

Jacobsen Declaration Exhibit M



DCC Recommended Practices

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NMRA Recommended Practices Configuration Variables For Digital Command Control, All Scales

This Recommended Practice received approval from the NMRA Board of Trustees in July 1995 and March 1997. Revisions to the previous approved version are indicated in green.

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NMRA RECOMMENDED PRACTICES	
Configuration Variables For Digital Command Control, All Scales	
Revised March 1997	RP-9.2.2

This Recommended Practice provides a map and descriptions for *Digital Decoder* Configuration Variables. Configuration Variables allow the decoder to be customized for each locomotive, or other mobile or stationary devices. Configuration Variables shall be stored in non-volatile memory and must not change when power is removed from the decoder over very extended periods of time. While all *Digital Decoders* 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

Table 1 identifies each of the Configuration Variables(CVs), along with additional information about each one. Following Table 1 is a written description of each of the CVs. CVs 1-512 are for Multi-Function Digital Decoders, while CVs starting at 513 are for Accessory Decoders. In Table 1 each Configuration Variable(CV) is identified by name and number, along with the following information:

- **Required:** Mandatory(M), Recommended(R) or Optional(O). CVs identified as Mandatory(M) must be implemented in order to conform to this Recommended Practice, while those marked as Recommended(R) are strongly encouraged, and those marked Optional(O) are at the manufacturer's discretion.
- **Default Value:** the required factory default value when the CV is provided in an implementation.
- **Read-Only:** indicates a CV whose value should be set by the manufacturer and which the user cannot modify
- **Uniform Spec:** Many CVs are implementation specific and no uniform specification is required. Others must be implemented in a uniform fashion in order to achieve compatibility. A "Y" in the Uniform Spec column indicates a CV which requires implementation by manufacturers according to a common specification.
- **Additional Comments:** CVs identified as "Reserved by NMRA for future use" are allocated for future needs and must not be used by an implementor without prior written approval from the NMRA Technical Department. CVs identified as "Values assigned by NMRA" indicate that the allowable values are defined by the NMRA and any requests for additional values should be directed to the NMRA Technical Department. CVs identified as "Reserved for manufacturer use" are allocated for use by implementors, for which no prior NMRA authorization is needed, and for which no common usage across decoders from different implementors can be assured by the NMRA.

Table 1 Configuration Variables

CV Name	CV#	Requ- ired	Default Value	Read Only	Uniform Spec	Additional Comments
Multi-function Decoders:						
Primary Address	1	M	3	-	Y	
Vstart	2	R	7	-	-	
Acceleration Rate	3	R	0	-	-	
Deceleration Rate	4	R	0	-	-	
Vhigh	5	O	1	-	-	
Vmid	6	O	1	-	-	
Manufacturer Version No.	7	M	-	Y	-	Manufacturer defined version info
Manufactured ID	8	M	-	Y	Y	Values assigned by NMRA
Total PWM Period	9	O	0	-	-	
EMF Feedback Cutout	10	O	-	-	-	
Packet Time-Out Value	11	R	-	-	-	
Power Source Conversion	12	O	-	-	Y	Values assigned by NMRA
Analog Mode Function Status	13	O	-	-	Y	
	14-16	-	-	-	-	Reserved by NMRA for future use
Extended Address	17+18	O	-	-	Y	
Consist Address	19	O	-	-	Y	
	20	-	-	-	-	Reserved by NMRA for future use
Consist Addr Active for F1-F8	21	O	-	-	Y	
Consist Addr Active for FL	22	O	-	-	Y	
Acceleration Adjustment	23	O	-	-	Y	
Deceleration Adjustment	24	O	-	-	Y	
Speed Table/Mid-range						

Cab Speed Step	25	O	1	-	Y	
	26-28	-	-	-	-	Reserved by NMRA for future use
Configuration Data #1	29	M	(1)	-	Y	
Error Information	30	O	-	-	Y	
Configuration Data #2	31	O	0	-	Y	Reserved by NMRA for future use
Configuration Data #3	32	O	0	-	Y	Reserved by NMRA for future use
Output Loc FL(f),FL(r),F1-F8	33-42	O	-	-	Y	
	43-48	-	-	-	-	Reserved by NMRA for future use
Manufacturer Unique	49-64	O	-	-	-	Reserved for manufacturer use
Kick Start	65	O	-	-	-	
Forward Trim	66	O	128	-	-	
Speed Table	67-94	O	-	-	-	
Reverse Trim	95	O	128	-	-	
	96-104	-	-	-	-	Reserved by NMRA for future use
User Identifier #1	105	O	-	-	-	Reserved for customer use
User Identifier #2	106	O	-	-	-	Reserved for customer use
	107-512	-	-	-	-	Reserved by NMRA for future use
Accessory Decoders:						
Decoder Address LSB	513	M	-	-	Y	6 LSB of accessory decoder address
Auxiliary Activation	514	O	-	-	-	Auxiliary activation of outputs
Time On F1	515	O	-	-	Y	
Time On F2	516	O	-	-	Y	
Time On F3	517	O	-	-	Y	
Time On F4	518	O	-	-	Y	
Manufacturer Version Info	519	M	-	Y	-	Manufacturer defined version info
Manufacturer ID	520	M	-	Y	Y	Values assigned by NMRA
Decoder Address MSB	521	M	0	-	Y	3 MSB of accessory decoder address
	522-540	-	-	-	-	Reserved by NMRA for future use
Accessory Decoder Configs	541	O	-	-	Y	similar to CV#29 for acc. decoders
	542-544	-	-	-	-	Reserved by NMRA for future use
Manufacturer Unique	545-593	O	-	-	-	Reserved for manufacturer use
	594-1024	-	-	-	-	Reserved by NMRA for future use

