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**Extended Packet Formats
For Digital Command Control,
All Scales**

Approved, July 2003

RP 9.2.1

The NMRA Communications Standard for Digital Communications (S-9.2) provides a minimal, basic packet format required for interoperability. This RECOMMENDED PRACTICE provides Extended Packet Formats that provide the framework to enable realistic operations to occur. These formats adhere to the general packet format as defined in S-9.2. While the baseline packet has a length of 3 data bytes separated by a "0" bit, a packet using the extended packet format definition may have a length of between 3 and 6 data bytes each separated by a "0" bit.

Format Definitions

Within this recommended practice, bits within the address and data bytes will be defined using the following abbreviations. Individual bytes within a specific packet format are separated by spaces. Bytes which are within square [] brackets can occur one or more times as necessary. Bits are numbered from right to left with bit 0 (the right most bit) being the least significant bit (LSB) and bit 7 (the left most bit) being the most significant bit (MSB).

A = Address bit

0 = Bit with the value of "0"

1 = Bit with the value of "1"

U = bit with undefined value either a "1" or a "0" is acceptable

C = Instruction Type field

D = Data

E = Error Detection Bit

A: Address Partitions

The first data byte of a Extended Packet Format packet contains the primary address. In order to allow for different types of decoders this primary address is subdivided into fixed partitions as follows.

Address 00000000 (0):

Broadcast address

Addresses 00000001-01111111 (1-127)(inclusive):

Multi-Function decoders with 7 bit addresses

Addresses 10000000-10111111 (128-191)(inclusive):

Basic Accessory Decoders with 9 bit addresses and Extended Accessory Decoders with 11-bit addresses

Addresses 11000000-11100111 (192-231)(inclusive):

Multi Function Decoders with 14 bit addresses

Addresses 11101000-11111110 (232-254)(inclusive):

Reserved for Future Use

Address 11111111 (255):

Idle Packet

B: Broadcast Command For Multi Function Digital Decoders

The format for this packet is:

{preamble} 0 00000000 0 {instruction-bytes} 0 EEEEEEEE 1

Instructions addressed to "broadcast address" 00000000 must be executed by all Multi Function *Digital Decoders*. The single instruction has the same definition as defined by the Multi Function Digital Decoder packet and can be one, two, or three bytes in length depending on the instruction. *Digital Decoders* should ignore any instruction they do not support. If a decoder supports Broadcast commands, the manufacturer must document which broadcast commands a decoder supports.

C: Instruction Packets For Multi Function Digital Decoders

The format for these packets are:

{preamble} 0 [AAAAAAAA] 0 {instruction-bytes} 0 EEEEEEEE 1

Multi Function *Digital Decoders* are used for the purpose of controlling one or more motors and/or accessories. The packet format used to control these devices consists of between 3 and 6 bytes where the first bytes are address bytes followed by one or two instruction bytes and ended by an error control byte.

The first address byte contains 8 bits of address information. If the most significant bits of the address are "11" then a second address byte must immediately follow. This second address byte will then contain an additional 8 bits of address data. When 2 bytes of address information are present they are separated by a "0" bit. The most significant bit of two byte addresses is bit 5 of the first address byte. (bits #6 and #7 having the value of "1" in this case.

Instruction-bytes are data bytes used to send commands to Multi Function *Digital Decoders*. Although it is unlikely that all *Digital Decoders* will implement all instructions, it is important that if they support packets with more than a single instruction, they can sufficiently parse the packet to be able to recognize if a byte is a new instruction or the second byte of a previous instruction.

Each instruction (indicated by {instruction-bytes}) is defined to be:

{instruction-bytes} = CCCDDDDD,
 CCCDDDDD 0 DDDDDDDD, or
 CCCDDDDD 0 DDDDDDDD 0 DDDDDDDD

Each instruction consists of a 3 bit instruction type field followed by a 5 bit data field. Some instructions have one or two additional bytes of data. The 3 bit instruction type field is defined as follows:

- 000 Decoder and Consist Control Instruction
- 001 Advanced Operation Instructions
- 010 Speed and Direction Instruction for reverse operation
- 011 Speed and Direction Instruction for forward operation
- 100 Function Group One Instruction
- 101 Function Group Two Instruction
- 110 Future Expansion
- 111 Configuration Variable Access Instruction

The last byte of the packet is the Error Detection Byte which is calculated the same as is done in the baseline packet using all address and all instruction bytes (see S-9.2).

