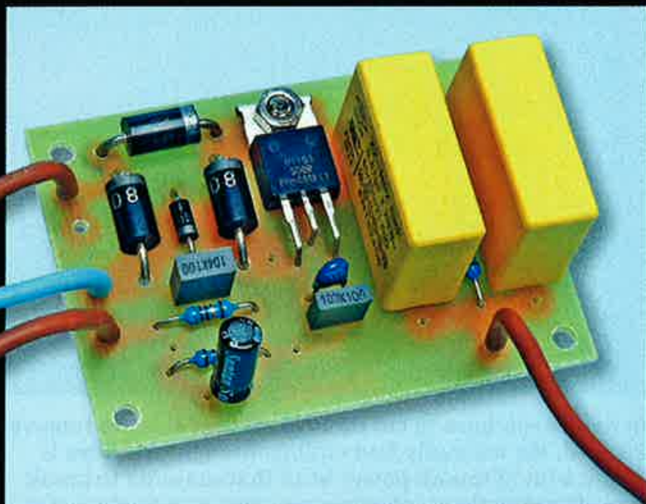
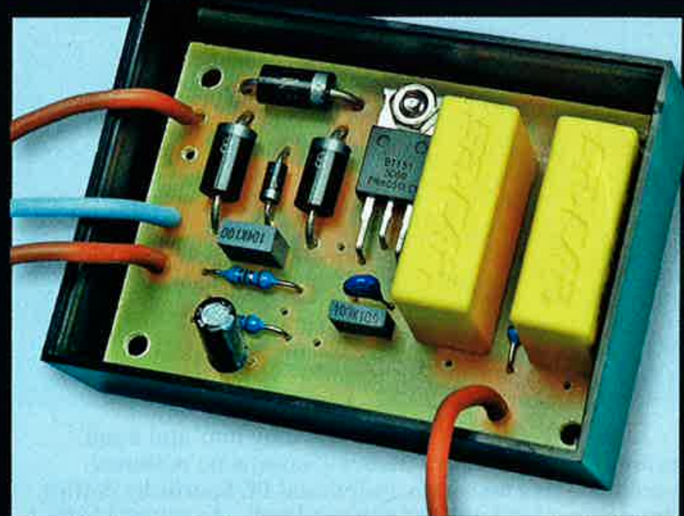




Replacement CDI Module for small petrol motors

By JOHN CLARKE

If the CDI module in your motorbike, outboard, ride-on mower or other small petrol motor fails, you could be in for a shock. Depending on the brand or model, they can cost up to $400. You can build this one for less than $50 and it will do the same job for most engines.

READERS HAVE BEEN asking us for years to design a drop-in CDI module for motorbikes, outboards and other small petrol motors. You can understand why. It can be a real shock to front up to your local dealer and find out the price for such a module. It is even harder to justify the prices charged when you see the circuit components involved.

Those days, a great many small petrol engines use a Capacitor Discharge Ignition (CDI) module. The high-voltage capacitor is charged directly from a generator located on the flywheel. A battery may still be included and used to drive lights and ancillaries but this is used independently of the ignition.

CDI is a great improvement on the old magneto ignition systems. Not only does the CDI deliver higher spark energy but it also dispenses with the points which were inevitably subject to wear and required periodic cleaning, adjustment and replacement.

The one drawback is that CDI systems don't last forever – they can fail. While the failure can be within the flywheel generating coils or the ignition coil, it is most likely to be the CDI module itself and then you will find that the replacement can be very expensive.

The CDI Module described here may be used to replace a failed factory unit for an engine that incorporates a generator and trigger coil to provide the high-voltage and the firing point. Most of these CDI systems operate in a similar way but there are variations in design that use the opposite polarity for voltage generation and are therefore unsuitable for our module.

While some tests can be performed to check for suitability, we cannot guarantee that the module will work for every engine. Even so, because this

CDI Module uses cheap and readily available parts, it may be worth a try if you are unwilling to fork out lots of hard cash for a genuine replacement module.

