Communications Standard for Digital Command Control, Basic Decoder Transmission All Scales

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This document is under formal review by the DCC Working Group under topic 0309302. It has not been approved by the WG, reviewed by the General Technical Committee or approved by the Board of Trustees. Send comments to sra@mitre.org.

This Recommended Practice covers the packet format, message formats, and basic communications protocol used for transmission of information 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 what 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 RP-9.3.1 and the General Feedback Packet Format specifications specified in this document.

~~Portions of intellectual property needed to develop products that conform to this RP utilize US Patent 6,539,292. The NMRA will grant a no-cost sub-license to use this intellectual property for any product that the NMRA has tested and certified conforms to this Recommended Practice.~~Portions of this RP utilize intellectual property from US Patent 6,539,292 that is needed to develop products that conform to this RP, and the required intellectual property has been licensed to the NMRA. The NMRA will grant a royalty-free sub-license to use this intellectual property for any product that the NMRA has tested and certified conforms to this Recommended Practice (as evidenced by the issuance of a NMRA Conformance Warrant for the product)[1].

This RP is organized as follows:

A. The General packet format.
B. Acknowledgement Transmission
C. Broadcast Transmission.
D. Data Transmission.
E. Address Transmission following an Idle Packet.
F. Message type specifications
G. The minimum requirements for conformance.

Additional background information can be found in Tech Note TN-9.3

A. General Packet Format for Decoder Communication

[1] Note: Parties wishing to utilize this intellectual property for other applications, and/or without applying for and receiving an NMRA Conformance Warrant on each specific product that incorporates this intellectual property, should contact the licensor directly to make appropriate licensing arrangements.

Communication from a decoder to a detector is in the form of messages transmitted within Channel 1 and/or Channel 2 with the timing characteristics as specified in RP-9.3.1. Channel 1 allows for a single 2 byte message. Channel 2 allows for a single 2 byte message, two 2 byte messages or a single 4 byte message. Each byte in each message is encoded using a 4/8 encoding scheme as specified in Appendix A. Using this style of encoding allows for 6 actual discrete data bits to be transmitted in a single 8 bit 4/8 transmission or 12 actual discrete data bits in a single two byte message.

The specifications for the formats of these messages follow.

Two Byte Acknowledgement Message (allowed in either channel)	
Byte 1	Byte 2
Acknowledgement Code	Acknowledgement Code or 6 LSB Flag bits
Special 4/8 code as defined in Appendix A	Special 4/8 code as defined in Appendix A or G5, G4, G3, G2, G1, G0

Two Byte Data Message (allowed in either channel)		
Byte 1		Byte 2
4 bit message identifier	2 MSB Data bits	6 LSB Data bits
I3, I2, I1, I0	D7, D6	D5, D4, D3, D2, D1, D0

Four Byte Data Message (only allowed in Channel 2)					
Byte 1		Byte 2	Byte 3		Byte 4
4 bit message identifier	2 MSB Data bits	6 LSB Data bits	4 bit message sub identifier	2 MSB Data bits	6 LSB Data bits
I3, I2, I1, I0	DA7, DA6	DA5, DA4, DA3, DA2, DA1, DA0	I7, I6, I5, I4	DB7, DB6	DB5, DB4, DB3, DB2, DB1, DB0

B. Acknowledgement Transmission

An acknowledgement transmission is a valid Operations Mode Acknowledgment as defined in Section E or RP-9.2.1.

If properly configured in CV 28 and CV29, a Digital Decoder may transmit an acknowledgement to any packet addressed to it by transmitting information during the first ~~transmission window~~cutout period (as specified in RP-9.3.1) that follows a packet addressed to one of the following decoder's addresses:

- A packet sent to the decoder's active address
- If the decoder is in a consist, a packet sent to the decoder's non-consist address
- A packet sent to the broadcast address (address 00000000)

Note: acknowledging a packet sent to a decoder's consist address requires special configuration (see RP-9.2.1 for details)

Acknowledgements are transmitted in a two Byte acknowledgement message as defined in Section A. An acknowledgement message can be transmitted in either channel 1 or in channel 2 as configured by the decoder.

Two Byte Acknowledgement Message (allowed in either channels)	
Byte 1	Byte 2
Acknowledgement Code	Byte 1 Acknowledgement Code or 6 LSB Flag bits
Ack 4/8 code as defined in Appendix A	Ack 4/8 code as defined in Appendix A or 4/8 code using G5, G4, G3, G2, G1, G0

AckCodes 1-6 defined in the following table are transmitted as unique 4/8 codes as defined in Appendix A.