Decoder and Consist Control Instruction (000)

With the exception of the decoder acknowledgment function (00001111), only a single decoder and consist control instruction may be contained in a packet.

Decoder Control (0000)

100 The decoder control instructions are intended to set up or modify decoder configurations.

This instruction has the format of

{instruction byte} = 0000CCCD, or {instruction byte} = 0000CCCD dddddddd

105 This instruction (0000CCCD) allows specific decoder features to be set or cleared as defined by the value of D ("1" indicates set). When the decoder has decoder acknowledgment enabled, receipt of a decoder control instruction shall be acknowledged with an operations mode acknowledgment.

110 CCC = 000 D = "0": Digital Decoder Reset - A Digital Decoder Reset shall erase all volatile memory (including and speed and direction data), and return to its initial power up state as defined in RP-9.2.4 section A. Command Stations shall not send packets to addresses 112-127 for 10 packet times following a Digital Decoder Reset. This is to ensure that the decoder does not start executing service mode instruction packets as operations mode packets (Service Mode instruction packets have a short address in the range of 112 to 127 decimal.)

115 D = "1": Hard Reset - Configuration Variables 29, 31 and 32 are reset to its factory default conditions, CV#19 is set to "00000000" and a Digital Decoder reset (as in the above instruction) shall be performed.

120 CCC = 001 Factory Test Instruction - This instruction is used by manufacturers to test decoders at the factory. It must not be sent by any command station during normal operation. This instruction may be a multi-byte instruction.

CCC = 010 Reserved for future use

CCC = 011 Set Decoder **Flags** (see below)

CCC = 100 Reserved for future use

125 CCC = 101 Set Advanced Addressing (CV#29 bit 5)

CCC = 110 Reserved for future use

CCC = 111 D= "1": Decoder Acknowledgment Request-

130 Set Decoder Flags

This instruction is under re-evaluation by the NMRA DCC Working Group. Manufacturers should contact the NMRA DCC Coordinator before implementing this instruction.

Set Decoder Flags is an expanded decoder control function that allows for the command station to turn on or off flags within a specific decoder or within a group of decoders.

135 Format:

{instruction bytes} = 0000011D cccc0aaa

140 aaa is the decoder's sub-address. This allows for up to 7 decoders to share the same decoder primary address, yet have certain functions (such as Configuration Variable Access Instructions) be performed on an individual basis. If aaa = 000 then the operation affects all decoders within the group. The decoder sub-address is defined in CV 31.

145 cccc is defined in the following table:

cccc	Meaning	Action if D = 1	Scope
0000	Disable 111 Instructions ¹	Instruction is ignored for all sub addresses.	Until next Digital Decoder Reset Packet is received.
0100	Disable Decoder Acknowledgement Request Instruction	Acknowledgement and Address are not transmitted in response to a Decoder Acknowledgement Instruction for all sub addresses.	Until power is removed.
0101	Activate Bi-Directional Communications	B-Directional Communications are enabled per CVs (See note below).	Permanent (sets CV 29 (or 541), bit 3) or internal Flag if sent to Consist Address.
1000	Set Bi-Directional Communications	Bi-Directional communications are enabled for specified sub address, all other sub addresses are disabled. (Not valid at Consist Address).	Permanent (sets CV 32, bit 0)
1001	Set 111 Instruction	Enables 111 Instructions for specified sub-address, all other sub addresses are disabled. (Not valid at Consist Address).	Permanent (sets CV 32, bit 1)
1111	Accept 111 Instructions	All previous multi-CV programming instructions are now valid. ²	One-Time

150 Note: This command is valid at both the decoder's base address and (if active) the consist address. If sent to the base address, the command effects both the base address and the active consist address (if any). If sent to the consist address, and D=0 this command has no effect on the base address. If sent to the consist address, and D=1 this command has no effect.

