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1 General

As a prerequisite for this standard, a Digital Command Control (DCC) command station transmits information to DCC 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 decoder operates upon as described in S-9.2, S-9.2.1, and S-9.2.1.1.

This standard specifies how a DCC decoder transmits information 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 standard, the decoder must satisfy both the electrical specifications, or the Physical Layer discussed in Section 3 and the method for transferring data, or the Data Link Layer discussed in Section 4. The decoder transmitted messages have several fundamental formats and are discussed in Section 5. Implementing bi-directional communications between the command station and the decoder requires some configuration variable changes and several new commands that are discussed in Section 6. Decoders utilize bi-directional communications by actively acknowledging commands with replies that inform the command station their command was executed. In addition, several new simple applications and enhancements to DCC commands are possible with this new tool. The new applications for mobile decoders are discussed in Section 7 and the new applications for accessory decoders are discussed in the final Section 8.

This standard is based on the RailCom® protocol developed by Lenz GmbH. The RailCom protocol is also the basis for the Rail Community RCN-217 Standard. "RailCom" is a Lenz Elektronik name for class 9 "electronics controls "under the number 301 16 303 registered German brand and also a name for the classes 21, 23, 26, 36 and 38 "Electronic Controls for Model Railways" in U.S.A Reg. No. 2,746,080 registered trademark. European patent 1 380 326 B1 was cancelled.

At this time, bi-directional communications, as presented in this standard, only supports DCC operations mode. At some future date, service-mode programming may also be supported.

1.1 Introduction and Intended Use (Informative)

In order to comply with this standard, all technical values and protocols are followed. Tables 5 and 6 define which of the messages from at least a decoder must be supported.

1.2 References

This standard should be interpreted in the context of the following NMRA Standards, Technical Notes, and Technical Information.

1.2.1 Normative

- S-9.1 DCC Electrical Standard
- S-9.2 DCC Communication Standard
- S-9.2.1 Extended Packet Formats
- S-9.2.1.1 Advanced Extended Packet Formats
- S-9.2.2 Configuration Variables for DCC

1.2.2 Informative

- TN-9.3.2 Bi-Directional Communications
- TN-9.2.1.1 Advanced Extended Packet Formats
- RCN-210 DCC packet structure
- RCN-211 DCC packet structure
- RCN-212 DCC operational commands for vehicle decoders
- RCN-213 DCC operation commands for accessory decoder
- RCN-214 DCC configuration commands
- RCN-217 RailCom DCC-Feedback
- RCN-218 DCC Automatic login
- RCN-225 DCC configuration variables
- TN-218 DCC Automatic login

There has been a concentrated effort to harmonize the Standards and Rail Community Norms (RCN) listed above. The text in this standard is based in part on the narratives in RCN-217. The graphics in this document are based in some cases on those found in RCN-217.

1.3 Terminology

To maintain continuity across multiple standards, some terms are used for multiple purposes. When encountered, the associated narrative will identify which term definition applies.

Term	Definition
Active Address	The address a decoder uses to receive addressed commands.
Bit Character Definitions	The following characters are used to indicate the meaning of a bit: 0 Bit value 0 1 Bit value 1 A Address bit C Instruction type or CID number D Data bit F Change flags G Instruction sub type H Manufacturer ID P Location information (position) or protocol support flag R Direction bit S Sequence number, session number, or number of requested CVs T Type of location information U Undefined bit or unique identifier V CV address bit X Subindex or don't care bit
{checksum}	Represents the single XOR checksum or CRC-8 + XOR checksum as appropriate for the given packet length.

Term	Definition
CID	System (Command Station) ID. 16-bit value typically represented by a hash of the system's Manufacturer ID and Unique ID.
Decoder	DCC device that receives commands for controlling vehicle or accessory animation and may transmit command replies or other information back to the system.
DID	Unique ID of a decoder (44-bit). HHHH HHHHHHHH (12-bit Manufacturer ID, represented as big endian) UUUUUUUU UUUUUUUU UUUUUUUU UUUUUUUU (32-bit Unique ID, represented as big endian)
Number values	Unless otherwise stated, values always refer to an 8-bit field. Binary values are marked according to the list above. Hexadecimal values are preceded by 0x.
Reply payload	All of the bytes sent in a decoder reply, including any identifier nibble, header byte, data, and CRC-8 byte. This designation occurs prior to message byte coding, as discussed in Section 4.1.
Session ID	8-bit number chosen arbitrarily by the System and incremented upon every reboot.
System	DCC device (or combination of devices) that sends DCC commands and processes Decoder feedback. Commonly referred to a Command Station or Central Unit. The system may also comprise separate feedback modules.
(►)	Commands sent from the command station to the decoder.
(◄)	Communications sent from the decoder to the detector.

Table of Contents

2 Physical Layer

This chapter describes the physical layer of the decoder transmission standard used for bi-directional communications. The physical layer definition includes the necessary equipment, the binary data bit waveform and timing information and the required cut-out timing that permits bidirectional communication to occur.

2.1 General

The information flow in the DCC system normally takes place in a forward direction from the command station and booster to the decoders. For transmission of information in the reverse direction to occur, it is necessary to interrupt the forward flow of energy and data. This happens in a compliant booster when it generates a cutout at the end of each DCC packet. This is accomplished by disconnecting the track power and short-circuiting the booster connections to both track rails. This function within the booster[1] is called the "cutout device". The cutout device can also be implemented as a separate unit outside of the booster. The actual data transmission takes place by means of a current loop and detector. The transmitting decoder must provide power from an attached energy source. Figure 1 shows the arrangement of the booster, detector and decoder during the cutout. The detector senses the current used for the decoder transmissions. This data reception process is shown as a voltage detected across a resistor in Figure 1.

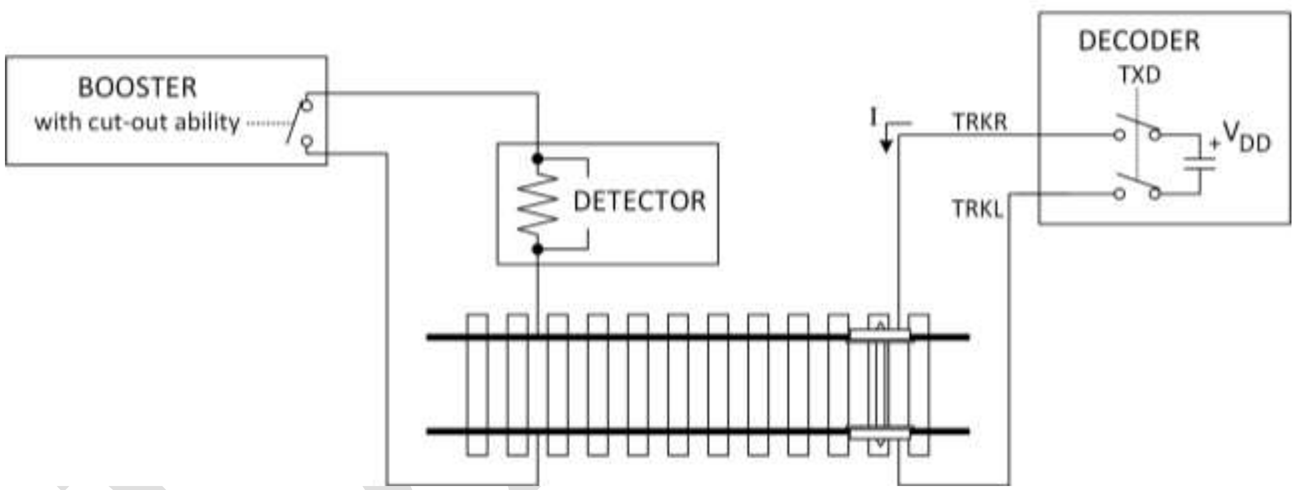

Figure 1. Decoder transmission physical layer circuit.

2.2 Decoder Transmitter

The decoder transmitter implements a current source, as part of a current loop, to transmit binary data. During standard operations, the decoder transmitter must not exceed a maximum of 34 milli-Amps (mA) injected into the current loop when transmitting data (unless the high current mode is selected as discussed below in Section 3.6). In addition, the decoder transmitter must comply with the transmitted waveform characteristics discussed below. The decoder must provide the power

[1] The DCC booster function is often implemented within a DCC command station.

necessary to execute bidirectional communication transmissions since DCC track power is disabled during decoder transmissions.

2.3 Detector

The detector interprets the current sent by the decoder transmitter and decides what binary data was transmitted. The detector may not generate a voltage drop greater than 200 milli-Volts (mV) on the current loop, at a maximum loop current of 34 mA. The detector is required to measure the received current during the middle 50% of each bit time. One detector or two detectors (connected in series) can be implemented on a single current loop. Generally, when two detectors are used, one is referred to as the global detector and may be located within the booster. The second detector is referred as a local detector and may be strategically located on a specific section of track or near a particular stationary layout asset such as a fuel depot or passenger platform. When idle, between cut-outs, the detector must also tolerate the DCC command waveform without damage. In addition, the detector must comply with the received waveform characteristics discussed below.

2.4 Cut-Out Function

A short-circuit function, usually within the booster or immediately external to the booster in a dedicated device, is used to cut-out, or disconnect and bypass, the DCC command waveform transmitter circuit. This function ensures the current loop is connected between the decoder transmitter and the detector during. During booster cut-out no power is provided to the track by the booster. The voltage drop across the cutout short-circuit device shall be no more than 10 mV at the maximum loop current of 34 milli-Amps (mA) during the cutout. The cut-out interval or window has precise timing requirements.

A cut-out is initiated and terminated by the booster cut-out circuit. The cut-out timing window must start between 26 and 32 micro-seconds (μs) after the zero crossing of the last DCC message end bit. The cut-out timing window must end between 454 and 488 μs after the zero crossing of the last DCC message end bit. The booster must restore a valid DCC signal immediately after terminating a cut-out window. The cut-out timing requirements are shown in Figure 2 and Table 1.

2.5 Message Structure and Timing

The bidirectional message consists of up to eight bytes. Each byte consists of eight bits preceded by a start bit and appended with a stop bit (there is no parity bit). The bytes are sent in two sequential groups called channels. Channel 1 consists of two bytes. Channel 2 follows channel 1 and consists of up to 6 bytes. Channel 1 starts no sooner than 80 μs after the zero crossing of the last DCC message end bit, and ends no later than 177 μs after the zero crossing of the last DCC message end bit. Channel 2 starts no sooner than 193 μs after the zero crossing of the last DCC message end bit, and ends no later than 454 μs after the zero crossing of the last DCC message end bit. The message structure and timing requirements are shown in Figure 2 and Table 1[2].

[2] If it is assumed the previous DCC message ended with a one bit with a nominal bit width of $116\mu s$, per S 9.1, then the maximum length cut-out would overlap 5 such one bits. However, if longer one bits are used (up to $125\mu s$ wide one-bits are possible), and a shorter cut-out start and cut-out window are used, it is possible to complete the cut-out with an overlap of only 4 one-bits. Since the Booster and Command Station control both timing parameters, this issue is resolved by their implementation of a compliant DCC waveform and bidirectional communications cut-out.

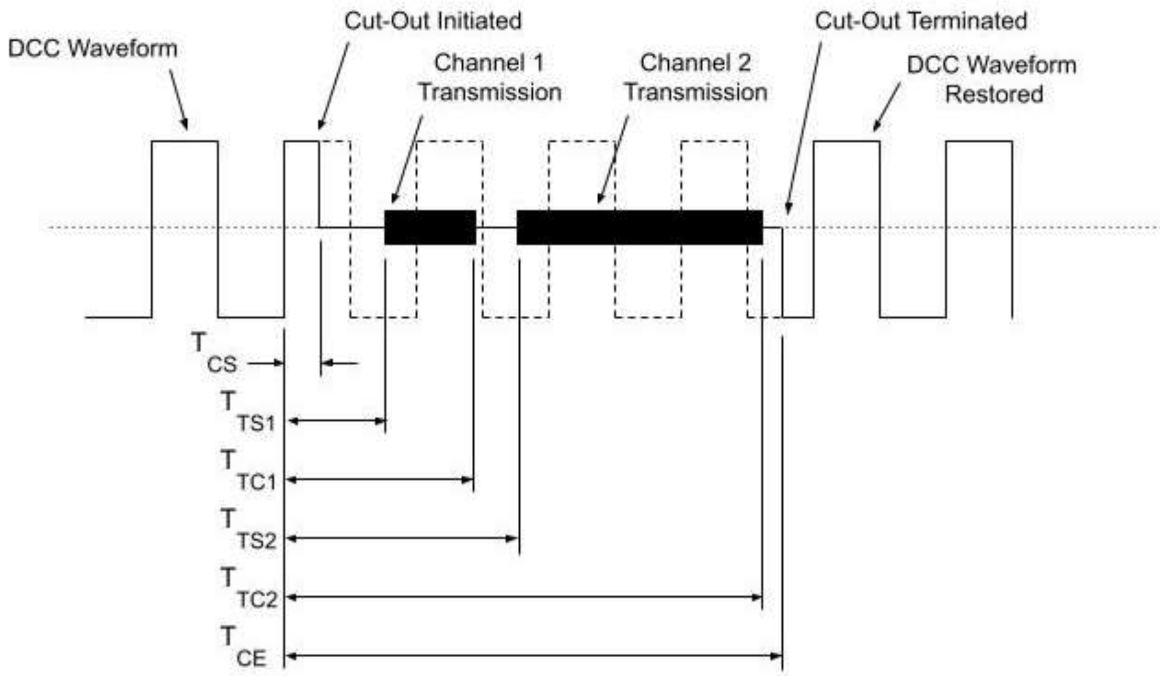

Figure 2. Message structure and timing.

Table 1. Message timing parameters.

Parameter	Name	Minimum	Maximum
Cut-out Start	T_{CS}	$26\mu s$	$32\mu s$
Cut-out End	T_{CE}	$454\mu s$	$488\mu s$
Start Channel 1	T_{TS1}	$80\mu s$	
End Channel 1	T_{TC1}		$177\mu s$
Start Channel 2	T_{TS2}	$193\mu s$	
End Channel 2	T_{TC2}		$454\mu s$

2.6 Current Loop Waveform

Binary data is transmitted from the decoder using an on-off, unipolar signaling waveform. The waveform uses current, not voltage. Since the current can flow in either direction between the rails, depending on decoder installation and orientation to the rails, the detector must resolve polarity ambiguity.

To provide an opportunity for the detector to determine the direction of travel, it is recommended that the decoder transmitter inject positive conventional current into the right rail, when viewed from a forward-motion-facing direction.

A zero bit is detected when a loop current of at least 10 mA is present. Note the maximum permitted loop current, stated above, is 34 mA unless the optional high-current bit is set in CV 28.

During standard operating conditions, the decoder transmits a zero bit with between 24 and 34 mA of current, unless the optional high-current bit is set in CV 28.

If the optional bi-directional communications high-current bit is set in CV 28 (bit 6) the decoder must transmit a zero bit with between 48 and 68 mA of current.

The decoder must transmit the required current for a zero bit in the presence of a voltage drop of no more than 2.2 Volts between the rails.

A one bit is detected when the loop current is less than or equal to 6mA.

To facilitate the detection of the zero and one bits by the detector, as discussed above in Section 3.3, the signal levels, in mA, must be met during the middle 50% of each bit time.

2.7 Bit Timing

Each bit in each byte of a bi-directional message is transmitted at a nominal data rate of 250 kilo-bits-per-second (kbps), or with a nominal bit time of 4 micro-seconds (μs). The required data rate accuracy is $\pm 2\%$.

Based on the message timing limits in Table 1, the 16 bits transmitted in channel 1 are afforded a maximum window of 97 μs. At the nominal bit rate 16 bits should take 64 μs for transmission.

Similarly, the channel 2 window is 261 μs long and the maximum of 48 transmitted bits in channel 2 would take 192 μs to transmit.

The bit rise and fall times must be less than 0.5 μs or 12.5% of the nominal bit time. The rise time is defined as the time in seconds required to traverse between 10% to 90% of the bit signal level difference, in mA, used for binary data. The fall time is defined as the time required to traverse between 90% to 10% of the bit signal level difference, in mA, used for binary data.

3 Data Link Layer

This chapter describes the data link layer of the decoder transmission standard used for bi-directional communications. The data link layer defines the structure of the binary messages used for bidirectional communication transmissions from decoders.

3.1 Message Byte Coding

The bytes transmitted in the message are code words. They are not data bytes. Every transmitted byte has exactly 4 one bits and 4 zero bits. This 4-out-of-8 code allows the detector to easily determine if a single bit error has occurred during transmission. Since there are 70 possible code words, any 6-bit data word can be transmitted using a 4-out-of-8 code word. For decoder transmissions, the mapping of 6-bit data words to 8-bit code words is shown in Table 2. The 64 possible, 6-bit data words are assigned along with 4 control words. The two remaining 4-out-of-8 code words are reserved for future use.

Table 2. Decoder transmitted message byte coding.

