This Recommended Practice received approval by the NMRA Board of Trustees in July 2003; modified and approved Board of Directors January 2007. Significant changes have been made throughout the RP from the 2003 version.

NMRA RECOMMENDED PRACTICE

Electrical Specifications for Digital Command Control Decoder Transmission, All Scales

January 2007	RP-9.3.1

This Recommended Practice covers the transmission method for information transmitted from a Digital Decoder to a communication receiver connected to the rails.

As a prerequisite for this Recommended Practice, a Digital Command Station transmits information to Digital Decoders by sending a series of bits using the NMRA digital signal described in S-9.1. This sequence of bits, termed a packet, is used to encode one or more instructions that the Digital Decoder operates upon as described in S-9.2, RP-9.2.1, and RP-9.2.2.

This Recommended Practice specifies how a Digital Decoder transmits in response to this received NMRA packet by generating a series of pulses during a specified absence of track power. This series of pulses is received by an external device called a detector. To successfully accomplish this transmission, and conform to this RP, the Digital Decoder must satisfy both the Electrical Specifications (Physical Layer) contained in this document and the General Feedback Packet Format specifications specified in RP 9.3.2.

Portions of intellectual property needed to develop products that utilize this RP have been licensed to the NMRA by Lenz GmbH[1]. The NMRA grants a no-cost sub-license to use the technology covered by this intellectual property to any user for their personal non-commercial use. The NMRA will grant a no-cost sub-license for the use of this technology for any Manufacturer's DCC product that the NMRA certifies meets all the requirements contained within this RP and has been granted a C&I Warrant by the NMRA.

A: Technique for Transmitting and Receiving Bits

Bits are transmitted using a current loop technique. Current is supplied to the track from the decoder's internal power supply during a specified period (see section B below). During this interval, a "cutout device" connects the rails so that the decoder, detector and cutout device are effectively in series.

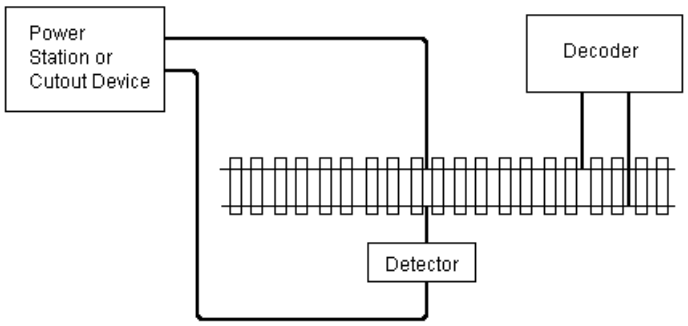

Figure 1A: Physical Arrangement of Devices

[1] The intellectual property donated is covered under patents 6,494,410 and 6,853,312

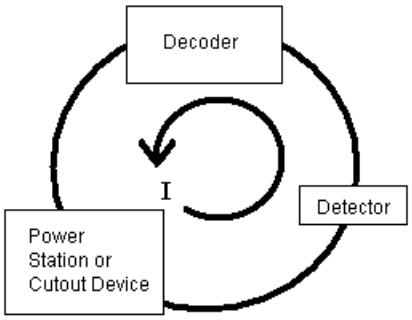

Figure 1B: Symbolic Current Loop

To transmit a '0' bit, the decoder must source 30 +4/-6 mA to the rails. The positive current should be directed into the track via the red decoder lead, and removed from the black decoder lead, where the lead colors are defined by the color assignments of Recommended Practice 9.1.1 To transmit a '1' bit, the decoder must neither sink nor source more than 0.1 mA of current. For conformance testing purposes, these current values will be measured at a decoder temperature of 25°C.

Transmitted bits are 4µs +/- 2% long. The transmitter's transition times between 10% and 90% or between 90% and 10% of its '0' bit current level must be less than 0.5µs.

The decoder must be able to source the '0' bit current when the voltage across the decoder's track inputs is from zero to 2.2 volts.

The decoder current source must be protected against unexpected return of full track voltage during a cutout period.

A detector must detect a current of greater than 10 mA during the entire center 2µs of the bit time as '0' bit, and must detect a current of less than 6 mA during the entire center 2µs of the bit time as a '1' bit.

The voltage across the input of each detector must not exceed 55 mV at currents up to 34mA when a cutout device has removed power, and has shorted the rails as specified in section C (below)[2]. A detector must be clearly labeled with the maximum current that it is capable of handling.

The voltage across the input of a cutout device must not be more than 10 mV at currents up to 34mA, when a cutout device has removed power and has connected its track outputs together as specified in section C (below). A cutout device must be clearly labeled with the maximum current that it is capable of handling.

The cutout device must cease connecting its track outputs together within 12us if track voltage is applied to these track outputs from another power source.

