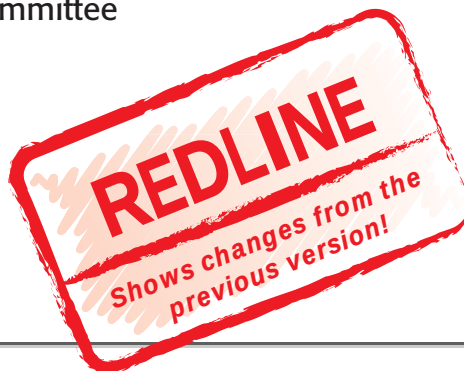


IEEE Standard for the Functioning of Interfaces Among Propulsion, Friction Brake, and Train-Borne Master Control on Rail Rapid Transit Vehicles

IEEE Vehicular Technology Society

Sponsored by the
Rail Transportation Standards Committee



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IEEE Std 1475™-2012
(Revision of
IEEE Std 1475-1999)

4 March 2013

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Sponsor

Rail Transportation Standards Committee
of the
IEEE Vehicular Technology Society

Approved 5 December 2012

IEEE-SA Standards Board

Abstract: The interfaces between and among functional systems on rail rapid transit vehicles are prescribed. The systems themselves are treated as “black boxes”; requirements for the input signals and the output response are given. For each category of interface, three types are listed in increasing technical sophistication.

Keywords: friction brake, IEEE 1475™, interfaces, master control, propulsion, rail vehicles, rapid transit

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PDF: ISBN 978-0-7381-8254-4 STD98156
Print: ISBN 978-0-7381-8255-1 STDPD98156

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Introduction

This introduction is not part of IEEE Std 1475-2012, IEEE Standard for the Functioning of Interfaces Among Propulsion, Friction Brake, and Train-Borne Master Control on Rail Rapid Transit Vehicles.

This introduction provides background on the rationale used to develop this standard, which may aid in the understanding, usage, and applicability of this standard.

Rail transit vehicles have been notable for their lack of standardization. Some real-life factors have contributed to this, primarily because of historic differences in the civil infrastructure and electrical power supply. This standard sets forth a framework for the interfaces among the propulsion system, friction brake system, and master control, but does not attempt to standardize the individual systems themselves and does not dictate that all vehicles must use the most advanced technology available.

This standard applies to rail transit vehicles, which are usually, but not exclusively, electrically powered. These vehicles include railway electric multiple unit (EMU) cars, Heavy rail vehicles (HRVs) (subway or elevated cars), Light rail vehicles (LRVs) (streetcars), including units that combine powered and unpowered trucks or axles. All of these vehicles can be operated under the control of a driver or varying levels of complexity of train control computer, which are lumped together for this purpose as vehicle on-board (master) control (VOBC). In general, the type of train operation does not normally affect the propulsion/brake interface, and this standard can be applied irrespective of the presence or absence of a human driver. Fully automated, driverless implementations of the above vehicle types are sometimes included in the mode of transit referred to as automated guideway transit (AGT) and, to the extent that the vehicle does not have other unique requirements, this standard can be applied. It is not intended that this standard be universally required for all AGT systems, and neither is it intended that this standard apply to locomotives hauling trains nor to locomotive-hauled (including “push-pull”) cars.

The classes of railway vehicles (such as those termed diesel multiple unit [DMU]), which use a diesel engine or other nonelectric prime mover, have features of the propulsion and braking systems used in these vehicles that are similar to those used in conventional electrically powered vehicles. To the extent that these systems are similar to those used in electrically powered vehicles, this standard can be applied.

This specification applies specifically to newly designed or newly modified systems. It is understood that for the necessity of backwards compatibility to older vehicles, which may employ what would be considered non-standard trainline systems, that the specific interface requirements of this standard do not strictly apply. It should be noted, however, that some of the concepts of redundancy and checking are still applicable.

NOTE 1—Self-propelled railway vehicles operating on common carrier railroad trackage are subject to regulations issued by governmental bodies (e.g., federal, state, and local bodies). In selected jurisdictions, this is also true for rail transit vehicles. The user should recognize that such regulations always take precedence over a consensus standard.

NOTE 2—Master control, as defined in 3.1 and utilized herein, is a term selected to apply broadly to any VOBC from manual control, as historically understood, to all forms of automatic train control (including, but not limited to, automatic train protection, automatic train stop, automatic train operation, and cab signals and all combinations thereof).

