Electrical Specifications for Digital Command Control Decoder Transmission, All Scales

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This note provides explanatory context for the corresponding version of NMRA RP 9.3.1.

Introduction

RP 9.3.1 envisions a system consisting of Digital Decoders that transmit information, "detectors" that receive it, and "cutout devices" that create the necessary electrical environment on the rails. Detectors and cutout devices may be standalone components, or integrated into other components such as boosters or command stations.

RP 9.3.2 defines the first use for the RP 9.3.1 transmission mechanism.

Digital Decoders send information in response to track packets, but note that there is no requirement in Recommended Practice 9.3.1 that the track packet be addressed to that specific decoder, nor that it contain any particular instruction. Requirements of that type may be specified in other Recommended Practices.

A: Technique for Transmitting and Receiving Bits

During transmission of a '1' bit, the decoder is required to meet the same electrical standards as other devices connected to the track during the cutout period.

The direction of the current is specified so that the absolute direction of travel can be determined. This can be done by combining the polarity of the current at the detector and information on whether the decoder-equipped locomotive is presently moving forward or backwards.

The 2.2V minimum voltage with which the decoder must be able to drive current can be measured by adding a high-valued resistor between track and decoder during the cutout time. The voltage is then measured across this resistor. The 2.2V value was chosen as a compromise between the voltages likely to be present within current and future decoders, and the need to have a large enough value to drive current through resistive circuits and diode-based occupancy detectors.

The bit length was chosen for ease of implementation with existing clock frequencies used in DCC devices.

Model railroads are typically inductive loads. Larger model railroads can behave like low-quality transmission lines of up to several hundred meters in length with characteristic impedance of tens or hundreds of ohms. Properly driving a sharp edge into loads like this requires care. During early layout testing, some versions of the current transmitter were found to cause oscillations in the transmitted current that prevented communication. Empirically, it has been found that a 100 Ohm source impedance, e.g. a parallel resistor at the decoder, improves stability of the signal on the rails.

Return of track power during or before transmission can happen for several reasons:

1) Use of the decoder without cutout devices
2) Shorting between separately equipped sections of the layout
3) Misconfiguration of the system, e.g. transmitting during the 2nd window when only a two-bit cutout is present.

These conditions can persist for a long time, and should be taken into account when designing the current source.

It is possible for another power source to be connected across the track leads of a cutout device while it is shorting the track. For example, this can happen if a locomotive bridges gaps between two parts of a layout during the cutout. To prevent this from invoking the short circuit protection of the other power source, or even possibly causing damage, cutout devices are required to cease shorting the rails when this happens. Although no time period is specified, operation within a few 10s of microseconds would be preferred.

B: Transmitting & Receiving Bytes

This data format has been chosen to be compatible with typical UART transmissions.

Note that the timing tolerances in part A are also relevant to the byte timing. Specifying that bits must be properly received only if the input level is stable for the center 1.5usec of the bit is intended to allow the traditional UART technique of synchronizing reception on the edge(s) of the start bit. Note that proper reception of a multi-byte message may require resynchronizing the bit stream on each start bit that it contains, depending on receiver stability.

C: Packet Transmission Intervals

Footnote 2 of NMRA Standard 9.1 specifies that timing of the DCC packets be measured with respect to a zero crossing of the track voltage. Section B of that Standard says that the zero crossing is permitted to have non-monotonic noise, which can result in ambiguity as to which zero crossing is intended as the reference. Recommended Practice 9.3.1 removes this ambiguity by specifying the first zero crossing. Section B of Standard 9.1 also permits the transition from –4V to +4V or vice versa to take up to 3.2μsec. The time values in Recommended Practice 9.3.1 have been chosen to allow a time jitter of up to 4μsec. This is somewhat conservative with respect to the track signal, but is intended to ease implementation.

The timing properties were chosen to meet a number of practical constraints in order to work with the majority of the equipment on the market.

The start time for the cutout was chosen within two constraints. An earlier start gives more time for transients on the attached layout to decay. This, along with defining the time at which detectors start looking for transmissions, reduces the likelihood that noise will be interpreted as a start bit. However, some existing decoders require sampling of the half-bit following the packet end bit to ensure that the length of both halves of the packet end bit was correct. This can take up to 1/2 the maximum allowed time for half of a 1 bit. See also footnote 3 in NMRA Standard 9.2, which states "the DCC bitstream must continue for an additional 26usec (minimum) after the packet end bit".

The detector start time T_{DS} was chosen to reduce the chance that incidental current on the layout will be interpreted as a start bit. When a cutout occurs there is a period of ringing where receipt of transmission cannot be reliably received. A later detector start time gives more time for transients on the attached layout to decay. This reduces the likelihood that noise will be interpreted as a start bit. The time was chosen empirically.

