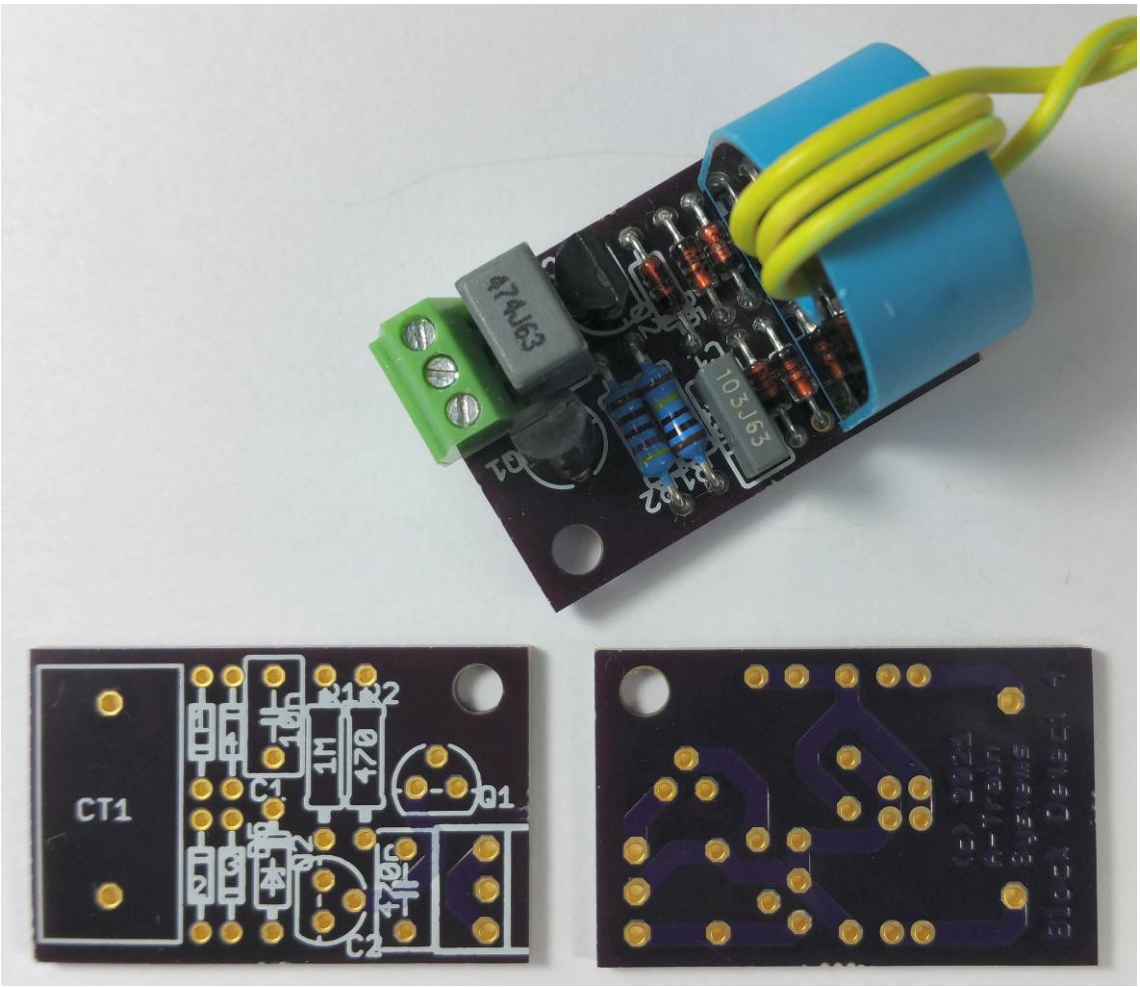
A DCC Block Detector using the ZMCT103C Current Transformer

Introduction

This DCC block detector is designed around the ZMCT103C 1000:1 current transformer, which is readily available at low cost from a wide selection of Chinese suppliers, rather than the more expensive 300:1 transformer, such as used in the NCE BD20 unit, especially as these transformers have recently become more difficult to source.

The assembled module and its printed-circuit board (PCB) are shown below –



Building the module requires some familiarity with electronic components, together with the ability to use a fine-tip soldering iron, but does not require any particular electronics expertise.

The PCB is available from OSH Park, a small company located in Lake Oswego, Oregon, via this link – AT-DCCBlockDetect-4. They will supply three PCBs for US$4.75 including free shipping to any destination worldwide.

If you then want to order a set of PCBs (in multiples of 3) click the button labelled **Order Board**, enter your e-mail address, name, and a password of your choice to establish an account with OSH Park, then follow their ordering process. You can pay either with a credit card or via PayPal. Your boards will be manufactured and delivered within two or three weeks depending on where you are in the world. If you prefer to use an alternative PCB supplier then,

instead of clicking Order Board, just click on **Download** to download a copy of the DCC Block Detect PCB file in Eagle board (.brd) format which you can then send off to your preferred supplier. Where the supplier cannot accept a file in Eagle .brd format, a copy of the PCB Gerber files can be downloaded from here.

