1 General

This STANDARD establishes ELECTRICAL requirements for interchange and ***safe*** and satisfactory performance of Two Rail equipment on model railroad layouts. The requirements in this Standard also address Three Rail Systems (see definition below).

1.1. The National Model Railroad Association (NMRA) has defined a set of Standards for digital communications on the rails (NMRA Digital Command Control) (MNRA DCC) in Standards S-9.1, S-9.2, and S-9.3, referenced below.

1.2. The NMRA in conjunction with the OpenLCB Group has defined a set of communications Standards (NMRA Layout Command Control) (NMRA LCC) for layout-level Ethernet and Wireless (Wifi) communications. These Standards are referenced below in Standards S-9.7.nnn and TN-9.nnn.
NOTE: OpenLCB stands for Open Layout Control Bus. 'Open' means that it is developed as an open-source connection standard. Like the DCC Standards, manufacturers and hobbyists can use these LCC Standards to create products to do all sorts of things that will work together.

2 References

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

2.1 Normative

2.1.1 NMRA STANDARD S-5 TRACTION POWER COLLECTION (1)
2.1.2 NMRA STANDARD MS-1.3 ELECTRICAL STANDARDS FOR MODULES, ALL SCALES
2.1.3 NMRA STANDARD S-9.1 ELECTRICAL STANDARDS FOR DIGITAL COMAND CONTROL (DCC)
2.1.4 NMRA STANDARD S-9.2 COMMUNICATIONS STANDARDS FOR DIGITAL COMMAND CONTROL, ALL SCALES
2.1.5 NMRA STANDARD S-9.3 DCC BI-DIRECTIONAL COMMUNICATIONS STANDARD
2.1.6 NMRA STANDARD S-9.7.0.3 Layout Command Control (LCC) Unique Identifiers
2.1.7 NMRA STANDARD S-9.7.0.4 Layout Command Control (LCC) Event Identifiers
2.1.8 NMRA STANDARD S-9.7.1.1 Layout Command Control (LCC) Controller Area Network (CAN) Physical Layer
2.1.9 NMRA STANDARD S-9.7.2.1 Layout Command Control (LCC) Controller Area Network (CAN) Frame Transfer
2.1.10 NMRA STANDARD S-9.7.3 Layout Command Control (LCC) Message Network
2.1.11 NMRA STANDARD S-9.7.3.1 Layout Command Control (LCC) Event Transport
2.1.12 NMRA STANDARD S-9.7.3.2 Layout Command Control (LCC) Datagram Transport
2.1.13 NMRA STANDARD S-9.7.4.1 Layout Command Control (LCC) Configuration Description Information (CDI)
2.1.14 NMRA STANDARD S-9.7.4.2 Layout Command Control (LCC) Memory Configuration
2.1.15 NMRA STANDARD S-9.7.4.3 Layout Command Control (LCC) Simple Node Information
2.1.16 NMRA STANDARD S-9.7.4.4 Layout Command Control (LCC) Firmware Upgrade
2.1.17 NMRA STANDARD S-9.7.4.5 Layout Command Control (LCC) Broadcast Time

