**A DCC Block Detector and Cutout   (BDC1)**

This is a design for a combined sensitive block occupancy detector and overload cutout unit for DCC systems. It will not work on DC.

**Introduction.**

It is often useful to divide a DCC layout into sections or blocks so a short in one block doesn't cause all other sections to lose their power. On large layouts, it is common to power each of several blocks with a separate booster which will have its own inbuilt cutout but on smaller layouts where the power requirement is less, a single booster would be used for the whole layout. It is this latter case where a block cutout is useful. A block cutout for this purpose must act fast enough so that it will trip before the main booster and preferably at a current less than the booster. As a layout will require several cutouts, a low cost is important.

A DCC cutout requires an electronic switch to break the track supply. A relay is not fast enough. It also must not drop more than a minimal voltage when supplying track current, up to the maximum current allowed. This means a switch with a very low resistance. Also there must be a method of sensing the current which itself doesn't contribute to a voltage drop. It should also be powered from the DCC supply and not require a separate power source. It requires more than a simple piece of electronics to meet these requirements.

DCC has the advantage that the current is alternating and at a reasonably high (5KHz to 8KHz) frequency. This allows the current to be measured using a 'current transformer' which has negligible voltage drop in the track circuit. As there is now a voltage proportional to the track current, it was possible to use this voltage to detect very small currents as well as a simple short or overload. With suitable amplification, currents of a milliamp could be detected so a combined unit with block detection of 'resistor axles' of 10Kohm was designed. (It would be possible to just use the BDC1 as just a block detector by leaving out the cutout components).

**Description**  (refer to schematic  BDC1_sch.pdf)

While it might have simplified the circuitry, this design does not use a programmable microcontroller (PIC) so is well suited to home construction.

The current is sensed with the CS1200 (Coilcraft) current transformer. Provided the secondary is terminated with a 200 ohm resistor, this gives a sensitivity of 1 volt per amp and a good frequency response a DCC frequencies. The primary is one turn with the wire simply threaded through the core centre hole so the voltage drop is negligible.

Detecting a high current (overload) is simple. The secondary voltage (DCC waveform) is divided down by the resistor chain R7 to R11. The values are chosen to give trip levels of 1, 2 or 3 amps and also keep the transformer load at 200 ohms when paralleled with R26. The selected voltage passes via R14 to U5/3 which is a comparator. Diodes D3 and D4 are voltage clamps to prevent damage to U5 as, under short circuit conditions and a high power booster, the transformer secondary voltage will exceed the safe limits of the amplifier. When the voltage applied to the comparator exceeds the threshold of +0.65v, the output at pin 6 will go low. However, as the waveform is alternating, the comparator will only trigger on the positive half cycles. D10 allows capacitor C8 to charge down through VR2 until the voltage falls below trigger level of the monostable in U2. U2 is set to trigger on a falling edge and has Schmidt inputs. VR2 allows for an adjustable short delay between the overload and the cutoff of between 0 and 20 millisecs. This was found necessary with some decoders which had a current inrush when power was supplied. This inrush was sufficient to keep tripping the cutout. However, the delay should be set to the minimum possible.

When the monostable is triggered by the overload, the output on pin 4 goes low and that on pin 13 goes high (complementary outputs). Pin 4 going low turns off Q5 thus removing base current from Q6 which also turns off. Q3 and Q4 are ‘back to back’ N channel power MOSFETs which comprise the electronic switch for the track power. Two MOSFETs are required as they have inbuilt diodes between the source and drain and so will only turn off in one direction. Resistors R22 and R24 ensure that the gate – source voltage is zero when Q6 is off. When Q6 is on, the gate voltage is the rectified track voltage, typically 12 to 15 volts so the MOSFETs are turned on. They do not need to be logic level devices. An ‘on’ MOSFET is just a low resistance and current can flow in either direction.

