Protect the bearings in your turbocharger

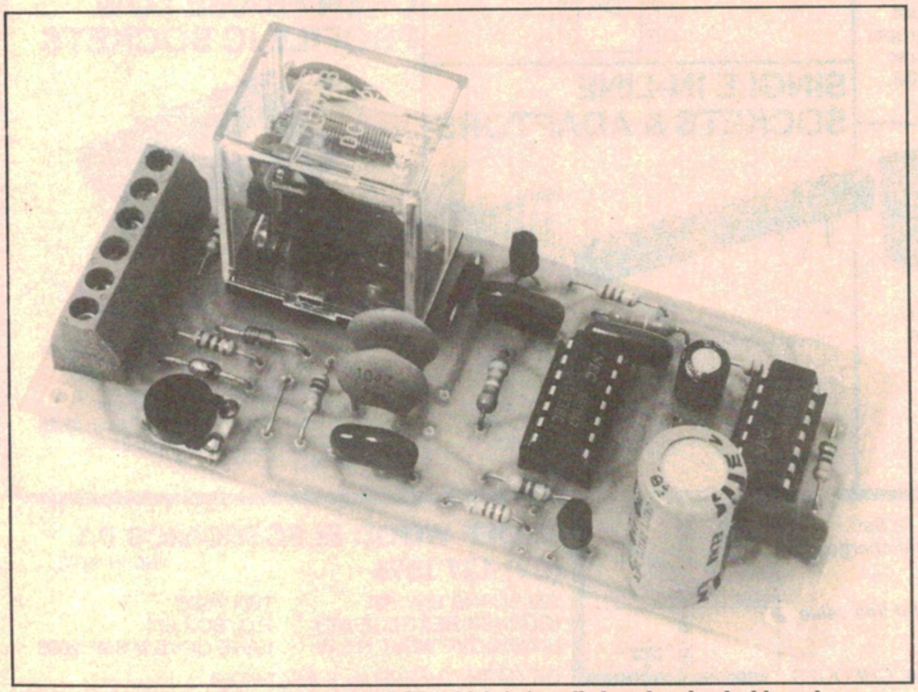
Turbo engine cool-down timer

Got one of those new turbocharged cars? If so, you need this project. When the ignition is switched off, it keeps the engine running for approximately 90 seconds to stop the turbocharger from overheating. A temperature sensor ensures that the circuit operates only when the engine reaches a preset temperature.

by COLIN DAWSON

Just about every car manufacturer presently has a turbocharged model or is planning to release one. In the last five years, this accessory has undergone a huge amount of development, having evolved from a strictly mug-lair "bolt-on" to a factory option for otherwise conservative machines.

So what exactly is a turbocharger? For those unfamiliar with automotive technology, it's basically a turbine-driven axial compressor.



All the parts are mounted on a small PCB which is installed under the dashboard.

The axial compressor forces air down the throat of the carburettor (or manifold in the case of fuel injection) and thereby increases the mass of petrol/air mixture fed to the engine so that more power is delivered. The turbine, for its part, is driven by the exhaust gases from the engine.

Although turbochargers seem to have most of the bugs ironed out these days, there are still some operating limitations. One of the most important is to idle the car for a minute or two before switching off. Without this precaution, the turbocharger bearings can overheat and fail prematurely.

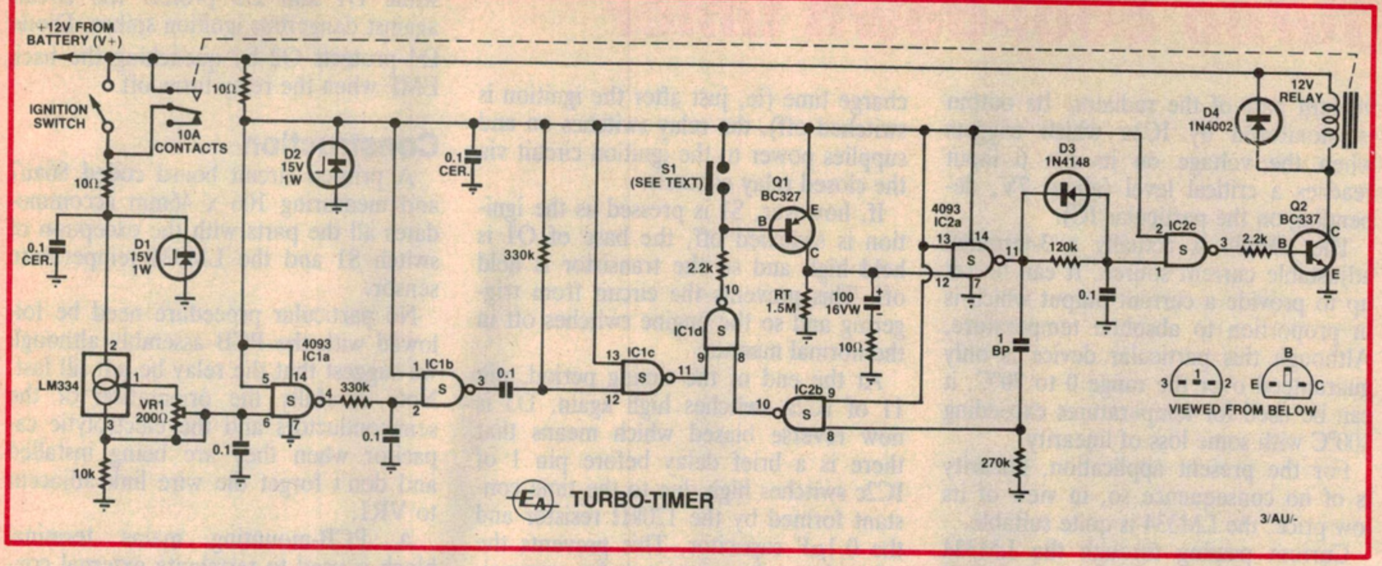
The problem arises because the compressor rotor operates at very high temperatures when the turbocharger is supplying boost. Now although the rotor is designed to withstand these high temperatures, the bearings are much more vulnerable. It is important that they not be allowed to get too hot.