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General Definitions

Binary numerical quantities are stored such that the rightmost bit is the least significant, and the leftmost is the most significant.

Configuration Variable MSB |d07|d06|d05|d04|d03|d02|d01|d00| LSB

Descriptions of Configuration Variables for Multi-Function Decoders

Configuration Variable 1 Primary Address

Bits 0-6 contain an address with a value between 1 and 127. Bit seven must have a value of "0". If the value of Configuration Variable #1 is "00000000" then the decoder will go out of NMRA digital mode and convert to the alternate power source as defined by [Configuration Variable #12](#). This setting will not effect the Digital Decoder's ability to respond to service mode packets (see RP 9.2.3)

Configuration Variable 2 Vstart

Vstart is used to define the voltage drive level used as the start voltage on the motor. The voltage drive levels shall correspond linearly to the voltage applied to the motor at speed step one, 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.

Configuration Variable 3 Acceleration Rate

Determines the decoder's acceleration rate. The formula for the acceleration rate shall be equal to (the contents of CV#3*.896)/(number of speed steps in use). For example, if the contents of CV#3 =2, then the acceleration is 0.064 sec/step for a decoder currently using 28 speed steps. If the contents of this parameter equals "0" then there is no programmed momentum during acceleration.

Configuration Variable 4 Deceleration Rate

Determines a decoders braking rate, in the same fashion as acceleration above ([CV #3](#)).

Configuration Variable 5 Vhigh

Vhigh is used to specify the motor voltage drive levels at the maximum speed step. This value shall be specified as a fraction of available rectified supply voltage. When the contents of CV#5 equal "11111111", the full available rectified voltage shall be applied. Values of "00000000" or "00000001" shall indicate that Vhigh is not used in the calculation of the speed table.

Configuration Variable 6 Vmid

Vmid specifies the voltage drive level at the middle speed step. Vmid is used to generate a performance curve in the decoder that translate speed step values into motor voltage drive levels and is specified as a fraction of available rectified supply voltage. Values of 00000000 or 00000001 shall indicate that Vmid is not used in the calculation of the speed table.

Configuration Variable 7 Manufacturer Version Number

This is reserved for the manufacturer to store information regarding the version of the decoder.

Configuration Variable 8 Manufacturer ID

CV8 shall contain the NMRA assigned id number of the manufacturer of this decoder. The currently assigned manufacturer ID codes are listed in [Appendix A](#) of this Recommended Practice. The use of a value not assigned by the NMRA shall immediately cause the decoder to not be in conformance to this RP. The CV shall be implemented as a read-only value, which cannot be modified.

Configuration Variable 9 Total PWM Period

The value of CV#9 sets the nominal PWM period at the decoder output and therefore the frequency is proportional to the reciprocal of the value. The recommend formula for PWM period should be: PWM period (uS) = (131 + MANTISSA x 4) x 2 EXP ,Where MANTISSA is in bits 0-4 bits of CV#9 (low order) and EXP is bits 5-7 for CV#9. If the

value programmed into CV-9 falls outside a decoder's capability, it is suggested that the decoder "adjust" the value to the appropriate highest or lowest setting supported by the decoder.

Configuration Variable 10 EMF Feedback Cutout

Contains a value between 1 and 128 that indicates the speed step above which the back EMF motor control cuts off. When 14 or 28 speed steps are used the LSB's of the value are truncated appropriately.

Configuration Variable 11 Packet time-out Value

Contains the maximum time period that the decoder will maintain its speed without receiving a valid packet addressed to it. See [RP 9.2.4 Section C](#) for further information.

Configuration Variable 12 Power Source Conversion(2)

Contains the identity of the alternate power source to be converted to should [CV #1](#) contain all zeros. This is also the primary alternative power source selected should the decoder perform power source conversion. The currently assigned Power Source Conversion codes are listed in [Appendix B](#) of this Recommended Practice.