Acknowledgement Codes	Acknowledgement Meaning	Required by Decoder	Required by Detector
AckCode-1	Command received	Yes	Yes
AckCode-2	Command received but not Supported	No	Yes
AckCode-3	Command received and the state within the decoder is the same as the request (positive Acknowledgement)	No	Yes
AckCode-4	Command received and the state within the decoder is not the same as the request (Negative Acknowledgement)	No	Yes
AckCode-5	Command received and the requested value is greater than the current value	No	Yes
AckCode-6	Command received but the configuration does not allow the response requested.	No	Yes

Note: Detectors are only required to accept the various acknowledgement codes as a form of "Command received".

During the transmission of Byte 2 the decoder can optionally transmit a 6 bit flag byte. The contents of this byte are defined by the Flag Message Byte as defined below in Section F with bits 0-3 of the Flag Message Byte being defined as G0-G3, and bits 6 and 7 of the Flag Message Byte being defined as G5 and G6. These 6 bits are then transmitted using the corresponding 4/8 code as defined in Appendix A.

C. Broadcast Transmission

Broadcast transmission is designed to allow detectors to receive specific information from the first decoder that enters a detection zone. Broadcast is thus only designed for mobile decoders and is not permitted for accessory digital decoders. Decoders located at permanent fixed locations should be configured to disable the use of broadcast transmission for transmission over the rails.

If properly configured in CV28 and CV29, a decoder may broadcast a message (as defined in section F) in Channel 1 during any cutout that follows a packet to a multi function decoder address except for the cutout period that immediately follows the packet end bit of one of the following packets.

- ~~Do not broadcast after a packet sent to the decoder's active address.~~
- ~~If the decoder is in a consist, do not broadcast after a packet sent to the decoder's non-consist address.~~
- Do not broadcast after a packet sent to the broadcast address (address 00000000).
- Do not broadcast after a packet sent to a decoder control instruction.
- Do not broadcast after an idle packet.

It is permissible (preferred) to transmit an acknowledgement or data instead of a broadcast,

- After a packet sent to the decoder's active address.
- If the decoder is in a consist, after a packet sent to the decoder's non-consist address.

When two or more decoders are transmitting information, the resulting 4/8 received code will not be valid and the resulting reception must be rejected by the detector.

Note: The receipt of a broadcast transmission message is **NOT** a form of a "Command received" acknowledgement.

D. Data Transmission

If properly configured in CV 28 and CV29, a Digital Decoder may transmit a single data message in channel one or two data messages in channel two during the first ~~transmission window~~ cutout period (as specified in RP-9.3.1) that follows a packet addressed to one of the following decoder's addresses:

- A packet sent to the decoder's active address
- If the decoder is in a consist, a packet sent to the decoder's non-consist address
- A packet sent to the broadcast address (address 00000000)

Note: Transmitting a data message following a packet sent to a decoder's consist address requires special configuration (see RP-9.2.1 for details)

Data is transmitted in either a two byte or four byte message as defined in Section A. A data message can be transmitted in either channel 1 or in channel 2 as configured by the decoder and allowed for in Section F. Note: Data transmission in channel one is only effective if either the decoder is the only decoder in a detection zone of if broadcast is disabled for all decoders in channel one.

Note: Receipt of data transmission messages other then a 1st byte of address message type or 2nd byte of address message type may be considered a valid form of a "Command received" acknowledgement.

E. Decoder request for Service

This section is under evaluation by the NMRA DCC Working Group under topic number xxx. Please contact the NMRA DCC Coordinator before implementing this function.

F. Message type specifications

Messages are specific data elements that are used to transmit information in Sections B, C and D. Messages can either be 2 byte data messages or 4 byte data messages as defined in Section A.

The following tables specify the message types currently specified. All unused identifiers and their formats are reserved by the NMRA for future use. Additional message types will be added to this RP as the need arises.

Two Byte Data Message Type Identifiers

4 bit Identifier	Message Type Name	Required
0000	CV Value	Yes
0001	1st byte of address	Yes
0010	2nd byte of address	Yes
0011	Actual speed/load	No
0100	Flags	No
0101	Routing number	No
0110	Location	No
0111	Fuel Water bit 7 defines which	No
1000	Temperature	No