How CDI works

Fig.1 shows the connections required for a typical CDI module. The generator (magneto) coil provides the high voltage to charge a capacitor (in the CDI module), while the trigger coil provides the signal to dump the capacitor's high voltage charge into the ignition coil. A kill switch shunts the high-voltage supply from the generator to prevent ignition.

Fig.2 shows how CDI works. It comprises three main components: the ignition coil, a capacitor (C1) and a Silicon Controlled Rectifier (SCR). The SCR behaves as a switch. It is normally a high impedance until a small trigger voltage is applied between its gate and cathode. It then conducts and behaves like a diode. After triggering, the SCR switches off when the current through it falls close to zero.

Initially, the SCR is off and capacitor C1 is discharged. Positive voltage from the generator then charges C1 via diode D1 and the primary winding of the ignition coil. The current path is shown in red as "I_C".

C1 is discharged when the SCR is subsequently triggered, allowing current to flow back through the ignition coil primary. This current path is shown in green as "I_D". The fast discharge of C1 and resulting current through the ignition coil causes a high voltage to be developed across the secondary winding of the ignition coil, to fire the spark plug(s).

Once the spark plug is extinguished, the collapsing field of the ignition coil develops a reverse current flow via diode D2 to partially recharge capacitor C1.

Typically, the generator coil delivers about 1A in charging the capacitor up to about 350V. If C1 is 1μF, then it will charge in about 350μs – much quicker than the time between sparks, even in a high-revving engine.

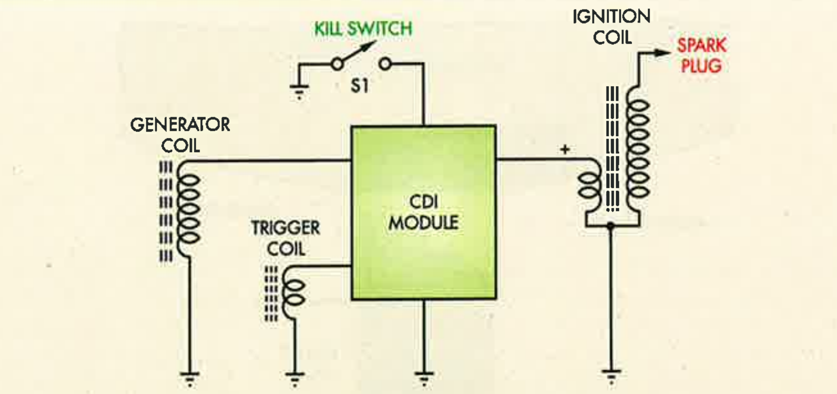
No RPM advance

Note that the CDI Module does not incorporate RPM advance and so it provides a fixed timing from the trigger coil – most common with small engines.

Some engines do incorporate RPM advance using a special trigger coil and magnetic core design that advances the firing edge with increasing RPM. This is achieved by having a stepped or shaped coil core that has a larger gap at its leading edge compared to the trailing edge – see Fig.3.

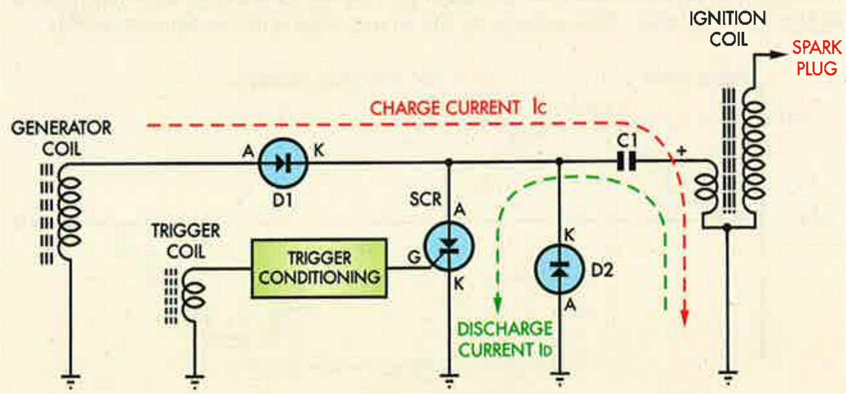
At low speeds the coil voltage required for triggering is developed at the trailing edge of the magnet but as revs increase, the leading edge of the magnet is able to induce more voltage in the coil and so firing occurs earlier. This is shown in Fig.4.

