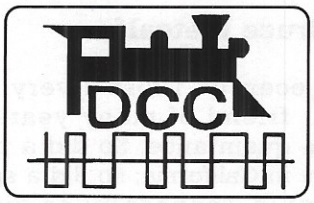
Recommended Practices for Digital Command Control



by Stan Ames

In past *Bulletins* we have presented the basic Digital Command Control proposed standards for your consideration. In this month's *Bulletin* we present two additional proposed Recommended Practices (RPs) that significantly enhance the possibilities for prototypical operation. Why the separation? NMRA Standards provide the primary basis upon which interchange is founded and therefore include only those factors that are considered vital to such interchange. NMRA Recommended Practices specify details of major components to improve design and function or to promote maximum interchange between and within units. Recommended Practices are less mandatory than Standards by virtue of their slightly less critical subject matter and/or the fact that deviation for specific reasons is permissible [as defined by the NMRA Charter and Constitution].

The proposed Digital Command Control Standards and Recommended Practices are intended to provide both elementary capabilities for the entry modeler as well as advanced capabilities for the most demanding advanced modeler. To help ensure the implementation of cost-effective products, the communications protocol, as defined in the proposed standards, only define 99 addresses (two digits) and a speed curve of 14 entries. While this has proven satisfactory for most applications, it clearly is not sufficient for either layouts that desire a high degree of prototypical operation or large club layouts. We therefore developed a set of Recommended Practices to improve the design and function of the communications such that the needs of mid-range and high-end users could be addressed.

Digital Command Control is intended to do much more than just control the speed and direction of a variety of locomotives. Locomotive engineers on the prototype perform more functions than just adjusting the speed of the locomotive. Allowing the modeler to control other locomotive functions such as lights, horn, bell, prime mover power (or steam pressure), and brakes increase both the fidelity to the prototype and the fun of operating a model train. Allowing control of other layout functions such as switch or signal control allows the tower operator and/or brakeman to interactively control the layout. For those so inclined, DCC can be integrated with a computer to allow creative new operating potentials such as operating a wayfreight while the computer controls the through trains. All this means that Digital Command Control can significantly increase operations for even the single-operator layout.

The following proposed Recommended Practices extend the basic operation by defining many more addresses (32,000), more speed steps (either 28 entries into a speed curve table or 128 direct speeds), multi-unit control, the ability to control a variety of individual functions, the ability to control accessories, and the ability to customize the operation of each locomotive. While several manufacturers have begun to implement these functions, it will be some time before the entire set is available. Compatibility is ensured because the basic packet format defined in the proposed standard remains unchanged.

You may notice that many possibilities are left undefined. That is because we have much to learn about the needs of more advanced users in light of the technology likely to be available in the next several years. For example, consider a decoder which can sense its load and automatically adjust the performance of the model locomotive based upon real locomotive performance experience. You should therefore consider these proposed Recommended Practices as living documents that are updated as our needs evolve.

Please send all comments and suggested revisions to these proposed RPs to the NMRA Digital Command Control Working Group, 8 Higate Road, Chelmsford, MA 01824. Additional information on DCC can be obtained through Digital Command Control Special Interest Group, 3019 Harvard, Lawrence, KS 66049.

DRAFT NMRA RECOMMENDED PRACTICE	
EXTENDED PACKET FORMAT FOR DIGITAL COMMAND CONTROL, ALL SCALES	
RP-EPF	Version 0.9 Revised 11-1-93

The NMRA Digital Command Control Standard Part-2 provides a minimal, basic packet format required for interoperability. This recommended practice provides extended formats for mid and high end users. These formats adhere to the standard general packet format as defined in Part-2. The intent of this recommended practice is to provide the framework to enable realistic operations to occur.

Format Definitions

Within this recommended practice, bits within the address and data bytes will be defined using the following abbreviations. Individual bytes within a specific packet format are separated by spaces. Note bytes within square [] brackets can occur one or more times as necessary up to the maximum packet length of 10 bytes. Bits are numbered from right to left with bit 0 (the right most bit) being the least significant bit (LSB) and bit 7 (the left most bit) being the most significant bit (MSB).

A = Address bit
0 = Bit with the value of "0"
1 = Bit with the value of "1"
U = bit with undefined value either a "1" or a "0" is acceptable
P = program bit "0" = read, "1" = write
C = Instruction Type field
D = Data
E = Error Detection Bit

Addressing

Various packet formats can be supported by a single command station[2] by partitioning the address space. An Address partition is a group of addresses within the primary 253 available addresses intended for a single purpose. The partition range is expressed as addresses between a minimum and maximum number which is the value of the eight bits of the first byte taken as a binary integer. This is true even if the pattern definition implies that the address includes more than eight bits. Partitions may be defined by the manufacturer or by the user. In order to avoid conflicts between incompatible packet formats it is recommended that only a single packet type be utilized in a single partition.

[1] This version has been baselined by the NMRA Electrical Committee: Digital Command Control Working Group and submitted to the NMRA Technical Department for consideration. It has not completed formal NMRA review nor has it been approved by the NMRA Board of Directors or the NMRA membership.

