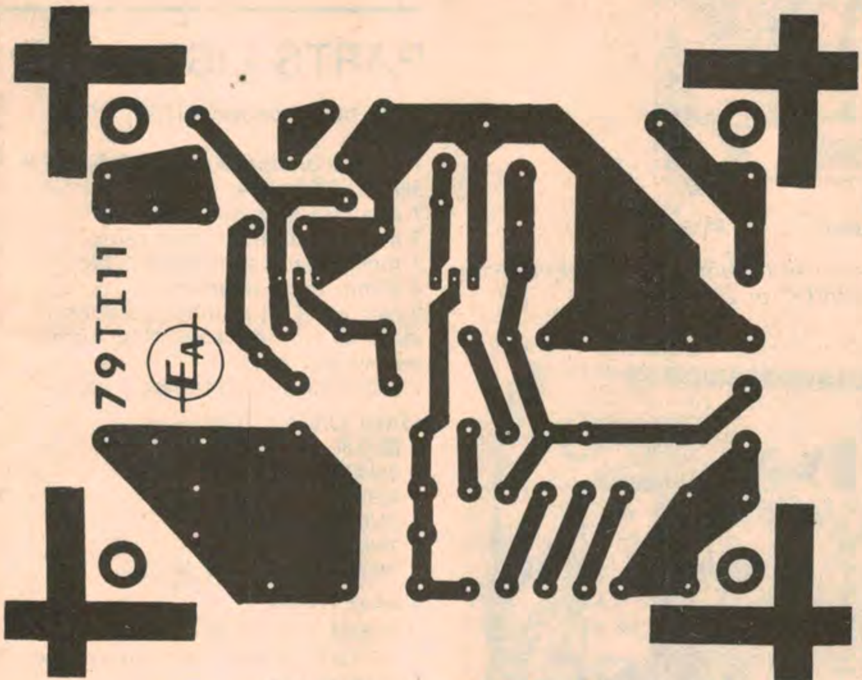
Well, now that all those readers have been disillusioned about CDI, what are they going to do with them? We have thought of that too. The answer is to make use of the inverter in a strobelight for auto tune-ups. Refer to our article on a "Power Timing Light" of February 1976. (File No 7/SC/5).



This circuit is suggested as a method of connection in cars with ballast resistor in the wiring harness.



Use two of these lug assemblies to make the connections to the ignition system.



Actual size artwork for the PCB.