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The Characteristics of the Standard Current Trip Circuit

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THE CHARACTERISTICS OF THE STANDARD CURRENT TRIP CIRCUIT

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ABSTRACT

This report sets out to characterise the standard trip circuit commonly used to prevent latchup on spacecraft circuits.

In addition a negative rail version, and a higher voltage version are examined.

The sensitivity of the circuit to Hfe , supply voltage and temperature were also measured.

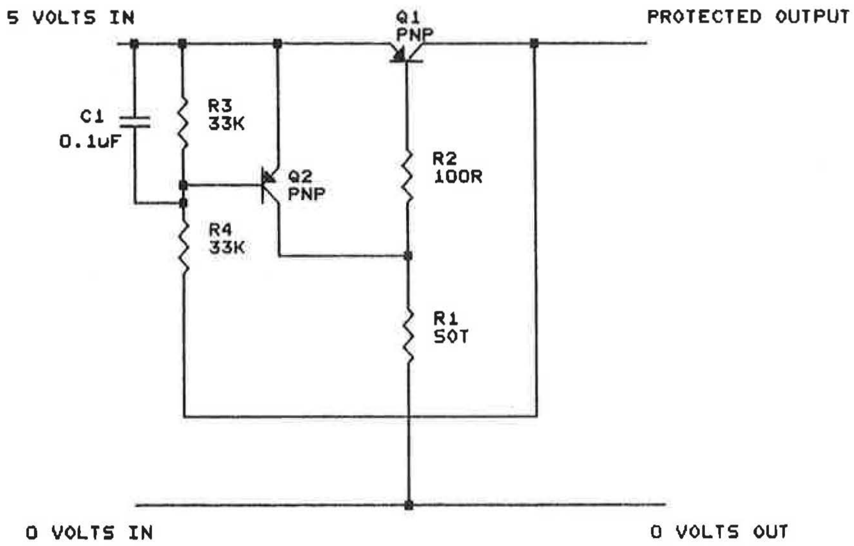

FIGURE 1 : THE STANDARD POSITIVE TRIP.

1 INTRODUCTION

A standard circuit is often used as a current trip for space projects (see figure 1). Its purpose is to protect circuits against damage due to latchup. CMOS circuits are particularly subject to latchup due to a buried SCR structure present in their substrate, formed by the manufacturing techniques used to produce the device.

If a susceptible circuit is subject to a high intensity cosmic ray pulse in space it may latch up, resulting in a current approaching 1 amp, which may fuse the bond wires or cause other damage.

The simplest protective measure is to place a current limiting resistor in series with the power line. The resistor value is chosen such that, in normal operation the resistor will not drop a significant voltage, but if the device latches up, the current will be limited to a safe value.

This simple arrangement works well for circuits which only take a few milliamps. However for higher current circuits, it is impossible to choose a suitable resistor value, as a resistor which would limit the current sufficiently in latchup conditions will drop an excessive voltage in normal operation. An active current trip circuit is then necessary .

Incidentally, whatever circuit is used, one also has to allow for the fact that the end of life current of a CMOS circuit flown in space may be significantly higher than its initial current, due to background radiation. The increase may amount to an order of magnitude or more, depending on the devices used and the continuous radiation flux they experience.

2 TESTS

This report addresses the following issues :

1 A negative voltage version of the trip.

2. +12volts and -12 volts versions of the trip.

