Special project for rural areas

Protect motors against low AC voltage

To urban dwellers, the expression "power failure" has connotations of blown fuses, black-outs or even the more ominous power rationing. The ensuing loss of power is always an inconvenience and, with respect to freezers etc, can be expensive. Another type of power failure rarely seen in cities but relatively common in rural areas is the "brown-out". Surprisingly, the partial power loss of a "brown-out" can be more of a menace than a complete black-out.

by COLIN DAWSON

The term "brown-out" refers to a reduction in mains voltage which causes incandescent lamps to go dim (hence, brown), television pictures to contract and motors to stall. This rarely occurs in cities but can be quite common in rural areas where fault conditions may go unrepaired for some hours (fallen trees, dead possums partially shorting the lines, etc) or where load conditions cause severe voltage drops at the ends of long distribution lines.

When a brown-out occurs, any induction motor such as used to run a refrigerator, washing machine, freezer or pump is in danger of being burned out if it is switched on while the low voltage condition is present. The reason for this is that while the motor is starting and in the process of coming up to normal operating speed, it draws very heavy current which means very high power dissipation in the windings.

Normally these heavy starting currents are only present for a few seconds and so do not cause any problems. But if the mains voltage is low, the motor will be unable to develop sufficient torque to achieve normal operating speed and will remain in a condition of "high slip" and high power dissipation, leading to eventual burnout.

Some motors are protected by thermal cutouts but even so, the starting winding on single-phase motors can still be burnt out. Whatever the damage, the loss of the motor can be very expensive and inconvenient and the loss of perishable goods in a freezer must also be made good.

We have experienced brown-outs in some areas of Tasmania where the mains voltage went so low that neon indicators in power points were extinquished, ie, the voltage dropped below 50VAC. These conditions, which often lasted hours, would certainly cause the burnout of any refrigerator or pump motor.

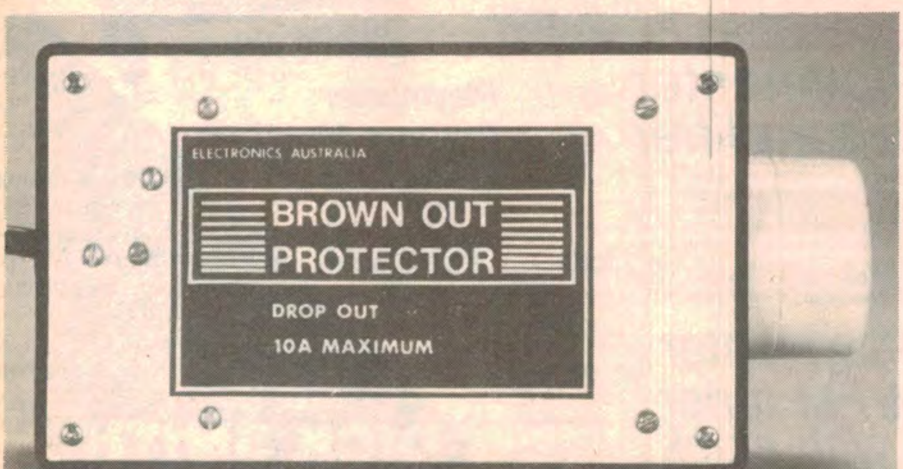
While the householder can disconnect motor-powered appliances whenever a brown-out occurs this would require constant monitoring. After all, a brown-out could easily occur late at night when he is asleep. The consequence is that he could awake next morning to find that the refrigerator motor had burnt out.

The EA Brown-out Protector provides constant protection for any single-phase induction motor, disconnecting power when the mains voltage drops and then reconnecting when voltage returns to normal levels. The cost of this protection is far less than the cost of repair of a typical fractional horsepower induction motor. It may be used with motors rated up to 2kW. The circuitry could also be adapted to switch the contactor for three-phase motors.

If the mains voltage should fall below a preset level, the Brown-out Protector automatically trips a relay and disconnects the load. While ever this condition exists, a LED will be illuminated or, alternatively, a buzzer can sound. The trigger or "drop out" voltage would typically be set at about 220V, but can be set at any voltage between 168V and 227V.