[2] It is possible to have multiple command stations, each with its own separate address partitions on the same layout so long as the command stations are electrically isolated.

For locomotive control there are two styles of operation. A locomotive can be individually controlled or it can be grouped with other locomotives and controlled as a multiple unit[3]. We refer to this second style of operation as consist control. Addresses for locomotives can be assigned as a single byte address, as defined in the base standard, or by an extended 2 byte address[4]. Extended addressing is intended for larger club layouts[5]. Extended 2 byte addresses must have a bit with the value of "1" in bit position 0 of the second byte[6] (UUUUUUUU UUUUUUU1).

Address partitions should be assigned for single byte locomotive control, two byte locomotive control[7], consist control and accessory control. For example, the user could define a partition between 1 and 99 for single byte locomotive control, 100-191 for consist control, and 192-254 for accessories control. A very large club might have 2 command control systems with one dedicated to accessory control and the other having a single partition for 253 consists. An even larger layout might have the need for multiple command stations that each contain single 253 consist partitions. In this case each command station would each operate 50-150 active trains.

PART 1 PACKET FORMATS

Multi Function Digital Decoders Packet

[AAAAAAAA] [{instruction-byte}] EEEEEEEE

Multi Function *Digital Decoders* are used for the purpose of controlling one or more motors and accessories. The packet format used to control these devices consists of between 3 and 10 bytes where the first bytes are address bytes followed by one or more instruction bytes and ended by an error control byte.

Address Bytes = [AAAAAAAA]

The first address byte contains 8 bits of address information. If the partition is set up for 2 byte addresses then a second address byte must immediately follow the first address byte. This second address byte will then contain an additional 7 bits of address data as bit 0 of two byte addresses must always have the value of "1".

Instructions = [{instruction}]

[3] Only one address is active for operations at any one time. If the *Digital Decoder* is configured for extended operations then the contents of Configuration Variables 32 and 33 shall define which address is currently valid for use.

[4] The Digital Decoder must be configured to accept the Extended NMRA Packet type in order to have the possibility of using the extended 2 byte address.

[5] It is recommended that manufacturers provide, at the user interface, locomotive and train identification consistent with realistic operation, and map this information into the internal packet addresses.

[6] The reason for this bit is to differentiate two byte locomotive control from accessory control (which uses 12 bit addresses) within the programming instructions, which apply to both address types..

[7] For large layouts it is recommended that the majority of the address space be reserved for consist control and accessory control. In this case individual locomotives sit idle on the layout until assigned to a consist.

Instructions are data bytes used to send commands to Multi Function *Digital Decoders*. While not all *Digital Decoders* will implement all instructions, it is important that they be able to parse all instructions so that they can properly decode the packet while ignoring the instructions they do not implement. Each instruction {instruction} is defined to be

{instruction} = CCCDDDDD or CCCDDDDD [DDDDDDDD]

An Instruction consist of a 3 bit instruction type field followed by a 5 bit data field. Some instructions have one or more additional bytes of data. The 3 bit instruction type field is defined as follows:

000 Consist Control
001 Advanced Operations
010 Speed and Direction Instruction for reverse operation
011 Speed and Direction Instruction for forward operation
100 Accessory Instruction One
101 Accessory Instruction Two
110 Future Expansion
111 Programming

Consist Control 000CDDDD

This instruction controls the operation of consists and resets[8].

C=0 Consist setup, auxiliary functions, and reset

If C=0 then DDDD contains a setup instruction. A single setup instruction can set or clear one, two, or all three functions. The state of these functions must be remembered across power loses and operating sessions.

0000 Digital Decoder Reset: A *Digital Decoder* reset shall erase all volatile memory (including any speed and direction data), and return to its initial power up state. This command has no effect on the contents of Configuration Variables 32-63. A Digital Decoder Reset packet will always reset the current block address to 1 for *Multi Function Digital Decoders* or block 4 for *Accessory Decoders*

1000 Consist Hard Reset - Performs a Digital Controller Reset (as defined above) and resets Configuration Variables 32-48 to their default configurations.

11UU Consist Activation: The Consist Address in Configuration Variable 32 is active. If Configuration variable 32 does not contain a valid address, Configuration Variable 1 will be placed into Configuration Variable 32 and used as the consist address. When Consist Control is active and the decoder is using single byte addressing, the decoder will ignore the following instructions addressed to its normal locomotive address (unless this single byte address is the same as its consist address): 001, 010, and 011. Functions controlled by 110 and 101 will respond only to the address specified by the appropriate bit in configuration variable 34 when the locomotive has the consist bit activated..

[8] A consist is assigned by setting configuration variables 32 and 33 (see RP-CV) using one of the programming instructions.

01UU The locomotive is removed from consist control and will respond to its normal locomotive address.

1U1U Reverse Locomotive Direction: The forward and reverse directions of the locomotive will be opposite their normal direction. While intended for allowing a locomotive to be placed in a consist head to head or tail to tail, it can also be used to change a locomotives orientation for normal operation.
0U1U The locomotives direction orientation is returned to normal.