Configuration Variable 13 Analog Mode Function Status

Indicates the status of each function (F1 through F8) when the unit is operating in analog power mode. A value of "0" indicates the function is off, while a value of "1" indicates the function is on. Bit 0 corresponds to F1, while Bit 7 corresponds to F8.

Configuration Variables 17,18: Extended Address

The Extended Address is the locomotive address when the decoder is set up for extended addressing (indicated by a value of "1" in bit location 5 of [CV#29](#)). CV#17 contains the most significant bits of the two byte address and must have a value between 11000000 and 11100111, inclusive, in order for this two byte address to be valid. CV 18 contains the least significant bits of the address and may contain any value.

Configuration Variable 19 Consist Address

Contains a seven bit address in bit positions 0-6. Bit 7 indicates the relative direction of this unit within a consist, with a value of "0" indicating normal direction, and a value of "1" indicating a direction opposite the unit's normal direction. If the seven bit address in bits 0-6 is "0000000" the unit is not in a consist.

Configuration Variable 21 Consist Address Active for F1-F8

Defines for functions F1-F8 whether the function is controlled by the consist address. For each Bit a value of "1" indicates that the function will 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 0. F8 by bit 7.

Configuration Variable 22 Consist Address Active for FL

Defines for function FL whether the function is controlled by the consist address. For each Bit a value of "1" indicates that the function will 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. FL in the forward direction is indicated by bit 0, FL in the reverse direction is controlled by bit 1.

Configuration Variable 23 Acceleration Adjustment

This Configuration Variable contains additional acceleration rate information that is to be added to or subtracted from the base value contained in Configuration Variable #3 using the formula (the contents of CV#23*.896)/(number of speed steps in use). This is a 7 bit value (bits 0-6) with bit 7 being reserved for a sign bit (0-add,1-subtract). In case of overflow the maximum acceleration rate shall be used. In case of underflow no acceleration shall be used. The expected use is for changing momentum to simulate differing train lengths/loads, most often when operating in a consist.

Configuration Variable 24 Deceleration Adjustment

This Configuration Variable contains additional braking rate information that is to be added to or subtracted from the base value contained in Configuration Variable #4 using the formula (the contents of CV#24*.896)/(number of speed steps in use). This is a 7 bit value (bits 0-6) with bit 7 being reserved for a sign bit (0-add,1-subtract). In case of overflow the maximum deceleration rate shall be used. In case of underflow no deceleration shall be used. The expected use is for changing momentum to simulate differing train lengths/loads, most often when operating in a consist.

Configuration Variable 25 Speed Table/Mid Range Cab Speed Step

A value between 2 and 127 shall be used to indicate 1 of 126 factory preset speed tables. A value of "00000010" indicates that the curve shall be linear. A value between 128 and 154 defines the cab throttle position (1-26) which will define where the mid range decoder speed value will be applied. In 14 speed mode the decoder will utilize this value divided by two. If the value in this variable is outside the range, the default mid cab speed of 14 (for 28 speed mode or 7 for 14 speed mode) shall be used as the mid speed value. Values of "00000000" or "00000001" shall indicate that this CV is not used in the calculation of the speed table.

Configuration Variable 29 Configurations Supported

- Bit 0 = Locomotive Direction: "0" = normal, "1" = reversed. [This bit controls the locomotive's forward and backward direction in digital mode only. Directional sensitive functions, such as headlights \(FL and FR\), will also be reversed so that they line up with the locomotive's new forward direction. See RP-9.1.1 for more information.](#)
- Bit 1 = FL location: "0" = bit 4 in [Speed and Direction instructions](#) control FL, "1" = bit 4 in [function group one instruction](#) controls FL. See [RP-9.2.1](#) for more information.
- Bit 2 = Power Source Conversion: "0" = NMRA Digital Only, "1" = Power Source Conversion Enabled, See [CV#12](#) for more information,
- Bit 3 = Advanced Decoder Acknowledgment: "0" = advanced acknowledgment disabled, "1" = advanced acknowledgment enabled. See RP-9.2.3 for more information.
- Bit 4 = Speed Table: "0" = speed table set by configuration variables [#2,#5](#), and [#6](#), "1" = Speed Table set by configuration variables [#66-#95](#)
- Bit 5 = "0" = one byte addressing, "1" = two byte addressing (also known as extended addressing) See [RP 9.2.1](#) for more information.
- Bit 6 = Reserved for future use
- Bit 7 = Accessory Decoder: "0" = Multifunction Decoder, "1" = Accessory Decoder (see [CV #541](#) for a description of assignments for bits 0-6)

*Note If the decoder does not support a feature contained in this table, it shall not allow the bit to be set improperly.