The Brown-out Protector incorporates a relay which controls the mains active line to the load. Provided that the mains voltage is normal, the relay contacts will be closed and power available to the load. When a brown-out is detected the relay contacts will open, disconnecting the active line to the load.

The relay chosen for this project is a Takamisawa VF24HN. Despite its small



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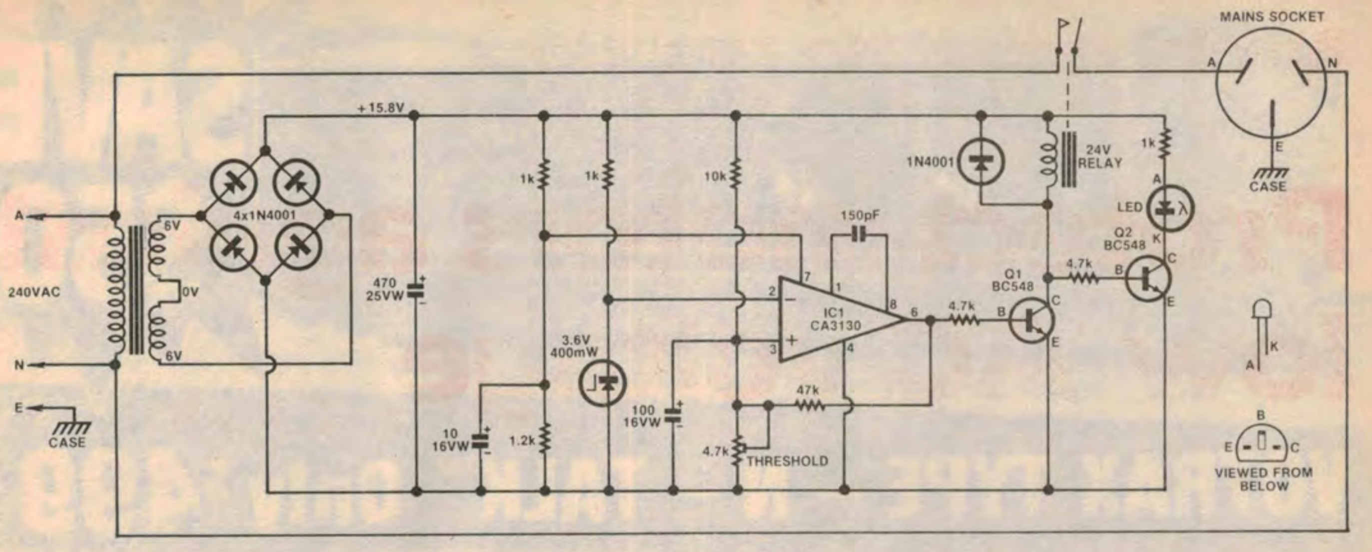


BROWN-OUT PROTECTOR

2/PC/-

size, it has a 25A rating on its contacts, which leaves a good margin of safety when used with motors of up to 2kW. The relay has a coil voltage of nominally 24V, rather than the more usual 12V. It is available from Associated Controls, 55 Fairford Rd, Padstow, NSW 2211.

Most readers will be aware that connection of an induction motor to the mains can itself cause a momentary voltage drop. This is evident in the flicker of lamps when a washing machine or airconditioner cuts in. The Brown-out Protector incorporates a delay circuit to compensate for this characteristic while still giving full protection.

How it works

Power for the circuit is derived from a 12V centre tapped transformer feeding a full wave bridge rectifier. The output of the rectifier is filtered by a 470μF capacitor and, when the relay is energised, supplies 15.8V. This rises to about 16.5V when the relay is released. Although the relay coil has a nominal rating of 24V, it will pull in at 14V and works quite effectively at 15-16V.

To detect a brown-out, a CA3130 Fet input op amp is employed as a comparator. A zener regulated 3.6V reference is applied to its inverting input (pin 2) and compared with a sample voltage on its non-inverting input (pin 3). The sample voltage is obtained by means of a two-resistor divider across the supply. Since this supply is provided by a transformer, it must vary in proportion to any changes in the mains voltage, as must the sample voltage.

