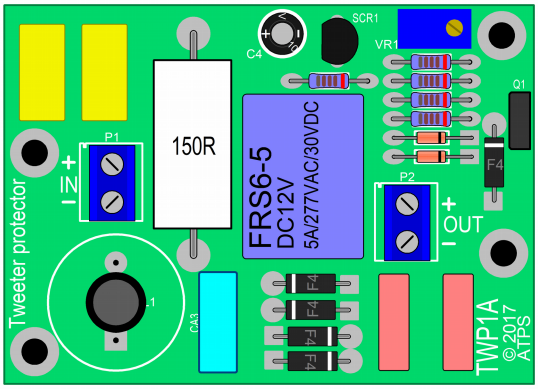
Australian Technical Production Services

Tweeter protector



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Further information may be found at **www.atps.net**.

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Credits

This Article contains contributions by: Richard Freeman

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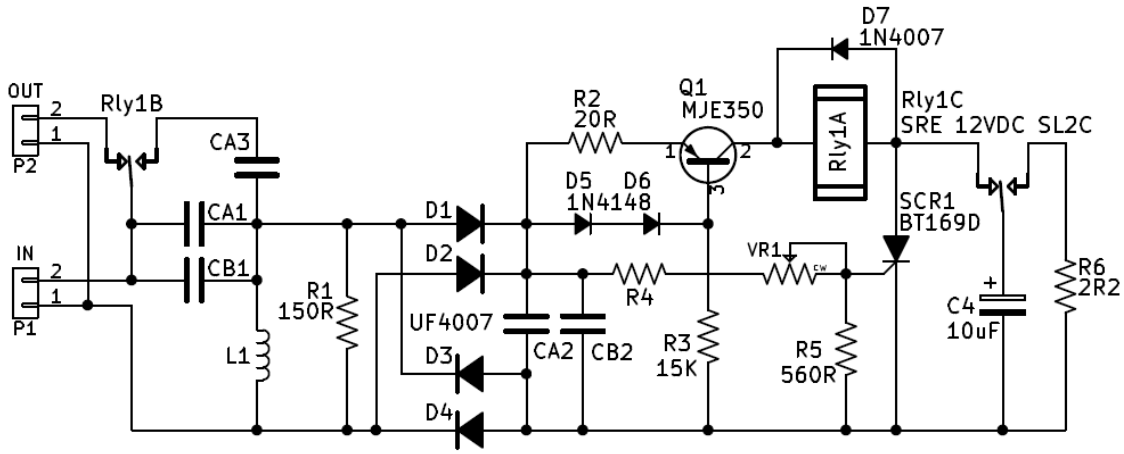
Introduction

The Tweeter protector is designed to monitor the signal (voltage) being fed to a speaker, and disconnect the speaker when that signal exceeds a pre-set level. This unit is completely signal powered, and presents an additional load over 109Ω, so it is not expected to cause any issues when used with a speaker system of 16Ω or less.

This module is designed as an an 'after market add on' to an existing speaker system (noting that fitting this module will constitute a modification, so may invalidate any manufacturers guarantee on the speaker). Once the circuit has tripped, the speaker will remain disconnected, until it is reset by a significant drop in signal.

A typical second, or higher order crossover, presents a resonant circuit to an amplifier if the driver is disconnected, this can be problematic with some amplifiers,so this circuit is designed to be installed before the high pass filter in the crossover.

Circuit Description



The Protection circuit consists of 4 sections:

Input filter

The input filter is used to approximate the expected frequency response of a passive crossover to avoid false triggering. Often a Speaker data sheet will provide the crossover frequency the manufacturer chose.

The input filter consists of CA1, CB1, and L1, while R1 provides a constant/predictable load for the filter, and CA3 compensates for the drop in impedance when the circuit is triggered.

As it is sometimes difficult to get a capacitor value close to the one you need, I decided to allow the input filter to be made up of two parallel capacitors – CA1 and CB1, so in the following calculations C1 = CA1 + CB1. The following equations are used to calculate the component values for the input Filter:

$$\mathbf{C_1 = 0.1125 / (150 \times F)}$$

$$\mathbf{L_1 = 0.2251 \times 150 \times F}$$

where: **150** is the resistance of **R1** in ohms, **F** is the desired crossover frequency in Hertz, **C1**=**CA1**+**CB1** in farads and 0.1125 and 0.2251

It is safer to set the input filter slightly lower than your speaker crossover, so for example if you have a speaker crossed at 3000Hz you may want to set the input filter at 2750Hz.