Four Byte Data Message Type Identifiers

4 bit Identifier	Message Type Name	Required
1111	CV Content/Address	No

Allowable locations where message types can be transmitted

Identifier	**Message Type Name**	**Channel 1 Broadcast**	**Channel 1 Data**	**1st message in Channel 2**	**2nd message in channel 2**
0000	CV Contents	No	Yes	Yes	Yes
0001	1st byte of address	Yes	Yes	Yes	No
0010	2nd byte of address	Yes	Yes	Yes	Yes
0011	Actual speed or load	No	No	Yes	Yes
0100	Flags	No	Yes	Yes	Yes
0101	Routing number	Yes	No	Yes	Yes
0110	Location	No	No	Yes	Yes
0111	Fuel or Water	No	No	Yes	Yes
1000	Temperature	No	No	Yes	Yes
1111	CV Contents/Address	No	No	1st Part	2nd Part

F.1. CV Contents (Identifier 0000)

The CV Contents message type is intended to be used by a decoder when it wishes to transmit the actual value of a CV following the receipt of a Configuration Variable Access Instruction verify byte request. Note that since reading a CV may take more time then the decoder has available, the response to the request may not occur in the ~~transmission window~~cutout period immediately following the first request.

Bits 7-0	Meaning
D7,D6,D5,D4,D3,D2,D1,D0	Actual value of last requested CV

F.2. 1st byte of address (Identifier 0001)

To transmit an address a decoder must use two message types. The 1st byte of address message type is used to transmit the first portion of the decoders address. It is used primarily during broadcast or upon request.

Bits 7-0	Meaning
0, CF, 0, 0, 0, 0, 0, 0	Decoder's primary address is CV1. CV1 which will be transmitted in the 2nd byte
0, CF, 1, 0, 0, 0, 0, 0	Decoder has speed and direction controlled by its consist address contained in CV19 which will be transmitted in the 2nd byte
1,CF,A13,A12,A11,A10,A9,A8	Decoder's primary address is a 2 byte address (CV17, CV18), A8-A13 as contained in B0-B6 of CV17. CV 18 is transmitted as the second byte

1. CF = 0 locomotive is not in a consist and is controlled by its primary address. CF=1 locomotive is in a consist and its speed and direction is controlled by CV19

F.3. 2nd byte of address (Identifier 0010)

The 2nd byte of address message type is used to transmit the second portion of the decoder's address. It is used primarily during broadcast or upon request.

Bits 7-0	Meaning
0,A6,A5,A4,A3,A2,A1,A0	A0-A6 as contained in Bit 0-Bit 6 of CV1
A7,A6,A5,A4,A3,A2,A1,A0	A0-A7 as contained in Bit 0-Bit 7 of CV18
A7,A6,A5,A4,A3,A2,A1,A0	A0-A7 as contained in Bit 0-Bit 7 of CV19

F.4. Actual speed or load (Identifier 0011)

The speed/load message types are used to transmit the actual speed of the device or the measured load.

Bits 7-0	Meaning
1,S6,S5,S4,S3,S2,S1,S0	Represents the actual current speed the locomotive is traveling as normalized to a 128 speed step value that is contained in its internal speed table.
0,L6,S5,S4,S3,S2,S1,S0	Actual load the decoder is currently encountering (as specified in the SUSI Technical Note 9.2.3)

F.5. Flag message type (Identifier 0100)

The flag message type is used by the decoder to transmit specific pieces of information. Bits 0-4 and bits 6-7 can also be transmitted as part of an acknowledgement as devined in section B above.

The flag message message has a flag type identifier in bits 6 and 7 to define what type of flag is being transmitted. Flag types 00 and 01 are defined below, flag type 11 is reserved for manufacturer unique information, and flag type 10 is reserved by the the NMRA for future use.

Multi-function decoder

Bit Position	Value	Meaning of Value
Bit 0	DF	DF = 0 locomotive is moving forward (per last DCC speed/direction packet received) integrated with CV29 and CV19 settings
Bit 1	=1	Decoder has an active Consist Address.
Bit 2	=1	Decoder has a fault Condition.
Bit 3	=1	Decoder has more data to send so please address it more often
Bit 4	Always 0	Reserved by the NMRA for future use, Detector must be able to accept value of 1 or 0.
Bit 5	Always 0	Reserved by the NMRA for future use, Detector must be able to accept value of 1 or 0.
Bit 6,7	0,0	Flag Type Identifier: Indicates that this flag byte is for a multi-function decoder

Accessory Decoder

Bit Position	Value	Meaning of Value
Bit 0	AB1	The first bit (AB1) indicates whether a current flows in one direction the second bit (AB2) in the other direction. which provides 4 states: no current at all (00 = turnout is inoperable for some reason, without consuming current it would not be able to make anything with it); current on both sides (11 = the turnout is in a invalid position between left and right); and the 2 valid states (01, 10) for right/left position.
Bit 1	AB2	
Bit 2	=1	Decoder has a fault Condition.
Bit 3	=1	Decoder has more data to send so please address it more often.
Bit 4	Always 0	Reserved by the NMRA for future use, Detector must be able to accept value of 1 or 0.
Bit 5	Always 0	Reserved by the NMRA for future use, Detector must be able to accept value of 1 or 0.
Bit 6,7	0,1	Flag Type Identifier: Indicates that this flag byte is for an accessory decoder

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F.6. Routing Number (Identifier 0101)

The routing number message type is used by the decoder to transmit the route identifier for the route it wishes to travel.