1UU1 Turn F0 on. F0 is a directional sensitive function that maintains its state over power interruptions. It is valid whether or not the locomotive is in a consist.
0UU1 Turn F0 off.

C=1 Unit Control

If C=1 then DDDD contains a unit sub address used primarily to address locomotives that have 2 byte addresses while they are in consists. All instruction bytes within a single packet that follow a instruction byte that starts with "0001" shall function only on the locomotive indicated by the unit sub address until a new sub address is supplied.

Advanced Operations 001DDDDD DDDDDDDD

This instruction contains two bytes and is intended to support advanced simulation. The five bit data allows for 32 separate Advanced Operations Sub-Instructions.

00111111 DDDDDDDD = Direct Speed Control

Instruction "11111" is defined to send an absolute *Digital Decoder* speed step. The subsequent single byte shall define speed and direction with bit 7 being direction ("1" is forward and "0" is reverse) and the remaining bits used to indicate speed. The most significant speed bit is bit 6.

The remaining 31 instructions are left to be defined in a subsequent Advanced Packet NMRA Recommended Practice.

Speed and Direction Instructions 010DDDDD and 011DDDDD

A speed and direction instruction is used send information to motors connected to Multi Function *Digital Decoders*. Instruction "010" indicates a Speed and Direction Instruction for reverse operation and instruction "011" indicates a Speed and Direction Instruction for forward operation. In these instructions the data is used to control speed with bits 0-3 being defined exactly as in Part 2 of the Standard. Bit 4 is used as a intermediate speed. Speed U0000 is stop, speed U0001 is emergency stop, speed 00010 the first speed step and speed 11111 is full speed. This provides 28 discrete speed steps in each direction. (see configuration variable RP for more information)

Accessory Instruction One 100DDDDD

Up to 5 auxiliary SPDT or SPST functions (functions 1-5) can be controlled by Accessory Instruction One. Bits 0-4 shall define the value of functions 1-5 with function 1 being controlled by bit 0 and function 5 being controlled by bit 4. If the function is a SPST, a value of "1" shall indicate that the function is "on" while a value of "0" shall indicate that the function is "off".

Accessory Instruction Two 101CDDDD[9]

C="0" Variable Functions F6, F7

Contains two variable output functions (F6, F7). Variable Function 1 (F6) has a variable output set by bits 1 and 0.

00 - reset device,
01 - increase by a step value as defined by the applicable configuration variable
10 -decrease by a step value as defined by the applicable configuration variable
11 - no change.

Variable Function 2 (F7) has a variable output set by bits 3 and 2 using the same encoding technique as Variable Function 1.

C ="1" Extra Functions

This instruction is being tailored for the support of sound and is still being defined as of this date.

Future Expansion 110DDDDD DDDDDDDD

This function is undefined at present but is two bytes in length.

Programming Instruction 111DDDDD [DDDDDDDD]

Programming is provided for the 32 flying programming configuration variables[10] in Block 2 (configuration variables 32-63). This instruction only writes the 32 configuration variables. If used, this instruction must be the last instruction byte within a packet. All Data Bytes until the Error Data Byte that follow this Instruction will contain the information to be stored in configuration variable locations. The contents of the first information Data Byte will be stored in the configuration variable address "DDDDD"+32. The contents of subsequent data bytes will be stored in subsequent configuration variables within the 32 byte allowable range. Bytes outside this range shall be ignored. Configuration Variables within a *Digital Decoder* will only be changed after the *Digital Decoder* receives a second packet with an identical programming instruction without receiving any intervening packets with instructions it must execute. At present there is no feedback, other than operator observation, to the command station on the success or failure of this action.

Error Byte = EEEEEEEE

See error control section

Broadcast Command For Digital Decoders

00000000 {instruction-byte} EEEEEEEE

[9] Accessory function 2 is in draft form. Manufactures are recommended to contact the NMRA Digital Command Control Working Group before implementing this function.

[10] The content of these configuration variables must be preserved over an indefinite power interruption.

Instructions addressed to "broadcast address" 00000000 must be executed by all Multi Function *Digital Decoders* that have broadcast enabled[11]. The single instruction-byte has the same definition as defined by the Multi Function Digital Decoder packet. Should CCC refer to a instruction not supported by the *Digital Decoder* the *Digital Decoder* should ignore the instruction.

Accessories Digital Decoder Packet

AAAAAAAA AAAADDDD EEEEEEEE

The accessory packet is intended for control of a number of simple functions. It is permissible to develop *Digital Decoders* that respond to multiple addresses so that more devices can be controlled by a single *Digital Decoder.*

There are three different type of *Accessory Digital Decoders.*

Type 1 - Type 1 *Accessory Digital Decoders* allow for the operation of 4 independent SPDT switches. The duration of time each output is active shall be controllable.

Type 2 - Type 2 *Accessory Digital Decoders* allow for the control of 2 variable functions with bits 1 and 0 intended for function 1 and bits 3 and 2 intended for function 2. These bits are defined as follows.

