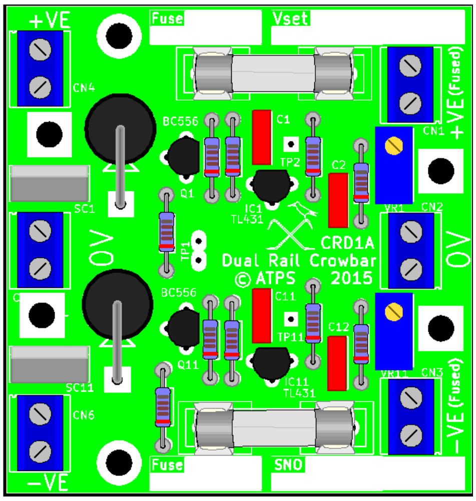
Australian Technical Production Services

Dual Rail Crowbar



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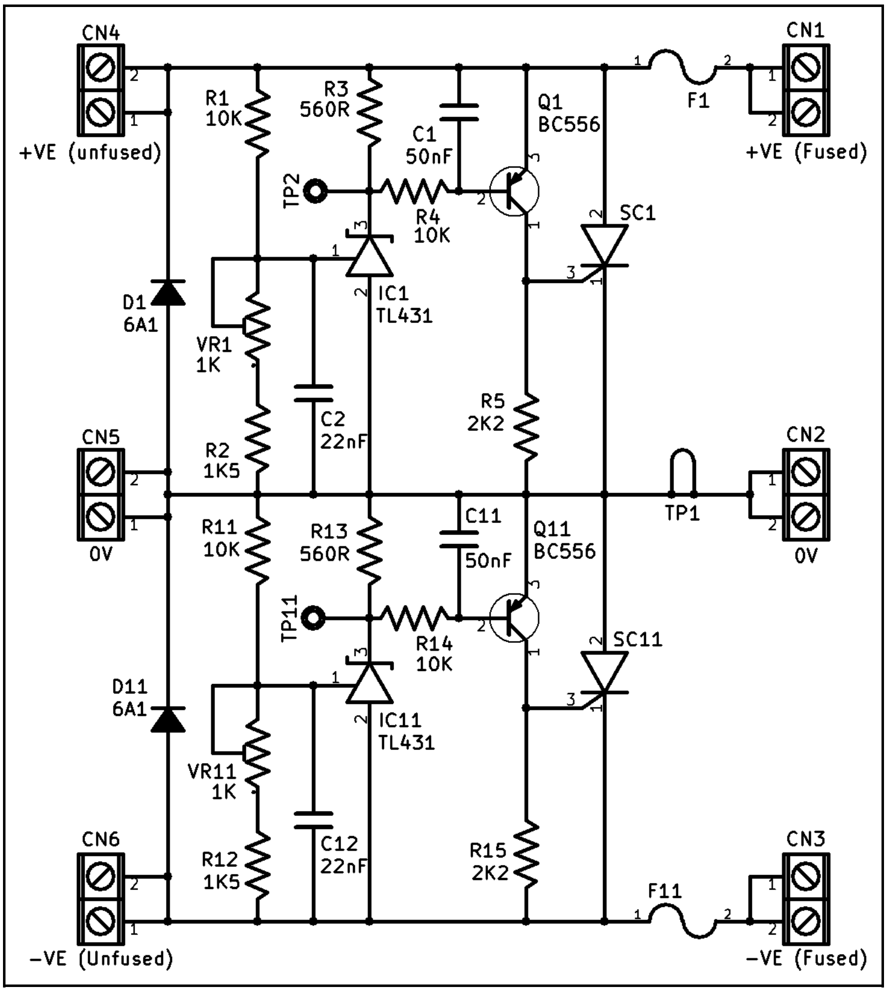
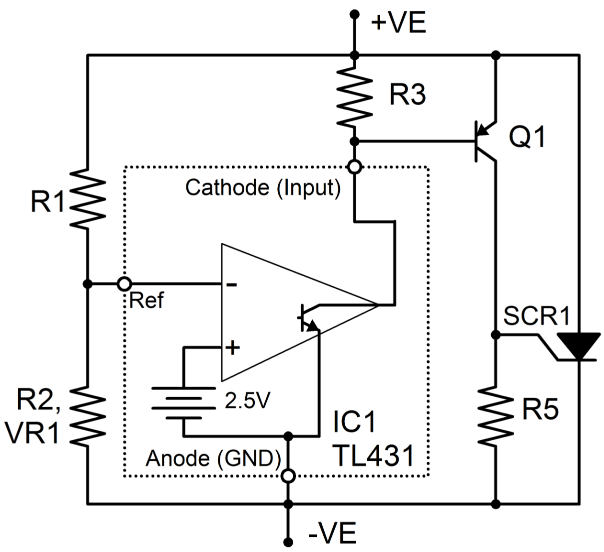
Dual rail crowbar