3. Sensitivity of the trip level to supply voltage .

4. Sensitivity to transistor Hfe.

5. Variation in the voltage dropped across the trip with current drawn.

6. The effects of temperature.

7. Trip operating speed.

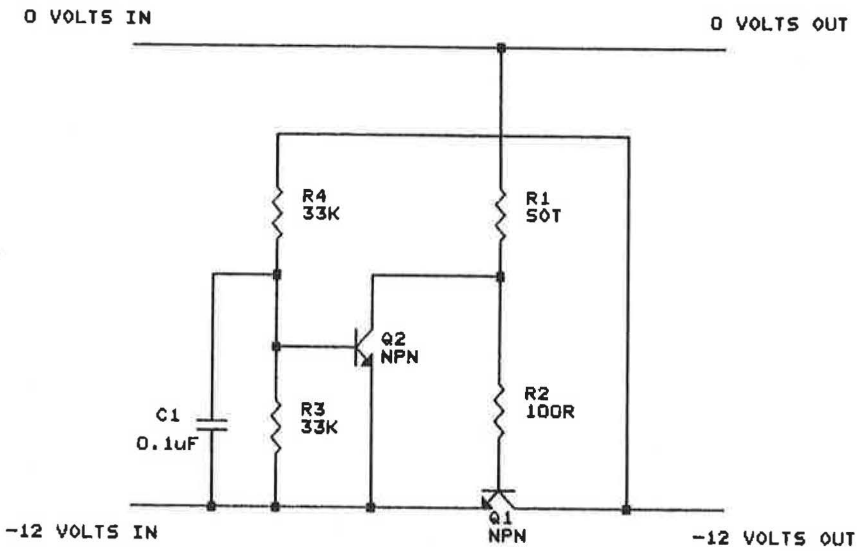

FIGURE 2 : THE NEGATIVE RAIL VERSION.

3 PERFORMANCE

3.1 A NEGATIVE RAIL VERSION

Analogue circuits often require a negative voltage supply. Minus 12 volts is commonly used. A trip circuit operating on a negative rail may therefore be needed.

Care often needs to be taken to ensure that the circuit is not damaged if only one rail trips. This issue is not addressed in this report however.

A negative rail current limiter was constructed simply by replacing the pnp transistors by npn ones. The resulting circuit worked successfully. The circuit is shown in figure 2.

Chart to show Variation in Supply Voltage against Trip Current with 207hfe and Trip set to 50mA @ -12v

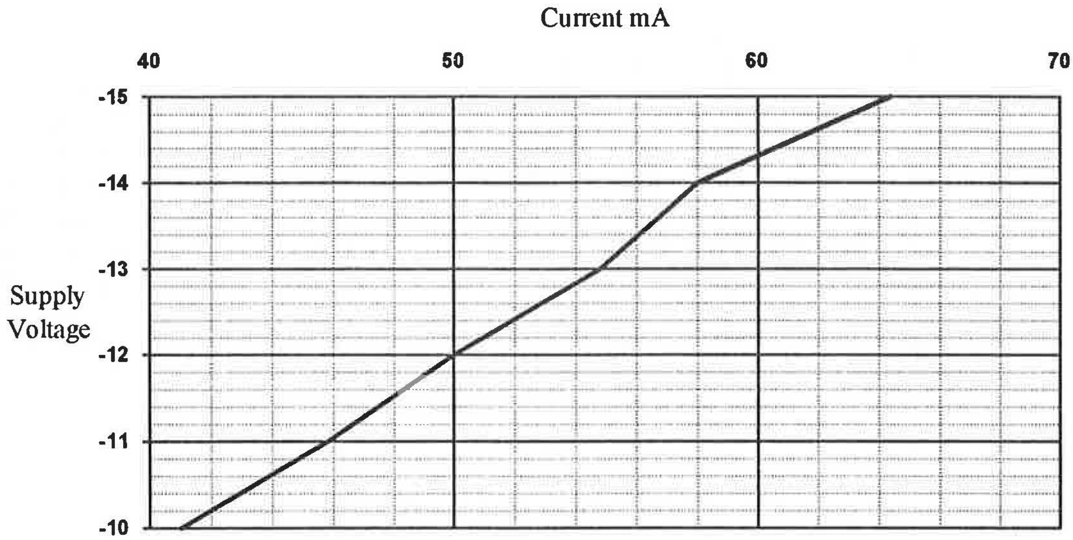

Fig. 3.

3.2 OPERATION AT +12 VOLTS AND -12 VOLTS.

Many circuits require a 12 volt supply as well as a 5 volt rail. It was thought that the existing circuit would probably function successfully at a higher voltage level, so it was tested at 12 volts in order to characterise it. It was found to run satisfactorarily at 12 volts, although the trip current varied with supply voltage (see figures 3).