00 - reset device,
01 - increase by a step value as defined by the applicable configuration variable
10 - decrease by a step value as defined by the applicable configuration variable
11 - no change

Type 3 - Type 3 *Accessory Digital Decoders* are for functions that need a 4 bit value to be sent to the output.

Accessory Decoder Broadcast

11111111 1000DDDD EEEEEEEE

Causes all Accessory Digital Decoders to perform the operation DDDD. If DDDD = "0000" this will cause all Accessory *Digital Decoders* to turn all functions off and perform a reset.

Programming

Certain configuration variables within a *Digital Decoder* may be read or written using a variety of different instructions.

Feedback Response

Feedback refers to the ability of the *Digital Decoder* to respond to an instruction given by a Command Station. If requested to do so, the *Digital Decoder* shall provide a Feedback Response by presenting a load of at least 30 ma on the

[11] The Digital Decoder Reset Packet can not be disabled and applies to all Digital Controllers.

Command Bus for a minimum of 500 microseconds[12]. This Feedback Response shall not be initiated before 200 microseconds after receipt of the Packet End Bit for the packet requesting the Feedback Response and shall be completed before 2000 microseconds after receipt of the Packet End Bit for the packet that requested the Feedback Response[13]. In order to successfully receive a Feedback Response signal the *Command Station* must be able to detect the increased current draw which is the response signal. In most cases this implies that no operations are occurring in the section of the layout where programming is occurring when feedback is desired.

Broadcast Programming

Broadcast Programming is a general purpose broadcast packet for reading or writing configuration variables for all *Digital Decoders* that have broadcast programming enabled. Configuration Variables within a *Digital Decoder* will only be changed after the *Digital Decoder* receives a second packet with an identical programming instruction without receiving any intervening packets with instructions it must execute.

11111111 PCCAAAAA [DDDDDDDD] EEEEEEEE

The second byte of this command is an instruction. The address ("A" bits) within this instruction refers to a configuration variable location between 0 and 31 offset by the contents of decoder's current block address. This allows 255 32 byte blocks to be potentially addressed. Instruction CC allows either full byte or half byte operation.

CC = "11" Full 8 bit byte
CC = "01" Only Bits 0-3 of the subsequent data bytes apply
CC = "10" Only Bits 4-7 of the subsequent data bytes apply

The data bytes following the instruction will be compared with the existing value or used to replace the existing value of the applicable configuration variable (depending on the value of the "P" and "CC" bits) starting at the address location specified. If the "P" bit indicates a read operation, the *Digital Decoder* shall respond using the Feedback response if the configuration variable(s) within the *Digital Decoder* have the same value as specified in the packet.

Address Directed programming

11111110 AAAAAAAA AAAAAAAC
PCCAAAAA [DDDDDDDD] EEEEEEEE

This packet allows multiple configuration variables to be read or written using the *Digital Decoder's* one byte address, two byte address or consist address[14]. If the instruction bit "C" in byte three has a value of "0" then the packet is for an Accessory Decoder ,a Multi-

[12] Increased load is recommended especially in the larger scales.

[13] It is permissible to provide this increased current draw by applying power to the motor or other similar device. In order that locomotives being controlled by Digital Decoders do not have a perceivable movement as a result of feedback, it is recommended that the command control signal be reduced such that insufficient current is available for motor movement.

[14] For the consist address to be valid, the *Digital Decoder* must be configured to accept the Extended NMRA packet format. If in Extended NMRA format the contents of Bit 1 of Configuration Variable 16 shall determine whether the 1 or 2 byte address is the valid address.

Function Decoder using a single byte address or a Multi-Function Decoder using the consist address. If the instruction bit in byte three "C" has a value of "1" then the packet is for Multi Function *Digital Decoders* using the extended 2 byte addresses.

The fourth byte of this command is an instruction. The address ("A" bits) within this instruction refers to a configuration variable location between 0 and 31 offset by the contents of decoder's current block address. This allows 255 32 byte blocks to be potentially addressed. Instruction CC within byte four allows either full byte or half byte operation.

CC = "11" Full 8 bit byte
CC = "01" Only Bits 0-3 of the subsequent data bytes apply
CC = "10" Only Bits 4-7 of the subsequent data bytes apply

The data bytes following the instruction will be compared with the existing value or used to replace the existing value of the applicable configuration variable (depending on the value of the "P" and "CC" bits) starting at the address location specified. If the "P" bit indicates a read operation, the *Digital Decoder* shall respond using the Feedback response if the configuration variable(s) within the *Digital Decoder* have the same value as specified in the packet. Configuration Variables within a *Digital Decoder* will only be changed after the *Digital Decoder* receives a second packet with an identical programming instruction without receiving any intervening packets with instructions it must execute.

Calculating the Error Byte

Packets five bytes or less shall have an error byte constructed using an XOR of all bytes within the packet. The error byte for packets of 6 or more bytes is awaiting results of testing to determine if a simple XOR of all bytes is sufficient for longer packets.

