MERG DCC Decoders (Versions 10 and 11)

Technical description (updated 21/4/2000)

Background.

The design started life as a copy of that by Dean Probst on his website. This was called a ‘N Decoder’ suitable for N scale locos. I built one and tested it ‘on the bench’ where it worked OK but even with a motor drawing 90mA, the L272M driver and the rectifier diodes ran hot and there was a substantial voltage loss in the L272. I had major problems with it in a real loco due to ‘brown outs’.
As my layout ran HO (US outline) locos, I needed a more powerful decoder so began a development of designs based on a MOSFET H-Bridge to drive the motor. MOSFETs are ideal for this application as they require no gate current, have low ‘on’ resistances - less than 0.2 ohms - and have ‘built-in’ reverse diodes which catch any inductive spikes. They are available in very small packages but have current ratings of several amps continuous and more than 10 amps for short bursts. All commercial decoders I have seen use surface mount dual MOSFETs in a H bridge. Disadvantages are a limit of 20 volts between the gate and source (Vgs), a high input capacitance (around 1000pF) and a need to avoid ‘shoot through’ where both the high and low side devices are on at the same time. As the ON resistance is so low, a very high - possibly destructive - current can flow as the supply is effectively short circuited.

The original design posted on the MERG resources page was Decod4. This used NDH8512C dual N-P MOSFET made by Fairchild. The circuit worked well and several are in use but Fairchild are discontinuing the NDH8521C. Decod4 also had extra circuitry for overvoltage protection. Decod4 was superseded by a new design approach using more readily available MOSFETs (Decod7) and a smaller version taking advantage of the PIC 16F84A in the SS package together with smaller MOSFETs and SOT323 transistors (Decod9). A number were made and are in regular use but they required double-sided PCBs with vias and were difficult to make. The design has now been revised to simplify construction. Decod10 uses single sided PCB with no holes, 0805 size resistors, SO-8 MOSFETs, SOT-23 transistors and a SO outline PIC. The layout allows the decoder to be cut in two down the middle and either used as two smaller sections or ‘folded back’ on itself to make a decoder which is half as long but with components on both sides. Double –sided PCB can be used for this but without the problem of accurate alignment of the sides or any through holes. With suitable choice of the output MOSFETs and bridge diodes, this version can be rated at upto 2.5 amps. A smaller version is Decod11. This is simply a scaled down Decod10 using 0603 size resistors, MSOP MOSFETs, SOT323 transistors and the SS version of the PIC 16F84A. Maximum rating of this is1.5amps. Both versions use the same PIC code (Decod10b.asm). Schematics and PCB layouts for both are on the MERG site. The schematic and principle are the same for both, only the semiconductor types are different.

The description will follow the schematic from left to right.

The Bridge Rectifier (D1 to D4)

Diodes for DCC rectification should have a fast switching time and, for safety sake, have a voltage rating at least that of the NMRA maximum of 27v. In a bridge configuration only two of the diodes conduct at any one time so it might be thought that the average diode current is half that supplied to the decoder i.e. a 1 amp decoder could use half amp diodes. However, under ‘stretched zero’ situations used for DC locos, one pair would be ON for most of the time. It is safer to rate the diodes at the full decoder current. Also the same diodes supply current to the ‘functions’ so this must also be allowed for.
Although slightly more expensive, Schottky diodes have an advantage for DCC decoders as they are available with a higher current rating for the same size compared with conventional fast diodes. They have a smaller voltage drop - about 0.4 v at full current compared with more than 1 v for ordinary diodes so run substantially cooler and allow more volts for the motor.
The BYD77B (Philips) is a conventional fast diode rated at 2 amps in a glass SM package and the RB051L-40 (Rohm) is a 3 amp Schottky in a plastic SMA package. The RB160L-40 is a 1 amp version which is cheaper. (GBP 0.25 each). The SMA package can only be used with Decod10 PCB as it is larger than the SOD-87 glass package (but the SOD-87 devices are OK for the Decod10 board).

The H bridge motor drive.

The circuit is of a fairly conventional design using dual P channel (Q12) and dual N channel (Q13) MOSFETs. Decod10 uses SO8 package devices and Decod11 uses the smaller MSOP package. Q1 and Q2 (Q1a/b on Decod11) are drivers for the P channel devices. They are ‘digital’ transistors with built-in base resistors. The logic level inputs to these transistors are motor direction lines. Either one or the other is turned on by the micro-controller provided Q8 is also on. The input to Q8 is the PWM (pulse width modulated) speed signal from the controller. This arrangement has two static direction lines and a single PWM input. It lends itself to further development as a feedback or ‘load compensated’ decoder as a back emf signal is easily obtained.
Resistors R4/R20 and R6/R21 were chosen so that the maximum Vgs of 20v for the MOSFETs is not exceeded if the supply rises to 27v to meet the NMRA specification.
Diode D5 is a 27v zener diode which also provides protection and catches any positive commutation spikes which may occur with some motors. R24 and R25 where found to be necessary as I found that with some motors, the commutation spikes were feeding back through the drain to gate capacitance of Q13 with sufficient energy to override the PIC outputs and causing a complete short circuit of the H bridge. (took me a while to find the reason for this.)
As with earlier decoders that I designed, the H bridge works with a DC input when there is no DCC. R1 or R5 sense the track polarity and turn on either Q1 or Q2. Also the rectified DC turns on Q8 through R2. The motor runs in the normal fashion except for some voltage drop in the rectifiers and a minimum threshold to turn on the MOSFETs. It works well with pulsed DC, either half/full wave rectified or true PWM.

