# General

Communication from a Digital Command Station to a Digital Decoder is accomplished by transmitting a series of bits that convey instructions. A bit is a signal which represents one of two conditions, which we will call "1" and "0". This portion of the standard covers the electrical characteristics of the digital command control signal that encodes these bits.

Please refer to Tables 2.1, 2.2 and 2.3 for definition and numerical values of parameters used throughout this document.

## Introduction and Intended Use (Informative)

## References

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

### Normative

* S-9 Electrical Standards
* S-9.2 DCC Communications Standard

### Informative

* RCN-210 DCC Bit Transmission, with which S-9.1 is intended to be in harmony.[[1]](#endnote-1)
* NEM-670 DCC Digital Control Signal Bit Representation, with which S-9.1 is intended to be in harmony.[[2]](#endnote-2)

## Terminology

|  |  |
| --- | --- |
| **Term** | **Definition** |
| Vehicle | Mobile model railroad device. This includes locomotives and other rolling stock. |
| Decoder (mobile) | DCC receiver for controlling vehicle animation. |
| Accessory Decoder | DCC receiver for controlling accessories. |
| Accessories | Fixed model railroad device. This includes turnouts, lights, signals and other devices not on the rails. |
| Power Station | A device that amplifies the low current DCC electrical signals transmitted by a Command Station for the purpose of providing high current DCC signals with sufficient power to operate model trains and any accessory decoders that are connected to the track. The power station may be a separate device or may be combined with the command station and/or throttle. Sometimes referred to as a booster. |

# Technique for Encoding Bits

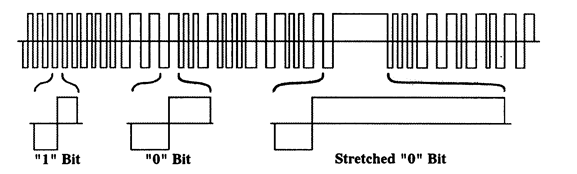
The NMRA baseline digital command control signal consists of a stream of transitions between two equal voltage levels that have opposite polarity[[3]](#footnote-1). Alternate transitions separate one bit from the next. The remaining transitions divide each bit into a first part and a last part. Digital Command Stations shall encode bits within this digital command control stream of transitions by varying the duration of the parts of the bits, or frequency of the transitions.

In a “1” bit, the first and last part of a bit shall have the same nominal duration, and that duration shall be **t1**[[4]](#footnote-2), giving the bit a nominal total duration of **(2x t1)**. Digital Command Station components shall transmit “1” bits with the first and last parts each having a duration within the **t1** range. The duration difference between the first and last parts of a “1” bit shall not exceed **t1d**.

A Digital Decoder must accept bits whose first and last parts have a duration within the **tr1** range as a valid bit with the value of “1”. Digital Decoders must accept “1” bits where the duration difference between the positive and negative components does not exceed **tr1d**.

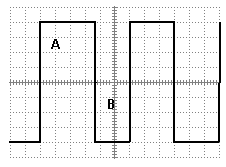
In a “0” bit, the duration of the first and last parts of each transition shall nominally be greater than or equal to **t0**. To keep the DC component of the total signal at zero as with the “1” bits, the first and last part of the “0” bit are normally of equal duration. Digital Command Station components shall transmit “0” bits with each part of the bit having a duration within the **t0** range with the total bit duration of the “0” bit not exceeding **t0tot**. A Digital Decoder must accept bits, whose first or last parts have a duration within the **tr0** range as a valid bit with the value of “0”. Figure 2.1 provides an example of bits encoded using this technique.

**Figure 2.1: Bit Encoding**



This is a differential signal with no ground. At the point where the signal line crosses the horizontal reference line, both rails will be at the same voltage.