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IEEE Standard for the Functioning of **and** Interfaces Among Propulsion, Friction Brake, and Train-Borne Master Control on Rail Rapid Transit Vehicles

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1. Overview

~~This standard applies to new procurements or major rehabilitation of rail transit vehicles occurring on or after the effective date of this standard (18 March 1999). Existing rail transit vehicles and those vehicles that are currently being procured need not comply except where specifically required by the authority having jurisdiction. Where a need exists to maintain compatibility with existing rail transit vehicles, those portions of this standard in conflict with the compatibility requirement need not apply.~~

1.1 Scope

This standard specifies ~~prescribes~~ the interface functionality among propulsion, friction brake, and train-borne master control. The ~~It~~ standard encompasses performance parameters, communication methods and the means for measurement and verification of performance. "Third party" systems performing functions traditionally carried out in one of the above systems are also covered.

1.2 Purpose

IEEE Std 1475 contains specifications leading to standardization, compatibility and interchangeability of Numerous functional protocols ~~presently exist~~ for interfaces among train-borne master control, propulsion, friction brake, spin-slide control, etc., reducing ~~This has led to a lack of standardization, compatibility, and interchangeability, with attendant higher~~ first cost and recurrent integration problems. This standard, ~~when in~~ use by ~~vehicle purchasers~~, car-builders and system suppliers, has ~~are expected to~~ lowered costs, reduced vehicle introduction problems, improved reliability, and facilitated upgrades. It further helps prioritize ~~Standards will ensure of~~ safety functionality.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

~~This standard shall be used in conjunction with the following publications. If the following publications are superseded by an approved revision, the revision shall apply. In case of a conflict between this standard and the referenced document, this standard shall take precedence. Those provisions of the referenced documents that are not in conflict with this standard shall apply as referenced.~~

ASME RT-1, Safety Standard for Structural Requirements for Light Rail Vehicles.¹

¹ ASME ~~IEEE~~ publications are available from the American Society of Mechanical ~~Institute of Electrical and Electronics~~ Engineers 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (http://www.asme_standards.ieee.org/).

EN 50126, The specification and demonstration of reliability, availability, maintainability and safety.²

EN 50128, Railway applications. Communications, signaling and processing systems. Software for railway control and protection systems.

EN 50129, Railway applications. Communication, signaling and processing systems. Safety related electronic systems for signaling.

IEC 61508, Functional Safety of Electrical /Electronic/Programmable Electronic Safety-related Systems.³

IEEE Std 1473-~~1999~~TM, IEEE Standard for Communication Protocol Aboard Trains.^{4,5}

IEEE Std 1483TM, IEEE Standard for Verification of Vital Functions in Processor-Based Systems Used in Rail Transit Control.

~~IEEE Std 100-1996, The IEEE Dictionary of Electrical and Electronics Terms, Sixth Edition.~~

~~IEEE P1476/D4.0, 16 April 1999, Interfaces for Passenger Train Auxiliary Power Systems.²~~

² EN publications are available from <http://www.techsfreet.com/index.html>.

³ IEC publications are available from the International Electrotechnical Commission (<http://www.iec.ch/>). IEC publications are also available in the United States from the American National Standards Institute (<http://www.ansi.org/>).

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² ~~Numbers preceded by P are IEEE authorized standards projects that were not approved by the IEEE SA Standards Board at the time this publication went to press. For information about obtaining drafts, contact the IEEE.~~

~~IEEE P1478/D4.0, 7 April 1999, Environmental Standards for Rail Rapid Transit Electronic Equipment~~

~~IEEE P1482/D699, June 1999, Rail Vehicle Monitoring and Diagnostics Systems.~~

3. Definitions, acronyms, and abbreviations, ~~and acronyms~~

3.1 Definitions

For the purposes of this document ~~standard~~, the following terms and definitions apply. ~~IEEE Std 100-1996, The IEEE Standards Dictionary of Electrical and Electronics Terms, Online~~ should be ~~referenced~~ consulted for terms not defined in this clause. ⁶ ~~Because the rail transit industry possesses a significant amount of unique terminology, the Urban Public Transportation Glossary [B2]³ has been utilized as a source for many of the following definitions. Webster's New Collegiate Dictionary [B3] has been utilized as a general reference.~~

~~**3.1.1 actual weight:** The measured weight of a finished, ready to run vehicle; the tare weight.
Synonym: empty weight.~~

adhesion (coefficient of): During rolling contact, the ratio between the longitudinal tangential force at the wheel-rail/running surface interface and the normal force.

alertness function: A device or system that monitors the operator for signs of incapacitation, usually by requiring movement or response to take place within a prescribed period of time.