Maximum values for times T_{TS1} and T_{TS2} (Transmission Start) are not specified because they are only limited by the requirement that the decoder cease transmission before times T_{TC1} and T_{TC2} (Transmission

Complete) respectively. Similarly, only maximum values are specified for times T_{TC1} and T_{TC2}, because early completion is a normal condition. The nominal times T_{TS1} and T_{TS2} are slightly later than the minimum times to allow additional time for the layout to damp down after the cutout starts, and to allow additional time between channels respectively.

Many existing command stations provide a continuous series of “1” bits between packets, starting with the packet end bit and running through the preamble bits to the “0” bit that starts the next packet. NMRA Standard 9.1 requires that these “1” bits be transmitted with lengths between 110 and 122 microseconds inclusive. NMRA Standard 9.2 requires that a command station send a minimum of 14 preamble “1” bits before the “0” packet start bit. It also requires that a decoder not accept any packet that is not preceded by less than 10 preamble bits, nor that a decoder require more than 12 preamble bits to accept a packet.

For a command station that provides the minimum of 14 preamble bits of 110usec each, and decoders that require 12 preamble bits, only 2 bits totaling 220 microseconds remains for the cutout. This, combined with the allowance for appropriate slew and margin timing, defines the length of the “short cutout”. Transmission channel 1 is then defined to fit within this cutout. It contains only enough time to transmit a single two-byte message.

It is desirable to be able to send more information than can fit into the short cutout. Many existing command stations (though not all) send more than the minimum number of preamble bits. For a command station that sends a total of 16 preamble bits, up to four “1” bit times can be used to create a longer cutout. Alternately, decoders that require only the minimum of 10 preamble bits when used with a command station that sends 14 preamble bits also allow four bit-times to be used for a cutout. These are common enough situations in practice that the “long cutout” has been defined in these terms. These go beyond what is required by Standards 9.1 and 9.2, however, so the Recommended Practice requires that cutout devices be able to provide both the short and long cutout times. Command stations may also provide the necessary interval for the cutout via other means, so long as the last 12 bits of the preamble for the next DCC packet does not start before time T_{PS}. Transmission channel 2 is defined so that it can be used to convey additional information within the long cutout when that cutout is in use.

Command stations that support multiple track protocols need to take into account the fixed timing of the cutout. Since the cutout has to occur during a specific interval after the packet end bit, waveforms for other protocols need to be delayed until after the cutout is completed.

Some existing decoders need the second half of a ‘0’ bit with a duration of greater than 90usec after the cutout to reliably synchronize to the preamble following a cutout. Figure 1 shows the location of this half-bit. Command stations that generate this are therefore more likely to operate well with existing decoders. Command stations that generate multiple protocols on the track can improve compatibility with these decoders by generating a similar 90usec interval between other protocols and the start of the DCC packet preamble, but since the NMRA Recommended Practices are silent on multi-protocol operation, this is not required by this Recommended Practice.

A track waveform that contains a pulse of less than 20usec before the first complete preamble bit following the cutout will in most cases allow these existing decoders to resynchronize. See Figure 1 in the Recommended Practice. In the case of a command station that is producing complete DCC “1” bits during the cutout time, the cutout device can provide this pulse by selecting the time at which the cutout ends. This is anticipated to be the most common case. Although no specific implementation is required by the Recommended Practice, a cutout device can determine the needed timing by examining the “1” bit duration in the DCC waveform, including the packet-end bit, or by examining the bit edges from the command station during the cutout interval. Although this timing is more complex than a fixed interval, cutout devices have to maintain synchronization with the DCC signal to accurately locate the packet end bit in any case.

Command station timing is defined in terms of the last 12 bits of the preamble, as these are the ones that a decoder may require to be present before accepting a packet. This can result in only 12 preamble bits on the track, rather than the 14 required to be transmitted by S9.2, but this was chosen to be compatible with existing command stations that send 16 preamble bits.

The "NMRA extended bidirectional DCC" terminology was introduced to simplify the distinction between short and long cutouts for the modeler. A command station that provides "extended bidirectional DCC" is compatible with the long cutout. This, together with the requirement that cutout devices be able to create a long cutout, ensures that both transmission channels are fully available for use. When both channels are available, the full set of capabilities and protocols defined in other Recommended Practices based on Recommended Practice RP-9.3.1 can be transmitted. Therefore, a modeler can look for the "extended bidirectional DCC" label to be certain that the command station will not prevent use of some or all features in these Recommended Practices.

Multiple cutout devices in series may interfere with their ability to provide precise timing. The user should be instructed to set only one of them to be active.

The programs in some existing decoders do not keep track of whether they are in the first or second half of the DCC bits. Because the timing of the decoder transmissions is referenced to the end of the 2nd half of packet end bit, this decoder logic will result in transmission starting from 55usec to 61usec late with respect to the nominal times. Unfortunately, the channel 1 window cannot be wide enough to accommodate this, so that adding bidirectional communications to this type of decoder will require changing the program to properly locate the 2nd half of the packet end bit.