Please note that neither A-Train Systems nor myself have any connection with OSH Park other than as a very satisfied customer of their services.

The parts required to build one DCC Block Detect module are listed in the table below –

Part	Reference	Quantity	Value
Terminal Block, 2.54mm pitch, 3-Way	X1	1	
Capacitor, Polyester, 63Volt	C1	1	10nF (0.01uF)
Capacitor, Polyester, 63Volt	C2	1	470nF (0.47uF)
Current Transformer (1000 turns)	CT1	1	ZMCT103C
Diode	D1 – D4	4	1N4148
Zener Diode	D5	1	BZX55-C5V6
Transistor, General Purpose NPN	Q1, Q2	2	2N3904
Resistor, Metal Film, 0.25Watt	R1	1	1M (1 Megohm)
Resistor, Metal Film, 0.25Watt	R2	1	470R (470 ohm)

Notes :

1. The terminal block is an optional part. You can solder wires direct to the PCB instead of using screw terminals. Note that the centre connection (X1-2) is Ground, and that the Block Detect output can be taken from either of the two outer connections (X1-1 or X1-3).
2. Suggested suppliers for the parts listed above are RS Components or Farnell for users in the UK, or Newark for users in the USA (part of the same company as Farnell). Mouser or Digikey are alternative sources in the USA, although their prices tend to be a little higher than Newark.
3. For the ZMCT103C current transformer, a number of Chinese suppliers can be found on the AliExpress website. Search for the part from a supplier with a 5-star rating, and PayPal is recommended as the safest way to pay for purchases.
4. The total cost of parts for a single DCC Block Detect module should be less than US$3.00, and even less if you omit the terminal block, plus the additional US$1.59 for the PCB.

You may be able to source equivalent parts locally at a lower cost, using the details available for each suggested part by clicking on the links below (assuming that you have sufficient electronics knowledge to understand the specifications). There is generally no problem buying components from established suppliers on eBay, for example, but beware of purchasing very low cost parts since these are often of low quality or may be manufacturers' substandard rejects.

Buying electronics components singly or in small quantities is much more expensive than buying in bulk (in quantities of 10 or more), so it is well worth considering carefully at the outset how many modules you might build, and then procuring all of the required components in a single purchase. This will also reduce any shipping charges.

The table below gives suggested part numbers for each DCC Block Detect component from each suggested supplier.

Click on the part number to view the relevant webpage with details of the part –

Part	Farnell	RS Cmp	Newark	Mouser	Digikey
Terminal Block, 2.54mm pitch, 3-Way	3228590	717-6634	40Y2992	571-2828343	ED10562-ND
Capacitor, 10nF 63V	2763228	312-1431	18AC7625	80-R82EC2100DQ50J	399-5450-1-ND
Capacitor, 470nF 63V	2429337	312-1481	18AC7609	80-R82DC3470AA60J	399-8901-ND
CTx, ZMCT103C					
Diode, 1N4148	2675146	843-1562	05AC0533	512-1N4148	1N4148FSCT-ND
Zener, BZX55-C5V6	1779202	544-3604	55R1525	78-BZX55C5V6-TAP	BZX55C5V6-TAPGICT-ND
Transistor, 2N3904	1700648	739-0442	83C3116	512-2N3904BU	2156-2N3904-ON-ND
Resistor, 1M 0.25W	9341137	165-1306	95W7694	279-LR1F1M0	RNF14FTD1M00TR-ND
Resistor, 470R 0.25W	9341951	165-0864	95W7764	279-LR1F470R	RNF14FTD470RCT-ND

Once you have acquired your PCBs and a full kit of components, the next step is to start the assembly. If you do not have any experience of soldering electronic components then you should first have a look at one or two of the guides available on the Internet (such as at https://www.makerspaces.com/how-to-solder/) and some of the multitude of videos available on YouTube, although there is nothing to beat getting some copper stripboard from one of the component suppliers and practising soldering wires (and a few spare components) to it before tackling the real module PCB.

Use resin-cored solder in wire form only – never use solder with an acid flux (as sold for plumbing purposes) – and use a fine-tip soldering iron with a maximum power rating of 25 Watts. All joints should be made as quickly as possible to avoid damaging the PCB and components. The greatest enemy of electronics is heat.

Fit those components with least height to the PCB first, ie. the diodes and resistors, so that, when you turn the PCB over and lay it down to solder the component wires on the underside of the board, the components do not fall out of the holes. Ensure that the diodes are fitted the right way round, with the band or stripe at one end of the diode towards the centre of the PCB, as shown on the PCB markings. It does not matter which way round the resistor (or the capacitor at a later stage) is placed on the PCB.

A tip here is to solder just one wire from each component, then turn the PCB over and check that all components are still flush with the PCB. If not, make them so before soldering the remaining wire(s) of the component.