Change in Base resistor vs Supply voltage

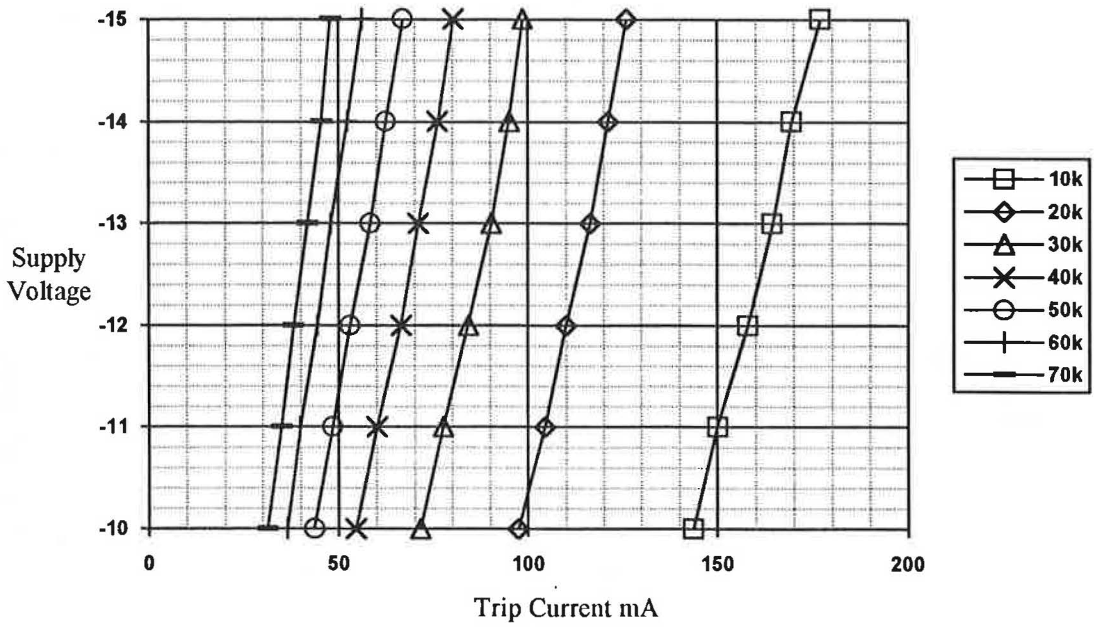

Fig. 4.

3.3 SUPPLY VOLTAGE VARIATIONS.

As previously indicated, for a given circuit, the trip current is a function of the supply voltage.

Using the -12 volt trip circuit, the trip current was measured for an increasing supply voltage. The current at which the circuit tripped was found to increase almost linearly with the supply voltage. At -10 volts the trip operated at 40 mA, whereas at -15 volts it did not trip until 64 mA was reached.(see fig 3)

The experiment was repeated using a range of base resistors, giving a range of nominal trip currents. In each case, the trip current increased with the size of the supply voltage (see fig 4).

The implication is that the designer needs to allow for supply voltage variations when setting trip levels.

Chart to Show Trip Current against Hfe

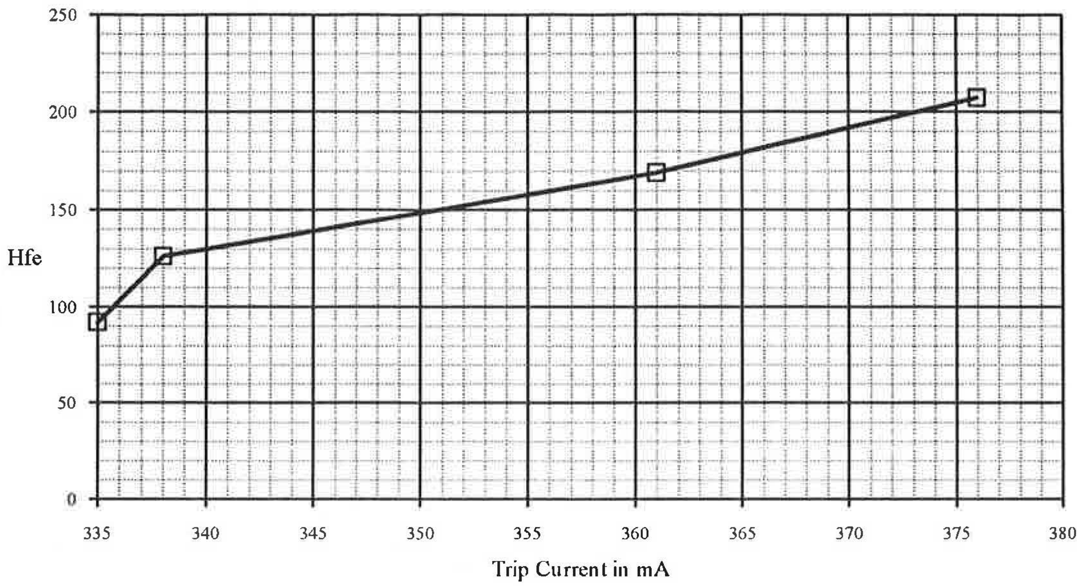

Fig. 5.