Consist Control (0001)

This instruction controls consist setup and activation or deactivation.

155 When Consist Control is in effect, the decoder will ignore any speed or direction instructions addressed to its normal locomotive address (unless this address is the same as its consist address). Speed and direction instructions now apply to the consist address only.

160 Functions controlled by instruction 100 and 101 will continue to respond to the decoders baseline address. Functions controlled by instructions 100 and 101 also respond to the consist address if the appropriate bits in CVs #21,22 have been activated.

165 By default all forms of Bi-directional communication are not activated in response to commands sent to the consist address until specifically activated by a Decoder Control instruction. Operations mode acknowledgement and Data Transmission applies to the appropriate commands at the respective decoder addresses.

The format of this instruction is:

{instruction bytes} = 0001CCCC 0 0AAAAAAA

170 A value of "1" in bit 7 of the second byte is reserved for future use. Within this instruction CCCC contains a consist setup instruction, and the AAAAAAA in the second byte is a seven bit consist address. If the address is "0000000" then the consist is deactivated. If the address is non-zero, then the consist is activated.

175 If the consist is deactivated (by setting the consist to '0000000'), the Bi-Directional communications settings are set as specified in CVs 26-28.

¹ This instruction also applies to accessory decoders.

² This instruction is used when writing CVs 17 and 18 are written to enable the changes.

When operations-mode acknowledgement is enabled, all consist commands must be acknowledged via operations-mode acknowledgement.

The format for CCCC shall be:

CCCC=0010 Set the consist address as specified in the second byte, and activate the consist. The consist address is stored in bits 0-6 of CV #19 and bit 7 of CV #19 is set to a value of 0. The direction of this unit in the consist is the normal direction. If the consist address is 0000000 the consist is deactivated.

CCCC=0011 Set the consist address as specified in the second byte and activate the consist. The consist address is stored in bits 0-6 of CV #19 and bit 7 of CV#19 is set to a value of 1. The direction of this unit in the consist is opposite its normal direction. If the consist address is 0000000 the consist is deactivated.

All other values of CCCC are reserved for future use.

Advanced Operations Instruction (001)

These instructions control advanced decoder functions. Only a single advanced operations instruction may be contained in a packet.

The format of this instruction is 001CCCCC 0 DDDDDDDD

The five bit sub-instruction CCCCC allows for 32 separate Advanced Operations Sub-Instructions.

CCCCC = 11111: 128 Speed Step Control - Instruction "11111" is used to send one of 126 *Digital Decoder* speed steps. The subsequent single byte shall define speed and direction with bit 7 being direction ("1" is forward and "0" is reverse) and the remaining bits used to indicate speed. The most significant speed bit is bit 6. A data-byte value of U0000000 is used for stop, and a data-byte value of U0000001 is used for emergency stop. This allows up to 126 speed steps. When operations mode acknowledgment is enabled, receipt of a 128 Speed Step Control packet must be acknowledged with an operations mode acknowledgement.

CCCCC = 11110: Restricted Speed Step Instruction - Instruction "11110" is used to restrict the maximum speed of a decoder. Bit 7 of the data byte ('DDDDDDDD' above) is used to enable ('0') or disable ('1') restricted speed operation. Bits 0-5 of the Data byte are the Speed Steps defined in S-9.2³. When operations mode acknowledgment is enabled, receipt of a Restricted Speed Instruction must be acknowledged with an operations mode acknowledgement.

The remaining 30 instructions are reserved for future use.

Speed and Direction Instructions (010 and 011)

These two instructions have these formats:

for Reverse Operation 010DDDDDD

for Forward Operation 011DDDDDD

A speed and direction instruction is used send information to motors connected to Multi Function *Digital Decoders*. Instruction "010" indicates a Speed and Direction Instruction for reverse operation and instruction "011" indicates a Speed and Direction Instruction for forward operation. In these instructions the data is used to control speed with bits 0-3 being defined exactly as in S-9.2 Section B. If Bit 1 of CV#29 has a value of one(1), then bit 4 is used as an intermediate speed step, as defined in S-9.2, Section B. If Bit 1 of CV#29 has a value of zero(0), then bit 4 shall be used to control FL⁴. In this mode, Speed U0000 is stop, speed U0001 is emergency stop, speed U0010 is the first speed step and speed U1111 is full speed. This provides 14 discrete speed steps in each direction.