6-Bit Data Value	8-Bit Code Word	6-Bit Data Value	8-Bit Code Word	6-Bit Data Value	8-Bit Code Word	6-Bit Data Value	8-Bit Code Word
0x00	10101100	0x10	10110010	0x20	01010110	0x30	11000110
0x01	10101010	0x11	10110100	0x21	01001110	0x31	11001100
0x02	10101001	0x12	10111000	0x22	01001101	0x32	01111000

6-Bit Data Value	8-Bit Code Word	6-Bit Data Value	8-Bit Code Word	6-Bit Data Value	8-Bit Code Word	6-Bit Data Value	8-Bit Code Word
0x03	10100101	0x13	01110100	0x23	01001011	0x33	00010111
0x04	10100011	0x14	01110010	0x24	01000111	40x3	00011011
0x05	10100110	0x15	01101100	0x25	01110001	05x3	00011101
0x06	10011100	0x16	01101010	0x26	11101000	0x63	00011110
0x07	10011010	0x17	01101001	0x27	11100100	0x37	00101110
0x08	10011001	0x18	01100101	0x28	11100010	0x38	00110110
0x09	10010101	0x19	01100011	0x29	11010001	0x39	00111010
0x0A	10010011	0x1A	01100110	0x2A	11001001	0x3A	00100111
0x0B	10001101	0x1B	01011100	0x2B	11000101	0x3B	00101011
0x0C	10001110	0x1C	01011010	0x2C	11011000	0x3C	00101101
0x0D	10001101	0x1D	01011001	0x2D	11010100	0x3D	00110101
0x0E	10001011	0x1E	01010101	0x2E	11010010	0x3E	00111001
0x0F	10110001	0x1F	01010011	0x2F	11001010	0x3F	00110011
ACK	00001111	"Command is understood and will be executed" or "YES"					
ACK	11110000	"Command is understood and will be executed" or "YES"					
Reserved[3]	11100001						
Reserved[4]	11000011						
Reserved	10000111						
NACK[5]	00111100	Optional. "Command or CV is not supported"					

3.2 Message Data Throughput

Using the message structure and coding scheme described above, it is possible to send 12 data bits in the channel 1 transmission and 6, 12, 18, 24, or 36 data bits in the channel 2 transmission.

[3] The 11100001 8-bit code word was previously used as the BUSY code word. It is no longer supported. Its former intended functionality is supported by the optional NACK.

[4] The 2012 version of S-9.3.2 included a statement in the table that the two reserved 8-bit code words, 11000011 and 10000111, are not approved for use.

[5] Additionally, the 2012 version of S-9.3.2 included the statement in the table that a NACK is sent when an instruction is received correctly, but the decoder does not support that instruction or when a 'NO' response is appropriate.

3.3 Message Control Words

Two acknowledgement words are provided that can be utilized for higher layer functionality related to bi-directional communication transactions. They are both required message control words. An optional negative acknowledgement is provided to identify unsupported commands or to respond to unidentified configuration variables (CV) and identify requests to write to a read-only CV byte. During programing on the main (POM) transactions, the first response to such a condition should be an acknowledgement of a successful transaction, then a second response with a negative acknowledgement for the unidentified CV. The acknowledgement and optional negative acknowledgement responses can be sent together in a channel 2 transmission.

3.4 Message Datagrams

Bi-directional messages sent by decoders are usually comprised of datagrams. Datagrams can themselves be comprised of 12, 18, 24, or 36 bits. The bits can be identifier bits, data bits, or control bits. Only 12-bit datagrams can be sent in channel 1 transmissions. In channel 2 transmissions, 12-, 18-, 24-, or 36-bit datagrams can be sent.

Optionally, the data channel can be filled with up to 8 ACK code words.

Unless otherwise stated, datagrams (except control words) begin with a 4-bit identifier, followed by 8, 14, 20 or 32-bit user data. This format is shown in Table 3. In the table, the “+” symbols separate 6-bit data values. The length of the datagram is determined by the identifier as discussed below.

Table 3. Message Datagram Formats.

Datagram	Data Value Assignments
12 bit	ID[3-0]D[7-6] + D[5-0]
18 bit	ID[3-0]D[13-12] + D[11-6] + D[5-0]
24 bit	ID[3-0]D[19-18] + D[17-12] + D[11-6] + D[5-0]
36 bit	ID[3-0]D[31-30] + D[29-24] + D[23-18] + D[17-12] + D[11-6] + D[5-0]

Some exceptions to the format include accessory decoder channel 1 transmissions and automatic decoder identification transmissions.

In the case of accessory decoders, the channel 1 transmission is a 12-bit datagram consisting of the 9 or 11-bit address of the accessory decoder. No identifier is sent.

In the case of automatic decoder identification transmissions, the two channels are combined. The channel timing is unchanged but a combined 48 bits is sent. See S-9.2.1.1.

4 Decoder Transmitted Message Types

Decoders never initiate communications. Decoders that support bi-directional communications reply to messages in transactions and those replies can be either unsolicited or solicited. Unsolicited replies are intended to allow a known decoder to report its location. Solicited replies are made in response to an addressed DCC command, instruction, or query (hereafter referred to as a command). In both unsolicited and solicited replies, the decoder must be properly configured to transmit the replies. The proper configurations are discussed in Section 6.

4.1 Unsolicited Decoder Reply Message Type

There is one type of unsolicited reply message that decoders can generate.

4.1.1 Type 1 Unsolicited Messages

Type 1 unsolicited reply messages are generated by properly configured mobile decoders in the cut-out sent after every valid DCC mobile command. The unsolicited reply includes part of the decoder's address, using a specific format, and it is sent in channel 1. The Type 1 unsolicited response can also be sent in channel 2, but under specific power-up conditions, and in response to a specific broadcast command. There will be reply collisions if multiple decoders are operating in the same district, and are served by the same current loop detectors. The Type 1 unsolicited messages are implemented with the mobile decoder Address application discussed in Section 7.2. The process for managing collisions is discussed in Section 7.2.1. The special use of Type 1 unsolicited responses in channel 2 is discussed in Section 7.2.2.

4.2 Solicited Decoder Reply Message Types

There are three types of solicited reply messages that a decoder can generate.

4.2.1 Type 2 Solicited Messages

When responding to a DCC command sent by the command station to a specific decoder address, the solicited reply message type from the decoder is determined by the range or partition of the addresses that the command address (the address sent in the command) belongs to. The partition is determined by evaluating the command address byte of baseline commands or only the high byte of a multibyte address sent in an extended format command. With one exception, all addressed decoder replies are sent only in channel 2.

4.2.2 Type 3 Solicited Messages

Replies to addressed commands that send updates from the decoder can be substituted for channel 2 acknowledgements. Often, a decoder will be required to acknowledge either a mobile decoder operations command or an accessory decoder control command. Instead of using channel 2 in the cut-out to send an 8-bit ACK control word, the decoder is permitted to use channel 2 to send an update, from an application with a pending update, to the command station. Both mobile and accessory decoders can utilize this Type 3 solicited response message.

4.2.3 Type 4 Solicited Messages

Solicited replies can be generated by accessory decoders when they require service or have information to share. Service requests (SRQ) are sent in the channel 1 cut-out following any valid accessory decoder control command. Since these commands can be infrequent, the command station occasionally sends a "no-operation" (NOP) command which allows accessory decoders a separate opportunity to respond with a service request. This triggers the command station to engage in a solicited transaction with the requesting accessory decoder. The NOP is a unique command that includes a threshold address, and any accessory decoder with an address at or below this NOP command threshold-address can submit a service request in channel 2 of the following cut-out. In the event that multiple accessory decoders make simultaneous requests, the command station will detect the collision and use a successive approximation search routine to identify the lowest address accessory decoder, service it, and then repeat the process until all accessory decoders are serviced. There is no identifier associated with a Type 4 solicited message SRQ and it is optional for accessory decoders to support it. The NOP command and the successive approximation search routine are discussed in Section 6.3.3 and the SRQ message is discussed further in Sections 8.1 and 8.2.

4.3 Table of Decoder Reply Channel Assignments

The command address partitions and the associated decoder reply channel assignments are shown in Table 4.

Table 4. DCC primary command addresses and decoder reply channel assignments.

DCC Primary Command Address	Intended Command Recipient	Channel 1 Decoder Reply Message	Channel 2 Decoder Reply Message
0	All DCC decoders. This is the command broadcast address.	None	Usually None. There is one application that permits a response to a particular broadcast command. See Section 7.2.2.
1-127	Any multi-function mobile decoder with a 7 bit address.	All known mobile decoders respond alternately with identifier 1 or 2 and part of their address.	Addressed Mobile decoder responds to command.
128-191	Any Accessory decoder with a 9 or 11 bit address.	Service request if accessory decoder needs attention.	Addressed Accessory decoder responds to command.
192-231	Any multi-function mobile decoder with a 14 bit address.	All known mobile decoders respond alternately with identifier 1 or 2 and part of their address.	Addressed Mobile decoder responds to command.
232-252	Reserved	None.	None
253	Any mobile or accessory decoder that can be addressed in the above address partitions: 1-127, 128-191, or 192-231.	None.	Addressed Mobile or Accessory decoder responds to command.
254	Unidentified (auto-discoverable) and identified decoders with a 44-bit address	Addressed mobile or accessory decoder responds or previously unknown decoder responds. Response uses both channel 1 and channel 2 in a bundled format without a datagram identifier. See 9.2.1.1.	

DCC Primary Command Address	Intended Command Recipient	Channel 1 Decoder Reply Message	Channel 2 Decoder Reply Message
255[6]	None. The all-ones byte indicates an idle message has been sent	None	None

4.4 Mobile Decoder Message Datagram Identifiers[7]

When sending type 1 unsolicited messages in channel 1, the mobile decoder uses one of two possible datagram identifiers. Two identifiers and associated 12-bit datagrams are needed to send the complete mobile decoder address. The mobile decoder address is framed in two datagrams regardless of whether it is a short 7-bit address, an 8-bit consist address, or a long 14-bit address. The decoder must alternatively send the two datagrams, during two cut-outs, to deliver the decoder address in channel 1. See Section 7.2 for the address framing in the two datagrams. The two identifiers for mobile decoder channel 1 datagrams are shown in Table 5. Support for these two identifiers is mandatory.

Table 5. Mobile decoder channel 1 datagram identifiers.

Identifier Number	Application Name	Datagram Length	Description
1	ADR: Address High	12 Bits	Sent in alternate succession with identifier 2. See Section 7.2
2	ADR: Address Low	12 Bits	Sent in alternate succession with identifier 1. See Section 7.2
3	Info1	12 bits	Optionally sent in sequence with identifies 1 and 2. See Section 7.2

When sending solicited messages in channel 2, mobile decoders can use several different datagram identifiers depending on the soliciting command or the specific circumstances of the solicitation. The permissible mobile decoder channel 2 datagram identifiers are shown in Table 6. The related commands are included for reference. The reuse of identifiers 1 and 2 in channel 2 datagrams, where the mobile decoder address can be sent in channel 2, is related to a unique solicitation called a track search and is discussed in Section 7.2.3. Only identifiers 0, 1, and 2 are mandatory. Identifiers 3 – 14 are optional. They can be fully implemented, or, if only partially implemented, their implementation must comply with the requirements listed in Section 6.1.

An addressed mobile decoder must always provide feedback in channel 2 to confirm that the DCC packet has been received correctly. A response in Channel 2 signals that the decoder received the

[6] This address is used for RailcomPlus.

[7] RailComPlus uses specific identifiers that should be avoided in the future when assigning new identifiers.

command without errors, but not that the command is accepted and executed by the decoder. If an addressed command to a specific mobile decoder does not result in the decoder generating one or more of the datagrams listed in Table 6, the addressed decoder must still respond with either an ACK or NACK control word, as appropriate.

Table 6. Mobile decoder channel 2 datagram identifiers.

Identifier Number	**Application or Datagram Name**	**Datagram Length**	**Description**	**Related Command**
0	POM: Programming on the Main	12 Bits	POM Command acknowledgement or verification.	POM Commands. See Section 7.1.
1	ADR: Address High	12 Bits	Part of a multi-datagram response to a track search solicitation	XF2 Track Search. See Sections 7.2 and 7.3.
2	ADR: Address Low	12 Bits	Part of a multi-datagram response to a track search solicitation	XF2 Track Search. See Sections 7.2 and 7.3.
3	EXT: Extended Command Response	36 Bits		XF1 Location information. See Section 7.3.
4	INFO: Information Transfer	36 Bits	Reserved. Intended for the transfer of decoder current status information.	No. See Section 7.4.
7	DYN: Dynamic Variable Transfer	18 Bits (if necessary, 2 times)		No. See Section 7.5.
8	XPOM: Extended POM	36 Bits	POM Command acknowledgement or verification.	POM Commands. See Section 7.6.
9	XPOM: Extended POM	36 Bits	POM Command acknowledgement or verification.	POM Commands. See Section 7.6.
10	XPOM: Extended POM	36 Bits	POM Command acknowledgement or verification.	POM Commands. See Section 7.6.

Identifier Number	Application or Datagram Name	Datagram Length	Description	Related Command
11	XPOM: Extended POM	36 Bits	POM Command acknowledgement or verification.	POM Commands. See Section 7.6.
12	CV-automatic transfer	36 Bits	Automatic transfer of configuration variables	No. See Section 7.7.
13	Logon + Block Transfer	Variable	Decoder Logon Assign or block transfer of data	Various. See S-9.2.1.1.
14	Time	12 Bits		XF2 Track Search. See Section 7.2.3.
14	Read-Background (ongoing)	Variable	Continued decoder data space read replies	ReadBackground. See S-9.2.1.1.
15	Logon Enable	48 bits in combined channel 1 and 2	Unsolicited reply to request to register with the system	Logon Enable. See S-9.2.1.1.

4.5 Accessory Decoder Message Datagram Identifiers

As discussed above, accessory decoders can respond by sending the optional type 4 solicited reply message in channel 1. The message constitutes a service request (SRQ) by the decoder to have the command station query the decoder with an addressed stop command so that it can reply in channel 2 of the following cut-out with a needed update. The SRQ is a 12-bit datagram sent without an identifier. It includes the accessory decoder address in the 11 least significant bits. The most significant bit of the SRQ 12-bit datagram informs the control station whether the accessory decoder is a basic format or extended format accessory decoder. The framing of the accessory decoder address in the 12-bit channel 1 response is described in Sections 8.1 and 8.2. An SRQ can only be sent in the channel 1 cut-out following a previous accessory command, or in a channel 1 cut-out following an accessory NOP command sent by the command station.

When sending solicited messages in channel 2, accessory decoders can use several different datagram identifiers depending on the soliciting command or the specific circumstances of the solicitation. The permissible accessory decoder channel 2 datagram identifiers are shown in Table 7. The related commands are included for reference. Only identifiers 4 and 7 are mandatory. All other accessory decoder identifiers are optional. They can be fully implemented, or, if only partially implemented, their implementation must comply with the requirements listed in Section 6.1.

An addressed accessory decoder must always provide feedback in channel 2 to confirm that the DCC packet has been received correctly. A response in Channel 2 signals that the decoder received the command without errors, but not that the command is accepted and executed by the decoder.

The decoder responds with an ACK or a NACK code word, as appropriate. Following an addressed control command, if the decoder is prepared to send an ACK in channel 2, it may use the opportunity to instead send an update from another application. The status, time, errors, and dynamic variable applications can all potentially generate updates that can be sent, as Type 3 solicited responses, in channel 2 of the cut-out following the addressed control command. The command station will recognize the update as an ACK for the control command.

Table 7. Accessory decoder channel 2 datagram identifiers.

Identifier Number	Application or Datagram Name	Datagram Length	Description	Related Command
0	POM: Programming on the Main	12 Bits	POM Command acknowledgement or verification.	POM Commands. See Section 8.3.
3	STAT4: Stationary 4	12 Bits		No. See Section 8.5.
4	STAT1: Stationary 1	12 Bits		No. See Section 8.4.
5	Time	12 Bits		No. See Section 8.6.
6	Error	12 Bits		No. See Section 8.7.
7	DYN: Dynamic Variable Transfer	18 Bits (if necessary, 2 times)		No. See Section 8.8.
8	XPOM: Extended POM (ALSO STATUS 2)	36 Bits		No. See Section 8.9.
9	XPOM: Extended POM	36 Bits		No. See Section 8.9.
10	XPOM: Extended POM	36 Bits		No. See Section 8.9.
11	XPOM: Extended POM	36 Bits		No. See Section 8.9.
12	Test Feature Identifier	Not defined.		Not applicable. See Section 8.11.
13	Logon + Block Transfer	Variable	Decoder Logon Assign or block transfer of data	Various. See S-9.2.1.1.

Identifier Number	Application or Datagram Name	Datagram Length	Description	Related Command
14	Read-Background (ongoing)	Variable	Continued decoder data space read replies	ReadBackground. See S-9.2.1.1.
15	Logon Enable	48 bits in combined channel 1 and 2	Unsolicited reply to request to register with the system	Logon Enable. See S-9.2.1.1

5 Bi-directional Communication CVs and Commands

Bi-directional communications require the assignment of specific configuration variables. In addition, specific commands are needed to implement bi-directional communications.