Other designs use electronic advance but these require extra power for the circuitry and tend to be used only with battery-powered systems.



TYPICAL MODULE FOR CDI WITH EXTERNAL CONNECTIONS SHOWN

Fig.1: how a typical CDI module is connected. The generator (magneto) coil provides a high voltage to charge a capacitor in the CDI module, while the trigger coil provides the timing signal to dump the capacitor's high voltage charge into the ignition coil.



BASIC CDI OPERATION

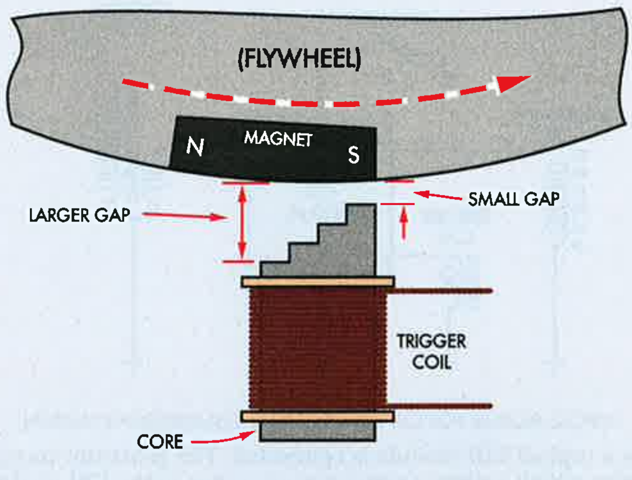
Fig.2: how the CDI module works. Initially, the generator coil charges C1 to a high voltage (via diode D1). A trigger pulse (from the trigger coil) then turns on the SCR and this quickly discharges C1 by allowing current to flow back through the coil primary.

Circuit details

The simplest circuit arrangement for the CDI module is shown in Fig.5. Voltage from the generator coil charges capacitor C1 (and C2) via diode D1 and the ignition coil primary. As previously mentioned, D2 is there to conduct the reverse current flow from the ignition coil after the capacitor has discharged.

The two in-series 1MΩ resistors across capacitor C1 are there to discharge the capacitor if the SCR does not fire. This is a safety feature that prevents a nasty electric shock if you happen to connect yourself across the capacitor. It takes about two seconds for the capacitor to discharge to a safe value.

Provision has been made on the PC board for two discharge capacitors, C1 & C2. This allows the use of either two 0.47μF capacitors or two 1μF capacitors. A higher capacitance will produce greater spark energy,



ADVANCE TRIGGER HEAD DESIGN

Fig.3: some engines achieve RPM advance using a special trigger coil with a stepped magnetic core that has a larger gap at its leading edge compared to the trailing edge. This advances the firing edge with increasing RPM.