³ In 128 speed step mode, the maximum restricted speed is scaled from 28 speed mode.

⁴ FL is used for the control of the headlights.

If a decoder receives a new speed step that is within one step of current speed step, the Digital Decoder may select a step half way between these two speed steps. This provides the potential to control 56 speed steps should the command station alternate speed packets.

230 Decoders may ignore the direction information transmitted in a broadcast packet for Speed and Direction commands that do not contain stop or emergency stop information.

When operations mode acknowledgment is enabled, receipt of any speed and direction packet must be acknowledged with an operations mode acknowledgement.

Function Group One Instruction (100)⁵

235 The format of this instruction is 100DDDDDD

Up to 5 auxiliary functions (functions FL and F1-F4) can be controlled by the Function Group One instruction. Bits 0-3 shall define the value of functions F1-F4 with function F1 being controlled by bit 0 and function F4 being controlled by bit 3. A value of "1" shall indicate that the function is "on" while a value of "0" shall indicate that the function is "off". If Bit 1 of CV#29 has a value of one (1), then bit 4 controls function FL, otherwise bit 4 has no meaning.

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When operations mode acknowledgment is enabled, receipt of a function group 1 packet must be acknowledged according with an operations mode acknowledgement.

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Function Group Two Instruction (101)⁶

This instruction has the format 101SDDDD

Up to 8 additional auxiliary functions (F5-F12) can be controlled by a Function Group Two instruction. Bit 4 defines the use of Bits 0-3. When bit 4 (S) is '1', Bits 0-3 (DDDD) shall define the value of functions F5-F8 with function F5 being controlled by bit 0 and function F8 being controlled by bit 3. When bit 4 (S) is '0', Bits 0-3 (DDDD) shall define the value of functions F9-F12 with function F9 being controlled by bit 0 and function F12 being controlled by bit 3. A value of "1" shall indicate that the function is "on" while a value of "0" shall indicate that the function is "off".

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When operations mode acknowledgment is enabled, receipt of function group 2 packet shall be acknowledged according with an operations mode acknowledgement.

Future Expansion Instruction (110)

260 The format of this two byte instruction is: 110DDDDDD 0 DDDDDDDDD and at the current time is reserved for future expansion.

Configuration Variable Access Instruction (111)

The Configuration Variable Access instructions are intended to set up or modify Configurations Variables either on the programming track or on the main line. There are two forms of this instruction. The short form is for modifying selected frequently modified Configuration Variables. The long form is for verifying or modifying any selected Configuration Variable. Only a single configuration variable access instruction may be contained in a packet.

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Configuration Variable Access Acknowledgment

If an configuration variable access acknowledgment is required, and the decoder has decoder **operations-mode** acknowledgment enabled, the decoder shall respond with an operations mode acknowledgment.

Configuration Variable Access Instruction - Short Form

This instruction has the format of

⁵ Any function in this packet group may be directionally qualified.

⁶ Any function in this packet group may be directionally qualified.

1111CCCC 0 DDDDDDDD

275 The 8 bit data DDDDDDDD is placed in the configuration variable identified by CCCC according to the following table.

CCCC = 0000 - Not available for use

CCCC = 0010 - Acceleration Value (CV#23)

280 CCCC = 0011 - Deceleration Value (CV#24)

The remaining values of CCCC are reserved and will be selected by the NMRA as need is determined.

285 Only a single packet is necessary to change a configuration variable using this instruction. If the decoder successfully receives this packet, it shall respond with an **operations mode** acknowledgment.