⁶ [IEEE Standards Dictionary Online subscription is available at:
http://www.ieee.org/portal/innovate/products/standard/standards_dictionary.html.](http://www.ieee.org/portal/innovate/products/standard/standards_dictionary.html)

³ ~~The numbers in brackets correspond to those in the bibliography in Annex A.~~

available adhesion: The maximum adhesion that can be utilized without causing wheel slip.

authority: A geographical or political division created specifically for the single purpose of providing transportation service.

authority having jurisdiction: The entity that defines the contractual (including specification) requirements for the procurement.

automated guideway transit: Any guided transit mode with fully automated operation (i.e., no crew on the train). The term usually refers, however, only to guided modes with small and medium-sized vehicles that operate on exclusive right-of-way.

automatic train control (ATC): The system for automatically controlling train movement, enforcing train safety, and directing train operations. ATC ~~must~~ includes automatic train protection (ATP) and may include automatic train operation (ATO) ~~and/or~~ automatic train supervision (ATS) or both.

automatic train operation (ATO): The subsystem within the automatic train control (ATC) system that performs any or all of the functions of speed regulation, programmed stopping, door control, performance level regulation or other functions otherwise assigned to the train operator.

automatic train protection (ATP): The subsystem within the automatic train control (ATC) system that maintains fail-safe protection against collisions, excessive speed, and other hazardous conditions through a combination of train detection, train separation, and interlocking.

automatic train stop: A wayside system that works in conjunction with equipment installed on the vehicle to apply the brakes at designated restrictions or on a dispatcher's signal, should the operator not respond properly.

automatic train supervision (ATS): The subsystem within the automatic train control (ATC) system that monitors trains, adjusts the performance of individual trains to maintain schedules, and provides data to adjust service to minimize the inconveniences otherwise caused by irregularities.

basic operating unit: (A) A single vehicle designed for independent operation. (B) A permanent or semipermanent combination, designed for independent operation, consisting of two or more vehicles of one or more types.

battery voltage: Voltage that is provided within specified limits by the low voltage power supply (or, in its absence, the control voltage on-board battery).

NOTE—[Low voltage power supply Battery](#) voltage limits are specified in IEEE [Std P 1476™ \[B2\]](#) [/D4.0.7](#)⁷
⁸

blending: The combination of two or more modes of braking (e.g., rheostatic electric brake, regenerative electric brake, and friction brake) to produce the desired total retarding effort.

[bogie:](#) *See:* [truck](#)

NOTE—[The term "bogie" is most commonly used outside North America.](#)

brakes [released](#) [applied](#): An indication that all friction brakes are [released to some agreed-upon level](#). *See:* [power interlock](#)

⁷ [Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.](#)

⁸ [The numbers in brackets correspond to those of the bibliography in Annex A.](#)

NOTE—Some systems also utilize a "brakes applied" signal, an indication that all friction brakes are applied to some agreed-upon ~~preset~~ level.

braking effort: Longitudinal retarding force generated by the friction brake system or the propulsion system (in electric brake).

builder: The entity manufacturing the product.

cab signal (system): A signal located in the cab, indicating a condition affecting the movement of a train and used in conjunction with interlocking signals and in conjunction with or in lieu of block signals.

car: *See: vehicle.*

car builder: The entity assembling or manufacturing the vehicle.

coast: The mode of operation of a vehicle or train in which both tractive effort from the propulsion system and braking effort from the propulsion and friction brake systems are zero.

NOTE—The inherent design characteristics of some propulsion systems require that a negligible level of electric brake be present in the coast mode.

cock: A pneumatic device having two positions, closed/shut and open/through.

consist: The makeup or composition (number and specific identity) of individual units of a train.

control voltage: Voltage that is provided for operating the controlled elements of the vehicle. *See also: battery voltage.*

NOTE—Control voltage may or may not be the same nominal potential as the battery voltage.

creep: [A condition in which the wheel is stably rotating slightly faster or slightly slower than pure rolling adhesion.](#)

crush loaded weight: The weight of a vehicle when loaded with crew, all seats occupied, and standees to a specified maximum number. [See: vehicle weights, AW3.](#)

cut out: The state of being disabled by the conscious use of a cutout device or function.

cutout: A device or function whose purpose is deliberately to disable a specified device or function, e.g., "dynamic brake cutout."

data recorder: The device used to record any type of data.

data recording: The act of recording any type of data; [also, the record produced by the data recorder.](#)

deadman: A pressure- or activity-actuated alertness device to detect inattention or disability of a train operator.