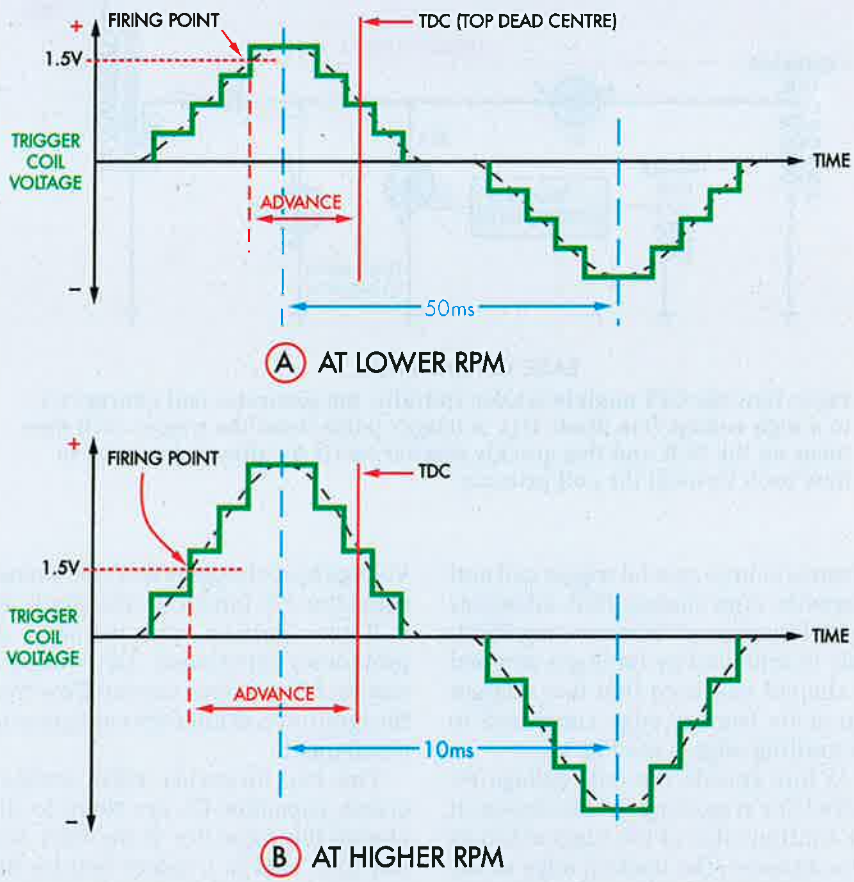


Fig.4: the effect of a stepped trigger core design is shown in these timing advance waveforms. At low speeds, the coil voltage required for triggering is developed only at the trailing edge of the magnet (waveform A). However, at higher revs, the leading edge of the magnet induce a greater voltage into the coil and so firing occurs earlier (waveform B).

provided the generator coil can charge the capacitors to the full voltage in the required time.

The trigger coil provides the necessary signal to trigger the SCR. When the coil voltage goes positive, it feeds current to the gate of the SCR via a 51Ω resistor and diode D3. D3 prevents reverse voltage on the gate while the 51Ω resistor limits the gate current to a safe value. A 1kΩ resistor ties the gate to ground to prevent false triggering, while the 100nF capacitor filters noise and transients that may cause the SCR to trigger at the wrong time.

A kill switch connection has also been provided to shunt the generator current to ground and stop the motor.

Circuit refinements

The simple circuit of Fig.5 works well but additional circuitry can improve reliability and provide for more consistent triggering. The extended circuit is shown in Fig.6.

First, diode D4 has been added across the generator and thus shunts negative excursions across the coil to less than -0.7V. Without D4, the anode of diode D1 can be subject to -350V from the negative swings of the generator. This means that diode D1 could have over 700V across it if the capacitor is charged to +350V.

While D1 is rated at 1000V, D4 reduces the maximum likely voltage across it to around 350V or so and thereby reduces the possibility of reverse breakdown of the diode.

Triggering in this version of the circuit has also been improved in two ways. First, we have added a series 10μF capacitor to the gate of the SCR. This capacitor prevents false triggering due to any DC offset from the trigger coil that may be more positive than it should be because of remnant magnetism in the coil's core. The 1kΩ resistor across the capacitor is there to discharge the capacitor and is high enough in value to prevent it triggering the SCR on its own. Diode D5 prevents the 10μF capacitor from being charged with reverse polarity when the trigger coil output swings negative.

A second improvement involves the use of a negative temperature coefficient (NTC) thermistor across the gate of the SCR. This thermistor reduces its resistance with increasing temperature and is used to compensate for the lowered triggering requirement of the SCR (for both voltage and current) at higher temperatures.