When you fit the transistor (as the next tallest components), ensure that the flat side of the package is towards the hole in the PCB, again as indicated by the board markings. Finally, fit the capacitor followed by the terminal block (if you decide to use one) and the current transformer. The recommendation is not to fit the variable resistor (and to buy no more than a few, if any) until checking how well the detector works on your layout.

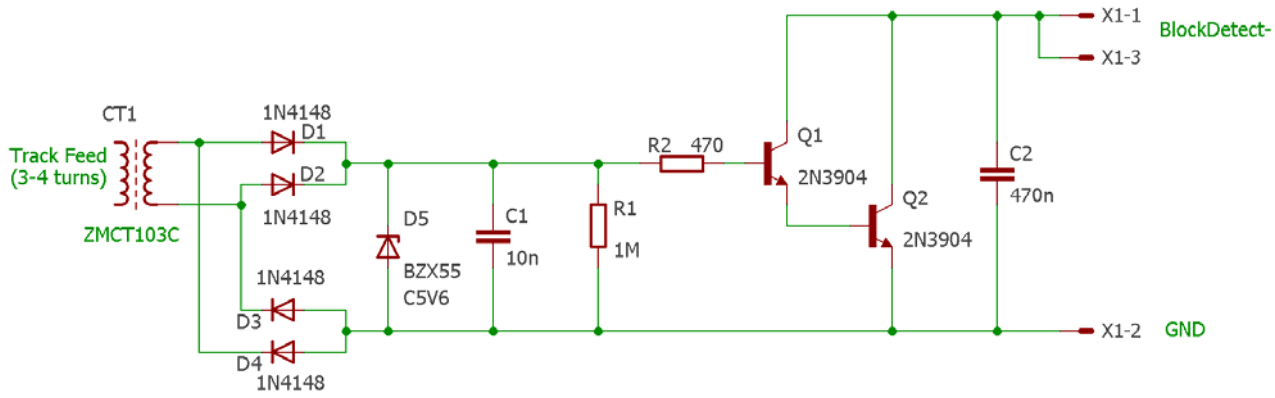
Carefully inspect the completed board to check that all of your soldered joints are bright and shiny, and that the solder has wicked through the PCB holes to the component side of the board. If you are uncertain of this then you can carefully apply your iron and a little extra solder to the joint again, but do not linger with the hot soldering iron. Check also that there are no solder bridges between copper pads or component pins anywhere on either side of the PCB. Use of a x5 or x10 hand lens or jeweller's loupe is highly recommended for this inspection.

To test the DCC Block Detect module, pass one of the feeder wires to an isolated section of track through the hole in the current transformer to form two or three loops, as shown in the photograph earlier in this section, and connect the DCC Block Detect output from either of the two outer connections (X1-1 or X1-3) to a spare input of an active AIU. Connect the centre connection (X1-2), which is Ground, to the AIU common Ground terminal. Now connect your isolated section of track to the DCC supply and place one of your locomotives on the track – the AIU input LED should light to show that the block is occupied.

You can check the sensitivity of the DCC Block Detect module by getting a selection of resistors with values between 1K and 10K. Remove your locomotive from your section of track and instead connect one of the test resistors between the rails. With two loops of feeder wire through the current transformer, resistors up to around 4K7 should take sufficient current (3mA or more) from the DCC supply to trigger the module and light the AIU LED. Adding a third loop of feeder wire should improve the sensitivity to allow resistors up to around 6K8 (2mA current) to trigger block detection. Further information about block detection can be found on Alan Gartner's Wiring for DCC website.

For those interested, a brief technical description of the block detector design is given below.

Because the higher transformer ratio reduces the current coupled into the detector, more sensitive detection circuitry is required compared to that used in the NCE BD20, for example, (while still being kept as simple as possible), and the final operational design is shown below –



The small alternating input current, coupled from the DCC track feeder by current transformer CT1, is fed into a full-wave rectifier comprising diodes D1 – D4. The resultant direct current, smoothed by capacitor C1, then develops a voltage across resistor R1.

When the DCC current through the track feeder rises, due to the associated track block being occupied, the detector input current rises in proportion and develops a voltage across resistor R1. Zener diode D5 limits any voltage rise to a maximum of 5.6 volts to protect the other detector components.

As soon as the voltage across R1 reaches around 1.4 volts, any additional input current will flow through resistor R2 and switch on transistors Q1 and Q2. When the Block Detect output (terminals X1-1 and X1-3) is connected to a microprocessor input (such as those of an Arduino module or the PIC microcontroller on an NCE Auxiliary Input Unit) these transistors, connected in a high-gain (Darlington) configuration, will draw sufficient current to pull that input to ground (GND or 0 Volts), providing a signal that the track block is occupied. Capacitor C2 provides additional smoothing of the output signal and protects the attached microprocessor input from any damaging voltage spikes.

Note that the block detector cannot sink enough current to light an LED on its own – any such indication needs to be done separately by the attached AIU, Arduino module, or additional circuitry.