Chart to Show Value of R1 against Hfe of Transistor to Trip at 50mA

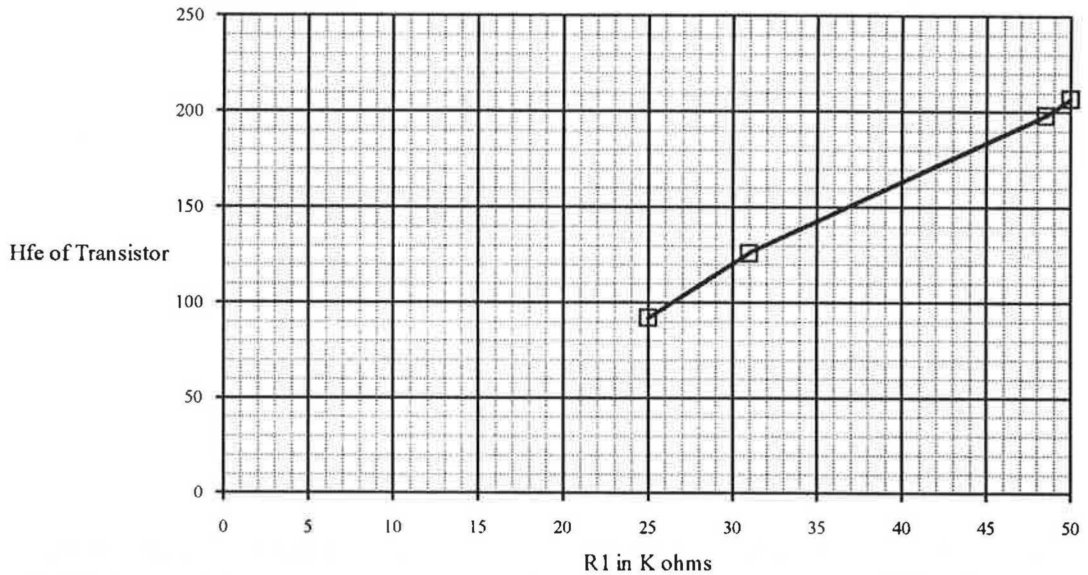

Fig. 6.

3.4 SENSITIVITY TO Hfe.

The circuit will trip when the voltage drop across the series pass transistor exceeds a certain level. As the degree of saturation of the series pass transistor depends on its Hfe for a given base current, the circuit is Hfe sensitive.

A number of transistors with differing values of Hfe were selected. Each one was substituted in the circuit in turn, and the trip current was measured. The trip current was found to vary with Hfe(see fig.5).

The base resistor was then adjusted for each transistor, to ensure that, the circuit tripped at a fixed current. 50 mA was chosen. Figure 6 shows the relationship between the resistor value required and Hfe for a 50 mA trip level. It can be seen that, as might be expected, the higher the Hfe, the higher the base resistor required. In fact the resistor required is proportional to the Hfe.

The implication of this is that it will normally be necessary to use a select on test resistor for the base resistor, as there is generally a large spread in transistor Hfe values.