Project description

A Crowbar is a circuit that places a short circuit across a power supply in the event that a fault occurs that results in the power supply providing a higher voltage than the circuit can handle. The crowbar tripping will usually result in the power supply going into current limit mode or (in the event it is completely cactus) blowing supply fuses.



This board is for two independent crowbars, one set up for a positive supply rail, the other for a negative supply rail, this makes it ideal for protecting audio equipment such as mixing consoles. The positive crowbar uses part references from 1 to 10 (i.e. R1 to R5) while the same parts in the negative crowbar have 10 added (i.e. R11 to R15).



The diagram on the left shows a simplified version of the circuit, with the internal workings of the TL431 inside the dotted square.

The TL431 acts as the voltage detector, it is essentially a comparator comparing the reference voltage on pin 1 with an internal 2.5V reference.

The trip voltage is set by a voltage divider consisting of R1 (R11) and the combination of VR1 and R2 (VR11 and R12). When the trip voltage exceeds 2.5V, the TL431 starts shunting current to ground, which will draw current through the base of Q1 (Q11) turn Q1 on, which in turn will fire the SCR SC1 (SC11), shorting out the power supply.

D1 and D11 provide reverse polarity protection, so if a power supply is connected in reverse they will short the power supply and blow the fuses.

Note that the crowbar will remain tripped until it loses power completely, either due to the fuse blowing, or the power supply being switched off.

A few words about notation

You may have noticed on the schematic I use component values like 4u7, 2K2, 8R2 and 51R, so what's this about?

In the 'old days' of paper schematics, (yes OK, I do still prefer to work off print outs, I must be a follower of the great Ned Ludd) diagrams could knock about a workshop for some time getting dirtier and more tattered as time went by, or alternatively would be photo-copied time and time again (and indeed some of the schematics in my library are copies of copies of copies). This meant that after a while, it could become difficult to distinguish small, but vitally important characters such as the decimal point (**.**) due to everyday wear and tear, dirt or just noise in one of the copies. To get around this it was decided to replace the decimal point with the multiplier.

So 2,200 Ohms becomes 2.2K Ohms, then we replace the decimal point with the multiplier (in this case K) to give us 2K2 Ohms. Since resistors are usually measured in Ohms, the word ohms (or the symbol Ω) is redundant and only takes up valuable real-estate, so we drop it to end up with 2K2.

Likewise with Capacitor values, 4.7uF changes to 4u7F, and then we drop the redundant F to end up with 4u7.

So what about 51Ω? Well since the standard ASCII character set does not include the Ω symbol, so instead R is often used to denote Ohms (much like u is used, instead of µ or mu), next Resistors frequently have values greater than 100Ω so we need to clarify that that this is 51 Ohms, rather than say, 51 KΩ, so as an exception to the dropping the unit of measurement rule above, we express this as 51R.

Likewise 8.2Ω, since we have no multiplier and cannot print an Ohms symbol (in ASCII), so R is used instead giving us 8R2.

Construction

The entire circuit fits on a single circuit board measuring 60 by 65mm.This should be compact enough to fit into most equipment.

Fit the Resistors first, followed by the capacitors, Diodes, Terminal blocks, Integrated Circuits, Transistors and finally the SCRs.

Provision has been made for a screw mounted metal bracket to hold the SCRs in place, this is advisable where higher current power supplies are in use (say 3 Amps or more) as this will also improve the connection to the Anode of the SCR.