There is a wide choice of suitable MOSFETs for this application and you can select on price and availability. The Vds rating must be at least twice the track voltage. For a 14v track, a Vds of 30 or more should be used. The on resistance Rds(on) should be as low as possible. There are two MOSFETs in series so the total resistance will be twice that of one MOSFET. The on resistance determines how hot the MOSFETs will get when supplying track current and also the voltage drop in the cutout device. Cheap power MOSFETs are available with an on resistance of 0.05 ohms or less and more expensive ones down to 0.005 ohms. Two devices with 0.05 ohms introduce 0.1 ohms into the circuit. At 3 amps this will drop 0.3 volts and dissipate 0.9 watts between them. However, in practice it is most unlikely that a block will draw 3 amps continuously if ever. For a single loco at a typical motor current of 300mA, the drop would be 30 millivolts.

In line with the usual practice of DCC boosters, the BDC1 uses a ‘cutout and retry’ protection principle. Once the monostable in U2 has been triggered, the MOSFET switch remains off for about 0.5 seconds set by R6 and C3. The power is then turned on again. If there is still an overload, the process is repeated. This means that under continuous overload conditions, the MOSFETs are only on for very brief intervals so do not get hot.

Q2 is turned on during an overload condition and will operate an audible warning device (12v) and cause current to flow in the opto coupler U4. This can be connected to external circuitry to indicate where the overload is. Alternatively, U4 can be left out and a local LED fitted instead.

The BDC1 is powered from the DCC booster output. The DCC power is rectified by D1 (a fast diode) and C1 is charged up to the track voltage. R1 prevents a surge current as C1 charges as this would otherwise trip the booster cutout. Regulator U1 reduces the voltage to a fixed 5v for the rest of the circuit.

**The occupancy detector circuit.**

The design objective was the detection of a 10K axle load as might be used on ‘resistor axles’ on rolling stock. This was quite a ‘tall order’ given that the current would be about 1.5 milliamps peak with a track voltage of 15v. The output of the current transformer now is only 1.5 millivolts so some amplification was required. U5/1 is a high gain amplifier stage adjustable with VR1 over x100 to x1800. It was found essential to use the amplifier in a linear mode so a reference voltage of halfway between 0 and 5v was created by U5/2 – a voltage splitter. The current transformer secondary is referenced to this 2.5v instead of 0v so allowing the amplifier output to swing + and – relative to the input. The choice of a suitable amplifier was also important. It had to work with a single 5v supply, have a low noise characteristic and be fast enough to amplify the DCC waveform without being limited by slew rate. The TS464 was the most suitable choice. Amplifiers like the LM324 and TL074 would not work.  D5 and D6 offer input protection together with R23 where a low value was needed to limit noise pickup on the input to U5/1. Note that the amplifier is an AC amplifier with C6 setting the low frequency response. DC drift is not a problem.

Occupancy detection uses a comparator in the same way as for the overload (U5/4). The threshold for both comparators is set at one diode drop above the 2.5v reference by D2. As for the overload, but without the delay circuit, an occupancy signal triggers the other monostable in U2. This is set to one second by C4 and R15. Occupancy detection will turn on Q1 and the opto coupler U3. J4/1 and J4/2 on the PCB allow a local LED if required as well as the opto. Alternatively, the opto can be omitted and a LED connected to the terminal block J3. Here a jumper should be fitted between J4/1 and J4/2.

As the sensitivity of the occupancy detector can be very high, some care is required in mounting the PCB away from wiring carrying high current DCC power. In extreme cases it may be necessary to mount the PCB in a metal box.

If you want to use the BDC1 purely as an occupancy detector, you can leave out all the components associated with the overload circuit but leave in R12. Fit a wire link between the source pad of Q3 and the source pad of Q4.

**Present situation.**

So far I have only tried one prototype on one layout. I cannot guarantee it will work in all circumstances. Would be interested to know how others get on. A quantity of the CS1200 transformers has been purchased by MERG for the 8 channel DTC kits. Some may be available for the BDC1.

It is important to note that this cutout arrangement acts in one track feed only. Where there are adjacent sections supplied by separate boosters or in reverse loops it is possible to get a short which would not be detected or protected by a single sided cutout like the BDC1.

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