5.1 System Requirements

This standard is designed to be backwards compatible so that non-compliant decoders can continue to operate and non-compliant command stations and boosters can control decoders that do comply with this standard.

Compliant command stations implementing bi-directional communications may not use zero-stretching to support analog vehicles operating on direct current (DC).

Compliant decoders implementing bi-directional communications must support the mandatory mobile or accessory decoder applications and identifiers. All decoders must also support the ACK control code word and optionally, the NACK control word. All decoders must support transmissions in both channel 1 and 2 as appropriate in this standard. Decoders must never reply to a broadcast command or to a command addressed to another decoder.

5.2 Bi-Directional Communication CVs

Several configuration variables (CV) are used in support of bi-directional communications.

5.2.1 CV 28

This CV is used to configure how a decoder uses bidirectional communications, when enabled (for the enable procedure see CV 29).

The CV 28 bits that are used here are maintained in standard S-9.2.2. For mobile decoders, the CV 28 bits are presented in Table 8. In Table 8, bits that are set to “1” are enabled and bits that are cleared to “0” are disabled. See S-9.2.2 to confirm the latest bit assignments.

Bits 0,1, and 2 are mandatory for support of bi-directional communications.

Table 8. The CV 28 bit-assignments for controlling bi-directional communications.

Bit	Description
0	Enable Channel 1 Address Broadcast (unsolicited Type 1 replies).
1	Enable Channel 2 Datagrams and Acknowledgement Code Words.
2	Switch Off Channel 1 Address Broadcast, dynamically. See Section 7.2.2.
3	Transmit identifier 3 in Channel 1 (unsolicited Type 1 replies).
4	Enable Programming Address 0003 (Long Address 3)
5	Reserved.
6	Enable High-current.
7	Enable Automatic Registration.

To assist with firmware version control, it is recommended that decoders be delivered with CV 28 bit 2 set to 0 for all decoders, bit 1 set to 1 for all decoders, and bit 0 set to 1 for mobile decoders, and set to 0 for accessory decoders.

If the decoder does not support a feature contained Table 8, it shall not allow the corresponding bit to be set improperly (i.e., the bit should always contain its default value).

For accessory decoders, the CV 28 bits are presented in Table 9. They mimic most of the bits in CV 28 for mobile decoders. In Table 9, bits that are set to “1” are enabled and bits that are cleared to “0” are disabled. See S-9.2.2 to confirm the latest bit assignments.

Bit 1 is mandatory for support of bi-directional communications.

Table 9. The CV 28 bit-assignments for controlling bi-directional communications.

Bit	Description
0	Enable Channel 1 Address Broadcast (unsolicited Type 1 replies).
1	Enable Channel 2 Datagrams and Acknowledgement Code Words.
2	Reserved.
3	Reserved.
4	Reserved
5	Reserved.
6	Enable High-current.
7	Enable Automatic Registration.

5.2.2 CV 29

This CV is used to enable bidirectional communications. The CV 29 bits that are used here are maintained in standard S-9.2.2. Bit 3 in CV 29 must be set to 1 to enable bi-directional communications. The use of CV 29 is identical for both mobile and accessory decoders.

5.2.3 CV 31 and CV 32

These two CVs hold a 16-bit index address (CV 31 is the high byte) to a page of 256 CVs. There are 65,536 pages available. See S-9.2.2 for details on the use of CVs 31 and 32. The use of CV 31 and CV 32 is identical for mobile and accessory decoders.

Indexed page 255 (CV 31 = 0, CV 32 = 255) is reserved by the NMRA for bidirectional communications with mobile decoders. See Section 6.2.4 for the list of CVs available in page 255.

5.2.4 Page 255 CV Assignments for Bi-directional Communications

The page 255 indexed CVs assigned by the NMRA for bi-directional communications with mobile decoders are shown in Table 10. Two index columns are presented, with either byte numbers or CV numbers. A read/write column identifies whether a CV can be read (R), written (W), or both.

When implementing bi-directional communications the mandatory indexed CVs for page 255 are CVs 257-258, and 385-387. All other CVs are optional.

Table 10. Indexed mobile decoder CVs used for bi-directional communications.

Indexed CV Byte Number	Actual Indexed CV with 10 bit CV address.	Description	Read Write
0-1	257-258	Manufacturer ID[8] in Little Endian[9] (according to NMRA [S-9.2.2 Appendix A])	R
2-3	259-260	Reserved	
4-7	261-264	Product ID (manufacturer-specific product identifier for the individual to be able to distinguish products. Little Endian)	R
8-11	265-268	MUN (Manufacturer Unique Number. Little Endian), 4-byte serial number for all devices from one manufacturer.	R
12-15	269-272	production date (number of seconds since 1.1.2000, Little Endian, Unsigned).	R
16-63	273-320	Manufacturer-specific assignment possible.	R/W
64-127	321-384	64 dynamic variables that can change during train operation, e.g., speed, fuel onboard, etc. See the mobile decoder application DYN in Section 7.5. Bytes 72-83 hold the levels of containers 1-12.	R/W
128	385	Manufacturer-specific read-only assignment possible.	R
129	386	Manufacturer-specific read-only assignment possible	R
130	387	Manufacturer-specific read-only assignment possible	R
131	388	Reserved.	

[8] These two CVs must match CVs 107 and 108, the extended manufacturer's ID.

[9] Little Endian means the least significant byte of a multi-byte word is stored at the lowest memory address, or stored in the least significant byte of a multi-byte address.

Indexed CV Byte Number	Actual Indexed CV with 10 bit CV address.	Description	Read Write
132	389	Container 1, specific consumption, “emptying rate”	R/W
133	390	Container 2, specific consumption, “emptying rate”	R/W
134	391	Container 3, specific consumption, “emptying rate”	R/W
135	392	Container 4, specific consumption, “emptying rate”	R/W
136	393	Container 5, specific consumption, “emptying rate”	R/W
137	394	Container 6, specific consumption, “emptying rate”	R/W
138	395	Container 7, specific consumption, “emptying rate”	R/W
139	396	Container 8, specific consumption, “emptying rate”	R/W
140	397	Container 9, specific consumption, “emptying rate”	R/W
141	398	Container 10, specific consumption, “emptying rate”	R/W
142	399	Container 11, specific consumption, “emptying rate”	R/W
143	400	Container 12, specific consumption, “emptying rate”	R/W
144	401	Write the level of all 12 containers to the specified value, at the same time. See bytes 72-83 above.	W
145	402	speedometer scaling at command station, value times 2 = maximum speed in km / h.	R/W
146-255	403-512	Reserved	

5.3 DCC Commands for Bi-Directional Communications

Fully implementing bi-directional communications requires the use of several new DCC commands that are sent by command stations. In addition, the responses by decoders to some specific DCC commands require special formatting.

5.3.1 Acknowledging Multi-CV Access Commands

5.3.1.1 Mobile decoder CVs 17, 18, and 29

A bidirectional communications response by a mobile decoder to a DCC command to write CVs 17,18, and 29 simultaneously requires multiple addressed datagrams in the same channel 2 response.

The process uses the short form of the CV access instruction command, as presented in S-9.2.1, Section 2.3.7.2, to write the first address byte to CV 17, the second extended address byte to CV 18, and set bit 5 to 1 in CV 29 indicating the use of the extended address. As noted in S-9.2.1, the instruction sub-type for this command is GGGG = 0100.

The required response by the decoder to this CV access instruction must send two consecutive datagrams, both with identifier 0, containing first the CV 17 data, then the CV 18 data. The format of the entire transaction is show below in Table 11.

It should be noted that since this is an operations mode programming task it falls under the mobile decoder POM application, which explains the use of identifier 0, the POM application identifier.

Table 11. CV access transaction for writing CVs 17 and 18, and bit 5 in CV 29.

Operation command: POM	
►	Write CVs CV17 and CV18, and set bit 5 in CV 29 {instruction bytes} = 11110100 0 DDDDDDDD 0 DDDDDDDD The first byte is written to CV 17 and the second byte to CV 18. The command packet must be sent twice, per Table 2.1 in S-9.2.1.
◄	No response for the first command packet. After successfully receiving both packets, decoder responds in channel 2 with two 12-bit datagrams sent together: 0000 (ID0) DDDD-DDDD + 0000 (ID0) DDDD-DDDD with D = CV data, first CV17, then CV18

5.3.1.2 Mobile Decoder CVs 31 and 32

Similarly, a bidirectional communications response by a mobile decoder to a DCC command to write CVs 31 and 32 simultaneously requires multiple addressed datagrams in the same channel 2 response.

The process uses the short form of the CV access instruction command, as presented in S-9.2.1, Section 2.3.7.2, to write the first index page address byte to CV 31 and the second address byte to CV 32. As noted in S-9.2.1, the instruction sub-type for this command is GGGG = 0101.

The required response by the decoder to this CV access instruction must send two consecutive datagrams, both with identifier 0, containing first the CV 31 data, then the CV 32 data. The format of the entire transaction is show below in Table 12.

It should be noted that since this is an operations mode programming task it falls under the mobile decoder POM application, which explains the use of identifier 0, the POM application identifier.

Table 12. CV access transaction for writing CVs 31 and 32.

Operation command: POM	
►	Write CVs CV31 and CV32 {instruction bytes} = 11110101 0 DDDDDDDD 0 DDDDDDDD The first byte is written to CV 31 and the second byte to CV 32. The command packet must be sent twice, per Table 2.1 in S-9.2.1.
◄	No response for the first command packet. After successfully receiving both packets, decoder responds in channel 2 with two 12-bit datagrams sent together: 0000 (ID0) DDDD-DDDD + 0000 (ID0) DDDD-DDDD with D = CV data, first CV31, then CV32

5.3.2 Reserved Bi-directional Communication Function States

Among the 127 function states that can be controlled with the short form of the binary state control instruction discussed in S-9.2.1, Section 2.3.6.4, there are 15 function states reserved by the NMRA for bi-directional communications. Specifically, binary states 1-15 are reserved for bi-directional communications.

Three of the 15 function states currently have instructions identified that support bi-directional communication applications. Table 13 shows the bi-directional communication function states where the function numbers are designated with the prefix XF.

Table 13. Bi-directional communication function states.

XF Number	**Purpose of the Function State**
1	Request Location Information. See Section 7.2.1.
2	Track Search to identify a mobile decoder. See Section 7.2.2.
3	CV automatic transfer enable. See section 7.7.
4-15	Reserved

5.3.3 NOP command for Accessory Decoders

As discussed in S-9.2.1, Section 2.4.6, and above in Sections 5.2.3 and 5.5, after any DCC addressed command sent to an accessory decoder, any other accessory decoder may reply in channel 1 of the following cut-out with an SRQ requesting the command station initiate a transaction with the decoder (See Sections 8.1 and 8.2 for information on the SRQ reply format). However, since DCC commands to accessory decoders are usually sent infrequently, a NOP command can be sent by the command station, at a configurable interval, that accessory decoders can respond to with an SRQ. The SRQ sent by an accessory decoder after a NOP, is also sent in channel 1 of the following cut-out, and depending on the application requesting the SRQ, may be followed by an update in channel 2 of the same cut-out. This process will ensure accessory decoders are serviced frequently enough by the command station. The NOP command itself requires no action be taken by decoders. In fact, the SRQ is an optional type 4 solicited reply. Only if accessory decoders need service, will they respond to the NOP with an SRQ. The recommended interval between sending NOP commands is 0.5 seconds, however this is obviously dependent of several factors including bandwidth availability and layout design. The command station is required to send its first NOP within 5 seconds of energizing the track to allow accessory decoders to identify that the command station is able to receive SRQs.

The SRQ sent by an accessory decoder includes its address to allow the command station to identify the decoder requesting service. Since more than one accessory decoder may send an SRQ in the same cut-out, there is a potential for a collision. In the case of a collision, the SRQs will not be received by the command station. To resolve this potential issue, the NOP command itself includes an accessory decoder address. The address included in the NOP will initially be the highest known accessory decoder address. Any decoder with an address at or below this NOP command decoder threshold address may respond with an SRQ. If the command station detects a collision from multiple decoders sending SRQs in the same cut-out, the command station reduces the decoder address it sends in the NOP potentially reducing the number of decoders that are allowed to respond and thereby reducing, but not eliminating, the chance for a collision. As long as collisions continue to occur, the command station continues to reduce the address sent in the NOP. Eventually only one decoder responds. The command station services that decoder and then raises the NOP threshold address to permit additional decoders to be serviced, one at a time.

The algorithm used to change the NOP address is referred to as a successive approximation search routine. In this routine the command station will repeatedly reduce the NOP command address, typically by half, in an iterative search to identify the single lowest addressed accessory decoder. After any iteration with a collision and another threshold address reduction, if no decoder responds, the address is increased by half the last iterative difference. Eventually the lowest active decoder requesting service (sending an SRQ) will be isolated. After servicing the lowest addressed decoder, the algorithm reverses to increase the address and find the next higher address decoder requesting service. Once all requesting decoders have been serviced, the command station should send subsequent NOPs with the highest known accessory decoder address to reset the search algorithm and wait for a fresh SRQ.[10] See TN-9.3.2 for an example of the search algorithm.

All mobile decoders and all accessory decoders that do not support bi-directional communications will consider the NOP command as invalid and not support it (they will ignore it). All command stations that support bi-directional communications must send a NOP within the first 5 seconds of energizing the layout to allow accessory decoders that support bi-directional communications to enable their capability to send an SRQ. The SRQ service must be enabled first, before accessory decoders begin using it. Accessory decoders must not transmit SRQs if the command station cannot receive them. Once a decoder begins sending SRQs, they cannot stop until the command station replies with a specific stop command. Obviously if the command station did not understand the SRQ, they cannot reply and release the decoder from an infinite loop of sending SRQs.

The NOP command is sent with either a 9-bit address, to a basic format accessory decoder or with an 11 bit address, to an extended format accessory decoder as described below in Table 14. Since 9-bit addresses are lower than 11-bit addresses, they will be serviced first when collisions occur between 9-bit and 11-bit accessory decoders sending SRQs in the same cut-out.

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[10] This search routine is similar in structure to the common conversion routine used by successive-approximation-register (SAR) analog-to-digital converters.

Table 14. Accessory decoder NOP command.

Operation command: NOP	
►	NOP command for facilitating accessory decoder service requests {instruction bytes} = $10A_7A_6A_5A_4A_3A_2\quad 0\overline{A_{10}}\,\overline{A_9}\,\overline{A_8}1A_1A_0T$ For 11-bit extended address decoders the 11 address bits are in the sequence: A7-A6-A5-A4-A3-A2-A10-A9-A8-A1-A0, with A10, A9,and A8 in ones complement. For 9-bit address, basic format decoders, the address bits are sent in the lower nine bits of the 11 bit address field in the NOP command. The “1 0” in bits 7 and 6 of the first byte establish the accessory decoder base address between 128 and 191. The “0” in bit 7 of the second byte should indicate an extended format three byte command is being sent. However, it is not. The lack of a third byte will result in decoders that do not support NOPs ignoring what appears to be an invalid DCC packet. The “1” in bit 3 of the second byte is a placeholder bit supporting the hybrid address/command format of accessory decoders and has no purpose for the NOP.- T = 0 for 9-bit address, basic format accessory decoders. T = 1 for 11-bit address extended format accessory decoders.

6 Applications for Mobile Decoders

6.1 Program on Main (POM) for Mobile Decoders

The mobile decoder POM application allows for the programming of mobile decoder CVs in operating mode, usually through the main track circuit, thus the name “program on main”. There are three commands and matching decoder responses in channel 2 available in this application. All three command responses use a 12 bit datagram containing the 4 bit identifier ID0 = 0000 and 8 data bits. The 8 data bits are the CV data that was the subject of the command the decoder is responding to.

The POM application can access mobile decoder CVs 1-256, and CVs 513-1024 directly with one command. To access the 65,536 indexed pages of CVs that are all numbered as CVs 257-512, the POM application must first use a special command to write the two-byte index address. It is discussed in S-9.2.1, Section 2.3.7.2. This special command and the unique decoder response, are also discussed above, in Section 6.3. Once the index page address is written, a standard POM application command (discussed in this Section) can access a CV address between 257-512 and yield the correct result.

Section 6.3 above discusses both the special case of responding to a single POM command to write a CV index page address to CVs 31 and 32, and the special case of responding to a single POM command to write a long format decoder address to CVs 17 and 18. Section 7.6 below discusses the extended POM application that can access 4 sequential indexed CVs with a single bi-directional communication transaction.

The general format for a single CV POM command and response is shown below in Table 15. The command structure is referenced from the long form of the CV access instruction, as presented in S-9.2.1, Section 2.3.7.3. The two-bit instruction sub type GG dictates which of three possible commands is to be executed: read a byte, write a byte, or write a bit. For all three commands the CV address uses the 10-bit format (VV-VVVV-VVVV) where a value of 1 is added to the command address to identify the desired CV. For example, to address CV 1 the 10-bit command address is "00 00000000". For the read and write byte commands, the 8 bits of data in the command (DDDD-DDDD) are the CV data to be read or written. For the bit writing command the data field (1111-DBBB) writes one bit, D, to bit position BBB (0-7).