Heatsink

Under normal use the SCRs will dissipate relatively low power, even with the crowbar tripped, so shouldn't need much in the way of heat-sinking.

To calculate required heat-sinking, first we need to calculate the power dissipation in the SCR in tripped state, this depends on the current of the source power supply and the SCR used.

For this example I am going to assume a short circuit current, or I_{SC} of 5 Amps, the SCR is a TYN640, and maximum ambient air temperature, or T_A is 45°C (not unusual inside equipment).

From the TYN640 data sheet we need the following parameters:

Junction to case Thermal resistance or $R_{th(j-c)}$	: 0.8°C/W
Maximum Junction temperature or T_J	: 120°C
Maximum forward Voltage drop or V_{TM}	: 1.2V

Using V_{TM} and I_{SC}, we calculate power dissipation when the SCR is triggered; $P_{DIS} = I_{SC} \times V_{TM}$ or 6 Watts

if we start with the Junction at 120°C, and work outwards, the Temperature of the case, or T_C needs to be less than; $T_C = T_J-(P_{DIS} \times R_{TH(J-C)})$ so ; 120-(6 × 0.8) = 115.2°C.

So now we just need to calculate the desired thermal resistance (to air) of the heatsink or $R_{TH(H)}$, to do this we subtract ambient air temperature from the case temperature and divide the result by the power dissipation of the

SCR, so; $R_{TH(H)} = (T_C - T_A) / P_{DIS}$, So $R_{TH(H)} = (115.2 - 45)/6 =$ or 11.7°C/W and if we allow, say 1°C/W for mounting etc, then any heat-sink less than 10°C/W would be more than adequate. Of course if you are using the fused input the SCR will only need to dissipate power briefly.

While provision has been made for 5mm (0.2”) pitch screw terminals you may decide that these add extra expense and potentially may decrease reliability (particularly if the equipment is to be transported frequently) so I would usually recommend soldering wires directly to the PCB, when and if practical.

The reverse polarity protection diodes are mounted vertically, with the Cathode down, Various diode data sheets I read, de-rate the power dissipation of diodes by around 20% when mounted horizontally, presumably as this obstructs cooling / airflow around the device.

Mounting is shown in the picture on the Left.

The trim-pots allow the trip voltage to be set to somewhere between 12 and 19 Volts which should cover most applications. If this does not cover the range you require, you may vary the values of R1 (R11) R2 (R12) and VR1 (VR11) if this range is not suitable, the trip voltage may be calculated by:

Vtrip=(Vref/R2)×R1+Vref where Vref is 2.5. and ideally R2 = R2 + VR1/2. So for example if I wanted a trip voltage of 24V, and for the sake of this exercise decide to stick with 10K as R1;

24 = (2.5/R2)×10,000+2.5

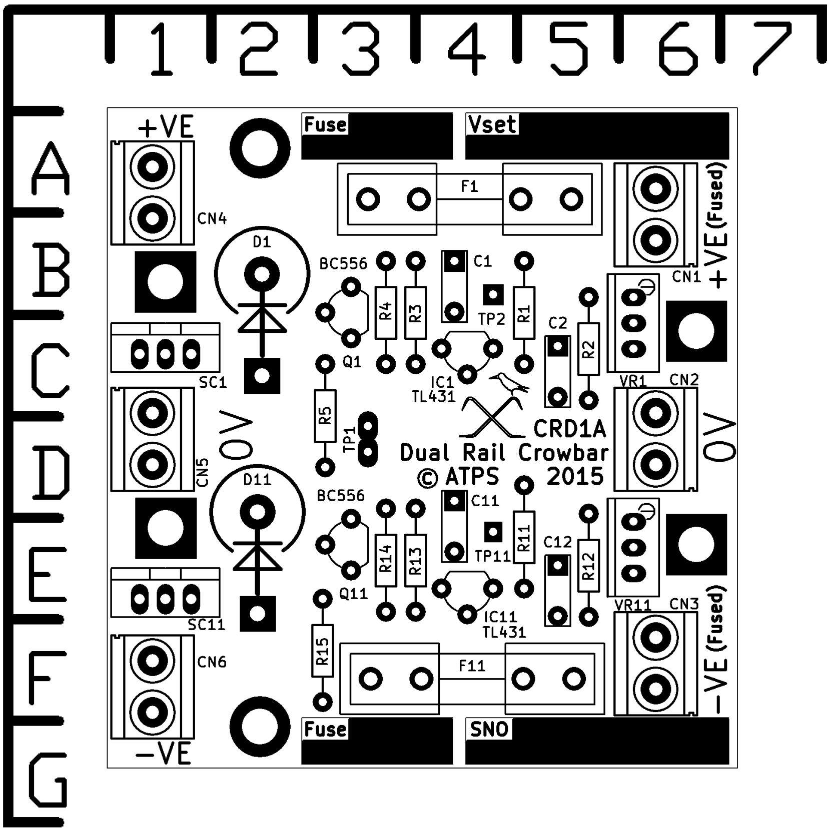
which is the same as;