Once tripped, this circuit will present a lower resistance to the input filter, which in turn will shift the crossover point of this filter to a higher frequency. As this may cause the circuit to reset while the problem still exists CA3 is included to compensate for the lower resistance load while the protection circuit is in the tripped state.

To calculate the value of CA3 we use the same formula as above, except we presume a load of 109 Ohms, and then subtract the value of C1:

$$\mathbf{CA3 = (0.1125 / (109 \times F)) - C1}$$

I do need to mention the power rating of **R1**. At 5 Watts, R1 will only handle the full output from a 200 Watt (into 4 ohms) amplifier. This may not seem like much if the speaker system is rated at 1000 Watts or more, but the thinking here, is that a typical Audio system will be delivering less than 10% of power to the Frequencies usually looked after by the Tweeter. The main exception to this rule is when feedback occurs. Of course feedback will cause the protection circuit will kick in, which will stop the feedback, and so R1 will not end up dealing with significant power. However, If you think there may be situations where the amplifier is going to deliver considerable power levels at high frequencies, then you might want to make R1 a higher powered resistor, which would need to be mounted off the PCB.

Noting here that a mildly inductive resistor for R1 will make the circuit slightly more prone to triggering at higher frequencies, but this would not be considered a problem.

Active crossover

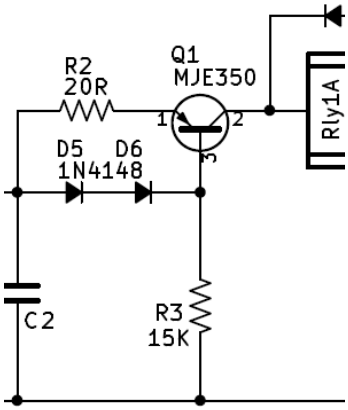
If you are using this with an actively crossed over speaker, the input filter can be bypassed by leaving out R1, L1, and CA3 and replacing CA1 and CB1 with wire links.

Note that even with active speakers it is still a good idea to have a capacitor in series with the tweeter to stop low frequency thumps that can occur when an amplifier is being turned on or off, from damaging the compression driver.

Rectifier and smoothing filter

D1 to D4 make up a full wave rectifier, while C2 (CA2 and CB2) smooths the supply out for the rest of the circuitry. Note the D1 to D4 are UF4007 rather than the usual 1N4007, as they need to be able to switch frequencies in excess of 20Khz. C2 needs to be rated to handle the peak voltage your amplifier will deliver, and be between 0.33 and 2µF, higher capacitance will delay triggering, while lower capacitance may stop it triggering properly. I suggest 0.82µF.

Current limit



Q1, D5-6, R2 and R3 limit the current to the relay, this is needed as a high power amplifier can easily output well in excess of 100 Volts, which would quickly destroy a 12 Volt relay.

For those unfamiliar with this circuit, it works as follows:

D5 and D6 maintain a total forward voltage drop of 1.2 Volts, when we take into account VBE (Emitter Base voltage) of Q1, this leaves 0.6V across R2.

If the current through R2 were to increase, that in turn would increase the voltage drop across R2, which would start to turn Q1 off, reducing the current, in turn decreases the voltage drop across R2. So this arrangement stabilises itself, with a constant current through R2.

R3 provides a current path to bias D5 and D6 on, and also to provide enough Base current to turn Q1 on.

So, the circuit stabilises with a voltage drop of about 0.6V across R2.

The current limit can be calculated by application of ohms law, E/R=I or in this case 0.6/20=0.030 or 30mA.

If you use a relay with a lower resistance coil, since the 0.6V drop across R2 is 1/20th of the 12V required to switch the Relay, the ideal value of R2 can be calculated by dividing coil resistance by 20.

SCR and trigger circuit

To work out the desired trigger voltage (**Tv)**, first we need to use the tweeter impedance (**Tz**) and Tweeter power (**Tp**) to calculate the peak voltage across the tweeter (**Vt**):

$$\mathbf{Vt = (\sqrt{(Tz \times Tp)) \times 1.414}}$$

Where 1.414 is to calculate peak, rather than RMS voltage.