For all three commands, the decoder responds in channel 2 with a 12-bit datagram that includes the 4-bit identifier, 0000, and the 8-bits of data that is in the CV after executing the command. Depending on which of the three commands are sent, there are different requirements for the timing of the response and how command execution delays are handled. See the individual commands for details on responses. Since the POM response is mandatory, all decoders supporting bi-directional communications must implement it.

Table 15. General POM command and response structure.

Operation command: POM	
►	To access a CV byte {instruction bytes} = 1110-GGVV VVVV-VVVV DDDD-DDDD For CV bit writing 1110-10VV VVVV-VVVV 1111-DBBB
◄	Response in Channel 2: 0000 (ID0) DDDD-DDDD with D = CV data or one or two control words.

6.1.1 The three available POM applications are discussed below. Read Byte

The POM CV read-byte command and response are shown below in Table 16. The associated response is a 12-bit datagram sent in channel 2. If the decoder needs more time to execute the read-byte command, the matching response datagram does not have to be sent in the cut-out immediately following the command. Instead, the decoder can send a NACK control word in channel 2 of the command cut-out. In that case, the command station must resend the same read-byte command to the addressed decoder before sending any new commands to that addressed decoder. Each time the command is received, but the decoder has not finished executing the command, the decoder can send a NACK control word. When the read operation is completed, the decoder transmits the command response, in the cut-out following the next resent read-byte command. If the decoder does not return the command response within 0.5 s, the transaction between the command station and decoder is considered failed.

If the CV is not supported, an ACK control word followed by a NACK control word can be sent in channel 2. It is permitted but not required that the two control words (ACK followed by NACK) be sent in the same cut-out. The command station should respond to a stand-alone ACK by resending the same command to the addressed decoder before sending a new command.

Reception of the command response datagram or the NACK, by the command station, completes the transaction.

Table 16. POM read byte command and response structure.

Operation command: POM read byte	
►	To read a CV byte {instruction bytes} = 1110-01VV VVVV-VVVV DDDD-DDDD
◄	Response in Channel 2: 0000 (ID0) DDDD-DDDD with D = CV data or send a NACK until the command is completed, or send an ACK then a NACK if the CV is not supported.

6.1.2 Write Byte

The POM CV write byte command and response are shown below in Table 17. The associated response is a 12-bit datagram sent in channel 2. If the decoder needs more time to execute the write-byte command, the matching response datagram does not have to be sent in the cut-out immediately following the command. Instead, the decoder can send a NACK control word in channel 2 of the command cut-out. In that case, the command station must resend the same write-byte command to the addressed decoder before sending any new commands to that addressed decoder. Each time the command is received, but the decoder has not finished executing the command, the decoder can send a NACK control word. When the write operation is completed, the decoder transmits the command response, in the cut-out following the next resent write-byte command. If the decoder does not return the command response within 0.5 s, the transaction between the command station and decoder is considered failed.

If the CV is not supported, or if the CV write byte command cannot be completed because some, or all, bits in the CV are read-only bits, an ACK control word followed by a NACK control word must be sent in channel 2. It is permitted but not required that the two control words (ACK followed by NACK) be sent in the same cut-out. The command station should respond to a stand-alone ACK by resending the same command to the addressed decoder before sending a new command.

Reception of the command response datagram or the NACK, by the command station, completes the transaction.

Table 17. POM write byte command and response structure.

Operation command: POM write byte	
►	To write a CV byte {instruction bytes} = 1110-11VV VVVV-VVVV DDDD-DDDD
◄	Response in Channel 2: 0000 (ID0) DDDD-DDDD with D = CV data or send a NACK until the command is completed, or send an ACK then a NACK if the addressed CV has at least one read-only bit, or send an ACK then a NACK if the CV is not supported.

6.1.3 Write Bit

The POM CV write bit command and response are shown below in Table 18. The command sends the data to be written with command bit D. The bit position to be overwritten is given by command bits BBB, which range between Bit 0 and Bit 7.

The associated response is a 12-bit datagram sent in channel 2. If the decoder needs more time to execute the write-bit command, the matching response datagram does not have to be sent in the cut-out immediately following the command. Instead, the decoder can send a NACK control word in channel 2 of the command cut-out. In that case, the command station must resend the same write-bit command to the addressed decoder before sending any new commands to that addressed decoder. Each time the command is received, but the decoder has not yet finished executing the command, the decoder must send a NACK control word. When the write operation is completed, the decoder transmits the command response, in the cut-out following the next resent write-bit command. If the decoder does not return the command response within 0.5 s, the transaction between the command station and decoder is considered failed.

If the CV is not supported, or if the CV write bit command cannot be completed because the bit is a read-only bit, an ACK control word followed by a NACK control word must be sent in channel 2. It is permitted but not required that the two control words (ACK followed by NACK) be sent in the same cut-out. The command station should respond to a stand-alone ACK by resending the same command to the addressed decoder before sending a new command.

Reception of the command response datagram or the NACK, by the command station, completes the transaction.

Table 18. POM write bit command and response structure.

Operation command: POM write bit	
►	To write a CV bit {instruction bytes} = 1110-10VV VVVV-VVVV 1111-DBBB
◄	Response in Channel 2: 0000 (ID0) DDDD-DDDD with D = CV data or send a NACK until the command is completed, or send an ACK then a NACK if the addressed CV bit is a read-only bit, or send an ACK then a NACK if the CV is not supported.

6.2 Address (ADR) Location Service

The address application is used to locate mobile decoders on the layout. Unsolicited responses from decoders are used for this application. The unsolicited responses contain the active address of the mobile decoder. There are two kinds of unsolicited responses that support the address application to provide location services. When permitted, the first kind of unsolicited response is sent in channel one of the cut-out after every addressed mobile decoder command. The response provides a method of locating a mobile decoder within a track section. This kind of basic location service is discussed in Section 7.2.1. and also, in the matching Section in TN-9.3.2. Collision mitigation for this first kind of location service is needed for support of multiple mobile decoders operating in the same track section. A dynamic response mechanism that provides this mitigation is discussed in Section 7.2.2. The second kind of unsolicited response that provides another location service can help determine the active address of a mobile decoder in a locomotive that is powering up on a track circuit. A specific broadcast command, reserved for bidirectional communications, is required to initiate the unsolicited response in this second kind of location service. The command and response are discussed in Section 7.2.3 and in the matching Section in TN-9.3.2.

6.2.1 Basic Location Service

After every addressed command to any mobile decoder, all mobile decoders (except the one being addressed in the command) must send a channel 1 response datagram containing part of their active address. Since only one datagram is sent in channel 1, and since two datagrams are needed to convey any decoder's address, all decoders must alternate the two address datagrams they send in channel 1, using two sequential cut-outs following any addressed mobile commands.

The two address datagrams use datagram identifiers 1 and 2 and are referred to as datagrams ADR1 and ADR2, respectively. Depending on the type of active mobile decoder address; either a 7-bit base address, a 7-bit consist address, or a 14-bit extended address, the two address datagrams will contain different information. For the three types of mobile decoder addresses, the contents of the address datagrams are shown in Table 19.

Table 19. Basic location service address application datagram contents.

ADR1 (Identifier 1)	**ADR2 (Identifier 2)**	**Mobile Decoder Address Type**
0 0 0 0 0 0 0 0	0 A6 A5 A4 A3 A2 A1 A0	Base Address (CV1)
0 1 1 0 0 0 0 0	R A6 A5 A4 A3 A2 A1 A0 Where R is the direction bit for the consist locomotive	Consist Address (CV19)
1 0 A13 A12 A11 A10 A9 A8	A7 A6 A5 A4 A3 A2 A1 A0	Extended address (CV17, CV18)

An optional information datagram can be sequenced with the two address datagrams, ADR1 and ADR2. This information datagram uses identifier 3 and is 12 bits long. The data byte in the datagram contains driving information.

The basic location service command and response sequence is shown below in Table 20.

Table 20. Basic location service command and response sequence.

Operation command and response: ADR basic location service	
►	Any addressed command sent to a mobile decoder
◄	Response in Channel 1 alternates: 0001 (ID1) DDDD-DDDD (ADR1 data). See Table 19 or 0010 (ID2) DDDD-DDDD (ADR2 data). See Table 19, or (optional) 0011 (ID3) DDDD-DDDD (Info1 data) where bits 7 – 5 = reserved, bit 4 = Set to request to be addressed so additional information can be sent in channel 2. Bit 3 = Set to indicate the locomotive is part of a consist.

Operation command and response: ADR basic location service	
	Bit 2 = Driving condition (1 = moving, 0 = standing) Bit 1 = Direction of travel. The bit indicates polarity of the DCC command track signal (as described in RCN-210, Section 2.3) but as it relates to CV 29, bit 1, and if applicable, CV 19, bit 7 (1 = negative polarity, 0 = positive polarity). Bit 0 = Rerailing direction. This bit indicates polarity of the DCC command track signal as described in RCN-210, Section 2.3 (0 = negative polarity, 1= positive polarity).

During consist operations, to minimize collisions between multiple decoder channel 1 responses in the same track section it is recommended that only the lead locomotive in the consist send the basic location service responses. The ability to send channel 1 basic location service address responses can be disabled in CV 28 by clearing bit 0, as discussed in Standard 9.2.2 and above in Section 6.2.1. An additional collision mitigation technique is discussed below in Section 7.2.2.

6.2.2 Dynamic Channel 1 Replies

To assist with mitigating collisions between different mobile decoders sending basic location service responses in channel 1, it is possible to configure a decoder to automatically cease sending continuous channel 1 responses, and only occasionally send a response. To enable this automatic cessation, bit 2 is set in CV 28, as discussed in Standard S-9.2.2 and above in Section 6.2.1. Once the bit has been set, the automatic cessation will begin AFTER the decoder receives 8 commands addressed to it. Once bit 2 in CV 28 is set and transmissions of the channel 1 responses have ceased, there are three conditions that, if any of them occur, the decoder will send a single channel 1 basic location service response. The three conditions are listed in Table 21. This occasional response process creates a dynamic channel 1 response profile that will reduce the risk of collision when multiple decoders are operating in the same track section.

Table 21. Dynamic channel 1 reply conditions.

Condition that will Initiate a Channel 1 Location Service Response
After a decoder restart
After a change of address
When no addressed commands are received for at least 5 seconds

6.2.3 Track Search Location Service

A second kind of location service can force a mobile decoder to send its active address as a type 1 unsolicited channel 2 response. This location service is only used when placing an individual locomotive on the layout (powering it up) or restarting a locomotive by tipping it off of one rail long enough to de-energize the decoder, and then putting it back down on the track. The track search location service (also known as on track search) can provide a method for quickly identifying the address of a mobile decoder.

Immediately after a mobile decoder receives power it will respond, for a period of 30 seconds, to a specific broadcast command, with a series of three datagrams sent together in channel 2. The three datagrams are the ADR1 and ADR2 active address datagrams discussed above in Section 7.2.1, and the Time datagram which uses datagram identifier 14. The Time datagram sends the time in actual seconds since the decoder was powered up. The Time datagram is sent so the command station or another intelligent monitoring system can record a time-stamp for the power-up status of the decoder.

The broadcast command that must be sent by the command station must be manually initiated by the operator within 30 seconds of the subject decoder being energized. The command is a specific binary state control instruction in short form. This type of command is discussed in S-9.2.1, Section 2.3.6.4. The binary state control instruction discussed in S-9.2.1 includes 15 states (states 1 – 15) reserved for bi-directional communications. It is the reserved state 2 that is used to execute this broadcast command for the track search location service. This state is referred to as XF2. When this broadcast command is sent, binary state number 2 is turned off. This condition is expressed as “XF2 off”. Binary state control instructions are considered Feature Expansion instructions, under Section 2.3.6 of S-9.2.1 which explains the use of the designator “XF”.

The structure of the broadcast command and channel 2 location response are shown in Table 22. The command is a broadcast command sent to address 0. In accordance with S-9.2.1, the command instruction begins with the feature expansion instruction type 110 followed by the binary state control instruction sub type 11101. The second byte of the instruction includes the desired state value in the most significant bit (in this case “0”) followed by the 7-bit state number (in this case the reserved state 2).

Table 22. Track search command and response structure.

Operation command: ADR Track search	
►	Binary state control instruction sent to broadcast address 0 within 30 seconds of decoder power-up {instruction bytes} = 1101-1101 0000-0010
◄	Response in Channel 2: three datagrams sent together 0001 (ID1) DDDD-DDDD (ADR1 data). See Table 19. 0010 (ID2) DDDD-DDDD (ADR2 data). See Table 19. 1110 (ID14) DDDD-DDDD (Time in seconds since decoder power-up).

6.3 Exact (EXT) Location Service

Another location service application is provided to identify when specific locomotives are at specific locations on the layout. This optional application is intended to support locomotive servicing operations such as fuel, water, and sand filling operations. It is an optional application. See TN-9.3.2 for additional information on using this application.

To implement this location service application, the command station sends a specific command to an addressed mobile decoder, requesting it send its location. Two unique location response profiles are possible when this command is sent. In the first response profile, if the decoder knows where it is then it can reply with a response that includes its location. In the second response profile, if the decoder does not know where it is, then it sends a partial datagram, and the detector that has the location information completes the response by transmitting the rest of the datagram on the track circuit, for reception by another detector.

The specific command that is sent for this location service application is a binary state control instruction in short form. This type of command is discussed in S-9.2.1, Section 2.3.6.4. The binary state control instruction discussed in S-9.2.1 includes 15 states (states 1 – 15) reserved for bi-directional communications. It is the reserved state 1 that is used to execute this addressed command for reporting location information. This state is referred to as XF1. When this addressed command is sent, binary state number 1 is turned off. This condition is expressed as “XF1 off”. Binary state control instructions are considered Feature Expansion instructions, under Section 2.3.6 of S-9.2.1 which explains the use of the designator “XF”.

The structure of the command is the same for both location response profiles. The command is an addressed command one or two bytes of mobile decoder address, as appropriate. In accordance with S-9.2.1, the command instruction begins with the feature expansion instruction type 110 followed by the binary state control instruction sub type 11101. The second byte of the instruction includes the desired state value in the most significant bit (in this case “0”) followed by the 7-bit state number (in this case the reserved state 1). The same command structure is presented for both location response profiles, as shown below.

6.3.1 Sending Location Information From the Decoder

If the mobile decoder knows its location it responds with a channel 2 datagram, using identifier 3, as shown below in Table 23. For this response profile, the 11-bit location information is not specified and must be determined by the decoder, or provided to it, for inclusion in the response.

Table 23. Command and response (decoder-only) for the EXT application.

Operation command and Response EXT by mobile decoder only	
►	Binary state control instruction sent to mobile decoder address {instruction bytes} = 1101-1101 0000-0001
◄	Response in Channel 2: one 18-bit datagram 0011 (ID3) 00 TTTT-PPPP-PPPP with: TTTT = 0000-0111: location information TTTT = 1000-1111: Reserved PPPP-PPPP lower 8 bits of an 11 bit position identifier: 0TTT-PPPP-PPPP

6.3.2 Sending Location Information From the Detector

If the mobile decoder does not know its location it responds with a partial channel 2 datagram, using identifier 3, as shown below in Table 24. A required local detector completes the response by sending the location data, as a partial datagram, using its own bi-directional transmitter, as specified in Section 3 above. The complete datagram is received by the global detector. For this response profile, the location is in 12-bit form. The most significant 4 bits are specified using a limited set of optional location categories, as shown in Table 24. The remaining 8 bits must be determined by the detector, or provided to it, for inclusion in the response.

Table 24. Command and response (decoder and detector) for the EXT application.

Operation command and Response: EXT by both mobile decoder and detector		
►	Binary state control instruction sent to mobile decoder address {instruction bytes} = 1101-1101 0000-0001	
◄	Part 1 of Response in Channel 2: by decoder 0011 (ID3) 01	Part 2 of response in Channel 2: by detector TTTT-PPPP-PPPP with: TTTT = 0000-0111: location information TTTT = 1000: Reserved TTTT = 1001: Reserved TTTT = 1010: diesel filling station TTTT = 1011: coaling station TTTT = 1100: water station TTTT = 1101: sanding station TTTT = 1110: charging station TTTT = 1111: general filling station PPPP-PPPP lower 8 bits of 12 bit position identifier: TTTT-PPPP-PPPP

6.3.3 Filling Containers

For information on filling the dynamic CV containers associated with filling station locations, see Sections 7.5 and 6.2.4 above.

6.4 Current Driving Information (INFO)

Identifier 4 is reserved for a future information transfer application. This Section is a place-holder for that future application. It is anticipated that a 36 bit datagram will be used, allowing for 32 bits of information transfer.

6.5 Dynamic Variables (DYN)

In response to any addressed operational command, for instance a speed and direction command, the mobile decoder can respond with an acknowledgement or communicate an update, for instance a changed dynamic variable (DV), stored as CV data. This optional DV application implements an update response message that will serve two purposes. It will be considered an acknowledgement to the operational command and, at the same time, it will efficiently convey dynamic information from the mobile decoder. The response to the addressed operational command is sent in channel 2 and can include 1 or 2 18-bit datagrams, conveying data from 1 or 2 CVs that contain the DV data.