This doesn't happen under normal operating conditions because oil circulation keeps the bearings cool. But if the engine is switched off immediately after a heavy load, heat continues to transfer from the rotor to the bearings. Since there is now no oil flow, the bearings can quickly overheat and become fatigued.

Cool it

During idling periods, and when the engine is not otherwise under load, a 'waste-gate' allows the exhaust flow to bypass the compressor, and so the rotor temperature is greatly reduced. This then is the reason why manufacturers recommend that turbocharged cars be idled for a minute or so before switching off — it gives the rotor time to cool and thus minimises heat transfer to the bearings.

The problem is many drivers forget about this cool-down time, at least until they are confronted with the expense of



replacing the turbocharger. That's where the Turbo-Timer comes in — provided the engine has reached operating temperature, it automatically extends engine operation after the ignition is switched off.

Note, however, that the Turbo-Timer is not a device that allows you to leave your car while the engine is still running. You must remain with the car until the engine cuts out so that you can secure the car properly. In the case of a manual car, this means leaving the transmission in either first or reverse gear.

Put simply, the Turbo-Timer is a device that ensures that the proper cool-down period is observed at the end of a journey. It is designed for those cars which are not supplied with an automatic cool down timer as standard equipment and will suit just about any turbocharged model.

Although it added somewhat to the circuit complexity, we thought it important that the circuit should not require any changes to the car's wiring. The main problem in implementing this philosophy was this: to trigger the circuit, the ignition must be switched off, producing a +12V to ground transition at the input. Since the same effect is ostensibly produced when the timer cuts out, the circuit must be able to trigger on the first transition but ignore the second.

Another requirement was that a circuit failure must not result in engine failure. Our circuit easily meets this requirement. No matter how drastic the circuit failure may be, it cannot possibly stop the engine from running.

Temperature sensor

In designing the circuit, we also had to consider situations where the Turbo-Timer would not be required.

Firstly, there's the situation where you've just been for a drive down to the corner shop. The engine hasn't even come up to operating temperature and certainly doesn't need a cool down period. A temperature sensor, mounted on or near the radiator, takes care of this contingency.

Another situation where the timer is unnecessary is after a slow drive through heavy traffic. The turbocharger will not have been doing any work and, again, doesn't need to be cooled. Because the engine will certainly have reached operating temperature in this instance, a manual defeat switch has been included. All you have to do is push the switch as the ignition is switched off.

Circuit Description

As you might expect, the circuit has a relay which bridges the car's ignition switch. Normally, the contacts of this relay are open, but during timer operation the contacts are closed. The rest of the circuit, ultimately, controls the relay.

What happens is that the circuit senses when the ignition is turned off. Then, if the engine has reached a preset temperature, it restores ignition by closing the relay contacts some 30ms later. While this may cause the engine to miss a couple of beats, it is short enough to ensure that it keeps running.

The circuit is based on two CMOS ICs with an LM334 used as the temperature sensor. The LM334 is fixed to the radiator cap or to some other con-

The circuit can be fitted to just about any turbocharged model.

Turbo cool-down timer

venient part of the radiator. Its output is monitored by IC1a which triggers when the voltage on its pin 6 input reaches a critical level (about 7V, depending on the particular IC).

The LM334 is actually a 3-terminal adjustable current source. It can be set up to provide a current output which is in proportion to absolute temperature. Although this particular device is only guaranteed over the range 0 to 70°C, it can be used for temperatures exceeding 100°C with some loss of linearity.