D: Electrical Specifications for All Devices

Each device that is electrically connected to the layout can impact the reliability of the current loop transmissions. This Requested Practice is designed to be compatible with a external purely-resistive load in the detection zone of 10 ohms or more during the cutout. Lighted passenger cars, resistor wheel sets, layout wiring, etc contribute to this load.

In order to maximize the number of current consuming devices on the layout, it is recommended that each device not source or sink more than 0.1 mA of current during the cutout. One simple method to satisfy this requirement is for each device to be isolated by a protection device such as a silicon diode. The forward-voltage curve of a diode reduces the current drawn by the device at the low voltages present during the cutout.

To reduce the difficulty of testing conformance with 0.1mA current-limit requirement, a test temperature has been specified for decoders. Many diodes will allow larger currents to flow at larger temperatures, and decoder designers should take into account the negative impact of excessive leakage current on the overall transmission on the layout.

Non-decoder-equipped locomotives will interfere with transmission unless they are modified to prevent their motor(s) from driving current into the layout during the cutout interval.

Diode-based occupancy detectors and circuit breakers may have another effect. Existing block occupancy detectors that use a single pair of diodes will introduce a 0.6 V offset voltage during the cutout, raising the effective track voltage. In this case, other equipment may require multiple protection diodes to reduce the current they draw. A total purely-resistive load of 50 Ohms or more should be compatible with proper operation. For improved compatibility with Recommended Practice 9.3.1 communications, occupancy detectors should be designed to reduce this offset voltage.

E: Compatibility and Subsets

As discussed in part D above, reliable operation of bidirectional communications is a function of all equipment electrically attached to the rails.

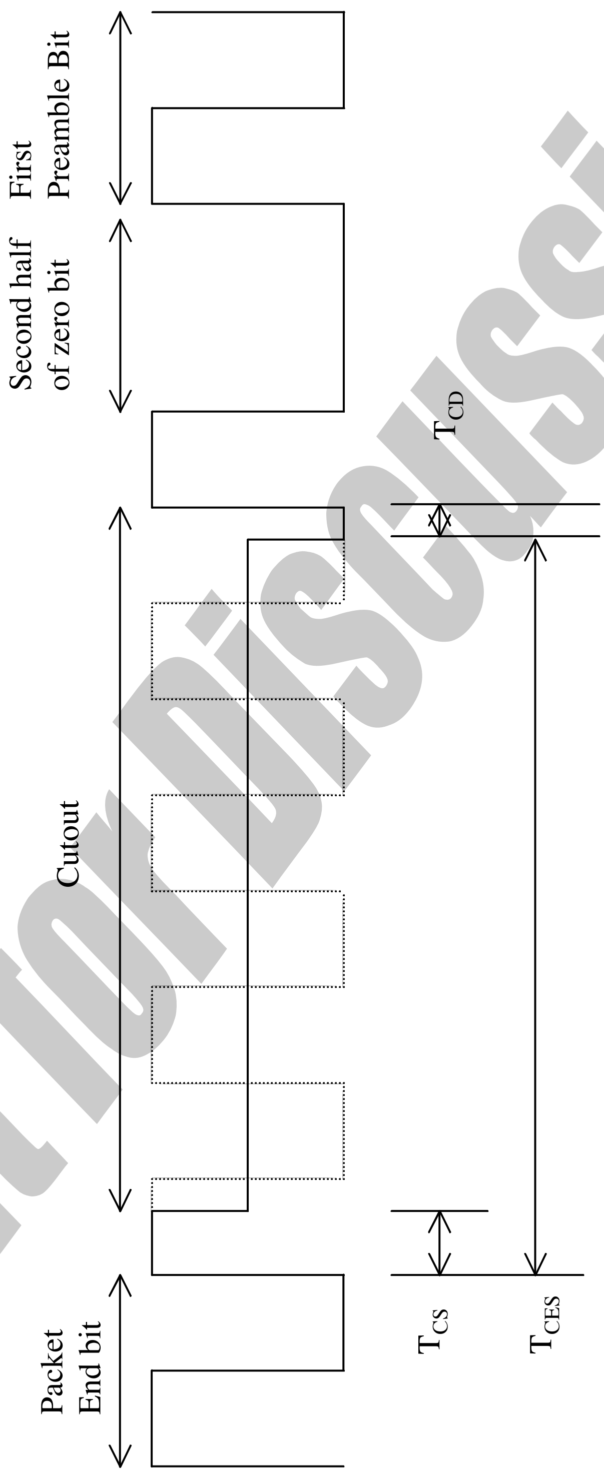

Figure 1: Added "0" half-bit