Configuration Variable 30 ERROR Information

In the case where the decoder has an error condition this Configuration Variable shall contain the error condition as specified by the manufacturer. A value of "0" indicates that no error has occurred.

Configuration Variables 33-42 Output Locations FL(f), FL(r), and F1-F8

Contains a matrix indication of which function inputs control which *Digital Decoder* outputs. This allows the user to customize which outputs are controlled by which input commands. The outputs that Function FL(f) controls are indicated in CV #33, FL(r) in CV#34, F1 in CV #35, to F8 in CV#42. A value of "1" in each bit location indicates that that function controls that output. This allows a single function to control multiple outputs, or the same output to be controlled by multiple functions. A value of "00000000" shall indicate that the decoder default output shall be used. CVs 33-36 control outputs 1-8. CVs 37-40 control outputs 3-10. CVs 41-42 control outputs 7-14. The defaults is that FL(f) controls output 1, FL(r) controls output 2, F1 controls output 3 to F8 controls output 10. The lowest numbered output is in the LSB of the CV, [as shown in the table below](#).

CV	Description	Output													
		msb													lsb
		14	13	12	11	10	9	8	7	6	5	4	3	2	1
33	Forward Headlight														d
34	Reverse Headlight													d	
35	Function 1												d		
36	Function 2											d			
37	Function 3										d				
38	Function 4									d					
39	Function 5								d						
40	Function 6							d							
41	Function 7						d								
42	Function 8					d									

Table 1: Output Position vs. CV (a 'd' indicates the default position)

Configuration Variable 65 Kick Start

Specifies the amount of extra Kick that will be supplied to the motor when transitioning between stop and the first speed step.

Configuration Variable 66: Forward Trim

Specifies a scale factor by which a voltage drive level should be multiplied, when the controller is driving the unit in the forward direction. It is interpreted as n/128. If the Forward Trim configuration variable contains a value of "0" then forward trim is not implemented.

Configuration Variables 67-94: 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 95: 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. If the Reverse Trim configuration variable contains a value of "0" then reverse trim is not implemented.

Configuration Variables 105, 106: User Identification #1 and #2

These CVs are reserved for use by the owner of the decoder to store identification information, e.g. NMRA membership number. CV#105 is ID #1 and CV#106 is ID #2

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Descriptions of Configuration Variables for Accessory Decoders

Configuration Variable 513 Decoder Address (LSB)

Contains the six least significant bits of the accessory decoder's address in bits 0-5. These bits are transmitted as bits 0-5 in the first byte of the accessory decoder packet. See [RP-9.2.1](#) for more information.

Configuration Variable 514 Auxiliary Activation

Bits 1-8 = Auxiliary activation: = "0" output is not activated by an auxiliary input, "1" output can be activated by an auxiliary input.

Configuration Variables 515-518 Time On for Functions F1-F4

Functions F1-F4 can have the time the outputs are active set by configuration variables #515-#518. Configuration Variable #515 controls Function F1, and Configuration Variable #518 Controls Function F4. Contains a time that the output is on each time the state of the function is activated. A value of all "0"s indicates continuous on.

Configuration Variable 519 Manufacturer Version Number

See [CV #7](#) for the description.

Configuration Variable 520 Manufacturer ID (See [Appendix A](#) for a list of Manufacturer Ids)

See [CV #8](#) for the description.

Configuration Variable 521 Decoder Address (MSB)

Contains the three most significant bits of the accessory decoder's address in bits 0-2. These bits are transmitted as bits 4-6 in the second byte of the accessory decoder packet. The bits transmitted are the ones complement of the value in this CV. See [RP-9.2.1](#) for more information.

Configuration Variable 541 Accessory Decoder Configurations Supported

- Bits 0-6 = Reserved for future use.
- Bit 7 = Accessory Decoder: = "0" Multifunction Decoder (See [CV-29](#) for description of bit Assignments for bits 0-6), "1" = Accessory Decoder

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Appendix A: Manufacturer ID codes as assigned by the NMRA

The Manufacturer ID codes that have been assigned by the NMRA Technical Department are now in a separate [PDF file](#).

Manufacturers not on this list shall apply to the NMRA Technical Department for the assignment of a unique manufacturer ID.

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Appendix B: Power Source Conversion codes as assigned by the NMRA

The following Power Source Conversion codes have been assigned by the NMRA Technical Department. Manufacturers wishing to use conversions not on this list shall apply to the NMRA Technical Department for the assignment for a conversion ID.

- 00000001 = Analog Power Conversion
- 00000010 = Radio
- 00000100 = Zero-1
- 00001000 = TRIX
- 00010000 = CTC 16 / Railcommand

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Footnotes

- (1) If any of these features are provided, then this CV is Mandatory.
 - (2) Allocation of these bits is done by the NMRA on an as needed basis.
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