In Table 10 of Section 6.2.4 the indexed CVs reserved for bi-directional communications are presented. Among them are 64 DVs, numbered actual CV numbers 321-384. They are accessed using the DV application (DYN) command where a 6-bit sub-index, numbered 0 thru 63, selects which DV to report from the mobile decoder. The 64 possible DVs are listed below in Table 25.

Table 25. Dynamic variables in indexed CVs 321-384.

DYN Sub-Index 6-bit Assignment	Indexed CV Byte Number	Actual Indexed CV with 10 bit CV address	Description
0	64	321	Uncoded scale speed up to 255 km/h.
1	65	322	Scale speed overage if more than 255 km/h.
2	66	323	Reserved.
3	67	324	Railcom version as 2x4 bit "main ver, minor ver.", 0x15 = Ver 1.5.
4	68	325	Change Flags from S-9.2.1.1 and RCN-218.
5	69	326	Flag Registers (unspecified at this time).
6	70	327	Input Registers (unspecified at this time).
7	71	328	Reception statistics: The vehicle decoder keeps statistics on all received DCC packets and transmits the number of faulty packets divided by total number of packets as a percent between 0-100.
8	72	329	Contents of container 1 as a percent between 0-100.
9	73	330	Contents of container 2 as a percent between 0-100.
10	74	331	Contents of container 3 as a percent between 0-100.
11	75	332	Contents of container 4 as a percent between 0-100.
12	76	333	Contents of container 5 as a percent between 0-100.
13	77	334	Contents of container 6 as a percent between 0-100.
14	78	335	Contents of container 7 as a percent between 0-100.
15	79	336	Contents of container 8 as a percent between 0-100.
16	80	337	Contents of container 9 as a percent between 0-100.
17	81	338	Contents of container 10 as a percent between 0-100.
18	82	339	Contents of container 11 as a percent between 0-100.
19	83	340	Contents of container 12 as a percent between 0-100.
20	84	341	Datagram 1 and Datagram 2 data contents from Basic Location Service Application response of Mobile Decoder Address, as discussed in Section 7.2.1.
21	85	342	Warning and alarm messages.
22	86	343	Trip meters (unspecified at this time).
23	87	344	Maintenance interval.

DYN Sub-Index 6-bit Assignment	Indexed CV Byte Number	Actual Indexed CV with 10 bit CV address	Description
24	88	345	Reserved.
25	89	346	Reserved.
26	90	347	Temperature using data 0-255 with -50°C offset and 255°C linear range covering $-50°C\ to\ 205°C$.
27	91	348	Direction status byte for east/west. See RCN-212, Section 2.2.3.
28-63	92-127	349-384	Reserved.

6.5.1 Specific Dynamic Variable Information

6.5.1.1 Dynamic Variable 0

The decoder calculates the speed in kilometers per hour (km/h) actually driven on the layout. This speed is multiplied by the scale which must be set in the decoder, e.g., the scale value 87 for HO. The product is the reported scale speed. The decoder will reply with raw (uncoded) scale speed values between 0 and 255 km/h, using only DYN sub-index 0.

6.5.1.2 Dynamic Variable 1

If the scale speed is higher than 255 km/h, reply with the scale speed overage reported as the difference when subtracting 256 km/h from the calculated scale speed. This reply is sent using DYN sub-index 1. DYN sub-index 0 is not used when the scale speed exceeds 255 km/h.

6.5.1.3 Dynamic Variable 20

This DV sends the mobile decoder address in two 18-bit DYN datagrams. The mobile decoder address (either 7-bit base address, 7-bit consist address, or 14-bit extended address) is framed into 2 bytes using the ADR application, as discussed above in Section 7.2.1. These two bytes are sent using this DV response with exactly 2 18-bit DYN datagrams. The contents of ADR2, datagram 2, hold the least significant bits of the address and are sent in the first 18-bit DYN datagram.

6.5.1.4 Dynamic Variable 21

Warnings and alarms are conveyed with DV21. They can report a warning or alarm related to any of the 64 DVs. They can also report warnings or alarms related to specific conditions, independent of the DVs. The format for this DV is to set bit 7 when conveying an alarm, or clear bit 7 when conveying a warning. Bit 6 is set if an alarm or warning is related to one of the 64 DVs, and cleared if related to one of the independent conditions identified below in Table 26. When bit 6 is set, the remaining least significant 6 bits of DV 21 convey the DV sub-index that has the alarm or warning condition.

Table 26. Independent DV 21 alarm and warning conditions for mobile decoders.

DV 21 Value	Independent Condition
128 = 1 0 0 0 0 0 0 0	Alarm: motor short circuit.
129 = 1 0 0 0 0 0 0 1	Alarm: function output short circuit.
130 = 1 0 0 0 0 0 1 0	Alarm: over temperature

6.5.1.5 Dynamic Variable 23

The maintenance interval is reset by writing 255 to indexed CV 344. The maintenance interval is implemented using a count-down timer that increments once each time the decoder is powered up. If the counter counts down to zero or down to a programmable threshold, in accordance with the manufacturer's instructions, a warning or alarm will be sent via CV 21.

6.5.1.6 Dynamic Variable 27

The direction status byte in DV 27 contains the bit assigned data shown below in Table 27. This data is associated with a special mode command defined in RCN-212, Section 2.2.3.

Table 27. Direction status byte DV 27-bit assignments.

Bit	Description
0	"VR" vehicle related direction in which to drive.
1	"OW" system related direction of travel: 0 = west. 1 = east.
2	Directional control: 0 = direction according to travel command. 1 = direction according to east-west control.
3	Change of direction: 0 = normal. 1 = locomotive currently in braking-phase of a change of direction.
4	OW hide: 0 = normal. 1 = OW direction arrows should not be displayed.
5	OW inverse: 0 = normal 1 = OW direction arrows displayed in reverse.
6	Reserved.
7	Reserved.

6.5.2 Dynamic Variable (DYN) Application Command Structure

The DYN application command structure uses any addressed operational command, as already discussed above, and a channel 2 response that consists of either 1 or 2 18-bit datagrams, both using identifier 7. Each datagram conveys a single DV. This means up to two DVs can be sent in a response. Which DVs are sent, what order, and how often is not specified. Thus, the user can create a custom commutation script (as permitted by the decoder manufacturer) to establish the desired frequency of reporting for each DV. The channel 2 response is sent with each datagram containing first the 4-bit identifier, then the 8-bit dynamic variable CV contents being reported, then the 6-bit sub-index, from Table 25, that indicates which DV and indexed bi-directional communication CV is being reported. Table 28 presents the command and response structure for the DYN application.

Table 28. Mobile decoder dynamic variable reporting command and response structure.

Operation command: DYN Dynamic variable reporting	
►	Any addressed operational command sent to a mobile decoder (See S-9.2)
◄	Response in Channel 2: one or two 18-bit datagrams sent together 0111 (ID7) DDDD-DDDD-XXXX-XX. See Table 25 for 6-bit (XXXX-XX) sub-index. [0111 (ID7) DDDD-DDDD-XXXX-XX. See Table 25 for 6-bit (XXXX-XX) sub-index]. If DV sub-index 20 is sent, the two 18-bit datagram slots in the DYN response are both needed to send the two bytes of mobile decoder address information used in the ADR application response discussed in Section 7.2.1.

6.6 Extended POM (XPOM) for Mobile Decoders

The optional extended format program on main application (XPOM) is an alternative to using POM to program mobile decoder CVs in operating mode. The XPOM application accesses data from up to 4 contiguous indexed CVs in one bi-directional communication transaction. Using XPOM can be more efficient than using POM when accessing multiple indexed CVs. The XPOM command is discussed in S-9.2.1, Section 2.3.7.4. As with POM there are three types of XPOM bi-directional communication applications: reading bytes, writing bytes, and writing bits.

As discussed in S-9.2.1, Section 2.3.7.4, the XPOM command uses between 4 and 8 instruction bytes to convey a 24-bit indexed CV address and any required write data for the 1 to 4 contiguous CVs being accessed. The 24 bit address is designed to include both the page index for the CVs and the offset in the page for the first (of as many as 4) desired CVs. To accomplish this, the address format (VVVV-VVVV VVVV-VVVV VVVV-VVVV) contains CVs 31 and 32 for the CV page index, with CV 31 in the first byte and CV 32 in the second byte. The third byte of the 24-bit CV address contains the lower 8 bits of the desired 10 bit indexed CV address, minus 1, or more specifically, the second instruction byte of the "Configuration Variable Access Instruction - Long Form" as discussed in S-9.2.1, Section 2.3.7.3.

Since XPOM commands can be very long, even intentionally exceeding the maximum permitted 30 ms interval between DCC packet start bits, each XPOM command to write bytes or bits must be sent twice to improve the integrity of the transaction. Although the command station is not required to send the repeated commands sequentially to the layout, they must both be sent before any broadcast commands are sent to the layout, or before another addressed command is sent to the mobile decoder receiving the XPOM command. The decoder must not execute the write command until it receives two identical command packets.

The XPOM application supports an additional important feature which explains why there are 4 datagram identifiers instead of 1 identifier for XPOM applications. Since decoders need time to access CVs, especially to write them to memory, and since there are occasions when more than 4 CVs need to be written to a decoder at one time, there are 4 XPOM identifiers provided with the XPOM application. This allows for a sequence of up to 16 CVs to be accessed with 4 sequential, but unique, XPOM commands, each one using a sequential identifier, numbered 8 through 11. The response acknowledgement process can be offset from the commands, even in the extreme case where the decoder is acknowledging the first command having received four sequential commands already. This is different from most bi-directional CV access command acknowledgement processes where the command station is prevented from sending a new addressed command to a decoder until the previous one is acknowledged. This XPOM command sequencing with 4 identifies can facilitate the command station accessing a large block of CV information continuously. For instance, the 1st, 5th, 9th, 13th, etc commands will all use sequence identifier 8. By the time the command station is ready to send the 5th command, the decoder will hopefully have responded to the 1st command, releasing sequence identifier 8 for reuse in the 5th command.

This sequencing feature has a lower priority than the command repeat requirement when writing bytes or bits so the command station must send each XPOM write command twice before changing the sequence identifier to send the next XPOM write command in the sequence.

For all three types of XPOM commands, and all four identifiers, the mobile decoder responds in channel 2 with a type 2 solicited response that contains a 36-bit datagram. In the datagram, after sending the appropriate identifier, the decoder sends the contents of the 4 contiguous CVs starting at the 24-bit CV address in the command. This response is the acknowledgement to any of the three types of commands. Even for XPOM write commands to less than 4 CVs, the response still contains 4 contiguous CVs.

Addressed mobile decoders are NOT required to respond in channel 2 to every XPOM command they receive. They only respond when they have completed executing an XPOM command. The response always sends the required 4 CV values. Even if a decoder receives a command to write to one or more read-only bytes or bits, the response is the same 4 stored CV values. If one or more requested CVs are not supported, the decoder responds with a zero value for that CV. The command station must determine if the write or read command was successful by comparing the command and response.

If the decoder is unable to respond to an XPOM command due to processing delays, or because two valid repeated write commands were not received or for any other reason, the command station must repeat the XPOM command. If sequenced XPOM commands are sent, the sequenced XPOM command that has not been replied to must be repeatedly sent and its sequence identifier cannot be released and reused until the transaction is complete. An XPOM command response time-out timer of not less than 2 seconds is required in the command station to accommodate the extended decoder write times often needed for up to 4 CV values. If the required response is not received before the timer expires, the transaction is considered complete (but failed) and any associated sequence identifier is released.

The general form for the XPOM application command and response structure is shown in Table 29. The command structure is referenced from S-9.2.1, Section 2.3.7.4. The two-bit instruction sub type GG dictates which of three possible commands is to be executed: read bytes, write bytes, or write bits, as shown in Table 29 below. The two-bit instruction sequence, SS, indicates the sequence identifier, as shown in Table 29 below. The 24-bit address is followed by from 0 to 4 data bytes, depending on the application and user needs. The data format for bit writing is discussed below in Section 7.6.3. For all three applications, the response is a channel 2 (type 2 solicited response) 36-bit datagram with identifier 8-11 and the 4 contiguous CV data values corresponding to the addressed CV in the command and the data from the three following CVs.

Table 29. General XPOM command and response structure.

Operation command: XPOM	
►	To access CV bytes or CV bits {instruction bytes} = 1110-GGSS VVVV-VVVV VVVV-VVVV VVVV-VVVV {DDDD-DDDD {DDDD-DDDD {DDDD-DDDD {DDDD-DDDD}}}} Where GG is the chosen CV access application using: GG = 01 for reading indexed CV bytes, GG = 11 for writing indexed CV bytes, GG = 10 for writing indexed CV bits, And where SS is the sequence identifier associated with the particular command and response datagram using: SS = 00 for identifier 8 (1000) SS = 01 for identifier 9 (1001) SS = 10 for identifier 10 (1010) SS = 11 for identifier 11 (1011)
◄	Response in Channel 2: GGSS (ID8 - 11) DDDD-DDDD DDDD-DDDD DDDD-DDDD DDDD-DDDD Where GG is the application and SS is the sequence identifier used in the associated command. Both are discussed in the command structure in the above table row.

The three available XPOM applications are discussed below.

6.6.1 Read XPOM Bytes

The XPOM indexed CV read-bytes command and response are shown below in Table 30.

Table 30. XPOM read-byte command and response structure.

Operation command: XPOM Read Bytes	
►	To read 4 CV bytes {instruction bytes} = 1110-01SS VVVV-VVVV VVVV-VVVV VVVV-VVVV { Where SS is the sequence identifier associated with the particular command and response datagram as presented above in Table 29.
◄	Response in Channel 2: 01SS DDDD-DDDD DDDD-DDDD DDDD-DDDD DDDD-DDDD Where SS is the sequence identifier used in the associated command and discussed in the command structure in the above table row, And the data bytes contain the four contiguous CV data values starting at the indexed CV address sent in the command.

6.6.2 Write XPOM Bytes

The XPOM indexed CV write-bytes command and response are shown below in Table 31.

Table 31. XPOM write-bytes command and response structure.

Operation command: XPOM Write Bytes	
►	To write 1 to 4 CV bytes {instruction bytes} = 1110-11SS VVVV-VVVV VVVV-VVVV VVVV-VVVV DDDD-DDDD {DDDD-DDDD {DDDD-DDDD {DDDD-DDDD}}} Where SS is the sequence identifier associated with the particular command and response datagram as presented above in Table 29. At least one CV data value, or as many as 4 contiguous CV data values, are sent in this command to write bytes to CVs.
◄	Response in Channel 2: 11SS DDDD-DDDD DDDD-DDDD DDDD-DDDD DDDD-DDDD Where SS is the sequence identifier used in the associated command and discussed in the command structure in the above table row, And the data bytes contain the four contiguous CV data values starting at the indexed CV address sent in the command.

6.6.3 Write XPOM Bits

The XPOM indexed CV write-bits command and response are shown below in Table 32. As with the matching POM write bits command discussed above in Section 7.1.3, the XPOM write bits command formats the data to be written using the format 1111-DBBB where the bit to be written (a 1 or 0) is designated as D and the bit location in the byte, that is to be written, is designated by BBB for bit 0 (000) through bit 7 (111).

Table 32. XPOM write bits command and response structure.

Operation command: XPOM Write Bits	
►	To write bits in 1 to 4 CV bytes {instruction bytes} = 1110-10SS VVVV-VVVV VVVV-VVVV VVVV-VVVV 1111-DBBB {1111-DBBB {1111-DBBB {1111-DBBB }}} Where SS is the sequence identifier associated with the particular command and response datagram as presented above in Table 29. At least one CV bit value, or as many as 4 contiguous CV bit values, are sent in this command to write bits to CVs.
◄	Response in Channel 2: 10SS DDDD-DDDD DDDD-DDDD DDDD-DDDD DDDD-DDDD Where SS is the sequence identifier used in the associated command and discussed in the command structure in the above table row, And the data bytes contain the four contiguous CV data values starting at the indexed CV address sent in the command.

6.7 CV Automatic Transfer

In response to any addressed operational command, for instance a speed and direction command, the mobile decoder can respond with an acknowledgement or take the opportunity to communicate indexed CV data. This optional CV automatic transfer application implements an update response message that will serve two purposes. It will be considered an acknowledgement to the operational command and, at the same time, it will efficiently convey indexed CV information from the mobile decoder. The response to the addressed operational command is sent in channel 2 and as a 36-bit datagram, with identifier 12 (1100). The 32 bits of data in the datagram include a 24-bit indexed CV address and 8 bits of CV data.

The 24 bit indexed CV address is designed to include both the page index for the CVs and the offset in the page for the CV being transferred. To accomplish this, the address format (VVVV-VVVV VVVV-VVVV VVVV-VVVV) contains CVs 31 and 32 for the CV page index, with CV 31 in the first byte and CV 32 in the second byte. The third byte of the 24-bit CV address contains the lower 8 bits of the desired 10 bit indexed CV address, minus 1, or more specifically, the second instruction byte of the "Configuration Variable Access Instruction - Long Form" as discussed in S-9.2.1, Section 2.3.7.3.