NOTE—A deadman can be contained within the master controller main handle grip, obtained by a separate foot switch, or obtained through an alertness type function. The device, when not properly maintained in an operational condition, will result in an emergency or full service brake application.

derail detector: A device so arranged as to detect a derailment condition.

doors closed and locked: The condition reached, ~~A state~~ as given by trainline signal indication, ~~in which doors are fully closed and locked~~ in the door-closing cycle when the drive has achieved a latching condition that will hold doors closed mechanically until a door-opening cycle is initiated.

doors open: A state, as given by trainline signal indication, in which doors are not fully closed and locked.

electric brake: A mode of operation of the propulsion system in which retardation is provided.

NOTE—Although generally considered synonymous with dynamic brake, electric brake is a more global term, in that it includes the possibility of providing retardation by drawing power from the line or by other means not dependent on conversion of kinetic energy into retarding power, which is the key element of dynamic braking ([sometimes called "electro-dynamic braking"](#)).

electric coupler: A device used to allow trainline signals to be transmitted from vehicle to vehicle or unit to unit in a train, with the connection of trainlines performed automatically when vehicles are coupled.

emergency brake: Fail-safe braking, [usually](#) open-loop, to a complete stop ~~with an assured maximum stopping distance, considering all relevant factors~~. Once the brake application is initiated, it is irretrievable, i.e., it cannot be released until the train has stopped or a predetermined time has passed.

empty weight: See: [vehicle](#) ~~actual~~ weight [AWO](#). *Synonym:* [tare weight](#)

event recorder: An on-board [data recording](#) device/system with crashworthy memory that records data to support accident/incident analysis.

fade: (A) The condition occurring during a braking cycle at low speed wherein the fundamental characteristics of the propulsion system utilized do not support the power requirement of the level of dynamic electric brake called for. Consequently, the level of dynamic electric brake actually generated decreases as a function of speed along an inherent characteristic. (B) In electric braking systems capable of supporting the level called for to zero speed, a deliberately created characteristic wherein the level of electric brake decreases as a function of speed to allow a smooth transition to friction brake for the purpose of the final stop.

fail-safe: A design philosophy applied to safety-critical systems ~~such~~ that the result of a hardware failure or the effect of software error ~~shall~~ either prohibits the system from assuming or maintaining an unsafe state or ~~shall~~ cause the system to assume a state known to be safe.

forward: The direction of motion of the train corresponding to the direction of vision of an operator or attendant when occupying his or her normal position in a normal orientation.

NOTE—For an unattended vehicle or a vehicle having operating positions at both ends, forward may be defined by (A) a defined orientation of the vehicle (e.g. movement away from the end of the vehicle where the hand brake is mounted), or (B) the prevailing direction of operation on the guideway segment being utilized.

friction brake: The system of pneumatic, electro-pneumatic, hydraulic, electro-hydraulic, or electric valves, controls, actuators and associated components which, in combination, provide the capability of braking the vehicle to a stop purely by the action of friction devices upon the wheel tread, disc rotors, or other surfaces.

full field: In a dc propulsion system, the motor connection in which, for series motors, the exciting field current is the same as the armature current, or, for separately excited motors, the exciting field current is at its maximum value relative to the armature current.

heavy rail transit: A mode of rail rapid transit generally characterized by fully grade-separated construction, operation on exclusive rights-of-way, and station platforms at the floor level of the vehicles.

heavy rail vehicle: A vehicle operating on a heavy rail transit system. Typically, electrically propelled, bidirectional, capable of operating in multiple unit, and designed for rapid, high-level boarding and discharging of passengers.

legacy systems: Non-standard trainline systems, to which the specific interface requirements of this standard do not strictly apply, which are utilized in order to maintain compatibility with existing vehicles.

light rail transit: A mode of rail transit characterized by its ability to operate on exclusive rights-of-way, street running, center reservation running, and grade crossings, and its ability to board and discharge passengers at track or vehicle floor level.

light rail vehicle: A vehicle that operates on a light rail transit system, capable of boarding and discharging passengers at track or vehicle floor level.

load weighing: A function incorporated in the propulsion or friction brake system that measures changes in sprung vehicle weight. Its purpose is to permit control of tractive effort proportional to passenger loading ~~in order to achieve a constant effort to weight ratio~~ for a given master control command.

master control: The train-borne device or system directly providing the control signals to the train; broadly applied to any vehicle on-board control (VOBC) from manual control, as historically understood, to all forms of automatic train control (including, but not limited to, automatic train protection, automatic train stop, automatic train operation, and cab signals and all combinations thereof). This definition is understood also to include those miscellaneous controls available within the operator's cab, not otherwise addressed in this standard.

master controller: A physical device utilized by a human operator to provide the master control of a train.

multiple unit: A system of simultaneous control of all vehicles in a consist from one master control by ~~through the~~ means of tramlines.

no motion: A safety-critical function utilized to indicate that the train is at zero speed or sufficiently close to zero speed ([as specified by the authority having jurisdiction](#)).