Effectively, the NTC thermistor forms a voltage divider with the 51Ω resistor. At 25°C, the thermistor is 500Ω and so it attenuates the signal from the trigger coil to 91%. However, at 100°C, the NTC thermistor resist-

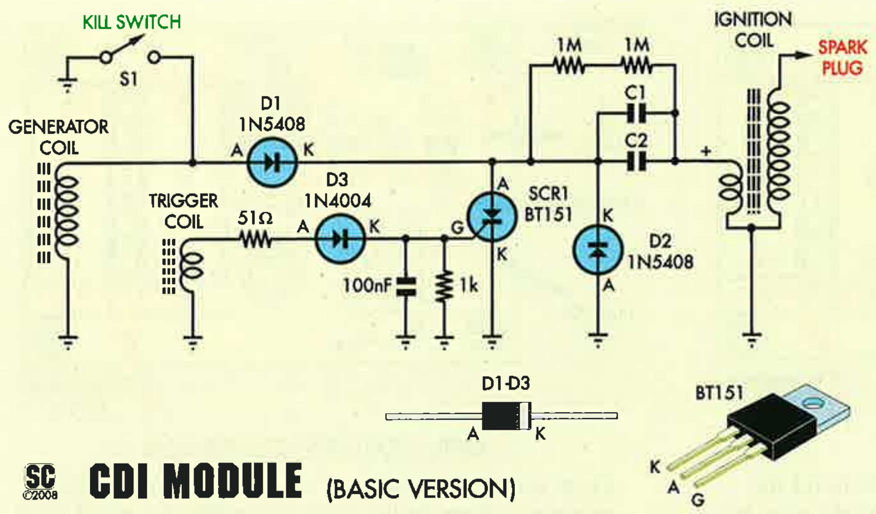


Fig.5: this is the circuit for the Basic Version. The kill switch is there to stop the motor by shunting the generator coil's output to ground, while the 1kΩ resistor on SCR1's gate prevents false triggering due to noise.

ance is around 35Ω and the trigger signal is divided down to 41% of the trigger coil value.

This attenuation in signal level attempts to match the SCR's reduced trigger level requirement at higher temperature. So as temperature rises, the signal is increasingly attenuated and as a consequence, the SCR fires at the same trigger coil voltage over a wide temperature range. Without the thermistor, the SCR would be subject to timing changes with temperature.

Construction

A small PC board coded 05105081 and measuring 64 x 45mm caters for both versions of the circuit. This can fit into a plastic box that measures 70 x 50 x 20mm and this box allows the whole module to be subsequently potted.

Begin by checking the PC board for the correct hole sizes. The four corner mounting holes should be drilled to 3mm, as should the hole for the SCR mounting tab. That done, check the PC board for breaks in the copper tracks or for shorts between tracks. Make any repairs before assembly.

Fig.7 shows the simple version of the circuit, while Fig.8 shows the more complex version. The choice is yours but we recommend the version

Parts List

- 1 PC board, code 05105081, 64 x 45mm
- 1 potting box, 70 x 50 x 20mm (Jaycar HB-5204 or equivalent)
- 1 500Ω NTC thermistor (Jaycar RN-3434)
- 1 M3 x 10mm screw
- 1 M3 nut

Semiconductors

- 1 C122E, BT151 500V SCR (SCR1)
- 3 1N5408 3A 1000V diodes (D1,D2,D4)
- 1 1N4004 1A 400V diode (D3 for Basic Version; D5 for Extra Features Version)

Capacitors

- 1 10μF 25V PC electrolytic
- 1 1μF 275VAC or 280VAC metallised polypropylene; *or*
- 2 0.47μF 275VAC or 280VAC metallised polypropylene; *or*
- 2 1μF 275VAC or 280VAC metallised polypropylene – see text
- 1 100nF MKT polyester
- 1 10nF MKT polyester

Resistors (0.25W 1%)

- 2 1MΩ 1 51Ω
- 1 1kΩ

Miscellaneous

Automotive wire, crimp connectors, neutral-cure silicone sealant.