The voltage regulator.

My initial designs used regulator ICs for the 5v logic supply. These were relatively expensive and hard to obtain in small (SOT-23) packages. Also the NMRA spec. called for the decoder to work down to a track voltage of 7v. Allowing for the drop in the bridge, this left very little for the regulator. I reverted to a discrete approach (which is actually a copy of Digitrax). R7 is a surge limiter. D6 sets the base voltage of Q10, in this case to 6.2v and the regulated voltage at the emitter is about 5.5v. C1 is a large as could be fitted. This arrangement almost meets the 7v spec. The reason for 5.5v rather than 5v will be explained in the next section.

The Brown-out circuit.

It was found essential to provide a brown-out reset for the PIC when used in real loco situations - dirty track, poor contact, rail gaps, putting the loco on the track with it live etc. The circuit and values I used were from the Microchip data sheet. D9 is 3.9v. Provided the PIC supply is more than 3.9 + 0.6 (4.5v), Q11 will be conducting and the MCLR (reset) pin 4 on the PIC will be held high. The PIC is run at 8 MHz so the spec requires 4.5 to 5.5 volts. Below 4.5v, Q11 will cease to conduct and MCLR will drop low so causing a reset. The basic supply voltage was chosen to be 5.5 to allow as big a margin as possible for short dips in the supply - the same reason C1 was made as large as possible.

The reset discriminator.

R22 and C2 provide a means for the PIC to distinguish between a short dropout or brown out and a genuine ‘power on reset’ (POR). After a reset condition, the PIC program checks the voltage on pin 3. If it is a logic low (<0.8v) then C2 has not had time to charge up so the supply must have been off for some time i.e. a POR or long dropout. In this case the program performs a complete reset and the loco speed defaults to stop. If pin 3 is still a logic high (>2.4v) then the dropout was short or less than 2.4v so the speed in the RAM will still be valid. The reset now uses this speed and the loco continues as if nothing had happened. This was found to be important if there was a short break in supply but the loco did not receive a valid speed instruction for some time. It would hesitate unnecessarily.

The PIC program.

The program is based on that by Dean Probst but with some significant modifications. Apart from the reset discriminator, the main change relates to the ability to revert to DC operation if there is no DCC. Until the PIC supply voltage reaches 4.5, the chip will be held reset and the port lines will be inputs - effectively open circuit. As previously described the motor will run in DC mode at a speed and direction dependent on the track voltage. When the PIC starts, it waits for a logic high on pin 8. It then waits for a logic low. (a high to low transition). If there is no transition it remains in DC mode. If there is a transition it checks the other input line (pin 9). If this is low, it must have been a DC pulse, e.g a PWM controller or pulsed DC so the PIC remains in DC mode. However, if pin 9 is high, there must have been AC on the track and the program assumes this to be DCC. Only now does it set the direction and PWM pins to outputs and go into DCC mode. Even if the AC is not true

DCC, the motor will be stopped and not subject to the AC voltage.
(Note. The PIC 16F84A-20/SS used for Decod11 has 20 pins. Pin 8 above is 9 and 9 is 10 for Decod11)

The PIC program uses the watchdog timer (as in the Probst program) to monitor loss of DCC. In the event of a watchdog reset, the decoder will revert to DC mode and check the track as before. Therefore the loco will automatically revert to DC operation if it runs onto a non-DCC section and switch back if DCC resumes. Unlike some commercial systems it is not possible to prevent it reverting to DC mode. These decoders will not work on pulsed DC or until the DC is more than 5v. I felt that it was more important for a decoder fitted loco to run well on a conventional track as this will be more common in the UK.

The motor drive arrangement has been modified to give two direction lines and a single PWM output. The program ensures that the direction can only change if the PWM output is low. This prevents possible shoot-through.

The H bridge drive method is different to most commercial decoders where the motor is driven during the PWM ON state and is effectively open circuit between the pulses. With Decod 10 /11, both low side MOSFETs are turned ON between the PWM pulses so the motor sees a low resistance in the OFF state. This has the effect of damping the motor and results in the motor speed being more closely related to the throttle position and less load dependent. Low speed running is improved, there is a much greater braking effect and brush sparking is minimised. The disadvantage is that the MOSFETs and bridge diodes run a bit hotter. This arrangement also seems to work perfectly with ironless rotor motors (Escaps etc).
(As the drive method is determined by the PIC software and the PIC can be reprogrammed in-situ, the drive can be converted back to the conventional method if wished. I will look at using a bit in CV29 for this option).

The function drivers.

My early decoders used NDC7002N dual MOSFETs as function drivers (same as Dean Probst). However I found these were very unreliable and often were ON with no gate voltage. You could not turn the function off! Possibly damaged while soldering? I reverted to the digital transistors which are cheaper and have been more reliable. The PCB layout allows for resistors in the driver collectors if you are using LEDs. For 12v bulbs, use zero ohm links. I use 560R resistors for white LEDs and 1K for ordinary LEDs.

Hope this is enough for folks to understand the schematic. Let me know if anyone wants more info.

Hope to design a back-emf decoder sometime. Also looking at the new PIC16F628 which is a pin-for-pin replacement but with much more memory, will run at twice the speed and has built-in PWM module. Scope here for extended addressing, acceleration / deceleration control, kickstart, and a much higher PWM frequency suitable for ironless rotor motors.

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