One of the arms of the divider is a 4.7kΩ trimpot and this is used to calibrate the device. It can be used to adjust the sample voltage for any given mains voltage, which effectively determines the drop-out point. With the mains at 240V, setting the sample at very slightly above 3.6V will cause the comparator to trigger at a relatively high voltage (230V or more). Setting the sample at progressively higher values will cause the drop-out to occur at correspondingly lower voltages. A trigger delay of about one second is provided by a 100μF capacitor connected between pin 3 and ground.

The output of the comparator (pin 6) goes high when the device is triggered. This drives the base of transistor Q1 through a 4.7kΩ resistor. The relay coil forms the collector load of Q1, and has a current drain of about 34mA when it is energised.

Once the Brown-out Protector is triggered, it is essential that it triggers cleanly and completely. It would be unsatisfactory to have the relay chattering when the mains voltage is at the critical level and for this reason the device has been provided with hysteresis. A 47kΩ resistor between the output of the comparator and the non-inverting input gives it a hysteresis of typically 13V. This means that if a drop-out occurs at 220VAC, the device will not reset until the mains voltage rises to about 233VAC.

The CA3130 was selected for use as the comparator because its output, when in the low state, goes fully to ground and thereby turns the BC548 transistor hard off. Many op amps go to 0.6V when in the low state and this would not guarantee turning the transistor off. A disadvantage of the CA3130, however, is that it cannot be operated from a supply voltage of higher than 16V. Since the voltage from the rectifier can be as high as 16.5V, another voltage divider is used to provide an op amp power supply of around 8.7V.

A second BC548 transistor, Q2, is used to drive a LED to provide a warning when a drop-out occurs. Its base is driven from the collector of Q1 which is normally low. In the event of a brown-out, Q1 will be turned off and its collector pulled high by the relay coil. This biases Q2 on and the LED will be activated.

PARTS LIST

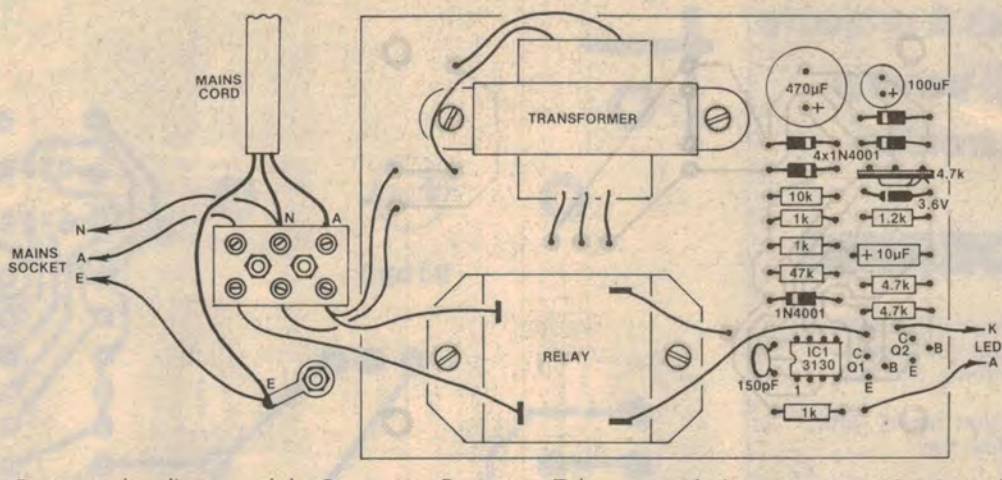
1 24V relay, code VF24HN
1 12V centre-tapped transformer
1 surface-mounting mains socket
1 10A mains cord and plug
1 plastic utility box, 158 x 96 x 60mm
1 printed circuit board, 102 x 86mm, code 83bp3
1 Scotchcal front panel

SEMICONDUCTORS
5 1N4001 diodes
1 3.6V zener diode
2 BC548 NPN transistors
1 CA3130 Fet input op amp
1 LED

