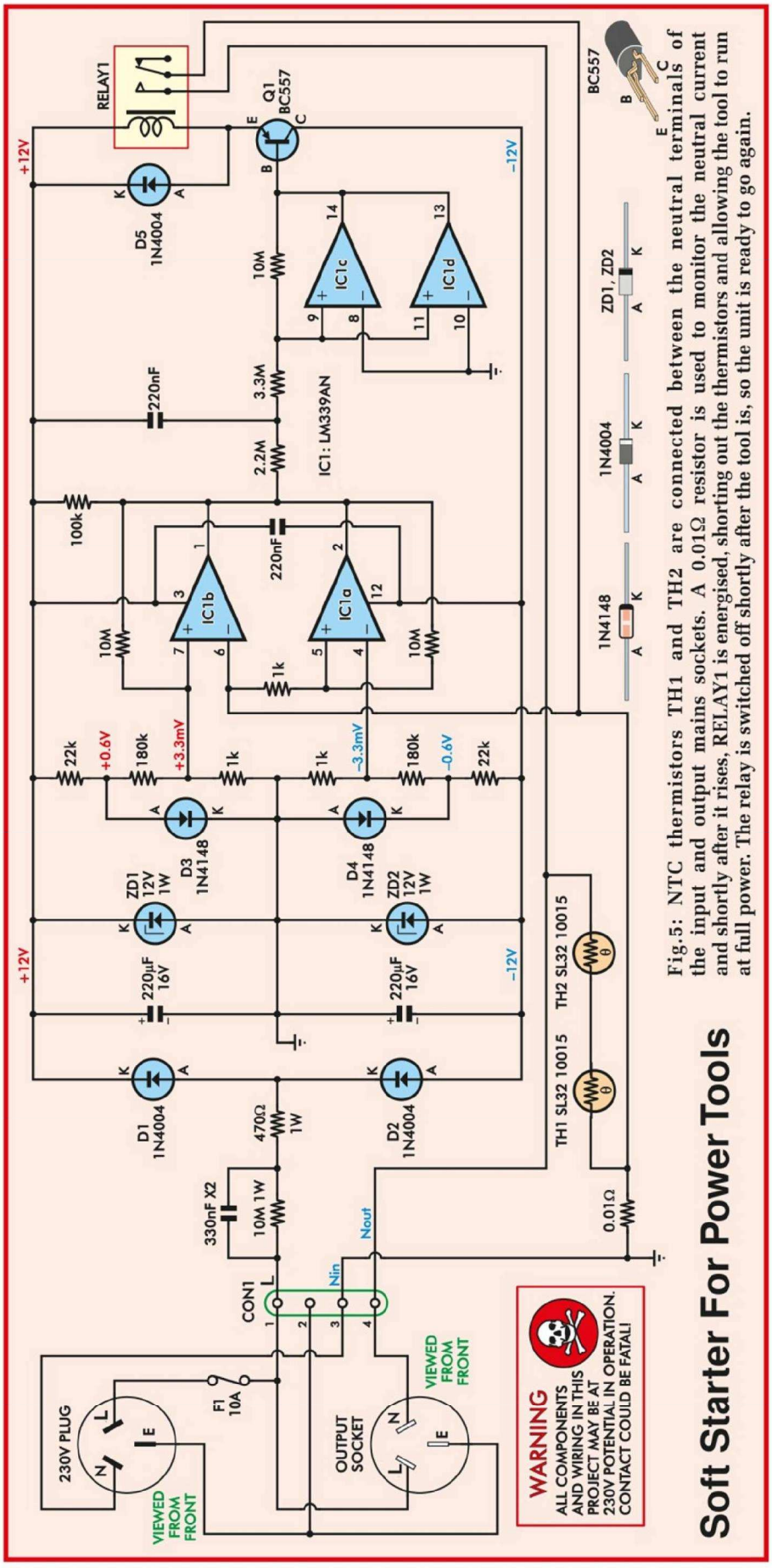

Fig.5: NTC thermistors TH1 and TH2 are connected between the neutral terminals of the input and output mains sockets. A 0.01Ω resistor is used to monitor the neutral current and shortly after it rises, RELAY1 is energised, shorting out the thermistors and allowing the tool to run at full power. The relay is switched off shortly after the tool is, so the unit is ready to go again.

The voltage at the non-inverting inputs then becomes (–3.8V × 10MΩ –12V × 3.3MΩ) ÷ 13.3MΩ = –5.8V. This is the hysteresis for this stage, and the capacitor must discharge by this additional amount before the relay turns off.

This allows the relay to stay on through brief dips in the load current. Diode D5 protects transistor Q1 from any voltage spike created when the relay turns off.

Power supply

The ±12V rails are derived from the mains live line via a 330nF X2 series capacitor, 470Ω current-limiting resistor and dual half-wave rectifier formed by diodes D1 and D2. These diodes charge the 220µF capacitors alternately with each mains half-cycle, to provide the positive and negative rails. 12V Zener diodes ZD1 and ZD2 limit the voltage across these capacitors to about 11.5V. The 330nF capacitor and 470Ω resistor limit the current and thus dissipation in ZD1 and ZD2 to well below their rated 1W.

If you ignore the X2 capacitor and two 1W resistors, this is a traditional AC-to-DC voltage doubler supply. The X2 capacitor has an impedance at 50Hz of around 9.65kΩ, which limits the mains current to about 230V ÷ 9.65kΩ = 24mA. It's a bit more complicated than this calculation implies, but that's a reasonable approximation.

We could have used a wirewound resistor of a similar value, but it would then dissipate $0.024A^2$ × 9.65kΩ = 5.5W. The capacitor dissipates virtually no power.

The parallel 10MΩ resistor discharges the X2 capacitor once power is removed, while the 470Ω series resistor limits the inrush current when power is first applied.

For more details on how this type of supply works, see the description in the original *Soft Starter* article (April 2013).

The specified relay has a nominal coil resistance of 1.1kΩ. This means with a 24V supply it will draw around 22mA. As stated earlier, the X2 capacitor limits the supply current to about 24mA; less due to the series 470Ω resistor and other factors.

When the relay is turned on, the X2 capacitor and 470Ω resistor form a voltage divider with the coil resistance. The supply rails then drop to about ±6V and the two Zener diodes cease conducting, since most of the input current flows through the relay coil.