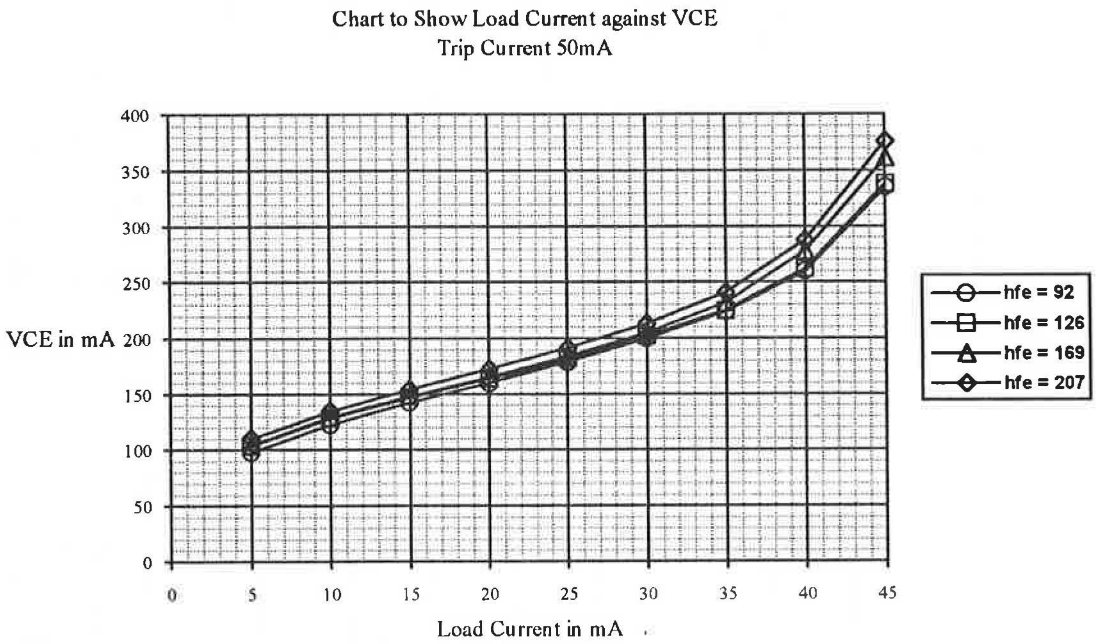

Fig. 7.

3.5 VOLTAGE DROP VS CURRENT.

The voltage dropped across the series pass transistor varies with the current drawn. In some applications, it is necessary to keep this voltage drop below a certain level, in order to prevent a circuit malfunction.

One solution is to raise the trip current level, by decreasing the base resistor. There is generally a limit to how far one can go in this direction! An alternative appeared to be to use a transistor with a higher Hfe. This was, however self defeating, as it is then necessary to increase the base resistor to compensate, in order to return to the required trip level. It is then discovered that the voltage drop actually increases with a higher Hfe! (see figure 7).

A better solution is to change the bias network to the trip transistor, causing the circuit to trip with a lower voltage drop across the series pass transistor.

Plot to show Trip Current against Temperature Change.
(Trip set to 50mA at room temperature.)

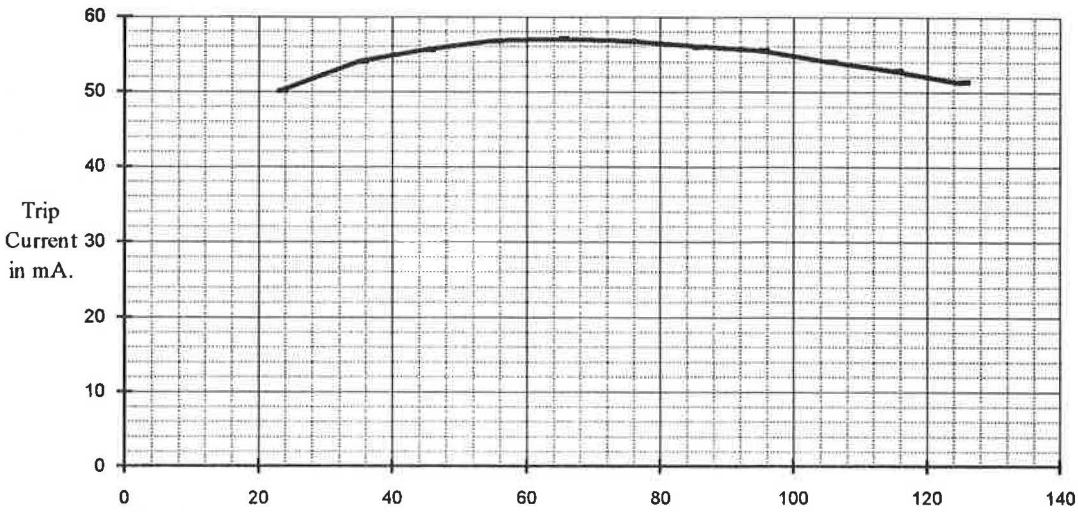

Fig. 8.

3.6 THE EFFECTS OF TEMPERATURE.

It was initially expected that the trip circuit would be highly sensitive to temperature, because the trip level depends on the base emitter voltage across Q2. The forward voltage drop at which Q2 begins to conduct substantially is quite temperature dependent, and would be expected to have a temperature coefficient of about 2.5 mV per degree celsius. This amounts to around 8% for a 20 degree change, or 16% for a +/- 20 degree change.