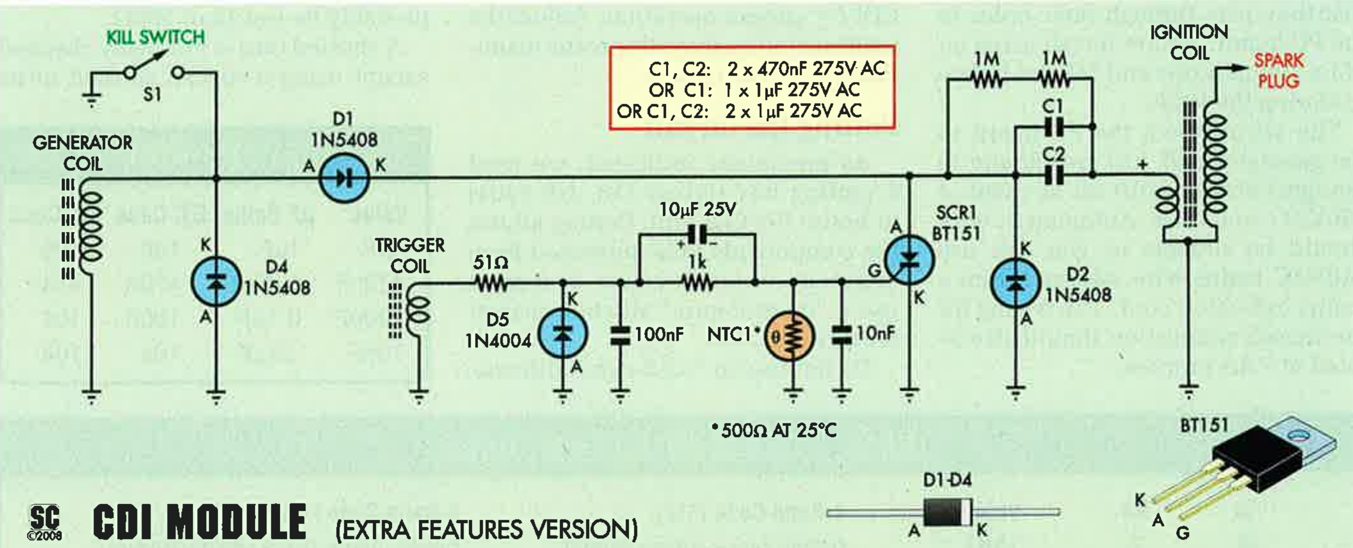
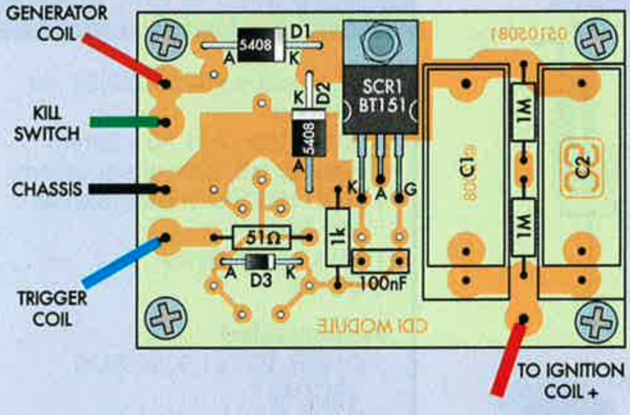
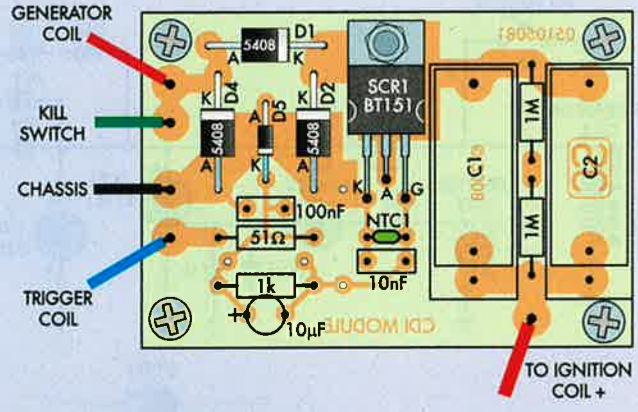


Fig.6: the Extra Features Version includes diode D4 to shunt negative excursions across the generator coil to less than -0.7V and thus limit the voltage across D1 to around 350V. It also features an improved trigger circuit, to ensure consistent firing of the SCR with variations in temperature.