## One Bit Timing



|  |  |
| --- | --- |
| For Power **Station** Output under Load: |  |
|  |  |
| Relationship for One Bits | Result |
| Period A < ***( t1min.)*** or Period A > ***( t1max.)*** | Bad |
| Period A = Period B | OK |
| |Period A – Period B| <= ***( t1dmax.)*** | OK |
| |Period A – Period B| > ***(t1dmax.)*** | Bad |
|  |  |
| **Decoders** must accept: |  |
|  |  |
| Relationship for One Bits | Result |
| Period A >= ***(tr1min.)*** & Period A <= ***(tr1max)*** | OK |
| Period A = Period B | OK |
| |Period A – Period B| <= ***( tr1d\_max.)*** | OK |
|  |  |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| ***Table 2.1 – DCC Bit Timing*** | | | | | | |
| **Parameter** | **Definition** | **Value** | | | **Unit** | **Comments** |
|  |  | Min. | Nominal | Max. |  |  |
| t1 | “1” Half Bit duration | 55 | 58 | 61 | µSec | Duration of a transmitted “1” half bit |
| tr1 | “1” Half Bit received duration | 52 | 58 | 64 | µSec | Allowed Duration for a received “1” half bit |
| t0 | “0” Half Bit duration | 95 | 100 | 9900 | µSec | Duration of a transmitted “0” half bit |
| t0total | stretched “0” Bit duration |  |  | 12000 | µSec | Max. total duration of stretched “0” bit |
| tr0 | “0” Half Bit received duration | 90 | 100 | 10000 | µSec | Allowed Duration for a received “0” half bit |
| t1d | “1” half bit duration delta |  |  | 3 | µSec | Max. difference in duration between transmitted “1”bit half bits. |
| Tr1d | Received “1” half bit duration delta |  |  | 6 | µSec | Max. difference in duration between received “1” bit half bits. |

## Command Control Signal Shape

The NMRA digital signal applied to the track by any Digital Command Control system, as measured at the power station output, shall have the following characteristics, as measured under conditions ranging from no load to the maximum continuous load permitted by the power source. Transitions that cross the region between **VtrL** and **VtrH**[[5]](#footnote-3) shall occur at the rate of **VtrA** or faster. This signal may contain non-monotonic distortion at the zero-crossing transitions, provided that this distortion shall have an amplitude of no greater than +/- **Vdist**[[6]](#footnote-4).

Digital Decoders shall be designed to correctly decode signals with transitions whose slope is **VtrRA** or faster across the voltage range from **VtrL** to **VtrH**. A Digital Decoder shall correctly decode properly addressed baseline packets at a probability of **Pdecode** or higher, as defined in S-9.2, in the presence of noise (and/or other types of signals) at frequencies above **FNoise** with a total peak-to-peak amplitude of less than (**1/ Vsnr**) of the peak-to-peak amplitude of the NMRA digital signal[[7]](#footnote-5).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| ***Table 2.2 DCC Signal parameters Shape/ Amplitude*** | | | | | | |
| **Parameter** | **Definition** | **Value** | | | **Unit** | **Comments** |
|  |  | Min. | Nominal | Max. |  |  |
| VtrL | Transition region Vmin. |  | -4 |  | Volt | Low limit of bit transition region |
| VtrH | Transition region Vmax. |  | 4 |  | Volt | High limit of bit transition region |
| VtrA | Transition rate | 2.5 |  |  | Volt/µSec | Transmitted bit voltage transition rate |
| Vdist | Distortion Amplitude |  |  | 2 | Volt | Distortion voltage during bit transition |
| VtrRA | Receive transition rate | 2 |  |  | Volt/µSec | Received bit voltage Transition rate |
| Pdecode | Decode probability | 0.95 |  |  |  | Percentage of packets decoded correctly |
| FNoise | Noise frequency | 100 |  |  | KHz | Frequency of noise or other signal |
| Vsnr | Peak Signal to Noise Amplitude Ratio | 4 |  |  |  | Peak DCC signal to peak FNoise |

## Power Transmission and Voltage Limits for Transmitting Power through the Rails

The baseline method for providing the power to operate locomotives and accessories, which shall be supported by all Digital Command Stations and Digital Decoders, is by full-wave rectification of the bipolar NMRA digital signal within the Digital Decoder[[8]](#footnote-6). In order to maintain power to the Digital Decoders, gaps in bit transmission are only allowed at specified times (see S-9.2, Section C).