DRAFT NMRA RECOMMENDED PRACTICE	
CONFIGRUATION VARIABLES FOR DIGITAL COMMAND CONTROL, ALL SCALES	
RP-CV	Version 0.9 Revised 11-1-93

[1]

This Recommended Practice provides a configuration variable map for all *Digital Decoders*. Configuration variables allow the decoder to be customized for each locomotive or device. As such configuration variables must not change across power loses over very extended periods of time. While all *Digital Controllers* need not implement all of these variables, it is recommended that if the applicable function is provided, that these variable assignments are adhered to.

General Definitions

All multi-byte values are stored in "big endian" format (most significant bytes occupy lower Configuration Variable addresses. Binary numerical quantities are stored such that the rightmost bit is the least significant, and the leftmost is the most significant. A two byte quantity would be represented in Configuration Variables as follows:

Configuration Variable n: |d15|d14|d13|d12|d11|d10|d09|d08| MSB
Configuration Variable n+1: |d07|d06|d05|d04|d03|d02|d01|d00| LSB

Some of the Configuration Variables contain values that define different parameters that control the device's operation. In order to maximize compatibility across controllers having different degrees of complexity and output accuracy, variable precision is used to define these Configuration Variables. To accomplish this, the command station sends a value specified with a full 8 bits of precision, and the controller then uses as many as it can to implement the given function. The advantage of using this method is that a value specified in this way, can have its precision extended arbitrarily by using digits to the right, up to the full 8 bits. Similarly, precision can be easily reduced by truncation. The effect is to improve forward and reverse compatibility.

Format Definitions

Within this recommended practice, bits within the address and data bytes will be defined using the following abbreviations.

A = Address bit
0 = Bit with the value of "0"
1 = Bit with the value of "1"
U = bit with undefined value either a "1" or a "0" is acceptable
C = Instruction Type field

[1] This version has been baselined by the NMRA Electrical Committee: Digital Command Control Working Group and submitted to the NMRA Technical Department for consideration. It has not completed formal NMRA review nor has it been approved by the NMRA Board of Directors or the NMRA membership.

D = Data

Configuration Variable Map[2]

Following is the address map for Digital Controllers

BLOCK 1 Configuration Variables 0-31 Multi Function Decoder Configuration

Configuration Variables 0-7 Basic Operation

Configuration Variable 0	Single Byte Address
Configuration Variable 1	Starting Decoder Speed Step
Configuration Variable 2	Baseline Acceleration Rate
Configuration Variable 3	Baseline Braking Rate
Configuration Variable 4	Mid Range Cab Speed Step
Configuration Variable 5	Mid Range Decoder Speed Value
Configuration Variable 6	Full Speed Decoder Speed Value

Configuration Variable 0 Single Byte Address

Contains an address with a value between 1 and 253. (The factory default shall be "00000011")

Configuration Variable 1, 5 and 6 Decoder Speed Steps

The controller uses three speed parameters, Vstart, Vmid, and Vhigh to generate a table in the decoder that translates speed step values into motor voltage drive levels. If bit 4 of configuration Variable 28 = "0", the speed table shall be generated from the values in Configuration Variables 1, 4, 5, and 6 upon reset, or upon receipt of any command that modifies their values.

The voltage drive levels in Configuration Variables 1, 5, and 6 shall correspond linearly to the voltage applied to the motor, as a fraction of available rectified supply voltage. When the voltage drive level is equal to zero, there shall be zero voltage applied to the motor. When it is at maximum (11111111), the full available rectified voltage shall be applied.

Vmid has two additional settings. A value of "00000000" indicates that the curve shall be linear while a value of "00000001" indicates that the factory default performance curve shall be used.

(The factory default value shall be: Vstart = "00000100", Vmid = "00000001", and Vhigh = "11111111")

Configuration Variable 2 Acceleration Rate

Determines a programmed increase in speed. The interpretation is different, depending on whether 14 or 28 speed steps are in use, in order to keep the parameter's effect constant in both cases. Thus, if 14 speed steps are in use, the formula is n*.064 seconds, and if 28

[2] To allow for future growth not all possible COnfiguration Variables have been defined. Manufacturers should check with the NMRA before using any undefined Configuration Variables to avoid any future conflicts.

speed steps are in use, then the formula is n*0.032 seconds. For example, if n=2 then the acceleration is 0.128 sec/step for a decoder using 14 speed steps, and 0.064 sec/step for a decoder using 28 speed steps.

This quantity specifies the interval between speed step changes, and is expressed as seconds per step, rather than steps per second. Interval rather than rate is used to save the controller from having to perform the calculation 1/x. If the contents of this parameter equals zero then there is no programmed acceleration. (The factory default value shall be "00000000")

Configuration Variable 3 Deceleration Rate

Determines a programmed decrease in speed, in the same fashion as acceleration above. (The factory default value shall be "00000000")

Configuration Variable 4 Mid Range Cab Speed Step

Contains a value between 1 and 28 which defines the cab throttle position which will define the position where the mid range decoder speed value will be applied. In 14 speed mode the value used will be 1/2 this value determined by shifting the register one position. A Value of "00000000" indicates that

(The factory default value shall be "00001110")

Configuration Variables 8-11 Extended Operations

Configuration Variable 8-9	2 Byte Extended Address
Configuration Variable 10	Load Feedback

Configuration Variable 8-9: 2 Byte Extended Address

The Extended Address is a 15 bit user defined address stored in bit positions 1-15. The 16th bit (bit 0 of Configuration Variable #9) must always contain the value "1".