'BASIC' CDI VERSION

Fig.7: follow this parts layout diagram to build the "Basic Version" of the CDI Module. It can be used for non-critical applications.



'EXTRA FEATURES' CDI VERSION

Fig.8: the "Extra Features" version is the one that we recommend you build. Take care with the orientation of the diodes and the 10µF electrolytic capacitor.

in Fig.8. In fact, the following assembly procedure assumes that you are building the "Extra Features" version.

Start by installing the diodes, taking care to orient each one correctly. The resistors can then go in – their values can be checked against the accompanying table and with a digital multimeter.

Next, install the thermistor, the smaller capacitors and the 10µF electrolytic, making sure it is oriented correctly. The discharge capacitor(s) can then be installed. As noted above, we have provided for two capacitors and also for two different lead spacing on the PC board.

The SCR is mounted horizontally with its leads bent down by 90° so that they pass through their holes in the PC board. Secure its tab using an M3 x 10mm screw and M3 nut before soldering the leads.

The wiring from the PC board to the generator coil, kill switch and to the ignition coil must all be rated at 250VAC and 7.5A. Automotive wire should be suitable or you can use 240VAC mains wire salvaged from a mains extension cord. The wiring for the chassis connection should also be rated at 7.5A or more.

By contrast, the trigger lead does not have to be heavy duty but should have suitable insulation for automotive use. Sheath the wires in some flexible tubing to prevent possible chaffing of the wiring insulation. Better still, you may be able to use the existing wiring for the original CDI module.

If you want the best spark possible, you can try adding a second 1µF capacitor in parallel with the first. This may improve the "fatness" (intensity) of the spark. In some cases though, a 1µF capacitance will give the best spark because 2µF may load the generator coil too much and lower the charge voltage.

Once the board is complete, run the external connections and test the CDI for correct operation. Adjust the ignition timing according to the manufacturer's instructions.

Potting the circuit

As previously indicated, we used a potting box (Jaycar Cat. HB-5204) to house the CDI unit. Potting allows the components to be protected from vibration, water and dust. You must use a "neutral-cure" silicone sealant for this job.

Do not use an "acid-cure" silicone, as this will corrode the wires and copper pattern on the PC board.

Note that the capacitor(s) will protrude a little from the top of the potting box. The box can be mounted on the engine frame using suitable brackets. It should be placed away from the exhaust side of the engine.

Make sure that any mounting screws for the box do not penetrate and make contact with the circuit.

Testing the generator coil

Sometimes the generator coil can fail due to either a shorted turn or a broken wire. You can test for a break in the coil by measuring its resistance – ie, between its output and ground. If the coil is OK, its resistance will probably be less than 200Ω.

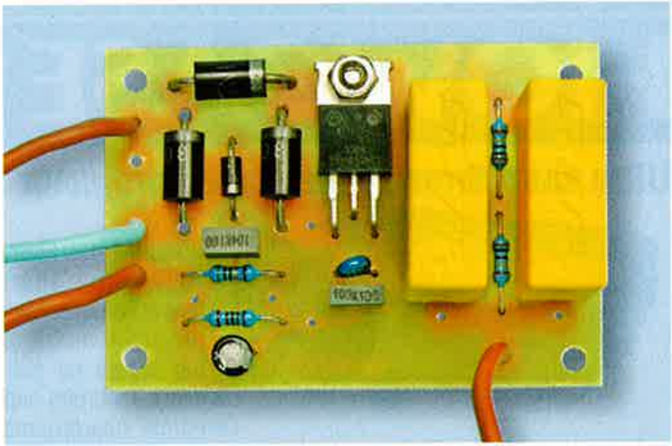
A shorted turn is not easily checked except using a special shorted turns