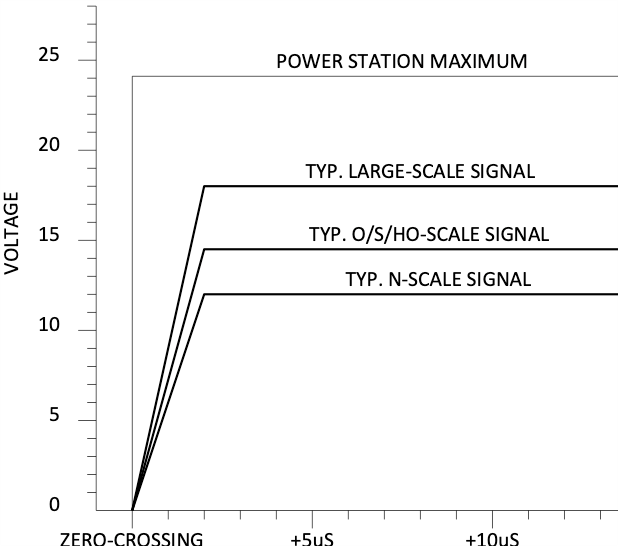
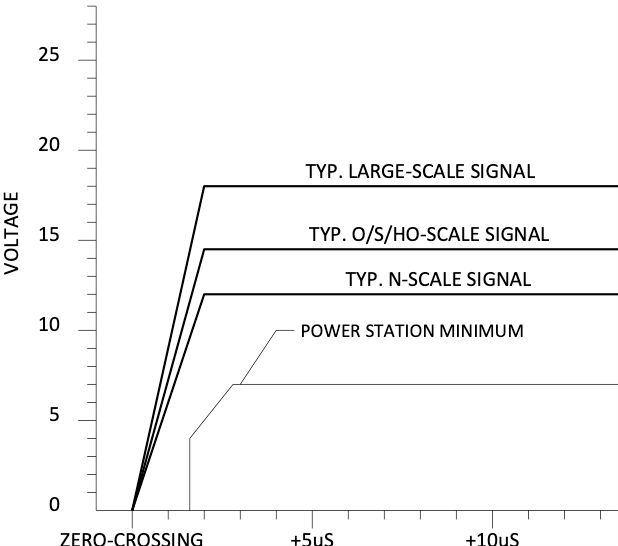
The peak value of NMRA digital signal, as produced by the power station and measured at the track, shall be confined to the range of **VDCCp** for the applicable scale, as specified in Table 2.3[[9]](#footnote-7). In no case should the peak amplitude of the command control signal exceed **VDCCp\_max** for the applicable scale.

Digital Decoders shall be designed to continuously operate and withstand, without permanent damage to the decoder; a peak maximum voltage within the range of **VDCCr** as specified in Table 2.3 for the applicable scale, measured at the track.

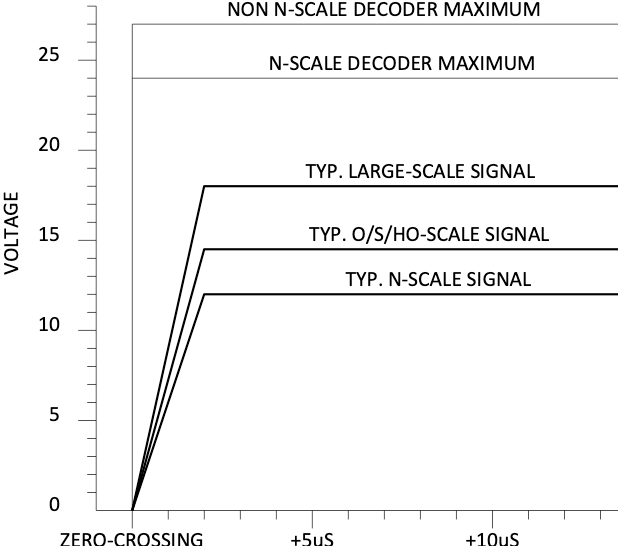
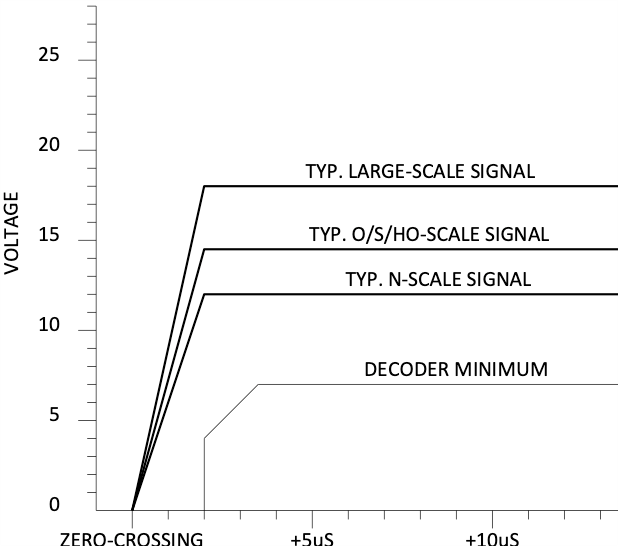
|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| ***Table 2.3 – Power transmission and amplitude limit parameters*** | | | | | | |
| **Parameter** | **Definition** | **Value** | | | **Unit** | **Comments** |
|  |  | Min. | Nominal | Max. |  |  |
| VDCCp –  N and smaller Scales | Voltage limits for track, N and smaller scales for power station | 8.5 | 12 | 22 | Volt | Voltage produced powering the track |
| VDCCp –  HO/S/O Scales | Voltage limits for track HO/S/O scales for power station | 8.5 | 15 | 22 | Volt | Voltage produced powering the track |
| VDCCp –  Large Scales | Voltage limits for track, large scales for power station | 8.5 | 18 | 24 | Volt | Voltage produced powering the track |
| VDCCr –  N and smaller Scales | Voltage limits for track, N and smaller scales for digital decoders | 7 | 12 | 24 | Volt | Peak voltage decoder should operate in and withstand |
| VDCCr –  HO/S/O Scales | Voltage limits for track HO/S/O scales for digital decoders | 7 | 15 | 27 | Volt | Peak voltage decoder should operate in and withstand |
| VDCCr –  Large Scales | Voltage limits for track, large scales for digital decoders | 7 | 18 | 27 | Volt | Peak voltage decoder should operate in and withstand |