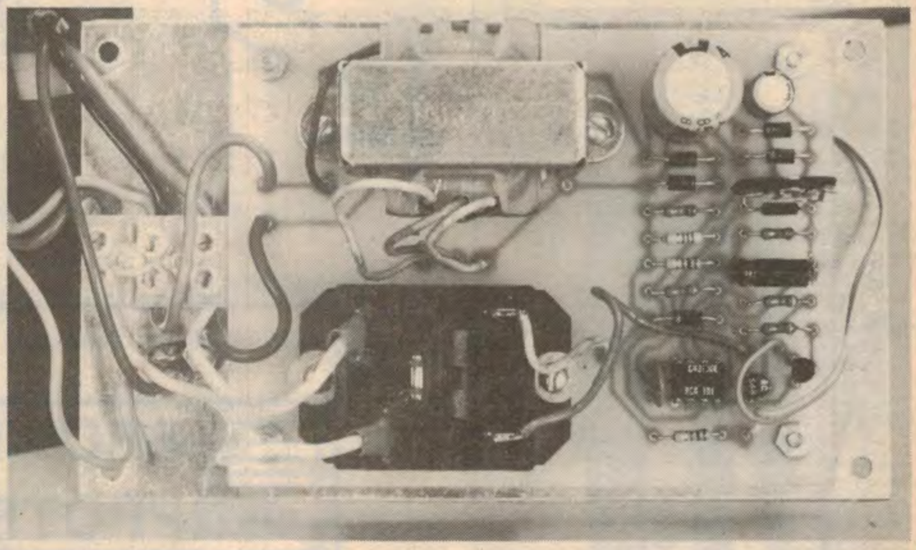
CAPACITORS
1 470μF/25VW electrolytic
1 100μF/16VW electrolytic
1 10μF/16W electrolytic
1 150pF ceramic

RESISTORS (¼W, 5%)
1 x 47kΩ, 1 x 10kΩ, 2 x 4.7kΩ, 1 x 1.2kΩ, 3 x 1kΩ
1 x 4.7kΩ 10mm vertical trimpot

MISCELLANEOUS
2 mains cord grommets
1 cable clamp
1 terminal strip (3 way)
Machine screws and nuts
Hook up wire (10A mains-rated where applicable)



Parts overlay diagram of the Brown-out Protector. Take care with the orientation of polarised components.



View inside the completed prototype. Make sure that you keep all mains wiring neat and tidy and note that mains voltages are present on the PC board.

Construction

The PCB, coded 83bp3 and measuring 102 x 84mm, was designed to fit into a plastic utility box. It will ultimately be affixed to the lid of the box so the mounting holes should be drilled in the lid of the box at this stage. Don't forget to leave room for the three-way mains terminal block, which will require two mounting holes of its own. Another hole will be needed for the mains earthing point and one for the LED.

The printed circuit board will have to accept a total of eight machine screws, each of about 3mm. Four of these are used to secure the PCB itself and two each are used for the transformer and relay. Check that the screws fit in their respective holes before mounting any components to the board. Also make sure that the holes associated with the mains transformer and relay are large enough to accept the wiring.

When mounting the components on the PCB, start with the smallest items. Watch the orientation of the diodes, transistors, IC and electrolytics. Don't forget to include two wires of about 100mm to connect to the LED. At this stage the transformer and the relay can be mounted. We have used an inexpensive M-2851 type transformer, although the PCB has also been designed to accept the "PCB mounting" style of transformer such as Ferguson PL12/5VA. The latter requires no mounting screws – it is held in position by its solder connections. The relay has mounting slots rather than holes and this necessitates the use of washers under the screws. The washers commonly available will probably prove too large in diameter, although this can be overcome by trimming them.

A hole must be drilled at either end of the box to accept a mains cord. Allowing for rubber grommets, these should be about 14mm. A mains socket is mounted over one of these holes and a cord clamp is mounted next to the other (see photo). The accompanying wiring diagram illustrates the correct method of connecting the mains wiring. Be careful not to transpose the neutral and active lines as this is a potentially fatal mistake. Although the appliance will function normally, it can still be "live" when switched off. The colour code for mains wiring is earth – green or green with a yellow trace; neutral – black or blue; active – red or brown. Note that the mains cord, plug, socket and internal wiring should all be rated at 10 amps.