We then use that result, and the Pad resistance (**Pr**), to calculate the Trigger Voltage (**Tv**):

$$\mathbf{Tv = Vt + (Vt \times (Pr/Tz)) - 1.2}$$

Where 1.2 is twice the expected forward voltage of the rectifier diodes D1 to D4 (typically 0.6V each)

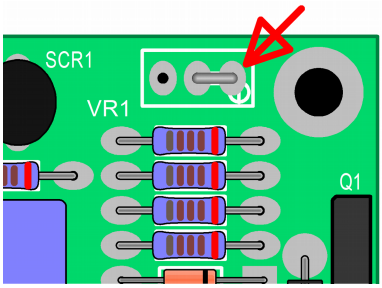
Noting that if there is no Pad resistor, you can just use:

$$\mathbf{Tv = ((\sqrt{(Tz \times Tp)) \times 1.414) - 1.2}}$$

The SCR is triggered when **Vgt** (Gate trigger voltage - the voltage between the Gate and the Cathode of the SCR) exceeds 0.56V. The trigger voltage is generated by a voltage divider consisting of R4+VR1 and R5. By making R5 = 560Ω the value of R4+VR1 can be calculated using the formula:

$$\mathbf{(R4 + VR1 = (Vt - 0.56) \times 1000}$$

I was in two minds about using a variable resistor, my concern being the reliability of a variable resistor in a speaker box, (which is prone to a lot vibration etc.) In the end I decided to use 25 turn trim-pots, as these usually are pretty reliable. If you want to just use a fixed resistor, the Trim-pot by can be linked out with a wire link between the two pads, as shown in the picture on the left.



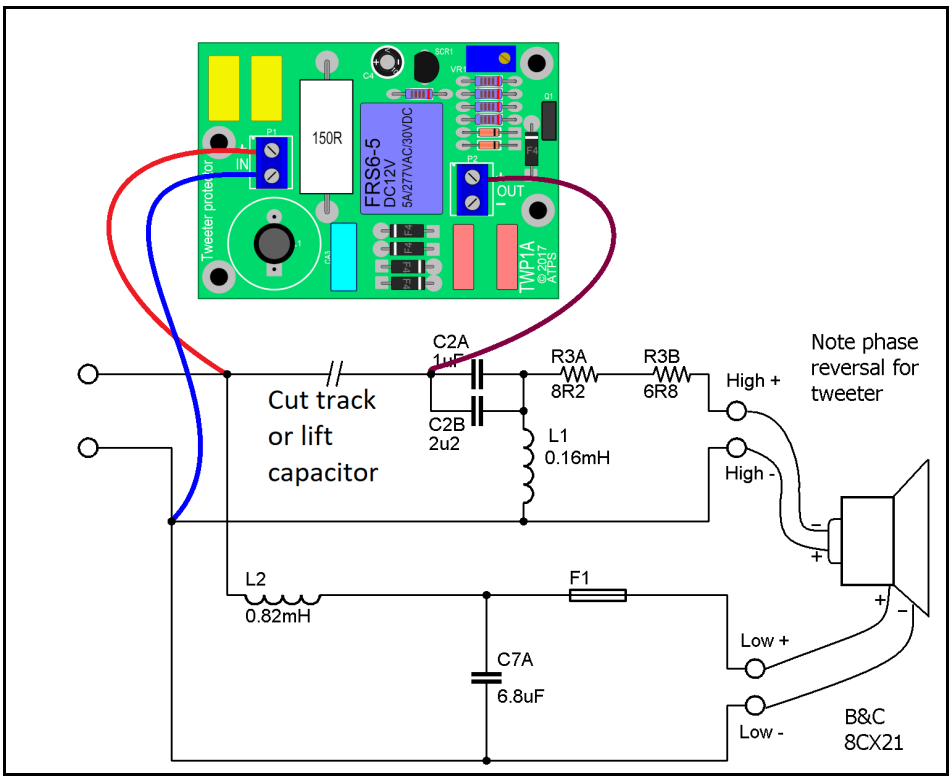
Ideally you want the trim-pot to cover 20 % or so of the range you are aiming for. So for example; if you wanted protection to trip at say 30 Watts at 8 ohms, this would be about 21.9V peak, subtract the voltage drop of the rectifier diodes, and this is now 20.7V.