Bits 7-0	Meaning
D7,D6,D5,D4,D3,D2,D1,D0	Route that the decoder desires to be routed over as defined in CV874.

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F.7. Location (Identifier =0110)

The location message type is used by the decoder to transmit its location.

Bits 7-0	Meaning
D7,D6,D5,D4,D3,D2,D1,D0	Last location that decoder identified (See CV876)

F.8. Fuel or Water (Identifier 0111)

The Fuel and Water message types are used by the decoder to transmit the fuel or water remaining.

Bits 7-0	Meaning
1,F6,F5,F4,F3,F2,F1,F0	Value represents % of fuel remaining (see CV879)
0,W6,W5,W4,W3,W2,W1,W0	Value represents % of Water remaining (See CV878)

F.9. Temperature (Identifier 1000)

The temperature message type allows the decoder to transmit the current temperture of the decoder.

Bits 7-0	Meaning
1,U6,U5,U4,U3,U2,U1,U0	Currently undefined and reserved by the NMRA for future use.
0,T6,T5,T4,T3,T2,T1,T0	Represents the temperature of the decoder in Celsius (See CV880)

F.10. CV Content/Address (Identifier 1111)

The CV Value/Address 4 byte message type allows the decoder to transmit the contents of an arbitrary CV along with its CV number. This can be used by the decoder to transmit information not identified via another message type.

Required	Identifier	1st of Channel 2	Sub Identifier	2nd of channel 2
	1111	CV value	00AA	AAAAAAAA

The AA in the sub identifier and the AAAAAAAA in the 2nd channel combine to form the complete CV address per RP-9.2.2

G. Required Elements for Conformance

The minimum requirements for Decoders and Detectors for conformance to this RP are as follows. All Decoders and Detectors that support this RP must conform to the prerequisite Standards and RPs and other conformance requirements as specified in the preamble to this RP; must adhere to the requirements in sections A and must implement the message type specifications specified as mandatory in Sections B and F; and must use the encoding specified in Appendix A. If RP-9.3.2 is implemented then CV28 becomes mandatory as a uniform spec and the Decoder Control instructions dealing with bi-directional as specified in RP-9.2.1 must also be supported.

Appendix A: 4/8 Data Encoding Translation

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The following table provides the translation table for encoding information using the 3/6 encoding scheme.

Hex to be transmitted	4/8 code transmitted	Hex to be transmitted	4/8 code transmitted
0x00	10101100	0x20	01010110
0x01	10101010	0x21	01001110
0x02	10101001	0x22	01001101
0x03	10100101	0x23	01001011
0x04	10100011	0x24	01000111
0x05	10100110	0x25	01110001
0x06	10011100	0x26	11101000
0x07	10011010	0x27	11100100
0x08	10011001	0x28	11100010
0x09	10010101	0x29	11010001
0x0A	10010011	0x2A	11001001
0x0B	10010110	0x2B	11000101
0x0C	10001110	0x2C	11011000
0x0D	10001101	0x2D	11010100
0x0E	10001011	0x2E	11010010
0x0F	10110001	0x2F	11001010
0x10	10110010	0x30	11000110
0x11	10110100	0x31	11001100
0x12	10111000	0x32	01111000
0x13	01110100	0x33	00010111
0x14	01110010	0x34	00011011
0x15	01101100	0x35	00011101
0x16	01101010	0x36	00011110
0x17	01101001	0x37	00101110
0x18	01100101	0x38	00110110
0x19	01100011	0x39	00111010
0x1A	01100110	0x3A	00100111
0x1B	01011100	0x3B	00101011
0x1C	01011010	0x3C	00101101
0x1D	01011001	0x3D	00110101
0x1E	01010101	0x3E	00111001
0x1F	01010011	0x3F	00110011
AckCode-5	00111100		
AckCode-2	10000111		
AckCode-3	11000011		
AckCode-6	11100001		
AckCode-4	11110000		
AckCode-1	00001111		