[NOTE—Typically](#) used to inhibit the ability of the doors to open when the train is moving and can be used for functions, such as emergency brake reset, that may require an indication of the no motion condition.

panic brake: Using any available form of braking, whether or not fail-safe, to obtain the shortest possible stopping distance.

parallel: In a [dc](#) propulsion system, the motor circuit in which the final parallel or series-parallel motor connection is achieved and the maximum available per-motor voltage is applied.

parking brake: A means that supplies static braking forces to maintain a vehicle or train [at standstill](#) ~~in a no motion state~~.

penalty brake: A function of the automatic train protection portion of the master control system, accomplished by a safety critical, full-service, or emergency brake application.

NOTE—Although most commonly associated with an overspeed operating condition, penalty braking may be initiated for a variety of reasons, depending on the vehicle design and the requirements of the authority having jurisdiction.

pneumatic brake pipe: A pressurized air line, continuous over the length of the train, used variously to indicate train integrity, provide indication of a emergency condition, equalize reservoir pressures, or propagate a brake application signal.

power [interlock](#) ~~knock-out~~: A function derived from friction brakes being applied above a [defined](#) low ~~preset~~ level on any truck that removes propulsion power on every vehicle in the train. [See: brakes released](#)

propulsion system: The system of motors, drive mechanisms, controls, and other devices that propels or retards a vehicle.

purchaser: An entity that contractually acts as the customer.

redundancy: The existence in a system of more than one means of accomplishing a given function.

regenerative brake: A form of dynamic brake in which the electrical energy generated by braking is returned to the power supply line, provided to on-board loads, or a combination thereof during the braking cycle instead of being dissipated in resistors.

reliability: The probability that a system will perform its intended functions without failure, within design parameters, under specific operating conditions, and for a specific period of time.

NOTE—The ambient environmental conditions for operation are specified by the authority having jurisdiction, or, in the absence of such specifications, are specified by IEEE Std P1478™/D4.0.

reverse: The direction of operation that is opposite to forward.

reverser: (A) The portion of ~~a the~~ master controller used to change the commanded direction of train movement. (B) The function within master control that performs as described in (A). (C) A circuit device used to change dc motor connections in order to change the direction of motor rotation and thus train movement.

rheostatic brake: A form of dynamic brake in which the electrical energy generated by braking is dissipated as heat in on-board resistors during the braking cycle.

safety critical: A term applied to a system or function, the correct performance of which is critical to safety ~~to or~~ personnel ~~and/or~~ equipment or both; also a term applied to a system or function, the incorrect performance of which may result in an unacceptable risk of a hazard. *See also:* **fail-safe**.

NOTE—A safety critical designation may require the incorporation of additional special safety design features.

sanding: Dropping or blowing of sand or similar material on the top of the rail head to increase the coefficient of friction to obtain better adhesion.

series: In a propulsion system, the dc motor connection in which all motors are connected in a series circuit for the purpose of applying to them some fraction (usually one-half) of the maximum available per- motor ~~premotor~~ voltage.

service: The operation of the vehicles under normal conditions with or without revenue passengers.

service braking ~~(maximum):~~ Variable, A nonemergency braking ~~application that obtains the (maximum) brake rate that is consistent with the design of the brake system, retrievable~~ under normal operating conditions, as commanded by ~~the of~~ master control.

~~3.1.73 service braking: See: service brake (maximum).~~

snow brake: A constant application of light friction brake intended to create enough heat to mitigate the buildup of snow and ice, which would interfere with the brake actuators.

straight air brake: An arrangement of brakes whereby air is admitted from the main reservoir through a brake valve to the straight air pipe to the brake cylinders in the operating unit.

NOTE—In most rail transit vehicle applications, an electro-pneumatic overlay is utilized to assist in the straight air brake command transmission

straight air pipe: A method of transmitting a pneumatic command from the active cab to the straight air brake equipment on each vehicle in the operating unit.

supplier: The entity that contractually acts as the source of a product.