Configuration Variable Access Instruction - Long Form

The long form allows the direct manipulation of all CVs⁷. This instruction is valid both when the Digital Decoder has its long address active and short address active. Digital Decoders shall not act on this instruction if sent to its consist address. The format of the instructions using Direct CV addressing is:

290 1110CCAA 0 AAAAAAAAA 0 DDDDDDDD

295 The actual Configuration Variable desired is selected via the 10 bit address with the two bit address(AA) in the first data byte being the most significant bits of the address. The Configuration variable being addressed is the provided 10 bit address plus 1. For example, to address CV#1 the 10 bit address is "00 00000000".

The defined values for Instruction type (CC) are:

CC=00 Reserved for future use

CC=01 Verify byte

300 CC=11 Write byte

CC=10 Bit manipulation

Type = "01" VERIFY BYTE

305 The contents of the Configuration Variable as indicated by the 10 bit address are compared with the data byte (DDDDDDDD). If the decoder successfully receives this packet and the values are identical, the Digital Decoder shall respond with an the contents of the CV as the Decoder Response Transmission, if enabled.

Type = "11" WRITE BYTE

310 The contents of the Configuration Variable as indicated by the 10 bit address are replaced by the data byte (DDDDDDDD). Two identical packets are needed before the decoder shall modify a configuration variable⁸. These two packets need not be back to back on the track. However any other packet to the same decoder will invalidate the write operation. (This includes broadcast packets.) If the decoder successfully receives this second identical packet, it shall respond with a configuration variable access acknowledgment.

315 Type = "10" BIT MANIPULATION

The bit manipulation instructions use a special format for the data byte (DDDDDDDD):

111CDAAA

⁷ Because of the length of this instruction, care must be taken to ensure that the maximum time between packets is not exceeded.

⁸ Note that CV 17 and CV 18 are a "paired CV". A "paired CV" refers to a pair of CVs which taken together hold one piece of data. A WRITE BYTE instruction to CV17 will take effect only when CV18 is written. Other paired CVs will work in a similar manner. See RP-9.2.2 for more information on paired CVs.

where AAA represents the bit position within the CV, D contains the value of the bit to be verified or written, and C describes whether the operation is a verify bit or a write bit operation.

C = "1" WRITE BIT
C = "0" VERIFY BIT

The VERIFY BIT and WRITE BIT instructions operate in a manner similar to the VERIFY BYTE and WRITE BYTE instruction (but operates on a single bit). Using the same criteria as the VERIFY BYTE instruction, a **operations mode** acknowledgment will be generated in response to a VERIFY BIT instruction if appropriate. Using the same criteria as the WRITE BYTE instruction, a configuration variable access acknowledgment will be generated in response to the second identical WRITE BIT instruction if appropriate.

D: Accessory Digital Decoder Packet Formats

Accessory Digital Decoders are intended for control of a number of simple functions such as switch machine control or turning on and off lights. It is permissible to develop *Digital Decoders* that respond to multiple addresses so that more devices can be controlled by a single *Digital Decoder*.

Basic Accessory Decoder Packet Format

The format for packets intended for Accessory Digital Decoders is:

{preamble} 0 10AAAAAA 0 1AAACDDD 0 EEEEEEEE 1

Accessory Digital Decoders can be designed to control momentary or constant-on devices, the duration of time each output is active being controlled by configuration variables CVs #515 through 518. Bit 3 of the second byte "C" is used to activate or deactivate the addressed device. (Note if the duration the device is intended to be on is less than or equal the set duration, no deactivation is necessary.) Since most devices are paired, the convention is that bit "0" of the second byte is used to distinguish between which of a pair of outputs the accessory decoder is activating or deactivating. Bits 1 and 2 of byte two is used to indicate which of 4 pairs of outputs the packet is controlling. The most significant bits of the 9 bit address are bits 4-6 of the second data byte. By convention these bits (bits 4-6 of the second data byte) are in ones complement.

If operations-mode acknowledgement is enabled, receipt of a basic accessory decoder packet must be acknowledged with an operations-mode acknowledgement.

Extended Accessory Decoder Control Packet Format

The Extended Accessory Decoder Control Packet is included for the purpose of transmitting aspect control to signal decoders or data bytes to more complex accessory decoders. Each signal head can display one aspect at a time.