For the present application, linearity is of no consequence so, in view of its low price, the LM334 is quite suitable.

Current passing through the LM334 produces a voltage across the associated 10kΩ load resistor. This becomes the output voltage and varies in proportion to temperature. The trimpot connected across pins 2 and 3 is used to calibrate the LM334 and allows the trigger voltage (approx. 7V) to be set for a wide range of temperatures.

The output of IC1a (pin 4) is normally high but goes low when the critical temperature is reached. This low is fed to pin 2 of IC1b by a 30ms delay circuit which prevents spurious signals from triggering the circuit. In other words, the trigger signal must be longer than 30ms in order to trigger IC1b.

What all this means in practice is that, when the engine reaches operating temperature, the output of IC1b goes high. The circuit is now armed.

Assume now that the ignition is switched off. When this happens, current through the LM334 ceases, pin 6 of IC1a goes low, and pin 3 of IC1b also goes low. This low is fed into a differentiator (0.1μF and 330kΩ) to produce a 0.5ms pulse which is then gated through by IC1c and IC1d to the base of PNP transistor Q1.

Q1 thus turns on for 0.5ms and completely charges the 100μF timing capacitor on its collector via a 10Ω resistor. When the transistor subsequently turns off, the 100μF capacitor immediately begins discharging via the 1.5MΩ timing resistor (RT). This gives a timing period (and thus a motor run-on time) of approximately 1.5 minutes.

During the discharge time, both inputs of IC2a are high, its output (pin 11) is low, and thus pin 1 of IC2c is pulled low via D3. This, in turn, means that pin 3 is high and so Q2 and the relay are on.

Thus, at the beginning of the discharge time (ie, just after the ignition is switched off), the relay switches on and supplies power to the ignition circuit via the closed relay contacts.

If, however, S1 is pressed as the ignition is switched off, the base of Q1 is held high and so the transistor is held off. This prevents the circuit from triggering and so the engine switches off in the normal manner.

At the end of the timing period, pin 11 of IC2a switches high again. D3 is now reverse biased which means that there is a brief delay before pin 1 of IC2c switches high due to the time constant formed by the 120kΩ resistor and the 0.1μF capacitor. This prevents the relay from dropping out for approximately 10ms.

So why has this been done? Earlier on, we stated that the relay drop out (end of timing sequence) has the same effect as switching the ignition off. By delaying the relay switch off at the end of the timing sequence, we can feed a blanking pulse to IC1d to prevent the circuit from retriggering.

Here's what happens. In addition to driving IC2c, the output of IC2a also feeds a differentiator consisting of a 1μF capacitor and a 270kΩ resistor. Thus, when pin 11 of IC2a switches high at the end of the timing sequence, a positive pulse is applied to pin 8 of IC2b and a corresponding negative pulse appears at pin 10.

This negative pulse effectively latches the output of IC1d high for about 250ms. This period easily encompasses the 10ms relay drop-out delay and the following 30ms trigger pulse, and thus prevents the circuit from false triggering.

Power for the circuit is derived from the car battery. The two 10Ω resistors and the associated 0.1μF ceramic capacitors provide supply decoupling, while D1 and D2 protect the circuit against dangerous ignition spikes. Diode D4 protects Q2 by quenching the back EMF when the relay turns off.

Construction

A printed circuit board coded 86au7 and measuring 106 x 46mm accommodates all the parts with the exception of switch S1 and the LM334 temperature sensor.

No particular procedure need be followed with the PCB assembly although we suggest that the relay be left till last. Note carefully the orientation of the semiconductors and the electrolytic capacitor when they are being installed and don't forget the wire link adjacent to VR1.

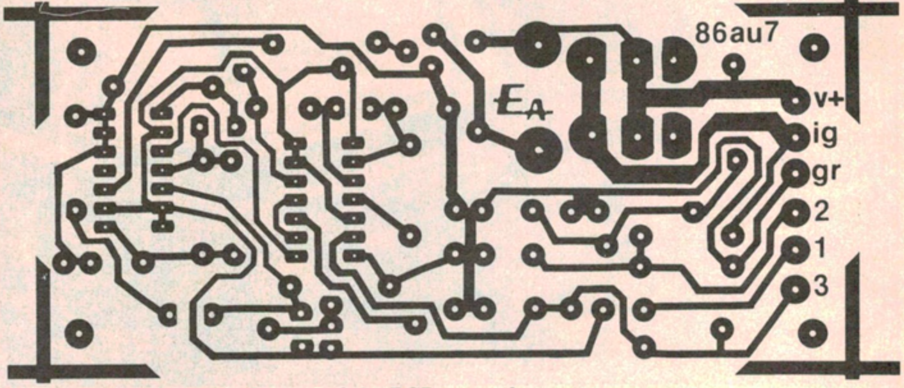
A PCB-mounting mains terminal block is used to terminate external connections to the PCB, the exception being the leads to S1. Note that although IC sockets were used in the prototype, we recommend that constructors solder the ICs straight in. Sockets only add to the cost and are a potential source of unreliability.