Fortunately, the circuit was far less temperature sensitive than expected. Rather than being linearly dependent on temperature, it showed a parabolic characteristic (see fig.8) , reaching a maximum at 65 degrees Centigrade. This is probably due to the temperature coefficient of Q1 and Q2 having opposite effects. A temperature rise which reduces the base emitter voltage across Q2 probably also reduces the voltage drop across Q1, which has a compensating effect.

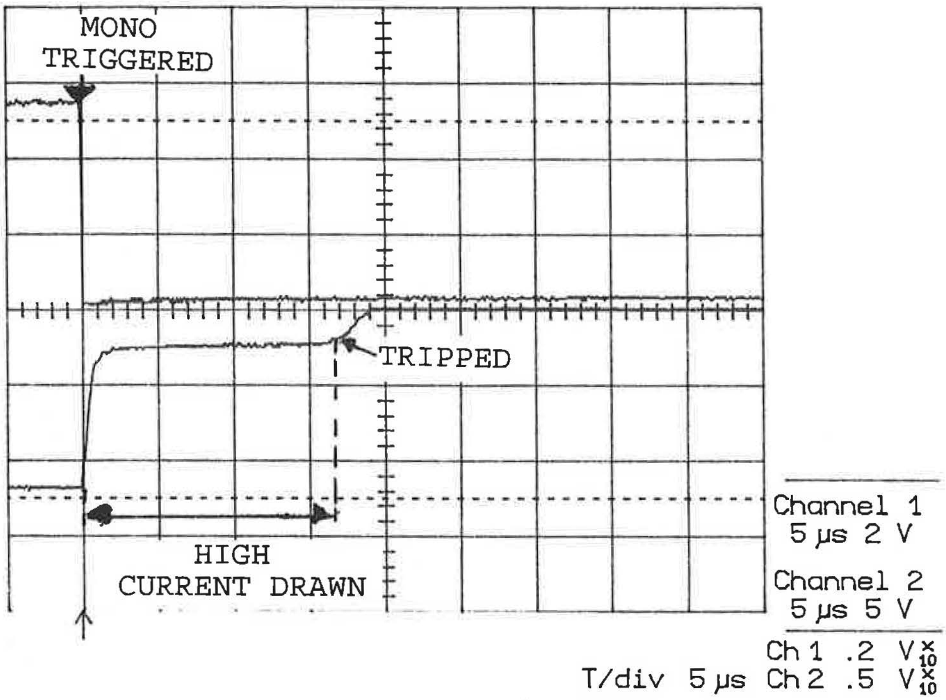

FIG.9 TRIP CHARACTERISTICS WITH A 10 nF SLUGGING CAPACITOR.

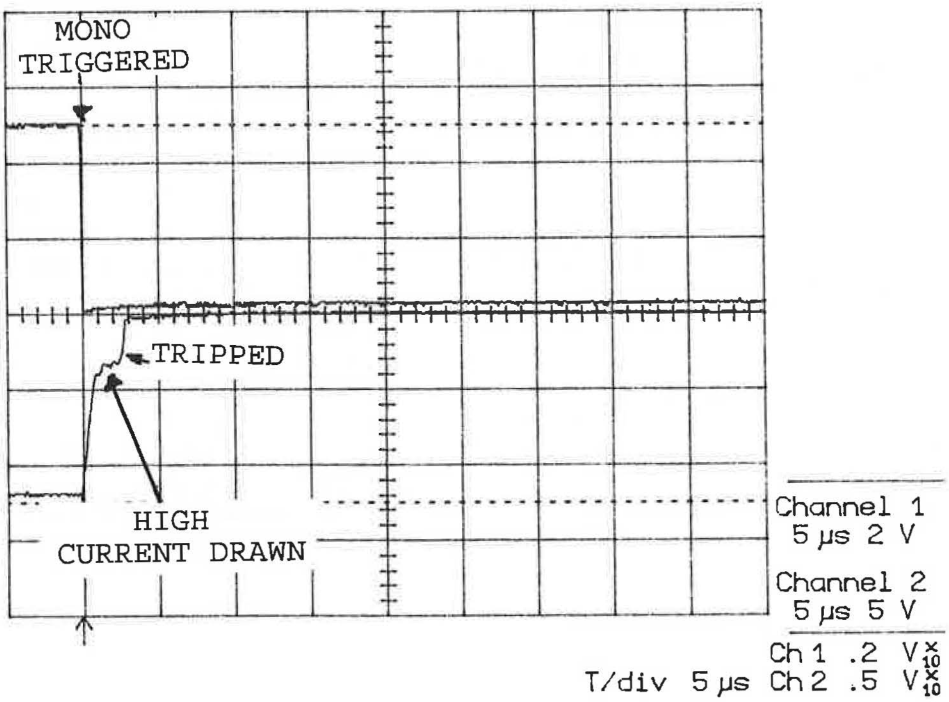

FIG.10 TRIP CHARACTERISTICS WITH A 1 nF SLUGGING CAPACITOR.