If we chose a 16K resistor for R4, and a 5K trim-pot, this would give a range of between 17.8 and 22.8V which translates to between 19.7 to 32.4 Watts. Since 25 turn trim-pots are usually supplied halfway through their travel, it would be set at about 25 Watts before adjustment.

The circuit resets, when the input signal drops below the drop out Voltage of the Relay, typically somewhere below 3 Volts. When the Relay drops out C4 is switched across the SCR, and since it discharged through R6 when the circuit was tripped, this resets SCR1 by placing a monetary short across it.

Installation

The Tweeter protector goes between the Amplifier input and the high-pass filter on the crossover board.



The high-pass filter will usually consist of a capacitor in series with the Tweeter, and will usually have an inductor across the tweeter, there may also be other circuitry across the tweeter to stop tweeter resonance, and also have a resistor in series with the tweeter to attenuate it.

The circuit to the left shows a typical crossover, Resistors R3A and R3B make up the 'pad resistor' referred to in the Calculations above. In this case the pad resistor would be 15 Ω, if there is no pad resistor then use 0 for the pad resistor, when calculating the trigger voltage.

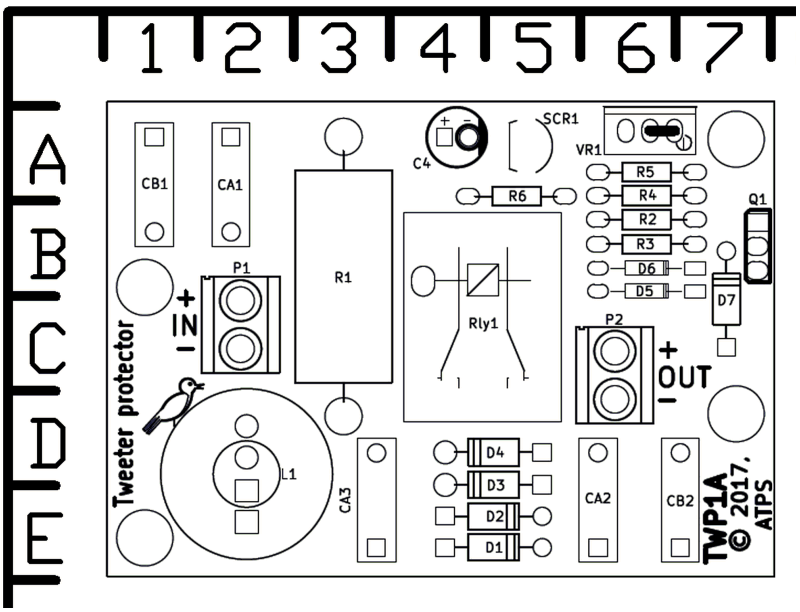
Depending on the type of capacitor used in the crossover, it may be easier to de-solder, and lift one end of the capacitor, than cutting a PCB track.

Notes

While I have allowed for screw terminals to be mounted on the PCB, I would strongly advise not using screw terminals in a high vibration environment, such as a speaker cabinet, instead solder wires directly to the PCB.