NOTE—The supplier may or may not be the actual builder.

switch (position): In a propulsion system, the historic name for the lowest level of positive tractive effort and power; so called because it is typically utilized for slow-speed switching movements, such as yard moves, train makeup, etc.

system integrator: The person or commercial organization responsible for the definition and management of the functional requirements and interfaces between systems to achieve functionality at the train system level.

tare weight: Synonym: empty weight; See: vehicle weights, AWO.

track brake: A magnetic friction brake that compresses against the running rail and is activated by an electrical signal.

traction system: *See: propulsion system.*

tractive effort: The force generated at the wheel-rail interface as a result of the action of the propulsion system. It will ~~may~~ be either positive during ~~indicating~~ motoring/powering or negative during ~~indicating~~ brake.

train: A consist of one or more basic operating units.

trainline(s): Wires or cables routed through ~~and/or~~ between vehicles or units or both by means of couplers, jumpers, or other means (including, if applicable, wireless) so that power or signals may be transmitted to all vehicles of the train.

transport time: In a controlling network, the time from when data enters into the network at the source to the time the data exits from the network at the destination.

trip switch/cock: A device mounted on the truck of a vehicle, responding to a raised arm on the wayside, used to cause an emergency brake application if a train attempts to pass a mandatory stop signal.

truck: A rail vehicle component that consists of a frame—normally two axles, brakes, suspension, and other parts—and supports the vehicle body and can swivel under it on curves. If powered, it may also contain traction motors and associated drive mechanisms. *Synonym (outside North America): bogie*

unit: *See:* **basic operating unit.**

vehicle: A land conveyance assembly for carrying or transporting people or objects, capable of traversing a guideway, having structural integrity and general mechanical completeness, but not necessarily designed for independent operation.

vehicle weights: Vehicle weights are defined in accordance with ASME RT-1-2009, as follows, except that the weight of each crew member and passenger as used in the calculation of the vehicle loads is to be 79.4kg (175 lb):

(A) **AWO weight (mass): empty load:** The weight of the vehicle ready to run with all mounted components, including full operating reserves of lubricants, windshield fluid, etc., but without any crew or passenger load. *Synonym: empty weight, tare weight*

(B) **AW1 weight (mass): fully seated load:** AWO plus the crew and fully seated passenger load.

(C) AW2 weight (mass): system load: AW1 plus four (4) passengers/m² in standing areas.

(D) AW3 weight (mass) crush load: AW1 plus six (6) passengers/m² in standing areas.

Synonym: crush loaded weight

(E) AW4 weight (mass) structural load: AW1 plus eight (8) passengers/m² in standing areas.

NOTE 1—Definitions reprinted from ASME RT-1-2009, by permission of The American Society of Mechanical Engineers. All rights reserved.

NOTE 2—An alternative passenger weight based upon specific service conditions, such as service to the airports and use of luggage racks, maybe specified by the authority having jurisdiction.

weak field: In a dc propulsion system, an operating mode or a motor connection in which the exciting field current is less than the full field value.

wheel diameter compensation: A function that corrects for either the wear of the wheel(s) or the difference(s) in rolling diameter between different wheels on the vehicle or both.

wheel slide: During braking, the condition existing when the rotational speed of the wheel is slower than that for pure rolling contact between tread and rail/running surface.⁹

wheel slip: The condition existing when the rotational speed of the wheel does not correspond with pure rolling contact between tread and rail/running surface.¹⁰ See also: wheel spin.

⁹ For convenience and simplicity, the definitions of wheel slide, wheel slip, and wheel spin ignore the presence of the microslip phenomenon generally called “creep,” physically necessary to generate longitudinal force at the wheel-rail interface.

¹⁰ See footnote 4 Z.

wheel spin: During acceleration, the condition existing when the rotational speed of the wheel is faster than that for pure rolling contact between tread and rail/running surface.¹¹

[NOTE—The term "wheel slip" is often used for this condition.](#)

3.2 Acronyms and abbreviations

AGT	automated guideway transit
ATC	automatic train control
ATO	automatic train operation
ATP	automatic train protection
ATS	automatic train stop; automatic train supervision
DMU	diesel multiple unit
EMU	electric multiple unit
HRV	heavy rail vehicle
LCD	liquid crystal display
LED	light emitting diode

¹¹ See footnote 4Z.

LRV	light rail vehicle
PWM	pulse width modulation
TRB	Transportation Research Board
VOBC	vehicle on-board (master) control

4. Type ~~Complexity~~ of interface

This clause defines the basic different types of individual signal interfaces, which when combined with other signals form the interface between two subsystems.