Plot showing Turn-off Time in Relation to C1

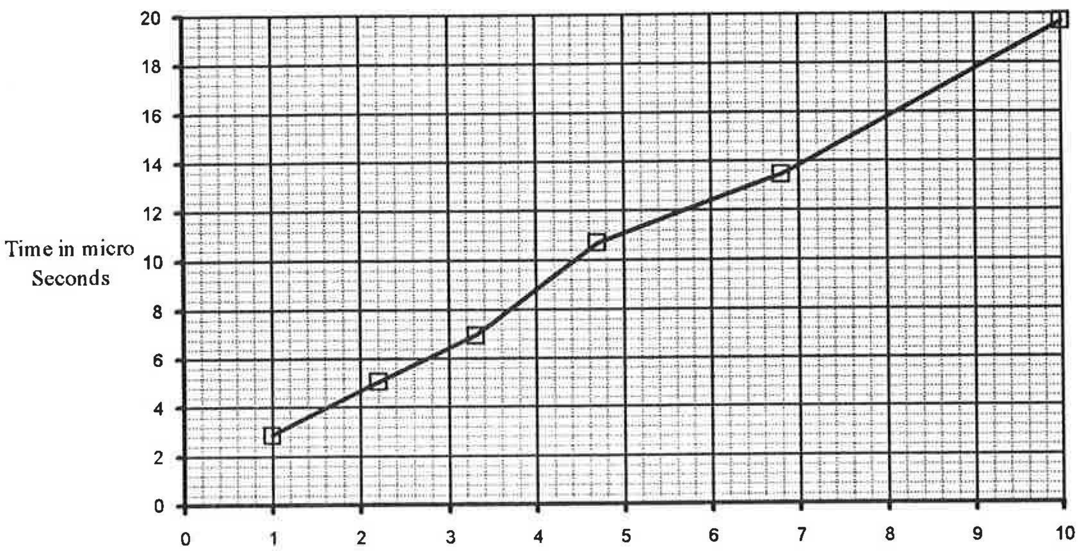

Fig. 11.

3.7 TRIP OPERATING SPEED.

The operating speed of the trip is an important factor in determining its effectiveness. The trip speed was found to mainly depend on the slugging capacitor.

The standard circuit has a slugging capacitor, C1 , which is presumably intended to prevent spurious tripping due to transients. It also allows the decoupling capacitors in the circuit to charge when the circuit is first turned on.

It is not possible to give a definitive value for this capacitor, as its value will depend on the circuit being protected. However, its normal value is 0.1uF.

In order to test the circuit, its output was short circuited by a transistor with a series resistor. When the shorting transistor was turned on, a high current was drawn until the circuit tripped. circuit tripped. Fig 9 and fig 10 show the output voltage vs. time for two different slugging capacitor values.

Figure 11 shows the relationship between trip time and slugging capacitor value.

The value of the decoupling capacitors used has little effect on the trip time. This is because the shorting transistor rapidly discharges the decouplers. Even 20uF of decoupling was found to have very little effect. In the event of a latchup, the energy in the decouplers will be dissipated in the tripped device, so an excessive amount of decoupling is not desirable.

4. CONCLUSIONS.

The tests showed that the circuit performs well. It is not, however possible to choose all components during the design phase, as the trip current depends on the Hfe of the series pass transistor. The resistor which sets the trip current must therefore be selected during the test phase.

Having selected the correct resistor value, the circuit is quite stable. The one tested was unexpectedly insensitive to temperature changes.

A negative voltage version was constructed by replacing the PNP transistos by NPN ones. This was found to work well.

The circuit was also found to work well at 12 volts rather than the usual 5 volts. Its trip current level was, however found to be voltage sensitive.

Several attempts were made to reduce the voltage drop across the series pass transistor. Increasing the transistor Hfe, or varying the values of the bias resistors, had very little effect in this direction. The only effective way of reducing the voltage drop was to operate the circuit at well below its trip current.