R2=2.5/((24-2.5)/10,000)

so R2 = 1,162 ohms, now ideally we want VR to be set somewhere around the middle, or 500Ω leaving 662Ω for R2, so we would go for the nearest E24 value of 680Ω, alternatively since VR1=1K was selected more to provide a wide range of trip voltages rather than accuracy, you may choose to go with R2=1,100Ω and VR2=100Ω

Note the maximum voltage the TL431 can handle is 36V, so this circuit is not suitable for supplies over 36 Volts per rail.

Layout.



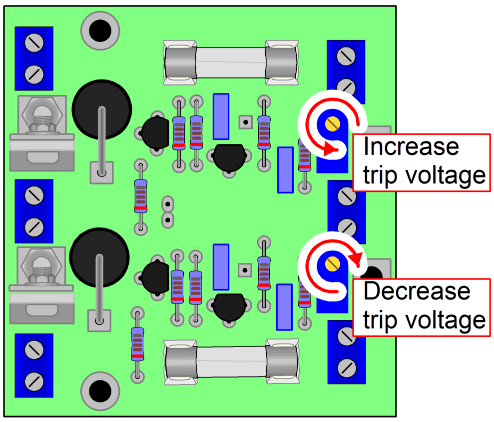
Parts locator

Part	Location	Description	Part	Location	Description
C2	C5	22nF	R13	E3	560R 1/4W 1% Resistor
C12	E5	22nF	R2	C5	1K5 1/4W 1% Resistor
C1	B4	50nF	R12	E5	1K5 1/4W 1% Resistor
C11	E4	50nF	R15	F2	2K2 1/4W 1% Resistor
D1	B2	6A1 6 Amp diode	R5	D2	2K2 1/4W 1% Resistor
D11	E2	6A1 6 Amp diode	R1	C4	10K 1/4W 1% Resistor
F1	A4	Optional Fuse (See text)	R4	C3	33K 1/4W 1% Resistor
F11	F4	Optional Fuse (See text)	R11	E4	10K 1/4W 1% Resistor
IC1	C4	TL431 precision shunt regulator	R14	E3	33K 1/4W 1% Resistor
IC2	E4	TL431 precision shunt regulator	SC1	C1	TYN640 (or equivalent) SCR
Q1	B3	BC327 NPN Transistor	SC11	E1	TYN640 (or equivalent) SCR
Q11	E3	BC327 NPN Transistor	VR1	C5	1K 25 Turn, Trimpot
R3	C3	560R 1/4W 1% Resistor	VR11	E5	1K 25 Turn, Trimpot

Setup

First you need to decide what voltage to set the crowbar to trip at, Analogue circuitry such as that found in mixing desks will generally survive up to 18V, as this is the maximum voltage for most Op-Amps.