This ability to respond to operational commands with CV data can be enabled and disabled using a binary state control instruction, in short form, reserved for bi-directional communications. This type of instruction is discussed in S-9.2.1, Section 2.3.6.4. The binary state control instruction discussed in S-9.2.1 includes 15 states (states 1 – 15) reserved for bi-directional communications. It is the reserved state 3 that is used to enable and disable the CV automatic transfer application. This state is referred to as XF3. Turning on the binary state "XF3 on" will enable CV automatic transfer and turning off the binary state "XF3 off" will disable the application. Binary state control instructions are considered Feature Expansion instructions, under Section 2.3.6 of S-9.2.1 which explains the use of the designator "XF".

The structure of the command response for enabling and disabling the application are discussed below in Section 7.7.1. The actual CV transfer response is discussed in Section 7.7.2.

6.7.1 Enabling and Disabling CV Automatic Transfer

The command and response structure to enable Automatic CV transfer is shown in Table 33. In accordance with S-9.2.1, the command instruction begins with the feature expansion instruction type 110 followed by the binary state control instruction sub type 11101. The second byte of the instruction includes the desired state value in the most significant bit (in this case "1" to enable) followed by the 7-bit state number (in this case the reserved state 3). The response must be in the cut-out following the command and can be an ACK control word or any substitute acknowledgement, for example, a DYN response, as discussed in Section 7.5, or a CV value as discussed below in Section 7.7.2.

Table 33. Command and response structure to enable automatic CV transfers.

Operation command: CV Automatic Transfer Enable	
►	Binary state control instruction in short form addressed to the mobile decoder: {instruction bytes} = 1101-1101 1000-0011
◄	Response in Channel 2: An ACK control word Or a substitute ACK response including a DYN response (See Section 7.5) or CV Auto response (See Section 7.7.2)

The command and response structure to disable Automatic CV transfer is shown below in Table 34. Disabling automatic CV transfer uses the same binary state control instruction, XF3 but in this case the state is cleared to disable the automatic transfer application. The response must be in the cut-out following the command and can be an ACK control word or any substitute acknowledgement such as a DYN response, as discussed in Section 7.5. The substitute acknowledgement cannot be a CV value.

Table 34. Command and response structure to disable automatic CV transfers.

Operation command: CV Automatic Transfer Disable	
►	Binary state control instruction in short form addressed to the mobile decoder: {instruction bytes} = 1101-1101 0000-0011
◄	Response in Channel 2: An ACK control word Or a substitute ACK response including a DYN response (See Section 7.5) or CV Auto response (See Section 7.7.2)

6.7.2 CV Automatic Transfer Message

The command and response structure to transfer a CV automatically is shown in Table 35. The command that initiates a CV transfer is any addressed operational command, such as a speed and direction command, sent to the decoder. Which CV is sent, what order CVs are sent in, and how often a CV is sent is not specified. Thus, the user can create a custom commutation script (as permitted by the decoder manufacturer) to establish the desired frequency of reporting for each CV.

The response is a 36-bit datagram that starts with identifier 12 and is followed by the 24-bit indexed CV address, discussed above, and then the one-byte data value in the CV.

Table 35. Command and response structure to automatically transfer a CV.

Operation command: CV Automatic Transfer	
►	Any addressed operational command sent to a decoder (See S-9.2)
◄	Response in Channel 2: 36-bit datagram with identifier 12 1100 (ID12) VVVV-VVVV VVVV-VVVV VVVV-VVVV DDDD-DDDD Where VVVV-VVVV VVVV-VVVV VVVV-VVVV is the 24-bit indexed CV address and DDDD-DDDD is the data value stored in the indexed CV.

6.7.3 Time Datagram

In the response of a track search location service application, as discussed above in Section 7.2.3, a 12-bit datagram is included that contains the time in seconds since the mobile decoder has been powered up. The identifier for this datagram is ID 14 (1110) and the 8-bits of data in the datagram, DDDD-DDDD contains the time since start-up in seconds. The use of the datagram in the track search application is shown above in Table 22. It is important to note that the mobile decoder Time datagram is not used in any other application at this time.

7 Applications for Accessory Decoders

The bi-directional applications that accessory decoders can support fall into two general categories: solicited command-response transactions via POM or XPOM, and solicited update replies that are either sent after a control command to an addressed accessory decoder or sent after a NOP command. The accessory decoder POM and XPOM applications use the accessory decoder POM and XPOM commands discussed in S-9.2.1, Section 2.4. The bi-directional POM application is discussed below in Section 8.3 and the XPOM application is discussed in Section 8.9.

Solicited update replies from accessory decoders can occur in three formats. The first format is similar to the solicited responses generated by mobile decoders who have updates such as dynamic variable CV information to share. For accessory decoders, this first solicited reply format is sent in channel 2 of the cut-out following a valid accessory decoder control command and also serves as an acknowledgement for that control command. Only the decoder addressed in the command may use this first reply format. This is a type 3 solicited reply message, as discussed briefly above in Section 5.2.2, and in detail below in the sections on accessory decoder applications that can utilize it, including status updates, error reports, time reports, and dynamic variable CV updates.

The second solicited reply format is the service request or SRQ response sent to the command station in the cut-out after an addressed accessory control command sent to another decoder. This is an optional Type 4 solicited reply that an accessory decoder can send in channel 1 to alert the command station that it has an update it needs to transmit. The command station then sends an addressed control stop command to the decoder which allows it to respond using a Type 3 solicited response. This SRQ via addressed control command is discussed below in Section 8.1.

The third format for solicited replies from accessory decoders expands on the SRQ via addressed control command format by allowing the decoder to send an SRQ after the command station sends a NOP command. This is also an optional Type 4 solicited reply that an accessory decoder can send in channel 1 to alert the command station that it has an update it needs to transmit. In addition, for at least one application at this time (the errors application) the decoder is permitted to send its update in channel 2 of the same cut-out it sends the SRQ in, following the NOP command, reducing the time to deliver the update. For any other update, the decoder must wait for the command station to send an addressed control stop command as a follow-up to the SRQ. The stop command allows the decoder to respond with its update using a Type 3 solicited response. This SRQ via NOP command is discussed below in Section 8.2. The NOP command is discussed in S-9.2.1, Section 2.4 and also above in Section 6.3.3.

The use of the SRQ via addressed command and via NOP command, increases the frequency with which accessory decoders can submit updates. The NOP command has a built-in collision mitigation process to allow for competing accessory decoders to both submit SRQs and have the command station service them.

Once a decoder begins sending SRQs, it must continue to do so until it receives the addressed stop command. It may not respond to any other addressed command until the addressed stop command is received. Accessory decoders that can transmit SRQs must first determine that the command station is able to receive them. As discussed above in Section 6.3.3, command stations that support bi-directional communications are required to transmit a NOP within 5 seconds of energizing the track so that accessory decoders can establish that the command station will reply to an SRQ.

7.1 Service Request (SRQ) via Addressed Control Command

In response to any addressed accessory control command, an accessory decoder with a different decoder address than the one in the command, and that has an update to transmit to the command station (or monitoring computer), can send an SRQ in the channel 1 cut-out following the addressed command. The SRQ is a 12-bit datagram but does not have an identifier.

The addressed control command and channel 1 SRQ reply format are shown in Table 36. An addressed control command to an accessory decoder includes the data and address in a combined instruction format. Both basic format and extended format accessory decoders can respond with an SRQ. The most significant bit of the 12-bit datagram SRQ will indicate to the command station whether the decoder is a 9-bit, basic format or 11-bit, extended format accessory decoder. The following 11 bits contain the decoder address.

The command station will follow the reception of a valid SRQ with an addressed control command containing a stop instruction for the accessory decoder. This stop command will tell the decoder to cease sending SRQs. The stop command is a valid addressed control command. The accessory decoder will therefore send its update in channel 2 of the cut-out following the stop command using the appropriate bi-directional communication application as discussed below.

If a valid SRQ is not received due to a collision between competing accessory decoders, they must continue sending SRQs via channel 1 cut-outs following either addressed control commands or NOP commands until they are serviced.

After the transaction is completed, if an accessory decoder has another update to share, it can initiate a new SRQ process using either available method: addressed control command response or NOP command response.

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Table 36. Addressed command and SRQ with update response format.

Control command: Update via SRQ	
►	Any basic format accessory control command sent to a decoder {instruction bytes} = 10AA-AAAA 1AAA-DAAR
►	Or any extended format accessory control command sent to a decoder {instruction bytes} = 10AA-AAAA 0AAA-0AA1 XXXX-XXXX
◄	Response in Channel 1: SRQ in a 12-bit datagram with no identifier If replying to a basic format accessory control command: 0AAA AAAA-AAAA If replying to an extended address accessory control command: 1AAA AAAA-AAAA
►	A control stop command is sent to the decoder requesting the SRQ. This command instructs the decoder to cease sending the SRQ and allows the decodeto reply with its update. If the decoder is a basic format accessory decoder the control stop command is: {instruction bytes} = 10AA-AAAA 1AAA-0AA0 If the decoder is an extended format accessory decoder the control stop command is: {instruction bytes} = 10AA-AAAA 0AAA-0AA1 0000-0000
◄	Response in Channel 2: Update that precipitated the SRQ Any valid update message via a bi-directional communication application as discussed below.

7.2 Service Request (SRQ) via NOP command

The NOP command and type 4 solicited reply format are shown below in Table 37. A NOP command with a threshold address higher to or equal to that of the accessory decoder will permit the decoder to reply with an SRQ in channel 1 of the following cut-out. If the precipitating application supports it, the update may be sent in channel 2 of the same cut-out following the NOP command. At this time, only the errors application supports such an update. The update format for the reply is discussed below in Section 8.7. The SRQ is the same optional 12-bit datagram discussed above in Section 8.1.

The sequencing of NOP commands depends on decoder types (basic or extended) and is discussed above in Section 6.3.3. The collision arbitration process that adjusts the threshold address in the NOP is also discussed in Section 6.3.3.

In the event of a collision between SRQs from multiple decoders, the command station will arbitrate the collision by lowering the threshold address and resending the NOP, repeating the adjustment until only a single decoder responds with an SRQ.

If a valid SRQ is not received due to a collision between competing accessory decoders, the decoders must continue sending SRQs via channel 1 cut-outs following either addressed control commands or NOP commands until they are serviced.

The command station will follow the reception of a valid SRQ with an addressed control command containing a stop instruction for the accessory decoder. This stop command will tell the decoder to cease sending SRQs. The stop command is a valid addressed control command. The accessory decoder will therefore send its update in channel 2 of the cut-out following the stop command using the appropriate bi-directional communication application as discussed below.

After the transaction is completed, if an accessory decoder has another update to share, it can initiate a new SRQ process using either available method: addressed control command response or NOP command response.

Table 37. NOP command and SRQ with update response format.

NOP command: Update via solicited SRQ response	
►	NOP command sent to a decoder with threshold address {instruction bytes} = 10AA-AAAA 0AAA-1AAT T = 0 for basic format (simple) accessory decoders to respond T = 1 for extended format (advanced) accessory decoders to respond
◄	Response in Channel 1: SRQ in a 12-bit datagram with no identifier **only if the decoder address is less than or equal to the NOP command threshold address.** If replying to a NOP for a basic format decoder: 0AAA AAAA-AAAA If replying to a NOP for an extended format decoder: 1AAA AAAA-AAAA
◄	Response in Channel 2 (same cut-out): Currently available only for the Errors application and **only if the decoder address is less than or equal to the NOP command threshold address.** The update message that precipitated the SRQ using the appropriate bi-directional communication application as discussed below in Section 8.7.
►	A control stop command is sent to the decoder requesting the SRQ. This command instructs the decoder to cease sending the SRQ and allows the decoder to reply with its update. If the decoder is a basic format accessory decoder the control stop command is: {instruction bytes} = 10AA-AAAA 1AAA-0AA0 If the decoder is an extended format accessory decoder the control stop command is: {instruction bytes} = 10AA-AAAA 0AAA-0AA1 0000-0000
◄	Response in Channel 2: Update that precipitated the SRQ Any valid update message via a bi-directional communication application as discussed below.

Program on Main (POM)

The optional accessory decoder POM application allows for the programming of configuration variables in operating mode, usually through the main track circuit, thus the name “program on main”. There are three commands and matching decoder responses in channel 2 available in this application. All three command responses use a 12-bit datagram containing the 4 bit identifier ID0 = 0000 and 8 data bits. The 8 data bits are the CV data that was the subject of the command the decoder is responding to.

The POM application can access accessory decoder CVs 1-256, and CVs 513-1024 directly with one command. To access the 65,536 indexed pages of CVs that are all numbered as CVs 257-512, the POM application must first write the two-byte index address by writing CV 31 and then writing CV 32. There is no short-form POM command for accessory decoders to write CV 31 and 32 simultaneously. Once the index page address is written, a standard POM application command (discussed in this Section) can access a CV address between 257-512 and yield the correct result.

There are two formats for the POM application. The first format supports the basic format decoder and is discussed in Section 8.3.1. The second format for the POM command supports the extended format decoder and is discussed in Section 8.3.2. Both formats are similar and follow the mobile decoder POM application discussed above in Section 7.1 and the mobile decoder POM command structure as discussed in S-9.2.1.

7.2.1 POM for the Basic Format Accessory Decoder

The general format for a single CV POM command and response with a basic format accessory decoder is shown below in Table 38. The command structure is referenced from basic format accessory decoder POM command discussed in S-9.2.1, Sections 2.4.3.1. The two-bit instruction sub type GG dictates which of three possible commands is to be executed: read a byte, write a byte, or write a bit. For all three commands the CV address uses the 10-bit format (VV-VVVV-VVVV) where a value of 1 is added to the command address to identify the desired CV. For example, to address CV 1 the 10-bit command address is "00 00000000". For the read and write byte commands, the 8 bits of data in the command (DDDD-DDDD) are the CV data to be read or written. For the bit writing command the data field (1111-DBBB) writes one bit, D, to bit position BBB (0-7).

For all three commands, the decoder responds in channel 2 with a 12-bit datagram that includes the 4-bit identifier, 0000, and the 8-bits of data that is in the CV after executing the command. Depending on which of the three commands are sent, there are different requirements for the timing of the response and how command execution delays are handled. See the individual commands for details on responses. Since the POM response is mandatory, all decoders supporting bi-directional communications must implement it.

Table 38. Basic format POM command and response structure.

Operation command: POM for a basic format accessory decoder	
►	{combined command/address} = 10AA-AAAA 1AAA-1AA0 To access a CV byte {instruction bytes} = 1110-GGVV VVVV-VVVV DDDD-DDDD For CV bit writing 1110-10VV VVVV-VVVV 1111-DBBB
◄	Response in Channel 2: 0000 (ID0) DDDD-DDDD with D = CV data or one or two control words.

The three available POM applications are discussed below.

7.2.1.1 Read Byte

The POM CV read-byte command and response for basic format accessory decoders are shown below in Table 39. The associated response is a 12-bit datagram sent in channel 2. If the decoder needs more time to execute the read-byte command, the matching response datagram does not have to be sent in the cut-out immediately following the command. Instead, the decoder can send a NACK control word in channel 2 of the command cut-out. In that case, the command station must resend the same read-byte command to the addressed decoder before sending any new commands to that addressed decoder. Each time the command is received, but the decoder has not finished executing the command, the decoder can send a NACK control word. When the read operation is completed, the decoder transmits the command response, in the cut-out following the next resent read-byte command. If the decoder does not return the command response within 0.5 s, the transaction between the command station and decoder is considered failed.

If the CV is not supported, an ACK control word followed by a NACK control word must be sent in channel 2. It is permitted but not required that the two control words (ACK followed by NACK) be sent in the same cut-out. The command station should respond to a stand-alone ACK by resending the same command to the addressed decoder before sending a new command.

Reception of the command response datagram or the NACK, by the command station, completes the transaction.

Table 39. Basic format POM read byte command and response structure.

Operation command: POM read byte for a basic format accessory decoder	
►	{combined command/address} = 10AA-AAAA 1AAA-1AA0 To read a CV byte {instruction bytes} = 1110-01VV VVVV-VVVV DDDD-DDDD
◄	Response in Channel 2: 0000 (ID0) DDDD-DDDD with D = CV data or send a NACK until the command is completed, or send an ACK then a NACK if the CV is not supported.

7.2.1.2 Write Byte

The POM CV write byte command and response for basic format accessory decoders are shown below in Table 40. The associated response is a 12-bit datagram sent in channel 2. If the decoder needs more time to execute the write-byte command, the matching response datagram does not have to be sent in the cut-out immediately following the command. Instead, the decoder can send a NACK control word in channel 2 of the command cut-out. In that case, the command station must resend the same write-byte command to the addressed decoder before sending any new commands to that addressed decoder. Each time the command is received, but the decoder has not finished executing the command, the decoder can send a NACK control word. When the write operation is completed, the decoder transmits the command response, in the cut-out following the next resent write-byte command. If the decoder does not return the command response within 0.5 s, the transaction between the command station and decoder is considered failed.