Configuration Variable 10: Load Feedback

Specifies the amount of load torque feedback (in other words, speed regulation), where such a facility exists in the controller. If load feedback exists, but its influence cannot be asserted over a range of values, It shall be controlled by the MSB.

Configuration Variable 12-15 Motor Control

Configuration Variable 12	Pulse Proportion
Configuration Variable 13	Pulse Period
Configuration Variable 14	Pulse Power Speed Step
Configuration Variable 15	Kick Pulse Duration

Configuration Variable 12 Pulse Proportion

Specifies the proportion of time during the pulse waveform that power is applied. It is interpreted as a fraction, so that the on-time is equal to n*100%/255

Configuration Variable 13 Pulse Period

Specifies the period (1/frequency) of the pulse power waveform. It is interpreted as n*200us. This makes frequency adjustable between 20 Hz and 5000 Hz. A value of "0" is not allowed if this variable is implemented.

Configuration Variable 14 Pulse Power Speed Step

Specifies the speed step at which pulsed power is to be applied when decreasing speed, and removed when increasing.

Configuration Variable 15 Kick Pulse Duration

Specifies the duration of a single starting pulse, that is applied to the motor each time it starts from a full stop. It is interpreted as n*200us.

Configuration Variable 16-30 Decoder Configuration

Configuration Variable 16	Functions Supported
Configuration Variable 18	Increment for Variable Function 1
Configuration Variable 19	Increment for Variable Function 2
Configuration Variable 20-24	Time on for functions
Configuration Variable 27	Packet time-out Value
Configuration Variable 28	Decoder Configurations
Configuration Variable 29	Page Value for Service Mode
Configuration Variable 30	Future Configurations

Configuration Variable 16: Functions Supported

Contains a "1" for every function between F0 and F7 that is installed. FO is defined by the LSB and variable function 2 (F7) by the MSB.

Configuration Variable 18	Increment for Variable Function 1 (F6)
Configuration Variable 19	Increment for Variable Function 2 (F7)

Contains the amount added (subtracted) to the output each time the output is incremented (decremented).

Configuration Variable 20-24 Time on for functions

Functions 1-5 can have the time the outputs are active set by configuration variables 20-24. Configuration variable 20 controls Function 1, Configuration Variable 21 controls Function 2, Configuration Variable 22 Controls Function 3, Configuration Variable 23 Controls Function 4, and Configuration Variable 24 Controls Function 5. The contents of the configuration variable 20 and 21 contains the time in tenths of a second that the output is on each time the function is turned on. The contents of the configuration variable 22 and 23 contains the time in hundreds of a second that the output is on each time the function is turned on. A value of all "0"s indicates continuous on.

Configuration Variable 27 Packet time-out Value

Contains the maximum time period that the decoder will maintain its speed without receiving a valid packet. A value of "0" indicates an infinite time-out. (The factory default value shall be "00000000")

Configuration Variable 28 Configurations Supported

Bit 0 = Broadcast Disable: "0" = Broadcast Enabled, "1" = Broadcast Disabled
Bit 1 = Extended Mode: "0" = Basic mode, "1" = Extended mode
Bit 2 = Analog Enable: "0" = Analog Disabled, "1" = Analog Enabled,
Bit 3 = Motor EMF Feedback: "0" = No Motor EMF Feedback, "1" = Motor EMF Feedback enabled
Bit 4 = Speed Table: "0" = speed table set by configuration variables #1,#4,#5, and #6, "1" = Speed Table not set by configuration variables #1,#4,#5, and #6;
Bit 5 = Address Type: "0" = Decoder responds to one byte address contained in Configuration Variable #1, "1" Decoder responds to two byte Address contained in Configuration Variables 8 and 9.
Bit 6 = 2 Byte Address Operation: "0" = 2 byte address not valid for Multi Function Digital Decoders Packets, "1" = 2 byte address are valid for Multi Function Digital Decoders Packets[3]
Bit 7 = Extended NMRA Accessory Decoder: "0" = Multi Function Digital Decoder, "1" = Extended NMRA Accessory Decoder

(The factory default value shall be "00000100")

Configuration Variable 29 Page Value for Service Mode

Used for addressing in service mode. The actual Configuration Variable being address in Service Mode is calculated by subtracted "1" from the contents of Configuration Variable 29 and the result shifted 2 bits to the left and added to the register being addressed. This allows service mode to address 1020 configuration variables. (The factory default value shall be "00000001")

Configuration Variable 30 Future Configuration variables

This CV is reserved for future NMRA Configuration variables. (The Factory Default is "00000000")

Configuration Variable 31 - Current Block Address

Contains the active configuration variable block being read or written. All block addresses contain the same value. (The factory default is "00000000")

BLOCK 2 Configuration Variables 32-63 Flying Programming Variables

Configuration Variables 32-39 Consist Control

Configuration Variable 32	Consist Address
Configuration Variable 33	Consist Configuration
Configuration Variable 34	Consist Functions Active
Configuration Variable 36	Consist Acceleration Rate
Configuration Variable 37	Consist Deceleration Rate
Configuration Variable 38	Consist Load Feedback

Configuration Variable 32 Consist Address (AAAAAAAA)

[3] Some care must be exercised in using this feature to ensure that the 2 byte address range does not overlap with the single byte address range which could result in the possibility for *Digital Decoders* using a single byte address trying to execute the second address byte as a data instruction.