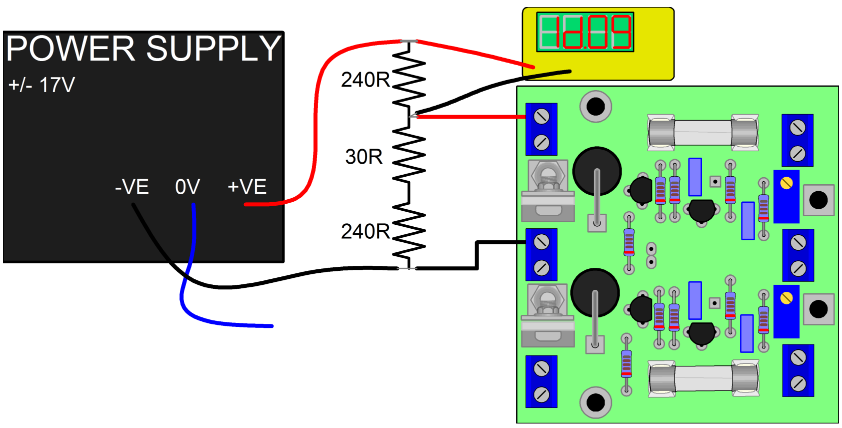
Now turn the trim-pots completely anti-clockwise, as this will set the trip point to the maximum voltage. Usually new trim-pots will be about midway, so will require about 12-13 turns to reach maximum, you will usually feel them click when they are at the end of their range.



If you have access to a variable voltage power supply, then set the supply to current limit at about an amp (or less), set the power supply to the desired trip voltage, connect up to the crowbar, and slowly anti-clockwise until the crowbar trips. Repeating for both rails.

If you do not have access to a variable power supply, you will need 2 × 240R 5 Watt resistors, 1 × 30R resistor (only needs to be 0.25W), the power supply for the equipment you wish to protect and a multimeter.

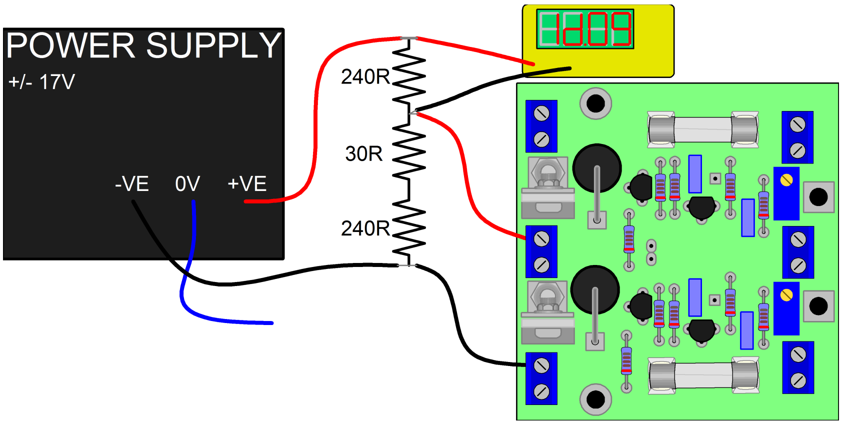
As before set the trimpots fully anti-clockwise, then connect up the supply (we are only using the positive and negative rails, the 0V rail can be left unconnected), multi-meter (set to measure voltage) and resistors as follows:



Slowly adjust trim-pot VR1 clockwise until the Crowbar trips – this will cause the voltage reading on the meter to increase to show the combined voltage of both rails (in this example, we have a +/-17 Volt supply, so the voltage will increase to 34 Volts).

To confirm that it should not nuisance trip, short out the 30R resistor, disconnect power momentarily and the voltage reading should now be the rated voltage of the one rail of the supply (in this example 17V).

Now connect up to the other side of the crowbar:



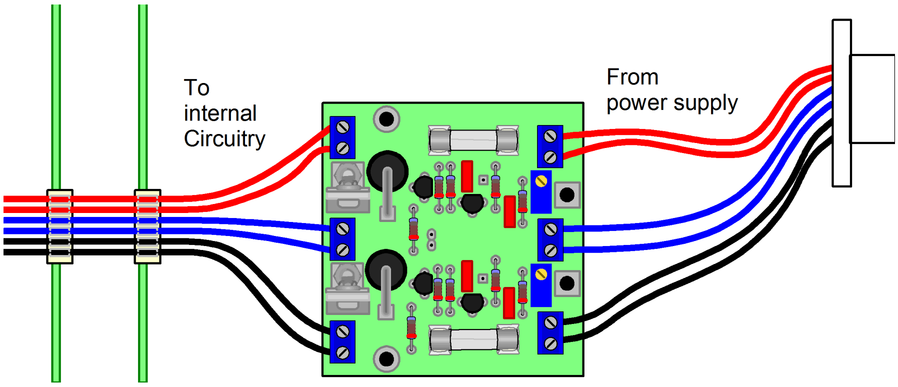
And repeat set-up for that side using VR11.