If the CV is not supported, or if the CV write byte command cannot be completed because some, or all, bits in the CV are read-only bits, an ACK control word followed by a NACK control word must be sent in channel 2. It is permitted but not required that the two control words (ACK followed by

NACK) be sent in the same cut-out. The command station should respond to a stand-alone ACK by resending the same command to the addressed decoder before sending a new command.

Reception of the command response datagram or the NACK, by the command station, completes the transaction.

Table 40. Basic format POM write byte command and response structure.

Operation command: POM write byte for a basic format accessory decoder	
►	{combined command/address} = 10AA-AAAA 1AAA-1AA0 To write a CV byte {instruction bytes} = 1110-11VV VVVV-VVVV DDDD-DDDD
◄	Response in Channel 2: 0000 (ID0) DDDD-DDDD with D = CV data or send a NACK until the command is completed, or send an ACK then a NACK if the addressed CV has at least one read-only bit, or send an ACK then a NACK if the CV is not supported.

7.2.1.3 Write Bits

The POM CV write bit command and response for basic format accessory decoders are shown below in Table 41. The command sends the data to be written with command bit D. The bit position to be overwritten is given by command bits BBB, which range between Bit 0 and Bit 7.

The associated response is a 12-bit datagram sent in channel 2. If the decoder needs more time to execute the write-bit command, the matching response datagram does not have to be sent in the cut-out immediately following the command. Instead, the decoder can send a NACK control word in channel 2 of the command cut-out. In that case, the command station must resend the same write-bit command to the addressed decoder before sending any new commands to that addressed decoder. Each time the command is received, but the decoder has not yet finished executing the command, the decoder can send a NACK control word. When the write operation is completed, the decoder transmits the command response, in the cut-out following the next resent write-bit command. If the decoder does not return the command response within 0.5 s, the transaction between the command station and decoder is considered failed.

If the CV is not supported, or if the CV write bit command cannot be completed because the bit is a read-only bit, an ACK control word followed by a NACK control word must be sent in channel 2. It is permitted but not required that the two control words (ACK followed by NACK) be sent in the same cut-out. The command station should respond to a stand-alone ACK by resending the same command to the addressed decoder before sending a new command.

Reception of the command response datagram or the NACK, by the command station, completes the transaction.

Table 41. Basic format POM write bit command and response structure.

Operation command: POM write bit for basic format accessory decoders	
►	{combined command/address} = 10AA-AAAA 1AAA-1AA0 To write a CV bit {instruction bytes} = 1110-10VV VVVV-VVVV 1111-DBBB
◄	Response in Channel 2: 0000 (ID0) DDDD-DDDD with D = CV data or send a NACK until the command is completed, or send an ACK then a NACK if the addressed CV bit is a read-only bit, or send an ACK then a NACK if the CV is not supported.

7.2.2 POM for the Extended Format Accessory Decoder

For extended format accessory decoders the same three POM applications discussed in Sections 8.3.1.1-8.3.1.3 are used and the replies are identical. The only change is in the structure of the combined command/address sent to the accessory decoder. It is presented below in Tables 42 – 44 where the extended format accessory decoder POM read byte, write byte, and write bit command and response structures are presented.

Table 42. Extended format POM read byte command and response structure.

Operation command: POM read byte for an extended format accessory decoder	
►	{combined command/address} = 10AA-AAAA 0AAA-0AA1 To read a CV byte {instruction bytes} = 1110-01VV VVVV-VVVV DDDD-DDDD
◄	Response in Channel 2: 0000 (ID0) DDDD-DDDD with D = CV data or send a NACK until the command is completed, or send an ACK then a NACK if the CV is not supported.

Table 43. Extended format POM write byte command and response structure.

Operation command: POM write byte for an extended format accessory decoder	
►	{combined command/address} = 10AA-AAAA 0AAA-0AA1 To write a CV byte {instruction bytes} = 1110-11VV VVVV-VVVV DDDD-DDDD
◄	Response in Channel 2: 0000 (ID0) DDDD-DDDD with D = CV data or send a NACK until the command is completed, or send an ACK then a NACK if the addressed CV has at least one read-only bit, or send an ACK then a NACK if the CV is not supported.

Table 44. Extended format POM write bit command and response structure.

Operation command: POM write bit for an extended format accessory decoders	
►	{combined command/address} = 10AA-AAAA 0AAA-0AA1 To write a CV bit {instruction bytes} = 1110-10VV VVVV-VVVV 1111-DBBB
◄	Response in Channel 2: 0000 (ID0) DDDD-DDDD with D = CV data or send a NACK until the command is completed, or send an ACK then a NACK if the addressed CV bit is a read-only bit, or send an ACK then a NACK if the CV is not supported.

7.3 Status 1

This mandatory application will transfer the status of an accessory decoder automatically. The command that initiates a status transfer is any addressed control command sent to the accessory decoder. The Status 1 response is a type 3 solicited response and serves as an acknowledgement for the addressed control command. The status information can contain switch or signal aspects, or other accessory decoder current state information. The response is sent in channel 2 but is different for basic and extended format accessory decoders. The status 1 command and response structure for basic and extended format accessory decoders is presented in Sections 8.4.1 and 8.4.2 respectively.

7.3.1 Status 1 Reports from Basic Format Decoders

The Status 1 application response from a basic format accessory decoder is a 12-bit datagram using identifier 4. The command and response structure is shown in Table 45. The current aspect is reported in bits 0-4 of the datagram. For basic format decoders only two current aspect states are needed and bits 0 and 1 are used for these state indications. The 5 bits, 0-4, are indicated for aspect states so there is a common format with the first datagram for the Status 1 report from extended format decoders.

Table 45. Status 1 command and response structure for a basic format accessory decoder.

Operation command: Status 1 Transfer for a Basic Format Accessory Decoder	
►	Any addressed control command sent to a basic format accessory decoder (See S-9.2.1)

◄	Response in Channel 2: One 12-bit datagram with identifier 4
	0100 (ID4) DDDD-DDDD
	Where the 8 data bits contain the following information:
	Bit 7 = Reserved
	Bit 6 = Command and Status Match
	    Bit 6 = 0 Initial state does not match the last command received
	    Bit 6 = 1 Initial state does match the last command received
	Bit 5 = Command and Status Match
	    Bit 5 = 0 The aspect reported back is the setpoint
	    Bit 6 = 1 The aspect reported is the atual value based on real feedback
	Bits 4 – 0 = Current aspect. Bits 0 and 1 are used for the two basic decoder aspect states.

7.3.2 Status 1 Reports from Extended Format Decoders

The Status 1 application response from an extended format accessory decoder requires two 12-bit datagrams, each using identifier 4. The decoder should send both datagrams in the same channel 2 cut-out. The command and response structure is shown in Table 46. The current aspect state is reported using 8 bits sent using the two datagrams, with the 5 least significant bits in the first datagram and the 3 most significant bits in the second datagram.

Table 46. Status 1 command and response structure for an extended format accessory decoder.

Operation command: Status 1 Transfer for an Extended Format Accessory Decoder	
►	Any addressed control command sent to an extended format accessory decoder (See S-9.2.1)

◄	Response in Channel 2: Two 12-bit datagrams with identifier 4
	First datagram: 0100 (ID4) DDDD-DDDD
	  Where the 8 data bits contain the following information:
	  Bit 7 = 0 for byte containing 5 least significant aspect statre bits
	  Bit 6 = Command and Status Match
	      Bit 6 = 0 Initial state does not match the last command received
	      Bit 6 = 1 Initial state does match the last command received
	  Bit 5 = Command and Status Match
	      Bit 5 = 0 The aspect reported back is the setpoint

Operation command: Status 1 Transfer for an Extended Format Accessory Decoder	
	Bit 6 = 1 The aspect reported is the actual value based on real feedback Bits 4 – 0 = Bits 0 to 4 of the current aspect. Second datagram: 0100 (ID4) DDDD-DDDD Where the 8 data bits contain the following information: Bit 7 = 1 for byte containing 3 most significant aspect state bits Bit 6 = Reserved Bit 5 = Reserved Bit 4 = Reserved Bit 3 = Reserved Bits 2 – 0 = Bits 7 to 5 of the current aspect state.

7.4 Status 4

This optional application will transfer the status of all four pairs of outputs from a basic accessory decoder automatically. The command that initiates a status transfer is any addressed control command sent to a basic format accessory decoder. The Status 4 response is a type 3 solicited response and serves as an acknowledgement for the addressed control command. The response is sent in channel 2 as a single 12-bit datagram with identifier 3. The 4 pairs of basic decoder outputs are mapped to the datagram data bits according to Table 47. Refer to S-9.2.1, Section 2.4 for more information on the accessory command structure and the meaning of the aspect states. The status 4 command and response structure is shown in Table 48. The current aspect is reported using 8 bits sent in one datagram.

Table 47. Status 4 aspect state bit mapping for a basic format accessory decoder.

Output Pair	4		3		2		1	
R bit in command to select this output or Color (**R**ed or **G**reen)	0 (R)	1 (G)	0 (R)	1 (G)	0 (R)	1 (G)	0 (R)	1 (G)
Status 4 response datagram data bit assignment for each aspect state	7	6	5	4	3	2	1	0

Table 48. Status 4 command and response structure for a basic format accessory decoder.

Operation command: Status 4 Transfer for a Basic Format Accessory Decoder	
►	Any addressed control command sent to a basic format accessory decoder (See S-9.2.1)
◄	Response in Channel 2: One 12-bit datagrams with identifier 3 0011 (ID3) DDDD-DDDD Where the 8 data bits contain the state aspect data assigned according to Table 47.

7.5 Time

The optional Time application allows accessory decoders to report the time remaining until they complete the last control command they received. This is particularly useful for slow-motion turnout motor controls or signal light bulb simulators. The command that initiates the time report can be any addressed control command sent to a basic or extended format accessory decoder. The Time application response is a type 3 solicited response and serves as an acknowledgement for the addressed control command. The response is sent in channel 2 as a single 12-bit datagram with identifier 5. The 8 data bits include a resolution bit in the most significant bit position, where a 0 indicates the time value should be read with a resolution of 0.1 seconds per least significant bit, and a 1 indicates the time value should be read with a resolution of 1 second per least significant bit. The time value itself is sent with the 7 least significant bits allowing for time intervals between 0 and 12.7 seconds, or 0 and 127 seconds. A time value of 0 should be used for accessory decoders whose aspects change state instantaneously, e.g., LED lighting. The Time command and response structure is shown in Table 49.

Table 49. Time command and response structure for accessory decoders.

Operation command: Time Report for an Accessory Decoder	
►	Any addressed control command sent to an accessory decoder (See S-9.2.1)
◄	Response in Channel 2: 12-bit datagram with identifier 5 0101 (ID5) DDDD-DDDD Where the 8 data bits contain the following information: Bit 7 = Time value resolution Bit 7 = 0 Time value resolution is 0.1 seconds per least significant bit Bit 7 = 1 Time value resolution is 1 second per least significant bit Bits 6 – 0 = Time value.

7.6 Errors

As with mobile decoders, there is also an optional Errors application for accessory decoders to report error or alarm conditions. The command that initiates the error report can be any addressed control command sent to a basic or extended format accessory decoder. The Error application response is a type 3 solicited response and serves as an acknowledgement for the addressed control command. The response is sent in channel 2 as a single 12-bit datagram with identifier 6.

Once a new addressed command is received, the previous error code is cleared. If any error is sustained or permanent the error will again be set and transmitted the next time the response is sent. However, an accessory decoder that is capable of sending SRQs must not send an additional SRQ for any sustained or permanent error that resets in the Error application reporting data.

The 8 data bits sent in the Errors application datagram include 6 bits with an error code, sent in the least significant bits of the 8 data bits. The available error codes are listed in Table 50. If there are multiple errors to be sent in one report, the decoder sends the first error code with bit 6 in the error data byte cleared. Additional error codes are sent with bit 6 set. The Error application error code memory is not cleared until after an addressed command is received following the transmission of the last error code.

The Error application command and response structure is shown in Table 51.

Table 50. Error codes for the accessory decoder Error application.

Error Code (6 bits)	Description
0x00	No Error
0x01	Command not executed due to invalid command or unsupported aspect.
0x02	Current consumption to high.
0x03	Supply voltage too low. Function execution not guaranteed.
0x04	Fuse failure
0x05	Temperature too high
0x06	Feedback error (unacceptable adjustment detected)
0x07	Manual adjustment, e.g., via buttionmon decoder
0x08 – 0x0F	Reserved.
0x10	Turnout lantern or signal lantern failure
0x11 – 0x1F	Reserved
0x20	Servo failure.
0x21 – 0x3E	Reserved.
0x3F	Internal decoder error (not NACK condition).

Table 51. Error command and response structure for accessory decoders.

Operation command: Error Report for an Accessory Decoder	
►	Any addressed control command sent to an accessory decoder (See S-9.2.1)
◄	Response in Channel 2: 12-bit datagram with identifier 6 0110 (ID6) DDDD-DDDD Where the 8 data bits contain the following information: Bit 7 = Reserved Bit 6 = First error in report, or additional errors Bit 6 = 0 This is the initial specified error in this report. Bit 7 = 1 This error is in addition to the specified error in this report. Bits 5 – 0 = Error code.

7.7 Dynamic Variables (DYN)

In response to any addressed control command, the accessory decoder can respond with an acknowledgement or communicate an update, for instance a changed dynamic variable (DV), stored as CV data. This optional DV application implements an update response message that will serve two purposes. It will be considered an acknowledgement to the control command and, at the same time, it will efficiently convey dynamic information from the accessory decoder. The response to the addressed control command is sent in channel 2 and can include 1 or 2 18-bit datagrams, conveying data from 1 or 2 CVs that contain the DV data.

In Table 10 of Section 6.2.4 the indexed CVs reserved for mobile decoder bi-directional communications are presented. The indexed CVs for accessory decoders has a similar layout to that of Table 10. Specifically, the 64 DVs, are the actual CV numbers 321-384. They are accessed using this accessory decoder DV application (DYN) where a 6-bit sub-index, numbered 0 thru 63, selects which DV to report from the accessory decoder. The 64 possible DVs are listed below in Table 52.

Table 52. Accessory decoder dynamic variables in indexed CVs 321-384.

DYN Sub-Index 6-bit Assignment	Indexed CV Byte Number	Actual Indexed CV with 10 bit CV address	Description
0	64	321	Flag register. (unspecified at this time).
1	65	322	Reserved.
2	66	323	Reserved.
3	67	324	Railcom version as 2x4 bit “main ver, minor ver.”, 0x15 = Ver 1.5.
4	68	325	Change Flags from S-9.2.1.1 and RCN-218.
5	69	326	Flag Registers (unspecified at this time).
6	70	327	Input Registers (unspecified at this time).
7	71	328	Reception statistics: The vehicle decoder keeps statistics on all received DCC packets and transmits the number of faulty packets divided by total number of packets as a percent between 0-100.
8	72	329	Contents of container 1 as a percent between 0-100.
9	73	330	Contents of container 2 as a percent between 0-100.
10	74	331	Contents of container 3 as a percent between 0-100.
11	75	332	Contents of container 4 as a percent between 0-100.
12	76	333	Contents of container 5 as a percent between 0-100.
13	77	334	Contents of container 6 as a percent between 0-100.
14	78	335	Contents of container 7 as a percent between 0-100.

DYN Sub-Index 6-bit Assignment	Indexed CV Byte Number	Actual Indexed CV with 10 bit CV address	Description
15	79	336	Contents of container 8 as a percent between 0-100.
16	80	337	Contents of container 9 as a percent between 0-100.
17	81	338	Contents of container 10 as a percent between 0-100.
18	82	339	Contents of container 11 as a percent between 0-100.
19	83	340	Contents of container 12 as a percent between 0-100.
20	84	341	Reserved.
21	85	342	Warning and alarm messages.
22-63	86-127	343-384	Reserved.

7.7.1 Dynamic Variable 21

Warnings and alarms are conveyed with DV21. They can report a warning or alarm related to any of the 64 DVs. They can also report warnings or alarms related to specific conditions, independent of the DVs. The format for this DV is to set bit 7 when conveying an alarm, or clear bit 7 when conveying a warning. Bit 6 is set if an alarm or warning is related to one of the 64 DVs, and cleared if related to one of the independent conditions identified below in Table 53. When bit 6 is set, the remaining least significant 6 bits of DV 21 convey the DV sub-index that has the alarm or warning condition.

Table 53. Independent DV 21 alarm and warning conditions for accessory decoders.