For each of the interfaces specified in Clause 5, standards are established using the ~~for up to~~ three signal interface types defined in the following sections of this clause. ~~levels of complexity~~ In using this standard, the authority having jurisdiction shall specify the type ~~a level of~~ ~~complexity for~~ each interface, consistent with the design requirements of the vehicle.

An example of a simplified block diagram for a consist of vehicles comprising Type I, Type II, and Type III interfaces is given in Annex B, Figure B.1, Figure B.2, and Figure B.3, respectively.

NOTE 1—The requirements for some interfaces, as defined in this standard, may preclude the use of some interface types. In those instances, this standard will specify the type of interface to be used (e.g., "Same as Type I interface").

NOTE 2—Similar to the discussion in 4.3, the authority having jurisdiction may wish as well to consider redundancy and "get home" capabilities needed to help confirm service reliability in conjunction with Type I and Type II systems.

4.1 Type I interfaces

A Type I interface, in the context of this standard, has the following characteristics:

- a) Interface signals are ~~primarily~~ of the discrete “off-on” form.
- b) Except where the nature of the interface requires otherwise (e.g., brake pipe for emergency brake), the signals are transmitted at the voltage level of the control battery system or from a power supply derived there from.
- c) Signal flow across a given interface is one-way.
- d) Depending upon the requirements of specific functions, the signal may be either “on” or “off” to signify the permissible or acceptable states.
- ~~d) Fault annunciation is limited to simple indicating lights or similar means.~~
- ~~e) No data recording or fault logging is provided, except as may be required by regulation.~~

An example of a simplified block diagram for a consist of vehicles comprising Type I interfaces is given in Figure B.1.

4.2 Type II interfaces

A Type II interface, in the context of this standard, has the following characteristics:

- a) Interface signals are ~~a mix of digital and~~ analog/or proportional signals, usually at the vehicle battery voltage or from a power supply derived there from.

- b) Signal flow across a given interface remains one way.
- c) Depending upon the requirements of specific functions, there may be specific minimum requirements on the signal value to signify permissive or acceptable states
- e) ~~Fault annunciation is still limited to indicating lights or similar means, but more indications, both local and trainlined, may be provided.~~
- d) ~~Data recording or fault logging, if provided, is done at one system level, either at the vehicle level or at the functional system level. Both levels may be provided, but there is no exchange of information between the levels.~~

An example of a simplified block diagram for a consist of vehicles comprising Type II interfaces is given in Figure B.2.

4.3 Type III interfaces

A Type III interface, in the context of this standard, has the following characteristics:

- a) Most interface functions extensively use serial communication links, data buses, or networks.
- b) Signal flow and communication across interfaces may be ~~are~~ two-way.
- c) Comprehensive system, vehicle, and train information on displays ~~are~~ is available to the operator in addition to performing the control functions necessary.

d) Depending upon the requirements of the functions being implemented, in addition to the transmission requirements of the interface, the transmitted data may require checks be made for verifying the integrity of the data.

~~d) Integrated data recording and fault logging is provided, in which information is shared among system levels, including train level, vehicle level, and functional system level.~~

A Type III network will interface many systems and subsystems. It is not the intent for this standard to specify onboard transit networks. That is done in IEEE Std 1473. It is expected that the system integrator will specify the network operating parameters for the suppliers of equipment. Consideration shall be made for allowing the train to operate in a limited manner when there is a complete network failure in order to remove the train from the system. As a consequence, the system integrator shall be responsible for specifying the overall system response and the individual network response to degraded mode and fallbacks for degradation of the network(s). Two examples of means of handling failures of the network(s) are with redundancy and bypass. The redundancy method shall be clearly defined and in sufficient detail for the suppliers to build it. The system integrator shall determine which core systems are to have signal bypass routing in the event of complete network failure. The means for bypass signal routing shall take into account that the network is not available and the signals must propagate other than through the network.