This procedure will set the trip voltage at around 1 volt above the supply (for a 15-17 volt supply).

Using the Crowbar

Series connection

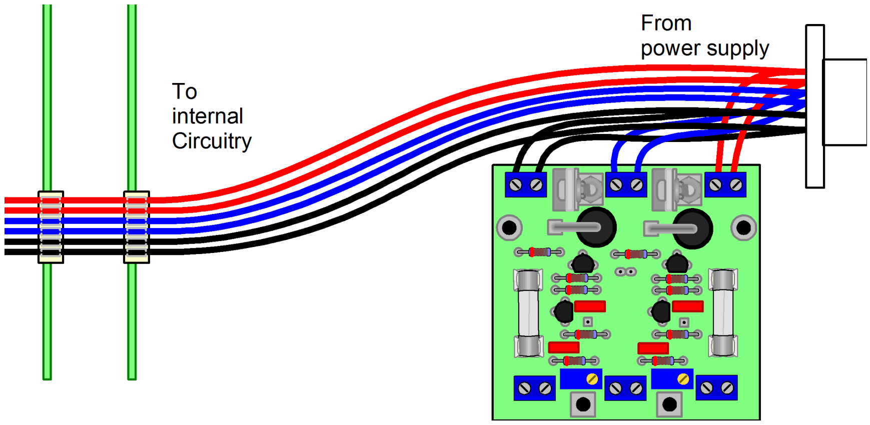
I would recommend wiring the crowbar in series, between the power supply and Electronics being protected, and fit appropriately sized fuses to the board, as per:



Connect the power supply to the fused terminals (+VE (fused) and -VE (fused)) then power out from +VE and -VE to the (protected) electronics, while the 0V rail connects to the 0V terminals.

Parallel connection

While I strongly recommend series connection as per the first diagram, if you have faith in up stream current limiting (and fuses etc.) the Crowbar could instead be wired across the power supply, using the unfused terminals (which are simply marked +VE and -VE).



Parts list

This circuit contains no critical parts and substitutes of components with similar ratings can be made. While 1% metal film resistors are specified and would be preferable for reasons of stability, resistor values are not critical, and the trim-pots will easily compensate for 5% tolerance resistors.

The SCR needs to be able to handle the surge from a failed power supply, this may include discharging filter capacitors. The SCR specified will handle a surge current of 480 Amps, this would assume a resistance of 0.05 ohms on a 25 volt (unregulated) rail in series with the filter capacitors, which is a very conservative assumption given that the ESR of a typical Filter capacitor alone, will be several times that.

The Transistors were chosen for their ability to handle relatively high current (in order to reliably trip the SCR) which could (presuming 36V, being the maximum voltage the TL431 can handle) be in the order of 100 to 630mA although this is of short duration (only until the SCR fires) so it is not expected to result in significant power dissipation in the Transistor.

Qty	Ref	Description	Notes
2	C1, C11	56nF MKT capacitor	
2	C2, C12	22NF MKT capacitor	
2	D1, D11	6A1 6 amp rectifier	
2	F1, F11	Optional fuse (See text)	
4	F1, F11	M205 Fuse clips	
2	IC1, IC2	TL431 precision shunt regulator	
2	Q1, Q11	BC327 PNP Transistor	
2	R1, R11	10K 1/4W 1% Resistor	
2	R2, R12	1K5 1/4W 1% Resistor	
2	R3, R13	560R 1/4W 1% Resistor	
2	R4, R14	33K 1/4W 1% Resistor	
2	R5, R15	2K2 1/4W 1% Resistor	
2	SC1, SC11	TYN640 (or equivalent) SCR	
2	VR1, VR11	1K 25 Turn, Trimpot	

Template

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Use the "Check scale" to confirm that the template has been printed to correct scaling, measure the distance of the scale with a ruler and confirm that it is indeed 80mm in length before using the Template.