Digital Decoders shall be designed to interpret a valid packet addressed to it whilst supplied a minimum voltage **VDDCr** as specified in Table 2.3 and to acknowledge the receipt of a command in that packet by some action E.G. turning on a low power output to illuminate an LED. The Digital Decoder is not required to turn the motor at this voltage. This an an indication of the Digital Decoder’s ability to read instructions addressed to it at the specified minimum voltage at the track.

**Minimum Voltage for Power Station** **Maximum Voltage for Power Station**



**Minimum Voltage for Decoders Maximum Voltage for Decoders**



# Document History

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| --- | --- |
| **Date** | **Description** |
| Jan 2019 | Tabularized data, removing it from the text and replacing with a variable to make future revisions less prone to missing changes in the text. Cleaned up grammar and language. |
| Feb 2019 | Table 3 increased large scale power station maximum voltage large to 24v from 22v. |
| Jan 21, 2021 | Updated Graphs on Last Page to reflect higher max voltage on large scale. Removed requirement for FCC & CE certification to meet NMRA Standard. |
| Apr 8, 2021 | Added Informative references RCN-210 and NEM-670 |

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1. RCN stands for RailCommunity Normen. The direct German to English translation of Normen is Norms, and in this context is intended to have an equivalent meaning to Standards. RailCommunity is an organization of manufacturers that creates German language standards for model railway electronics. [↑](#endnote-ref-1)
2. NEM stands for Norms of the European Model Railroads. Norms, in this context, is intended to have the equivalent meaning to Standards. MOROP is the organization that maintains the NEM documents. MOROP is an organization that creates model railway standards primarily targeted at the European market. [↑](#endnote-ref-2)
3. Note that since a locomotive or piece of rolling stock can be placed upon a given section of track facing in either direction, it is impossible to define, from the point of view of a Digital Decoder, whether the first or last part of a bit will have the "positive" voltage polarity. [↑](#footnote-ref-1)
4. All timing measurements are done between zero-volt crossings. [↑](#footnote-ref-2)
5. 0 volts is the midpoint of the differential voltage. [↑](#footnote-ref-3)
6. This standard specifically permits super-imposing non-NMRA signals upon the rails for other purposes, provided that the NMRA Digital Decoder can reject these signals. [↑](#footnote-ref-4)
7. This measurement is made with the Digital Decoder electrically connected to a track or accessory bus. [↑](#footnote-ref-5)
8. Alternate means for supplying power are acceptable, provided that Digital Command Station power units are capable of producing the baseline track signal, and Digital Decoders are capable of operation from the baseline track signal as described by this standard. [↑](#footnote-ref-6)
9. Care should be taken to ensure that any motors exposed directly to the digital signal for extended periods have a stall rating that exceeds the amplitude of the signal, or sufficiently high impedance at 4-9 kHz to reduce the current to normal operating level. This appears to only be a concern for high-precision core-less can motors, which present a low impedance load, or for layouts using an NMRA digital signal with an amplitude in excess of ± 18 volts. [↑](#footnote-ref-7)