When considering the implementation of a Type III interface for train control, and the use/implementation of redundant or parallel networks in order to ensure system reliability, the system integrator shall be responsible for recognizing that each network may not at any instant in time be broadcasting exactly the same information (due to errors and tolerances between redundant sources, differences caused by asynchronous sampling, etc.) and, therefore shall ensure:

— that all systems, under normal operating conditions, are operating from the same network

- that the system responses are well enough defined to ensure that data disagreements from asynchronous sampling do not cause incorrect operation when, due to fault conditions, not all equipment is operating from the same network
- there is a means to regularly switch between networks to validate the consistency of the data
- there is a means to annunciate when a network failure is present, so that the necessary maintenance actions can be taken to restore the redundancy

The system integrator shall reference existing network standards (e.g., IEEE Std 1473) applicable to onboard transit network systems and known existing network degraded mode(s) and network fallbacks. The information the system integrator provides for its onboard networks(s) shall be complete enough for the suppliers to connect into the network and operate meeting the requirements set forward for operability, efficiency and compatibility. It is recognized that an additional specialty network may be added later if needed by an equipment supplier and authorized by the system integrator. This is the minimum list of items to be covered by the system integrator, but it is not all inclusive:

- bandwidth
- arrangement of data in the packets
- addressing
- timing
- steps to take when equipment fails
- network communication protocol

- [network\(s\) architecture](#)
- [redundancy details if applicable](#)
- [listing of different networks and their associated nodes](#)

An example of a simplified block diagram for a consist of vehicles comprising Type I, ~~Type II, and Type III~~ interfaces is given in ~~Annex B, Figure B.1, Figure B.2 and Figure B.3, respectively.~~

5. Functional interfaces

[5.1 Safety-critical interfaces](#)

[Certain of the interfaces listed herein are identified as having “safety critical requirements” such that the systems or hardware or both shall have safety characteristics that have been verified and validated in a safety program approved by the authority having jurisdiction, meeting one or more of the following standards, as applicable to the type of interface utilized:](#)

- [IEEE Std 1483, IEEE Standard for Verification of Vital Functions in Processor-Based Systems Used in Rail Transit Control.](#)
- [The set of EN 50126, The specification and demonstration of reliability, availability, maintainability and safety; EN 50128, Railway applications. Communications, signaling and processing systems. Software for railway control and protection systems; and EN 50129, Railway applications. Communication, signaling and processing systems. Safety related electronic systems for signaling.](#)
- [IEC 61508, Functional Safety of Electrical/Electronic/Programmable Electronic Safety-related Systems](#)

The system integrator shall ensure that the interfaces between all of the subsystems addressed herein have successfully undergone the analysis and validation required in the approved safety program. The authority having jurisdiction shall ensure that the results of these analyses and validations are documented and available before final approval is given to the design of the interfaces.

CAUTION

Although this Standard contains references to safety functions and recommended analysis tools to analyze design safety, the criteria for acceptable design of interfaces for the purpose of safety of rail transit vehicles are outside the scope of this standard, and are the responsibility of the authority having jurisdiction and the system integrator.

5.2 Emergency brake

5.2.1 Interfaces

The emergency brake interface shall be Type I or Type III; to meet the safety critical requirements, the interfaces for the emergency brake shall be one ~~Type I. The emergency brake interface shall be~~ chosen from the following:

- a) Type I systems – Trainlined pneumatic brake pipe
- b) Type I systems – Trainlined pneumatic brake pipe with one digital battery trainline overlay (one or two wire, single or double break)
- c) Type I systems – Four digital battery voltage trainlines; loop configuration with origin and destination being the same device. Two of the wires shall be connected to battery positive voltage and two shall be connected to battery negative voltage.

~~2 wires—battery positive~~

~~2 wires—battery negative~~

NOTE—If the four-wire method is used, the voltage drop over wire length should ~~must~~ be considered. The purchaser may select combinations of these methods.

- d) Type III systems – Digital message, originated by, transmitted over, and received by a set of safety-critical devices whose safety characteristics have been verified and validated in a safety program approved by the authority having jurisdiction. 13

NOTE—This should not be interpreted to preclude the redundant provision of a Type I means to initiate emergency brake in addition to the Type III means.

CAUTION

Emergency brake conditions should, in all cases, lead to application of full friction brake command and override of any default command settings due to the loss or failure of train command interface (e.g., loss of Type III network).

5.2.2 Signal origin(s)

Any of the following systems or components, as utilized, shall be capable of initiating an emergency brake application as specified by the authority having jurisdiction:

- Master control
- Brake pipe and brake pipe control details

- Coupler equipment
- Derail detector
- Main reservoir or accumulator pressure, as applicable
- Passenger/crew emergency function
- Trip cock/trip switch
- Truck excess swivel
- Logic functions within the propulsion or friction braking systems

NOTE—Initiation by one or more of the above means should be understood to include the possibility that the initiation is as a result of the functioning of a safety system or design (train “break in two” protection, multiple cabs activated, etc.)

5.2.3 Signal destination(s)

The following systems shall receive an emergency brake signal:

- Master control
- Friction brake system
- Propulsion system
- Spin-slide system (if a separate functional system)