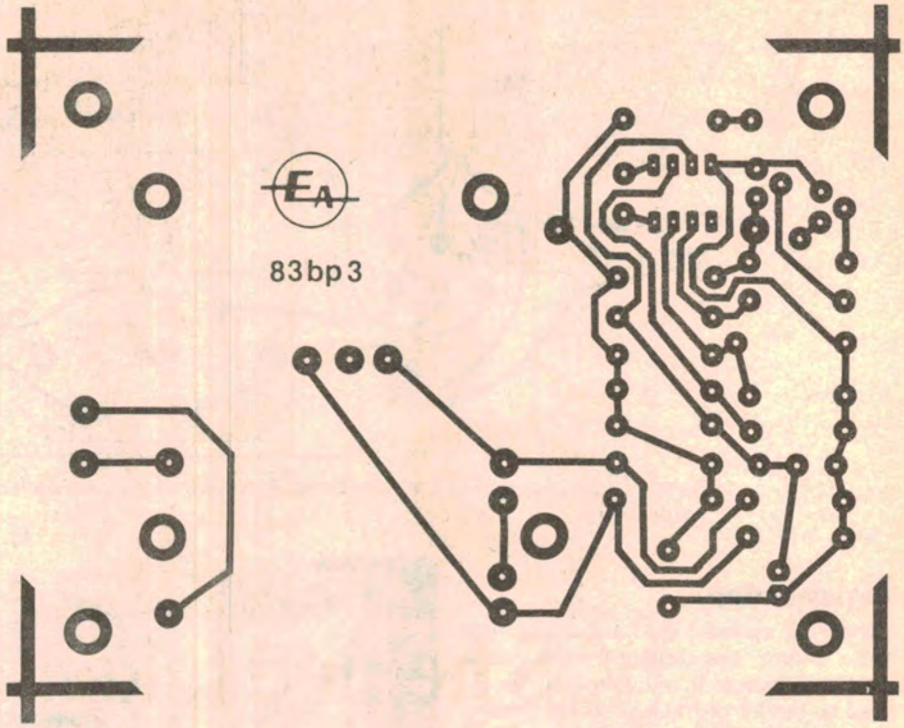
Make sure there are no points of exposed mains wiring. This means leaving the insulation flush with the terminal block or PCB. Pay particular attention to the relay's mains connections. We used heat-shrink tubing, but a better approach may be to use Utilux connectors, provided that they will fit inside the box you choose.

Solder the connection to the LED and then mount the PCB in place. Construction is now complete and the Brown-out Protector is ready for a test. This should be done without any load connected.

> We estimate that the current cost of components for this project is approximately
>
> **$25**
>
> This includes sales tax.

Calibration

Switch the device on and allow it to run for a few seconds. Provided that there are no obvious signs of a problem, the device is ready for calibration. This



Here are actual size artworks for the PCB and front panel.

can be done by either of two methods, the simplest of which is to use a Variac. In this case, the voltage applied to the device is simply set at 220V and the trimpot adjusted until the comparator just triggers. Make any adjustments slowly to allow for the trigger delay and don't handle the PCB while power is on, as mains voltages are present.

Triggering should always occur at the chosen voltage now, with resetting at about 13V above this value. For those constructors without access to a Variac, the second method of calibration only requires the use of a multimeter. This should be set to the lowest DC voltage range which will accommodate 4V, and used to measure the sample voltage at pin 3 of IC1. Adjust the trimpot to the point just before triggering occurs (with a 240V supply). Again, this must be done slowly to allow for the trigger delay.

Take note of the voltage at which the triggering occurs – it may take several attempts to determine this point with reasonable accuracy. Add 9% to this value (240V is 9% higher than 220V), and set the sample voltage to this value. The trigger point should now be 220VAC. Other trigger points can be set in the same way – just calculate the percent difference between 240VAC and the desired voltage and apply this to the sample voltage.