Construction

Parts locator

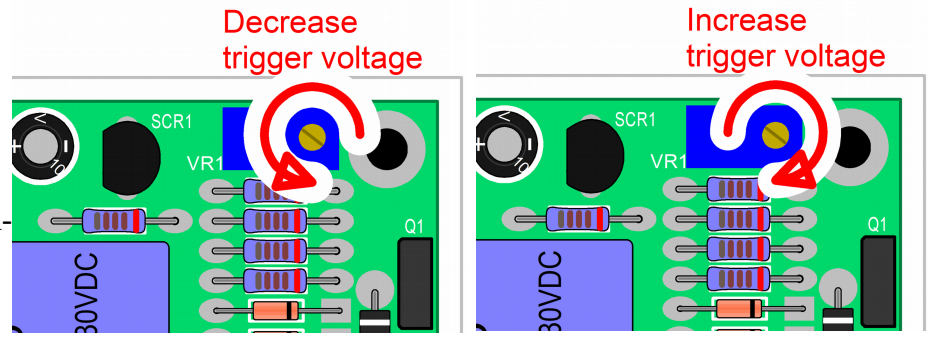


Part	Location	Description	Part	Location	Description
CA1	A1	Calculate	L1	D2	Calculate
CB1	A2	Calculate	P1	C2	
CA2	E6	0.47uF >100V	P2	C6	
B2	E6	0.47uF >100V	Q1	B7	MJE350 or equivalent
CA3	E3	Calculate	R1	B3	150R 5W
C4	A4	10µF 63V	R2	B6	20R
D1	E4	UF4007	R3	B6	15K
D2	E4	UF4007	R4	A6	Calculate
D3	D4	UF4007	R5	A6	560R
D4	D4	UF4007	R6	A5	2R2
D5	C6	1N4148	RLY1	C4	SRE-12VDC-SD-2C
D6	B6	1N4148	SCR1	A5	BT169
D7	C7	1N4007	VR1	A6	Calculate

Adjustment:

To increase the trigger voltage turn trim-pot clockwise, to decrease turn Anti-clockwise

To set-up the trigger voltage I suggest connecting the protection circuit to the output of an amplifier (before you install it in the speaker), adjust the trim-pot fully clockwise (you will usually hear a small click when you get to the end).



Next run a signal at least 2 octaves higher then the crossover frequency, and set the output of the amplifier to the required trigger voltage*.

Now slowly turn the trim-pot anti-clockwise until you hear the relay click.

***Note: Many Multimeters (particularly lower cost ones) have poor frequency response, and are only accurate below 1Khz, this will result in the trip point being higher than you expect.**

I suggest using an Oscilloscope to set trigger levels.

Calculation Summary and scratch pad:

The blank area to the right of these equations is to give you room to rewrite these equations using the correct Values. Explanations of these equations are provided in the Circuit description.

As an alternative, an open office spreadsheet to calculate this is available at:

www.atps.net/Projects/Projects.html

Input Filter

(Butterworth alignment)

C1 = CA1+CB1

F = Crossover Frequency

150 = (suggested) resistance of R1

109 = parallel resistance of R1 and the 400 Ohm Relay coil, for a 320 ohm Relay use 102

C1 = 0.1125/(150 × F)

In Farads, multiply by 1,000,000 for µF

CA3 = (0.1125/(109 × F)) – C1

The capacitors will need to be rated for peak voltage out of the amplifier, an amplifier capable of 1000W RMS into 8Ω can deliver 126V peak, so I suggest capacitors with at least 150V rating.

L1 = 0.2251 × 150 × F

In Henries, multiply by 1,000 for mH

The inductor will have to handle less than 250mA, and inductor resistance of up to 15Ω or so, will make little difference to the filter.

Trigger Voltage

Vt = Tweeter Voltage

Tz = Tweeter Impedance

Tp = Tweeter Power

Pr = Pad Resistor'

1.76 = twice the Forward voltage of D1-D4, plus 0.56V (across R5)