B: Transmitting & Receiving Bytes

A byte consists of 8 data bits. Each byte transmitted or received is framed by a start bit ('0'), and a stop bit ('1'). The least-significant bit of each byte is transmitted first. The detector must accept bytes in which the bits are transmitted at 250Kb/s +/- 2.5%.

Each message consists of two bytes. The time between the end of a stop bit and the beginning of the start bit of sequential bytes within a message must be less than 4.5µs.

[2] The detector's impedance is specified as a voltage drop at the maximum current to facilitate conformance and inspection testing.

The specifications for the contents of data transmitted in each message are provided in Recommended Practice RP-9.3.2.

C: Packet Transmission & Timing

An interval for transmitting data is provided after each NMRA DCC packet on the layout.

To prevent interference with the transmission current, power on the layout must be interrupted between the DCC packets. This interruption is called a ‘cutout’. The device that performs this is called a 'cutout device'. During the cutout period, power must be disconnected from both track outputs, and these track outputs connected to each other such that the detector and the decoder form a current loop.

The transmission interval is divided into two portions, called channels. Each channel can be used independently for transmission.

A transmission within a channel consists of one or more messages.

Two lengths for the cutout are defined: A "Channel 1 Cutout" and a "Channel 2 Cutout". Cutout devices must have the ability to be configured for no cutout, or a cutout of either specified length.

All time values in this section are relative to the trailing edge of the second half of the packet end bit. The timing is referenced to the first zero-volt crossing in that edge, as specified in S-9.1, line 52.

Table 1 provides the timing values for the cutout, and transmission and detection of the message(s). The various timing values are defined below. Figure 1 is illustrative of their relationships, and is not definitive.

Cutout Device Timing

Time T_{CS} (Cutout Start) specifies the start of the cutout. The cutout device must ensure that the value of T_{CES} (Cutout End for the Channel 1 Cutout) and T_{CEL} (Cutout End for the Channel 2 Cutout) exceed the minimum specified value.

Detector Timing

The detector must not accept transmissions starting before time T_{DS} (Detector Start). A zero level whose leading edge starts before this time must not be interpreted as a start bit. Detectors must reject bytes that were not completely received when track power was restored.

Decoder Transmission Timing

This Recommended Practice allows different decoders to transmit in channel 1 and channel 2 following a single DCC packet.

Transmission in channel 1 must not start before time T_{TS1} (Transmission Start channel 1). The last stop bit of the last message in channel 1 must be completely transmitted by time T_{TC1} (Transmission Complete channel 1).

Transmission in channel 2 must not start before time T_{TS2} (Transmission Start channel 2). The last stop bit of the last message in channel 2 must be completely transmitted by time T_{TC2} (Transmission Complete channel 2). Note: if the system is configured such that only the same decoder can transmit in both channel 1 and channel 2 then T_{TS2} shall not apply.

Command Station Timing

Standard S-9.2 requires that a command station provide at least 14 preamble bits before a packet start-bit. This is both necessary and sufficient for a command station to conform to this Recommended Practice when used with a Channel 1 only cutout device.

To be used with a channel 1 and channel 2 cutout device, the command station must provide additional time for the cutout to take place after the packet end bit and before the start of a valid preamble. In order to be labeled as providing "NMRA extended bidirectional DCC", the command station must not start transmission of the last 12 preamble bits before a time T_{PS} (Preamble Start) after each packet end bit.

Parameter	Name	Minimum	Maximum
Cutout Start	T_{CS}	26µs	30µs
Detector Start	T_{DS}		78µs
Transmission Start - Channel 1	T_{TS1}	80µs	
Transmission Complete - Channel 1	T_{TC1}		175µs
Cutout End [Channel 1 Cutout]	T_{CES}	200µs	Nominal next bit edge
Preamble Start from Command Station [Channel 1 Cutout]	T_{PS}	Nominal 2 X "1" bit time	
Transmission Start - Channel 2	T_{TS2}	187µs	
Transmission Complete - Channel 2	T_{TC2}		446µs
Cutout End [Channel 2 Cutout]	T_{CEL}	448µs	Nominal next bit edge
Detector End	T_{DE}	See text	
Preamble Start from Command Station [Channel 2 Cutout]	T_{PS}	Nominal 4 X "1" bit time[3]	

Note: all values in this table are relative to the trailing edge of the second half of the packet end bit.

Table 1: Timing Specifications[4],[5]

[3] For Command stations that transmit one bits with a time of less then113us, the cutout duration will span into the beginning of the 5th bit so the Nominal preamble start is 5X 1 bit times.

[4] Starting the transmission in channel 1 later then the minimum provides more time to ensure that the ringing of the layout has ended.

[5] Starting the transmission in channel 2 later then the minimum increases the minimum dead time between channel 1 and channel 2.