2.2 Informative

2.2.1 NMRA RECOMMENDED PRACTICES MRP-1.3 ELECTRICAL RECOMMENDED PRACTICES, ALL SCALES, MODULES

2.2.2 NMRA RECOMMENDED PRACTICES RP-5 ELECTRIC TRACTION, GENERAL
2.2.3 NMRA RECOMMENDED PRACTICES RP-5.1 ELECTRIC TRACTION, TROLLEY WIRE FROG
2.2.4 NMRA RECOMMENDED PRACTICES RP-9 RECOMMENDED ELECTRICAL PRACTICES
2.2.5 NMRA TECHNICAL NOTES (TN) AND TECHNICAL INFORMATON (TI)
2.2.5.1 TN-9 NMRA Tech Note, Wiring for DC & DCC
2.2.5.2 TN-9.1.1 NMRA DCC Decoder Test User Manual
2.2.5.3 TN-9.1.2 Sender Board Theory of Operation
2.2.5.4 TN-9.1.3 Sender V3 Getting Started Guide
2.2.5.5 TN-9.1.1.3 21 MTC Decoder Interface
2.2.5.6 TN-9.1.1.4 PluX Decoder Interface
2.2.5.7 TN-9.1.1.5 Next 18 and Next 18S Decoder Interface
2.2.5.8 TN-9.1.2 Power Station Interface
2.2.5.9 TN-9.2.1.1 DCC Advanced Extended Packet Formats
2.2.5.10 TN-9.7.0.1 Layout Command Control (LCC) Glossary
2.2.5.11 TN-9.7.0.2 Layout Command Control (LCC) Common Information
2.2.5.12 TN-9.7.0.3 Layout Command Control (LCC) Unique Identifiers
2.2.5.13 TN-9.7.0.4 Layout Command Control (LCC) Event Identifiers
2.2.5.14 TN-9.7.1.1 Layout Command Control (LCC) Controller Area Network (CAN) Physical Layer
2.2.5.15 TN-9.7.2.1 Layout Command Control (LCC) Controller Area Network (CAN) Frame Transfer
2.2.5.16 TN-9.7.3 Layout Command Control (LCC) Message Network
2.2.5.17 TN-9.7.3.1 Layout Command Control (LCC) Event Transport
2.2.5.18 TN-9.7.3.2 Layout Command Control (LCC) Datagram Transport
2.2.5.19 TN-9.7.4.1 Layout Command Control (LCC) Configuration Description Information (CDI)
2.2.5.20 TN-9.7.4.2 Layout Command Control (LCC) Memory Configuration
2.2.5.21 TN-9.7.4.3 Layout Command Control (LCC) Simple Node Information
2.2.5.22 TN-9.7.4.4 Layout Command Control (LCC) Firmware Upgrade
2.2.5.23 TN-9.7.4.5 Layout Command Control (LCC) Broadcast Time
2.2.5.24 TI-9.1.1 Sources for Connectors for DCC Decoders
2.2.5.25 TI-9.2.3 Serial User Standard Interface for DCC

NOTE: NMRA STANDARD S-5 TRACTION POWER COLLECTION focuses on the relative physical location or position of scale equipment components for reliable operation with overhead wire or outside third rail applications.

3 Terminology

Term	Definition
Block Control	A system of insulated sections of track permitting independent control of one motive unit in each insulated section of track. Block Control allows model engineers to run their tracks.
Center Third Rail (or Center Stud)	Center Third Rail (or Center Stud) provides a means to conduct electricity between outside gauge rails to conduct electricity to powered equipment.
Command Control	A system permitting powered equipment in the same electrical section of track to be independently controlled. Command control enables model engineers to focus on running trains independently. Early command control systems first employed analog technologies including General Electric (GE) Automatic Simultaneous Train Control (ASTRAC), Keller Engineering OnBoard Sound and Engine Control, and Power Systems Inc. (PSI) Dynatrol. More recent systems use digital signal technology through-the-rails and by far the vast majority are based on NMRA DCC including Digitrax, North Coast Engineering (NCE), Model Rectifier Corporation (MRC) and more. Other successful digital systems including Marklin Digital, Ring Engineering and Hornby Zero 1 apply other digital methods. Recent digital decoders including SoundTraxx Blunami and Hornby HM7000 use over-the-air Bluetooth technology to supplement NMRA DCC architecture.