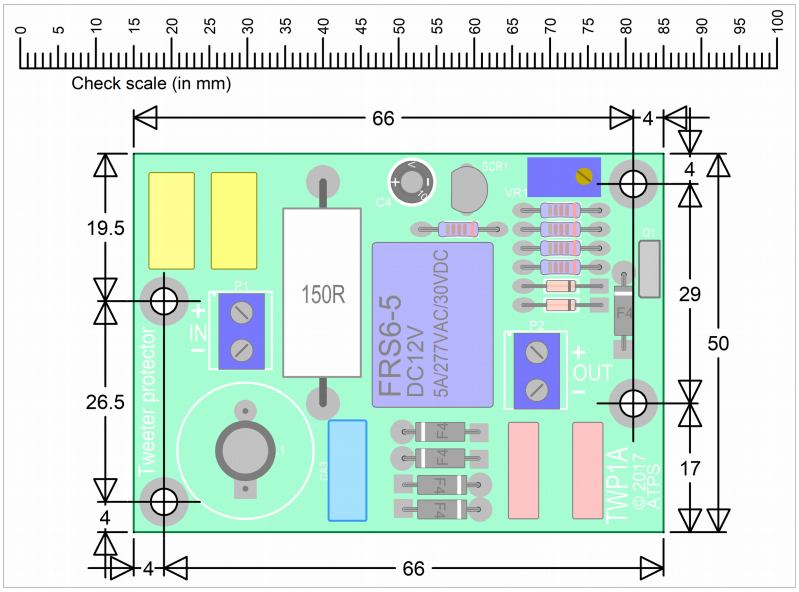
Vt = (√(Tz × Tp)) × 1.414

Tv = Vt + (Vt × (Pr/Tz)) – 1.76

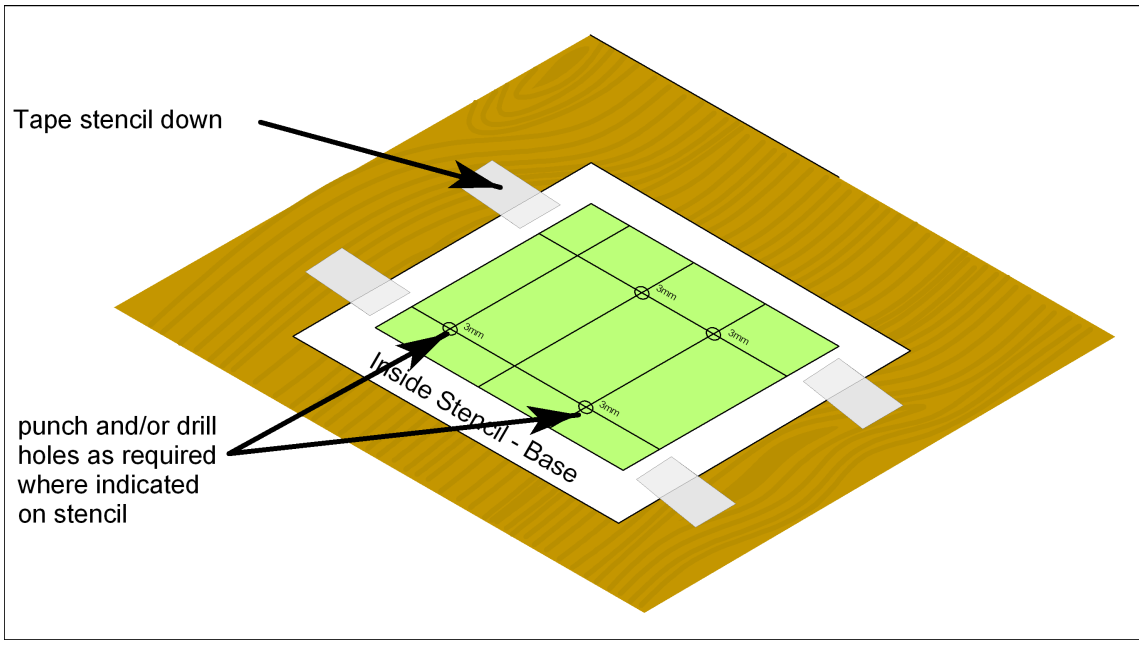
R4 + VR1 = (Tv – 0.56) × 1000

Template

Inside Stencil – Base



Note: print PDF as “Actual size” DO NOT “Fit” “ Shrink oversized pages” or “Custom scale”. Cut around the template, tape where you wish to mount the crossover and using a punch. Mark where the screws to mount the PCB are to go, as shown below.



Bill of Materials

Part no	Qty	Description	Notes
CA1	**1**	Calculate	
CB1	**1**	Calculate	
CA2, CB2	**2**	0.47uF >100V	
CA3		Calculate	
C4	**1**	10µF 63V	
D1-4	**4**	UF4007	
D5-6	**2**	1N4148	
D7	**1**	1N4007	
L1	**1**	Calculate	
Q1	**1**	MJE350 or equivalent	
R1	**1**	150R 5W	
R2	**1**	20R ¼ W Metal film	
R3	**1**	15K ¼ W Metal film	
R4	**1**	Calculate	
R5	**1**	560R ¼ W Metal film	
R6	**1**	2R2 ¼ W Metal film	
RLY1	**1**	SRE-12VDC-SD-2C	
SCR1	**1**	BT169	
VR1	**1**	Calculate	

* Relay notes

I designed the PCB using what was (for me) a readily available relay, with the expectation anything I could get in Australia would be widely available overseas also, it turned out to be less common than I hoped.

For Australian buyers this Relay is available from Jaycar as Catalogue number SY4062.

Songle SRE-12VDC-SL-2C or FRS6-5-DC12 are also available on Ebay with a 320Ω coil, just confirm that contacts are rated at 5 Amps.

Relays with a 320Ω coil may be used, however R4 will need to be changed to 16Ω, and when calculating CA3, use 102 instead of 109.