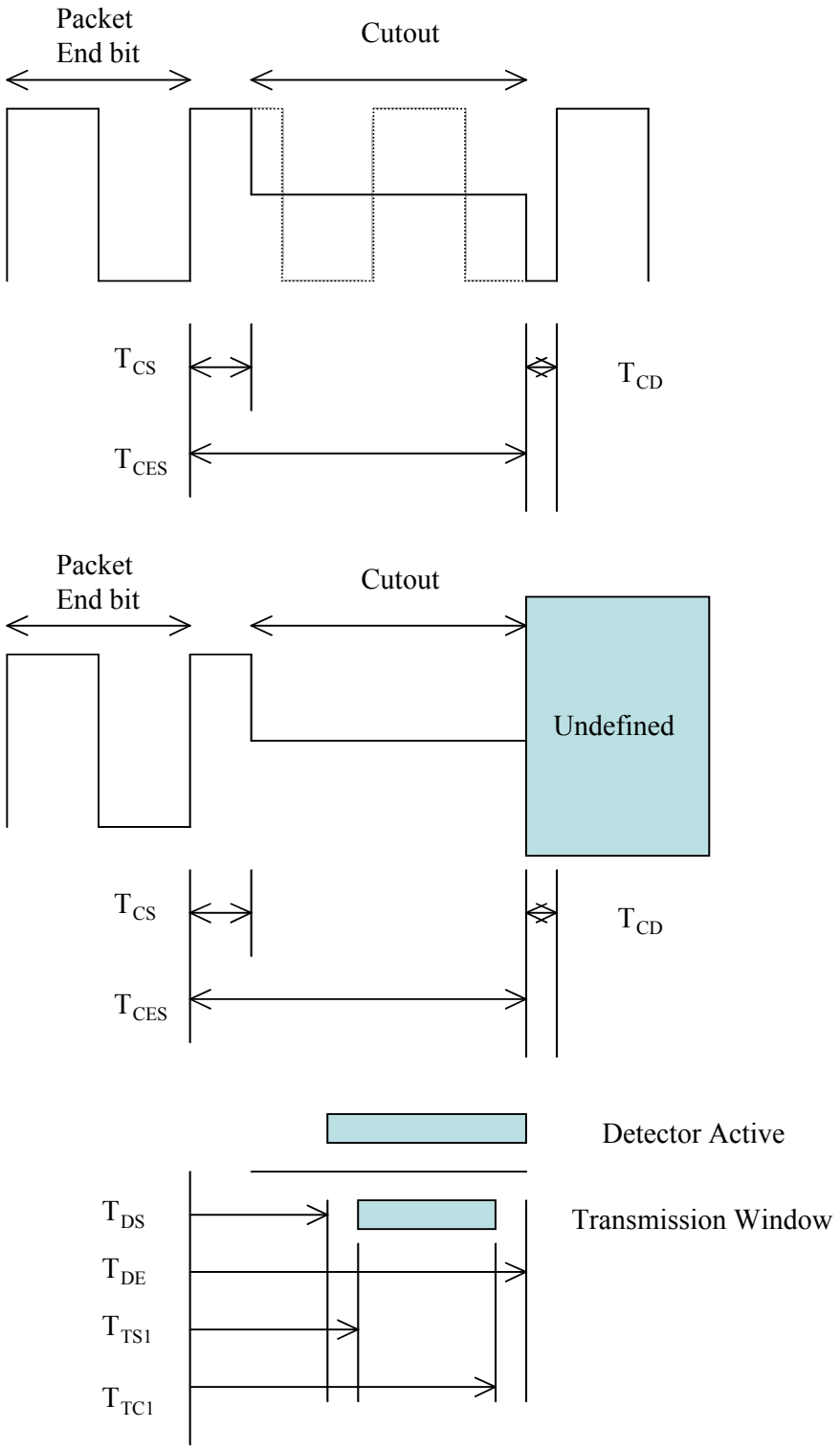

Figure 1: Timing diagram

The upper part shows a schematic track signal and timing relationships for a Single-Channel cutout when the command station is sending a sequence of DCC "1" bits. The middle part shows the more general case where the command station is sending an arbitrary waveform after the cutout period. The lower part shows the decoder and detector timing.

D: Electrical Specifications for Devices

Mobile decoders measured under load must not sink more than 0.1 mA of current or source more than 0.1 mA of current during the cutout unless transmitting a '0' bit. For conformance testing purposes, these current values will be measured at a decoder temperature of 25°C.

Electrical equipment that is intended to connect to the rails must neither source nor sink more than 0.1 mA during the cutout interval at all voltage levels from 0 to 2.2 volts. This equipment must be able to survive the power interruption during the cutout without losing any of its internal state(s), no have any operational problems after power is restored.

E: Conformance Compatibility and Subsets

To be compatible with decoders that use this Recommended Practice to transmit information, all types of equipment intended to be electrically connected to the rails must conform to Section D: Electrical Specification.

For conformance, DCC components, including command stations, decoders and other devices, must conform to all sections of this Recommended Practice including the prerequisite Standards and RPs and other conformance requirements as specified in the preamble to this RP.