Contains an 8 bit consist addresses. Addresses "00000000", "11111110" and "11111111" are not valid consist addresses. The default for Configuration Variable 32 is "00000000"

Configuration Variable 33 Consist Configuration

(AAAAUCCC)

AAAA is a 4 bit unit address intended for locomotives with 2 byte addresses in a consist. A value of 0000 indicates that no unit address is defined for the locomotive.

CCC defines 3 variables.

1UU Consist Address in Configuration Variable 32 is Active (can only be set of Configuration Variable 32 has a valid consist address.

U1U Consist Direction is Opposite Normal Locomotive Direction

UU1 Function F0 indication where a value of "1" indicates it is on for this locomotive.

The default for Configuration Variable 33 is "00000000"

Configuration Variable 34 Consist Functions Active DDDDDDDD

Defines for functions other than F0 whether the function is controlled by the consist address or the locomotive address. For each Bit a value of "1" indicates that the function will only respond to instructions addressed to the consist address. A value of "0" indicates that the function will only respond to instructions addressed to the locomotive address. F1 is indicated by bit 1. F7 by bit 7. The default for Configuration Variable 34 is "0000000U" for single byte addressing and "11111111" for two byte addressing.

Configuration Variable 36 Consist Acceleration

This Configuration Variable contains additional acceleration rate information that is to be added to the base value contained in Configuration Variable #3. This additional acceleration information is only valid while the unit is in an active consist.

Configuration Variable 37 Consist Deceleration

This Configuration Variable contains additional braking rate information that is to be added to the base value contained in Configuration Variable #4. This additional braking information is only valid while the unit is in an active consist.

Configuration Variable 38 Consist Load Feedback

This Configuration Variable contains additional load feedback information that is to be added to the base value contained in Configuration Variable #10. This additional load feedback information is only valid while the unit is in an active consist.

Configuration Variables 40-47 Sound Control

These Configuration Variables are reserved for sound control.

Configuration Variables 48-62 Function Status

Configuration Variable 48	Output 0 Location
Configuration Variable 49	Output 1 Location
Configuration Variable 50	Output 2 Location
Configuration Variable 51	Output 3 Location
Configuration Variable 52	Output 4 Location
Configuration Variable 53	Output 5 Location
Configuration Variable 54	Output 6 Location
Configuration Variable 55	Output 7 Location
Configuration Variable 58	Functions Inactive Forward Direction
Configuration Variable 59	Functions Inactive Backward Direction
Configuration Variable 60	Variable Function 1 Status
Configuration Variable 61	Variable Function 2 Status

Configuration Variable 48-55 Output Locations

Indicates which function or functions will activate the specified output. This allows the user to customize which outputs are controlled by which input commands. For each output the 8 bit variable is defined by bit 0 referring to Function 0 and Bit 7 by Function 7.

Configuration Variable 58: Functions Inactive Forward Direction

A value of "1" in a bit location indicates that function is inactive in the forward direction. Function 1 information is indicated by the LSB while Function 8 is indicated by the MSB.

Configuration Variable 59: Functions Inactive Reverse Direction

A value of "1" in a bit location indicates that function is inactive in the reverse direction. Function 1 information is indicated by the LSB while Function 8 is indicated by the MSB.

Configuration Variable 60: Variable Function 1 Status

Indicates the current value of Variable Function 1

Configuration Variable 61: Variable Function 2 Status

Indicated the current value of Variable Function 2

Configuration Variable 63 - Current Block Address

Contains the active configuration variable block being read or written. All block addresses contain the same value.

BLOCK 3 Configuration Variables 64-95 Speed Table

Configuration Variable 64-91: Speed Table

The speed table is defined to be 28 bytes wide, consisting of 28 values for forward speeds. A digital controller that uses this table shall have at least 64 voltage drive levels and can have as many as 256 so that a smooth power curve can be constructed. Note that voltage drive levels are specified in fixed point, in the same way as other parameters. This means that a drive level of 1/4 maximum voltage corresponds to 0100000, not 0010000, as you

would expect if the number specified a fraction with a fixed denominator, i.e. value 32 out of a fixed 128 levels (see Definitions section).

Configuration Variable 94: Reverse Trim

Specifies a scale factor by which a voltage drive level should be multiplied, when the controller is driving the unit in reverse. It is interpreted as n/128, so that 100%, or equal drive levels for forward and reverse operation is given as 10000000 binary (the default). If the Reverse Trim configuration variable contains a value of "0" then reverse trim is not implemented and the speed table refers to both forward and reverse direction

Configuration Variable 95 - Current Block Address

Contains the active configuration variable block being read or written. All block addresses contain the same value.