DV 21 Value	Independent Condition
128 = 1 0 0 0 0 0 0 0	Alarm: short circuit switching output 1.
129 = 1 0 0 0 0 0 0 1	Alarm: short circuit switching output 2.
130 = 1 0 0 0 0 0 1 0	Alarm: short circuit switching output 3.
131 = 1 0 0 0 0 0 1 1	Alarm: short circuit switching output 4.
132 = 1 0 0 0 0 1 0 0	Alarm: short circuit switching output 5.
133 = 1 0 0 0 0 1 0 1	Alarm: short circuit switching output 6.
134 = 1 0 0 0 0 1 1 0	Alarm: short circuit switching output 7.
135 = 1 0 0 0 0 1 1 1	Alarm: short circuit switching output 8.
136 = 1 0 0 0 1 0 0 0	Alarm: over temperature

7.7.2 Dynamic Variable (DYN) Application Command Structure

The DYN application command structure uses any addressed control command, as already discussed above, and a channel 2 response that consists of either 1 or 2 18-bit datagrams, both using identifier 7. Each datagram conveys a single DV. This means up to two DVs can be sent in a response. Which DVs are sent, what order, and how often is not specified. Thus, the user can create a custom commutation script (as permitted by the decoder manufacturer) to establish the desired frequency of reporting for each DV. The channel 2 response is sent with each datagram containing first the 4-bit identifier, then the 8-bit dynamic variable CV contents being reported, then the 6-bit sub-index, from Table 52, that indicates which DV and indexed bi-directional communication CV is being reported. Table 54 presents the command and response structure for the DYN application.

Table 54. Accessory decoder dynamic variable reporting command and response structure.

Operation command: DYN Dynamic variable reporting	
►	Any addressed control command sent to an accessory decoder (See S-9.2.1)
◄	Response in Channel 2: one or two 18-bit datagrams sent together 0111 (ID7) DDDD-DDDD-XXXX-XX. See Table 52 for 6-bit (XXXX-XX) sub-index. [0111 (ID7) DDDD-DDDD-XXXX-XX. See Table 52 for 6-bit (XXXX-XX) sub-index].

7.8 Extended POM (XPOM) for Accessory Decoders

The optional extended format program on main application (XPOM) is an alternative to using POM to program accessory decoder CVs in operating mode. The XPOM application accesses data from up to 4 contiguous indexed CVs in one bi-directional communication transaction. Using XPOM can be more efficient than using POM when accessing multiple indexed CVs. The accessory decoder XPOM command is discussed in S-9.2.1, Section 2.4. As with POM there are three types of XPOM bi-directional communication applications: reading bytes, writing bytes, and writing bits.

As discussed in S-9.2.1, Section 2.4, the XPOM command uses between 4 and 8 instruction bytes to convey a 24-bit indexed CV address and any required write data for the 1 to 4 contiguous CVs being accessed. The 24 bit address is designed to include both the page index for the CVs and the offset in the page for the first (of as many as 4) desired CVs. To accomplish this, the address format (VVVV-VVVV VVVV-VVVV VVVV-VVVV) contains accessory decoder CVs 31 and 32 for the CV page index, with CV 31 in the first byte and CV 32 in the second byte. The third byte of the 24-bit CV address contains the lower 8 bits of the desired 10 bit indexed CV address, minus 1, or more specifically, the second instruction byte of the “Configuration Variable Access Instruction - Long Form” as discussed in S-9.2.1, Section 2.3.7.3 for mobile decoders.

Since XPOM commands can be very long, even intentionally exceeding the maximum permitted 30 ms interval between DCC packet start bits, each XPOM command to write bytes or bits must be sent twice to improve the integrity of the transaction. Although the command station is not required to send the repeated commands sequentially to the layout, they must both be sent before any broadcast commands are sent to the layout, or before another addressed control command is sent to the accessory decoder receiving the XPOM command. The decoder must not execute the write command until it receives two identical command packets.

The XPOM application supports an additional important feature which explains why there are 4 datagram identifiers instead of 1 identifier for XPOM applications. Since decoders need time to access CVs, especially to write them to memory, and since there are occasions when more than 4 CVs need to be written to a decoder at one time, there are 4 XPOM identifiers provided with the XPOM application. This allows for a sequence of up to 16 CVs to be accessed with 4 sequential, but unique, XPOM commands, each one using a sequential identifier, numbered 8 through 11. The response acknowledgement process can be offset from the commands, even in the extreme case where the decoder is acknowledging the first command having received four sequential commands already. This is different from most bi-directional CV access command acknowledgement processes where the command station is prevented from sending a new addressed command to a decoder until the previous one is acknowledged. This XPOM command sequencing with 4 identifies can facilitate the command station accessing a large block of CV information continuously. For instance, the 1st, 5th, 9th, 13th, etc. commands will all use sequence identifier 8. By the time the command station is ready to send the 5th command, the decoder will hopefully have responded to the 1st command, releasing sequence identifier 8 for reuse in the 5th command.

This sequencing feature has a lower priority than the command repeat requirement when writing bytes or bits so the command station must send each XPOM write command twice before changing the sequence identifier to send the next XPOM write command in the sequence.

For all three types of XPOM commands, and all four identifiers, the accessory decoder responds in channel 2 with a type 2 solicited response that contains a 36-bit datagram. In the datagram, after sending the appropriate identifier, the decoder sends the contents of the 4 contiguous CVs starting at the 24-bit CV address in the command. This response is the acknowledgement to any of the three types of commands. Even for XPOM write commands to less than 4 CVs, the response still contains 4 contiguous CVs. The format of the accessory decoder response is identical to the XPOM response used by mobile decoders.

Addressed accessory decoders are NOT required to respond in channel 2 to every XPOM command they receive. They only respond when they have completed executing an XPOM command. The response always sends the required 4 CV values. Even if a decoder receives a command to write to one or more read-only bytes or bits, the response is the same 4 stored CV values. If one or more requested CVs are not supported, the decoder responds with a zero value for that CV. The command station must determine if the write or read command was successful by comparing the command and response.

If the decoder is unable to respond to an XPOM command due to processing delays, or because two valid repeated write commands were not received or for any other reason, the command station must repeat the XPOM command. If sequenced XPOM commands are sent, the sequenced XPOM command that has not been replied to must be repeatedly sent and its sequence identifier cannot be released and reused until the transaction is complete. An XPOM command response time-out timer of not less than 2 seconds is required in the command station to accommodate the extended decoder write times often needed for up to 4 CV values. If the required response is not received before the timer expires, the transaction is considered complete (but failed) and any associated sequence identifier is released.

The general form for the accessory decoder XPOM application command and response structure is shown in Table 55. The command structure is referenced from S-9.2.1, Section 2.4. The command formats for both basic and extended format accessory decoders is shown in Table 55. The two-bit instruction sub type GG dictates which of three possible commands is to be executed: read bytes, write bytes, or write bits, as shown in Table 55 below. The two-bit instruction sequence, SS, indicates the sequence identifier, as shown in Table 55 below. The 24-bit address is followed by from 0 to 4 data bytes, depending on the application and user needs. The data format for bit writing is discussed below in Section 7.6.3. For all three applications, the response is a channel 2 (type 2 solicited response) 36-bit datagram with identifier 8-11 and the 4 contiguous CV data values corresponding to the addressed CV in the command and the data from the three following CVs.

Table 55. General XPOM command and response structure for accessory decoders.

Operation command: XPOM	
►	For basic format accessory decoders {combined command/address} = 10AA-AAAA 1AAA-1AA0 Or for extended format accessory decoders {combined command/address} = 10AA-AAAA 0AAA-0AA1 To access CV bytes or CV bits {instruction bytes} = 1110-GGSS VVVV-VVVV VVVV-VVVV VVVV-VVVV {DDDD-DDDD {DDDD-DDDD {DDDD-DDDD {DDDD-DDDD}}}} Where GG is the chosen CV access application using: GG = 01 for reading indexed CV bytes, GG = 11 for writing indexed CV bytes, GG = 10 for writing indexed CV bits, And where SS is the sequence identifier associated with the particular command and response datagram using: SS = 00 for identifier 8 (1000) SS = 01 for identifier 9 (1001) SS = 10 for identifier 10 (1010) SS = 11 for identifier 11 (1011)
◄	Response in Channel 2: GGSS (ID8 - 11) DDDD-DDDD DDDD-DDDD DDDD-DDDD DDDD-DDDD Where GG is the application and SS is the sequence identifier used in the associated command. Both are discussed in the command structure in the above table row.

The three available XPOM applications are discussed below.

7.8.1 XPOM for Basic Format Accessory Decoders

The basic format accessory decoder XPOM indexed CV read-bytes command and response are shown below in Table 56.

Table 56. Basic format accessory decoder XPOM read-byte command and response structure.

Operation command: XPOM Read Bytes for Basic Format Accessory Decoders	
►	{combined command/address} = 10AA-AAAA 1AAA-1AA0 To read 4 CV bytes {instruction bytes} = 1110-01SS VVVV-VVVV VVVV-VVVV VVVV-VVVV { Where SS is the sequence identifier associated with the particular command and response datagram as presented above in Table 29.
◄	Response in Channel 2: 01SS DDDD-DDDD DDDD-DDDD DDDD-DDDD DDDD-DDDD Where SS is the sequence identifier used in the associated command and discussed in the command structure in the above table row, And the data bytes contain the four contiguous CV data values starting at the indexed CV address sent in the command.

The basic format accessory decoder XPOM indexed CV write-bytes command and response are shown below in Table 57.

Table 57. Basic format accessory decoder XPOM write-bytes command and response structure.

Operation command: XPOM Write Bytes for Basic Format Accessory Decoders	
►	{combined command/address} = 10AA-AAAA 1AAA-1AA0 To write 1 to 4 CV bytes {instruction bytes} = 1110-11SS VVVV-VVVV VVVV-VVVV VVVV-VVVV DDDD-DDDD {DDDD-DDDD {DDDD-DDDD {DDDD-DDDD}}} Where SS is the sequence identifier associated with the particular command and response datagram as presented above in Table 29. At least one CV data value, or as many as 4 contiguous CV data values, are sent in this command to write bytes to CVs.
◄	Response in Channel 2: 11SS DDDD-DDDD DDDD-DDDD DDDD-DDDD DDDD-DDDD Where SS is the sequence identifier used in the associated command and discussed in the command structure in the above table row, And the data bytes contain the four contiguous CV data values starting at the indexed CV address sent in the command.

The basic format accessory decoder XPOM indexed CV write-bits command and response are shown below in Table 58. As with the matching POM write bits command discussed above in Section 8.3, the XPOM write bits command formats the data to be written using the format 1111-DBBB where the bit to be written (a 1 or 0) is designated as D and the bit location in the byte, that is to be written, is designated by BBB for bit 0 (000) through bit 7 (111).

Table 58. Basic format accessory decoder XPOM write bits command and response structure.

Operation command: XPOM Write Bits for Basic Format Accessory Decoders	
►	{combined command/address} = 10AA-AAAA 1AAA-1AA0 To write bits in 1 to 4 CV bytes {instruction bytes} = 1110-10SS VVVV-VVVV VVVV-VVVV VVVV-VVVV 1111-DBBB {1111-DBBB {1111-DBBB {1111-DBBB }}} Where SS is the sequence identifier associated with the particular command and response datagram as presented above in Table 29. At least one CV bit value, or as many as 4 contiguous CV bit values, are sent in this command to write bits to CVs.
◄	Response in Channel 2: 10SS DDDD-DDDD DDDD-DDDD DDDD-DDDD DDDD-DDDD Where SS is the sequence identifier used in the associated command and discussed in the command structure in the above table row, And the data bytes contain the four contiguous CV data values starting at the indexed CV address sent in the command.

7.8.2 XPOM for Extended Format Accessory Decoders

The extended format accessory decoder XPOM indexed CV read-bytes command and response are shown below in Table 59.

Table 59. Extended format accessory decoder XPOM read-byte command and response structure.

Operation command: XPOM Read Bytes for Extended Format Accessory Decoders	
►	{combined command/address} = 10AA-AAAA 0AAA-0AA1 To read 4 CV bytes {instruction bytes} = 1110-01SS VVVV-VVVV VVVV-VVVV VVVV-VVVV { Where SS is the sequence identifier associated with the particular command and response datagram as presented above in Table 29.
◄	Response in Channel 2: 01SS DDDD-DDDD DDDD-DDDD DDDD-DDDD DDDD-DDDD Where SS is the sequence identifier used in the associated command and discussed in the command structure in the above table row, And the data bytes contain the four contiguous CV data values starting at the indexed CV address sent in the command.

The extended format accessory decoder XPOM indexed CV write-bytes command and response are shown below in Table 60.

Table 60. Extended format accessory decoder XPOM write-bytes command and response structure.

Operation command: XPOM Write Bytes for Extended Format Accessory Decoders	
►	{combined command/address} = 10AA-AAAA 0AAA-0AA1 To write 1 to 4 CV bytes {instruction bytes} = 1110-11SS VVVV-VVVV VVVV-VVVV VVVV-VVVV DDDD-DDDD {DDDD-DDDD {DDDD-DDDD {DDDD-DDDD}}} Where SS is the sequence identifier associated with the particular command and response datagram as presented above in Table 29. At least one CV data value, or as many as 4 contiguous CV data values, are sent in this command to write bytes to CVs.
◄	Response in Channel 2: 11SS DDDD-DDDD DDDD-DDDD DDDD-DDDD DDDD-DDDD Where SS is the sequence identifier used in the associated command and discussed in the command structure in the above table row, And the data bytes contain the four contiguous CV data values starting at the indexed CV address sent in the command.

The extended format accessory decoder XPOM indexed CV write-bits command and response are shown below in Table 61. As with the matching POM write bits command discussed above in Section 8.3, the XPOM write bits command formats the data to be written using the format 1111-

DBBB where the bit to be written (a 1 or 0) is designated as D and the bit location in the byte, that is to be written, is designated by BBB for bit 0 (000) through bit 7 (111).

Table 61. Extended format accessory decoder XPOM write bits command and response structure.

Operation command: XPOM Write Bits for Extended Format Accessory Decoders	
►	{combined command/address} = 10AA-AAAA 0AAA-0AA1 To write bits in 1 to 4 CV bytes {instruction bytes} = 1110-10SS VVVV-VVVV VVVV-VVVV VVVV-VVVV 1111-DBBB {1111-DBBB {1111-DBBB {1111-DBBB }}} Where SS is the sequence identifier associated with the particular command and response datagram as presented above in Table 29. At least one CV bit value, or as many as 4 contiguous CV bit values, are sent in this command to write bits to CVs.
◄	Response in Channel 2: 10SS DDDD-DDDD DDDD-DDDD DDDD-DDDD DDDD-DDDD Where SS is the sequence identifier used in the associated command and discussed in the command structure in the above table row, And the data bytes contain the four contiguous CV data values starting at the indexed CV address sent in the command.

7.9 Status 2

This optional application is for the support of legacy accessory decoders and should not be used in new accessory decoder designs. The application will automatically transfer the status associated with mechanical adjustment processes of an accessory decoder. The command that initiates a status transfer is any addressed control command sent to the accessory decoder. The Status 2 response is a type 3 solicited response and serves as an acknowledgement for the addressed control command. The response is a 12-bit datagram, using identifier 8, that is sent in channel 2 and is the same for basic and extended format accessory decoders. The 8 bits conveying the status consist of a 4-bit configuration, sent in the 4 most significant bits. The permitted configurations are presented in Table 62, Next, in bit 3, a status report type bit is sent, then finally in the three least significant bits, the reported status is sent. The status 2 command and response structure for basic and extended format accessory decoders is shown below in Table 63.

Table 62. Status 2 accessory decoder configurations.

Configuration (4 bits)	Description
0x0	Uncoupler.
0x1	Turnout switch.
0x2	Three-way switch.
0x3	Double-crossing switch.

Configuration (4 bits)	Description
0x5 – 0x07	Reserved.
0x8	Track lock signal.
0x9	Shape signal Hp0 / Hp1.
0xA	Shape signal Hp0 / Hp1 / Hp2.
0xB	Distant signal Vr0 / Vr1.
0xC	Distant signal Vr0 / Vr1 / Vr2.
0xD	Railway barrier.
0xE – 0xF	Reserved.

Table 63. Status 2 command and response structure for accessory decoders.

Operation command: Status 2 Transfer for Accessory Decoders	
►	Any addressed control command sent to an accessory decoder (See S-9.2.1)
◄	Response in Channel 2: One 12-bit datagram with identifier 8 1000 (ID8) DDDD-DDDD Where the 8 data bits contain the following information: Bit 7 - 4 = Configuration. See Table 62. Bit 3 = Status Report Type Bit 3 = 0 Reported status is the setpoint (adjustment process is not complete) Bit 3 = 1 Reported Status is the actual value (based on real feedback) Bits 2 – 0 = Reported status.

7.10 Test Feature identifier

Identifier 12 is reserved for a test feature application for bi-directional communications. This Section is a placeholder for that future application. This datagram size has not been defined.

8 Document History

The previous, initial version of S-9.3.2 received NMRA approval on December 10, 2012. It was essentially a German-to-English translation of the May 2, 2012, approved version of Rail Community standard RCN-217. Changes to nearly every section were required to create this revision to S-9.3.2. All the translated text was clarified, and the document is now consistent with the current version of RCN-217. In addition, the new NMRA standards template was used. Therefore, the document history will be reset with this version of S-9.3.2.

Date	**Description**	**Chapter**
April 10, 2026	Complete rewrite of the standard to clarify the previous translated version, to match the current version of RCN-217, and to comply with the new NMRA standards template.	All

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