The circuit can be tested off the car if you prefer. Set the trigger temperature to minimum (clockwise) and solder a 100kΩ resistor in parallel with the 1.5MΩ resistor (RT). This will give a timing period of only a few seconds.

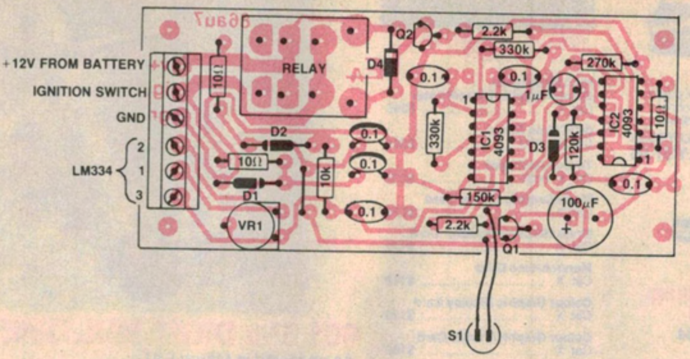
With the ground and battery connections made, briefly connect the ignition input to the battery input. When you break this contact, the relay should pull in and stay in for a few seconds. Assuming all is well, remove the 100kΩ resistor across RT.

Installation

Once construction has been completed, the circuit can be housed in a suitable case and installed underneath the dashboard — preferably adjacent to the fusebox. Finding a suitable location for S1 may be a little trickier — it will either have to be mounted on the dash-



Above: actual size reproduction of the PCB artwork.



Above: the parts layout diagram. Take care when installing polarised components.

board or installed on the steering column.

Alternatively, if you don't wish to override the circuit, S1 can be deleted altogether.

The temperature sensor is mounted on the radiator, remote from the rest of the circuit. One suggested mounting method is to secure the sensor to one finger of the radiator cap using a small saddle clamp. Alternatively, the sensor can be secured to the guard flange on top of the radiator or to one of the mounting flanges.

Whatever you do though, don't go drilling holes through the header tank on the radiator. Note that the LM334 comes in a TO92 package — the same plastic encapsulation as used for most small transistors. The wiring between the sensor and the PCB should be run using colour-coded automotive cable.

The ignition and +12V connections are best picked up from the fusebox. These connections can be made using either piggyback spade connectors or "Scotchlock" splice connectors. The chassis (GND) connection can be made to any convenient point under the dash.

Make absolutely sure that the ignition and +12V leads are correctly secured. You could be in real trouble if one of these leads comes adrift and shorts to chassis. It is a good idea to bundle the leads together using cable ties so that, even if one does come adrift, it cannot possibly create a short.

Finally, the circuit must be calibrated. To do this, bring the engine up to operating temperature and adjust VR1 fully anticlockwise. Now turn VR1 clockwise until the circuit triggers when the ignition is turned off. Further adjustments to VR1 can then be made, if necessary, as a result of on road experience.

PARTS LIST

- 1 printed circuit board, code 86au7, 106 x 46mm
- 1 project box to suit (optional)
- 1 pushbutton momentary contact switch (optional, see text)
- 1 6-way PCB-mounting terminal block
- 1 12V DPDT relay, 10A contacts

Semiconductors

- 1 LM334 adjustable current source
- 2 4093 quad Schmitt NAND gates
- 1 BC327 PNP transistor
- 1 BC337 NPN transistor
- 1 1N4148 silicon diode
- 1 1N4002 silicon diode
- 2 15V 1W zener diodes

Capacitors

- 1 100µF 16VW electrolytic
- 1 1µF 16VW bipolar electrolytic
- 2 0.1µF ceramic
- 4 0.1µF metallised polyester

Resistors (0.25W, 5%)

1 x 1.5MΩ, 2 x 330kΩ, 1 x 270kΩ, 1 x 120kΩ, 1 x 10kΩ, 2 x 2.2kΩ, 3 x 10Ω, 1 x 200Ω small horizontal trimpot

Miscellaneous

Automotive hookup wire, spade connectors, "Scotchlock" connectors, cable ties, machine screws and nuts.

Advice on Using the Turbo-Timer

This circuit must be used with discretion. Never leave the car with the engine still running, as the vehicle will not be properly secured.

Finally, never idle your car for an extended period of time inside your garage. Carbon monoxide fumes from the exhaust are dangerous.