Term	Definition
Current	A flow of charged particles, such as electrons or ions, moving through an electrical conductor.
Interchange	Interchange, a chief objective of NMRA Standards, is the concept of common scale and gauge equipment having ability to operate on other common scale and gauge racks, modules or layouts created complying with NMRA standards.
Outside Third Rail	Outside third rail provides a ground level alternative outside gauge rails to center third rail means of conducting electrical power to powered equipment.
Overhead Wire or Catenary	Overhead wire provides a high level (above train) alternative to center third rail means of conducting electrical power to powered equipment. Overhead wire systems may be labelled "trolley" systems.
Powered Equipment or Rail Equipment	Motive power, locomotives, engines, and other models capable of self-propulsion on rails.
Three Rail Systems	Three Rail Systems in this context may include: center third rail, center studs, outside third rail, and overhead wire or catenary with the understanding that the third rail, wire, or stud provides one of two power conducting rails. Typically, in three rail systems the various third rail options listed above carry a positive electrical potential while outer gauge rails are both common electrical returns. Thus, three rail system trackage avoids electrical shorts encountered with reverse loops, wyes, and turntables when reversing the physical direction of powered equipment. However, three rail system equipment must be built or modified to avoid electrical shorts and ensure safe, reliable interchange on two rail layouts. Some equipment originally designed/manufactured for center third rail (or center studs) operation may not provide insulation between outer gauge rails.
Two Rail Systems	Two rail trackage and equipment closely approximate prototype equipment appearance. Electrically two rail systems conduct electrical energy by a positive potential on one rail and a negative potential on the second rail. When track turns back upon itself such as in reverse loops, wyes, and turntables; electrical shorts are encountered requiring complex electricity management (insulation, switches, etc.).
Voltage	Electrical potential or electromotive force

4 Requirements

4.1 POWER

A. Full throttle voltage available at rails or motor shall provide sufficient current for optimal operation in compliance with local safety standards at maximum anticipated load. (1) (2)

B. High frequency voltage superimposed upon the rails shall not interfere with the normal operation of powered equipment. (3)

C. Power may be supplied to equipment through one or more means to include the following: rails, center studs, overhead or catenary wires, center or outside third rail, or stored power such as batteries on board powered equipment and/or consisted non-powered equipment, and on-board solar energy conversion.

4.2 CONTROL

A. Direction control by polarity reversing shall be provided for direct current (DC) motors. Positive DC potential applied to the positive motor connection either directly or through a Digital Command Control (DCC) decoder, battery, or other electrical energy source shall produce forward motion. (4)

B. Alternatively, direction control by motor electrical field modification may be provided for alternating current (AC) motors.

C. Speed control shall be provided by means of voltage adjustment which may be achieved by devices external or internal to powered equipment.

4.3 POWERED EQUIPMENT

A. Equipment shall be responsive to direction and speed controls of 4.2. above.

B. Metallic couplers shall be insulated from the rails. (5)

4.4 NON-POWERED EQUIPMENT

A. Wheelsets shall be insulated to prevent undue conductance between rails. (6)

B. Metallic couplers shall be insulated from the rails.

4.5 COMMAND CONTROL SYSTEMS

A. Certain command control systems: may not conform to NMRA DCC Standards intended to meet interchange requirements. Interchange may be facilitated by doing either or both of the following:

1. Power and control means shall include a method of fully conforming to 4.1 and 4.2 above.

2. Powered equipment shall include means of fully conforming to 4.3. above.

NOTES:

(1) Commercial equipment suppliers are responsible to comply with national, regional, and local policies, regulations, and laws governing electrical equipment.

(2) Generally, HO scale motors operate safely at 12 to 14 volts maximum. Other scales may operate safely at higher or lower voltages using either direct current (DC) or alternating current (AC). Digital Command Control (DCC) equipment operates safely between 7 and 27 volts in accordance with power parameters defined for various scales in Table 2.3 of NMRA STANDARD S-9.1 Electrical Standards for Digital Command Control.

(3) When using a power source delivering a wave with greater harmonic content than full wave rectified sine wave, exercise care not to operate in such a manner to exceed the rated current or otherwise overheat the motor.

(4) Direct Current powered equipment uses the “right hand rail” to provide positive potential to motors or decoders. Therefore, the “left hand rail” provides a return negative potential function. The term "right hand rail" as used herein means the rail to the right of the observer standing between the rails with their back to the front of the locomotive. When the “right hand rail” is positive, the powered equipment should move forward. Typically, AC powered equipment uses a “center third rail (or stud)” to provide positive potential to motors or decoders and outside rails provide a current return function.

(5). Locomotives may use uninsulated front couplers with due care not to couple two such locomotives head-to-head.

(6) Where a resistance path for lighting, detection, signaling or other purposes is required, such resistance shall not cause significant drop in propulsion power.

5 Document History

Date	Description
August 1984	Previous Revision of NMRA STANDARDS S-9 ELECTRICAL
March 15, 2024	Revision of NMRA Standard S-9 ELECTRICAL, DRAFT

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