Table 2: Capacitor Codes

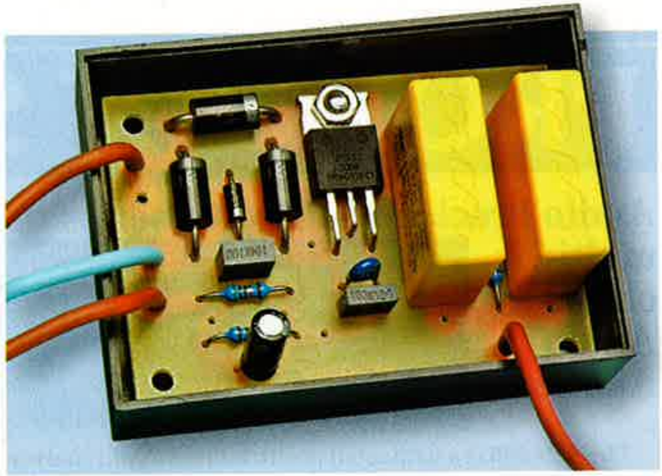
Value	µF Value	IEC Code	EIA Code
1µF	1µF	1u0	105
470nF	0.47µF	470n	474
100nF	0.1µF	100n	104
10nF	.01µF	10n	103

Table 1: Resistor Colour Codes

❑	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	2	1MΩ	brown black green brown	brown black black yellow brown
❑	1	1kΩ	brown black red brown	brown black black brown brown
❑	1	51Ω	green brown black brown	green brown black gold brown



This completed CDI module is the "Extra Features" version. You may have to experiment with the number of discharge capacitors to get the best spark – see text.



The board should be installed in a plastic case and potted using neutral-cure silicone sealant to ensure reliability (ie, to protect against vibration, moisture and dust).

tester. However, you can get some idea if the coil is delivering sufficient voltage by measuring it with a multimeter set to read AC volts up to 300V. The voltage is measured when the engine is turned over.

Take care if making this measurement, since the generated voltage can give you an electric shock. DO NOT touch any of the wiring when turning the motor over.

Note that the voltage measured across the generator coil will not be anywhere near the voltage that it develops when running. That's because the multimeter does not respond well to the low-frequency voltage fluctuations that occur when kicking the engine over. In addition, most multimeters do not respond to the peak of the waveform but to the average of a sinewave.

In practice, you should get a reading of about 50V AC from the coil.

Another way of testing the coil voltage is to connect the CDI module and measure the DC voltage between the cathode of D1 and the chassis while kicking the motor over. The reading should at least get to 200V DC if you can kick the motor over fast enough.

Alternatively, if an oscilloscope is available, the voltage waveform can be measured with the probe set to 10:1.

One point we have not mentioned is the polarity of the voltage. The capacitor needs to charge to a positive voltage before the trigger signal occurs. **If the voltage from the generator coil is negative before triggering occurs, it will mean that the CDI module described here is not suitable for replacing the module in your engine.**

You can check the polarity using a multimeter set to DC volts – it's just a matter of checking that the voltage on SCR1's anode goes positive before the SCR is triggered and negative after the trigger.

Trigger coil testing

The trigger coil can be tested in the same way as the generator coil (ie, measure the voltage between D3 or D5's cathode and chassis as the motor is kicked over). This voltage will be quite small compared to that from the generator coil and only occurs over a short portion of each engine revolution.

Typically, you might measure a trigger voltage of less than 1V using a multimeter set to read AC volts. The trigger coil voltage can also be observed on an oscilloscope.

Of course, the real test is when it is used with the CDI module itself, as it must be able to trigger the SCR. SC

Warning

This CDI module is not intended for use as a replacement for CDI units that generate their own high voltage from an inverter requiring a 12V battery supply.

To replace one of these units, you could adapt one of our previous designs, such as the High Energy Ignition (SILICON CHIP December 1995 and January 2006) or the Multi-Spark CDI (September 1997). Alternatively, you could consider using the Programmable Ignition System from March, April & May 2007.