{preamble} 0 10AAAAAA 0 0AAA0AA1 0 000XXXXX 0 EEEEEEEE 1

XXXXX is for a single head. A value of 00000 for XXXXX indicates the absolute stop aspect. All other aspects represented by the values for XXXXX are determined by the signaling system used and the prototype being modeled.

If operations-mode acknowledgement is enabled, receipt of an extended accessory decoder packet must be acknowledged with an operations-mode acknowledgement.

Broadcast Command For Accessory Decoders

Broadcast Command for Basic Accessory Decoders

The format for the broadcast instruction is:

{preamble} 0 10111111 0 1000CDDD 0 EEEEEEEE 1

This packet shall be executed by all accessory decoders. CDDD is defined as specified in the paragraph on Basic Accessory Decoder Packet Format.

Broadcast Command for Extended Accessory Decoders

The format for the broadcast instruction is:

{preamble} 0 10111111 0 00000111 0 000XXXXX 0 EEEEEEEE 1

All extended accessory decoders must execute this packet. XXXXX is defined as specified in the paragraph on Extended Accessory Decoder Packet Format.

Accessory Decoder Configuration Variable Access Instruction

Accessory decoders can have their Configuration variables changed in the same method as locomotive decoders using the **Configuration Variable Access Instruction** - Long Form instruction defined above. For the purpose of this instruction, the accessory decoders' address is expanded to two bytes in the following method. If operations-mode acknowledgement is enabled, the receipt of an Accessory Decoder Configuration Variable Access instruction must be acknowledged in the same manner as the Configuration Variable Access Instruction – Long Form.

Basic Accessory Decoder Packet address for operations mode programming

10AAAAAA 0 1AAACDDD

Where DDD is used to indicate the output whose CVs are being modified and C=1.
If CDDD= 0000 then the CVs refer to the entire decoder. The resulting packet would be

{preamble} 10AAAAAA 0 1AAACDDD 0 (1110CCAA 0 AAAAAAAA 0 DDDDDDDD) 0 EEEEEEEE 1
Accessory Decoder Address (Configuration Variable Access Instruction) Error Byte

Extended Decoder Control Packet address for operations mode programming

10AAAAAA 0 0AAA0AA1

Please note that the use of 0 in bit 3 of byte 2 is to ensure that this packet can not be confused with the legacy accessory-programming packets. The resulting packet would be:

{preamble} 10AAAAAA 0 0AAA0AA1 0 (1110CCAA 0 AAAAAAAA 0 DDDDDDDD) 0 EEEEEEEE 1
Signal Decoder Address (Configuration Variable Access Instruction) Error Byte

E: Operations Mode Acknowledgment

The operations-mode acknowledgment mechanism as defined in RP-9.3.1 and RP-9.3.2 are the only valid acknowledgement in operations mode. Whenever an acknowledgment is requested, the decoder shall respond using this mechanism described in RP-9.3.1 and RP-9.3.2.

Appendix A.

This Appendix contains additional useful information and/or legacy instructions. A DCC product need not implement any items described in this appendix.

Accessory Decoder Configuration Variable Access Instruction⁹

The following command is included for backward compatibility for some older accessory decoders. It's use is discouraged in new decoder designs.

⁹ For backward compatibility, decoders should check the length of instruction packets when bit 7 of byte 2 is zero.

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The format for Accessory Decoder Configuration Variable Access Instructions are:

{preamble} 0 10AAAAAA 0 0AAA11aa 0 aaaaaaaa 0 DDDDDDDD 0 EEEEEEEE 1

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Where:

A = Decoder address bits

a = Desired CV address - (CV 513 = 10 00000000)

D = Data for CV

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The bit patterns described by aa aaaaaaaa in the second and third bytes and DDDDDDDD in the fourth byte are also identical to the corresponding bits in the Configuration Variable Access Instruction - Long Form (see RP-9.2.1).

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The purpose of this instruction is to provide a means of programming all parameters of an accessory decoder after it is installed on the layout. It is recommended that Command Stations exercise caution if changes to the address (CV 513 and CV 521) are allowed.