BLOCK 4 Configuration Variables 96-127 - Decoder and Manufacturer Information

Configuration Variable 96-113 Decoder Configuration (Read Only)

Configuration Variable 96-97	Configurations Supported
Configuration Variable 98	Maximum Number of Bytes in a Packet
Configuration Variable 99	Speed And Direction Volatility
Configuration Variable 100	Functions Supported
Configuration Variable 101	Range for Variable Function 1
Configuration Variable 102	Range for Variable Function 2

Configuration Variable 96 - Configurations Supported

Contains a "1" in every location for a configuration supported. A value of "0" in a bit location indicates that particular function is not implemented. Bits not described shall have a value of "0".

Bit 0 = Broadcast Disable: "0" = Broadcast Enabled, "1" = Broadcast Disabled
Bit 1 = Extended Mode: "0" = Basic mode, "1" = Extended mode
Bit 2 = Analog Enable: "0" = Analog Disabled, "1" = Analog Enabled,
Bit 3 = Motor EMF Feedback: "0" = No Motor EMF Feedback, "1" = Motor EMF Feedback enabled
Bit 4 = Speed Table: "0" = speed table set by configuration variables #1,#4,#5, and #6, "1" = Speed Table not set by configuration variables #1,#4,#5, and #6;
Bit 5 = Address Type: "0" = Decoder responds to one byte address contained in Configuration Variable #1, "1" Decoder responds to two byte Address contained in Configuration Variables 8 and 9.
Bit 6 = 2 Byte Address Operation: "0" = 2 byte address not valid for Multi Function Digital Decoders Packets, "1" = 2 byte address are valid for Multi Function Digital Decoders Packets[4]

[4] Some care must be exercised in using this feature to ensure that the 2 byte address range does not overlap with the single byte address range which could result in the possibility for *Digital Decoders* using a single byte address trying to execute the second address byte as a data instruction.

Bit 7 = Extended NMRA Accessory Decoder: "0" = Multi Function Digital Decoder, "1" = Extended NMRA Accessory Decoder

Configuration Variable 97 - Configurations Supported

Reserved for future NMRA use

Configuration Variable 98 Maximum Number of Bytes in a Packet

Contains the maximum number of bytes in a packet that the decoder can support.

Configuration Variable 99 Speed And Direction Volatility

Contains the maximum time period over a power interruption that speed and direction data will be remembered. It is measured in one hundreds of a second with a value of all 1s indicating that speed and direction is remembered across operating sessions.

Configuration Variable 100 Functions Supported

Contains a "1" for each of the 8 functions supported. Bit 0 refers to F0 and bit 7 refers to variable function 2 (F7).

Configuration Variable 101 Range for Variable Function 1

Contains the maximum value that Variable function 1 can have.

Configuration Variable 102 Range for Variable Function 2

Contains the maximum value that Variable function 2 can have.

Configuration Variables 104-111 User Information

Configuration Variables 104-107 User Identifier (NMRA Number)

Configuration Variables 112-127 Manufacturer Information (Read only)

Configuration Variable 112-113 Manufacturer ID
Configuration Variable 114-115 Receiver ID
Configuration Variable 116-126 Reserved for Manufacturer Use

Configuration Variable 127 - Current Block Address

Contains the active configuration variable block being read or written. All block addresses contain the same value.

BLOCK 4 Configuration Variables 128-159 - Accessory Control

Configuration Variable 128-129 Decoder Address
Configuration Variable 130 Decoder Type
Configuration Variable 131 Configurations Supported
Configuration Variable 132 F1 Time On
Configuration Variable 133 F2 Time On
Configuration Variable 134 F3 Time On
Configuration Variable 135 F4 Time On

Configuration Variable 136 Step Value F1
Configuration Variable 137 Step Value F2
Configuration Variable 138 Max Range F1
Configuration Variable 139 Max Range F2

Configuration Variable 128-129 Decoder Address

Contains the Auxiliary 2 Byte address. Bits 0-3 are always 0

Configuration Variable 130 Decoder Type

Bits 0-7 = Decoder Type
00000001 - Four On Off Functions
00000010 - Two Variable function
00000100 - Single output

Configuration Variable 131 Configurations Supported

Reserved for future use

Configuration Variable 132 F1 Time On
Configuration Variable 133 F2 Time On
Configuration Variable 134 F3 Time On
Configuration Variable 135 F4 Time On

Contains a time in tenths of seconds that the output is on each time the state of the function is changed. A value of all "0"s indicates continuous on.

Configuration Variable 136 Step Value F1
Configuration Variable 137 Step Value F2

Contains the amount added (subtracted) to the output each time the output is incremented (decremented).

Configuration Variable 138 Max Range F1
Configuration Variable 139 Max Range F2

Contains the maximum output for the function. A value of "0" indicated that no maximum is set.

Configuration Variable 159 - Current Block Address

Contains the active configuration variable block being read or written. All block addresses contain the same value.