IEEE Standard for Rail Transit Vehicle Event Recorders

Sponsor

Rail Transit Vehicle Interface Standards Committee
of the
IEEE Vehicular Technology Society

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Abstract: On-board devices/systems, with crashworthy memory, that record data to support accident/incident analysis for rail transit vehicles, are covered. The requirements of this standard are limited to event recorder functions and interfaces. Data transmission methods are excluded. The information in this standard is independent of the hardware and/or software employed for other vehicle systems.
Keywords: crashworthiness, input signal, rail transit vehicle event recorder, rail vehicles, rapid transit, self-test

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Introduction

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Event recorders (called flight recorders) have been standard equipment on commercial airliners for many years. Recently, the Federal Railroad Administration (FRA) has required them for specific railroad applications, as described in 49 CFR Part 229 [B1].[a] Other modes of public transportation, including rapid rail transit not regulated by the FRA, have recently begun to consider technical requirements for event recorders applicable to those modes. Because there are similarities between the rail modes under FRA jurisdiction and those that are not, a natural starting point for technical requirements is 49 CFR Part 229 [B1].

As subsystems incorporate advanced processing capabilities and are linked together, and as processing capability is added to car and train monitoring and diagnostics systems (MDSs), an increasing number of the signals required by the FRA will become available in a central location. In fact, typical MDS functionality meets and exceeds the formal definition of an event recorder. However, an MDS usually does not meet all requirements and implications of the FRA rule, particularly the physically and electrically secure retention of the most recent 48 hours of operating data.

It is intended that data collected by event recorders meeting this standard be used to help reduce the potential probability of future accidents in cases where equipment design, maintenance practices, training, or procedures can be modified based on such data.

A rail transit event recorder ideally captures signals that could help an accident investigator determine the following:

— The status of the car at the time of, during, and preceding the accident;

— The status of the intelligent systems at the time of, during, and preceding the accident;

— The status of human (crew) controls and indicators at the time of, during, and preceding the accident.

The preceding statuses determine the sources of signals. An example might be brake status:

a) The actual status of the brakes could be determined by brake pipe pressure, brake cylinder pressure, and brake apply relay status.

b) The intelligent system output for the brake status could be obtained from a network, car controller, or propulsion and brake controllers.

c) The crew information could be obtained from the master controller position, and indicator lights or gauges in the cab.

It is not the intent of this standard to preclude the requirements of an event recorder system being satisfied by a combination of on-board and wayside equipment. Neither is it the intent to define the circumstances under which event recorders must be purchased or installed (e.g., new rolling stock, major or minor overhauls, upgrades, or remanufacture of existing rolling stock)—only the requirements to be met are given, if the event recorders are purchased or designed to this standard.

[a]The numbers in brackets correspond to those of the bibliography in Annex A.

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IEEE Standard for Rail Transit Vehicle Event Recorders

1. Overview

1.1 Scope

This standard covers on-board devices/systems, with crashworthy memory, that record data to support accident/incident analysis for rail transit vehicles. The requirements of this standard are limited to event recorder functions and interfaces, exclude the data transmission method(s), and are independent of the hardware and/or software employed for other vehicle systems. Functions, parameters, signals, systems, and subsystems that shall be captured are identified. Diagnostic features or self-test options are described.

1.2 Purpose

There is currently no defined, independent standard defining event recorders for rail transit vehicles. Each order of new rail transit vehicles or overhaul of old rail transit vehicles requires engineering effort by all parties to determine which signals to capture, how often to sample, and how long to preserve the information, requiring a learning curve for every project. Users of this standard include those who specify, purchase, design, and build rail transit vehicles and their subsystems. They should benefit from a simplified process of integrating diagnostic information from multiple subsystem suppliers.

2. References

This standard shall be used in conjunction with the following publications. 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.

IEEE Std 100-1996, IEEE Standard Dictionary of Electrical and Electronics Terms.[1]

IEEE Std 1473-1999, IEEE Standard for Communications Protocol Aboard Trains.

IEEE P1482/D699, June 1999, Draft Standard for Rail Vehicle Monitoring and Diagnostic Systems.[2]

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[1]IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (http://www.standards.ieee.org/).

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3. Definitions, abbreviations, and acronyms

3.1 Definitions

For the purposes of this standard, the following terms and definitions apply. IEEE Std 100-1996 should be referenced for terms not defined in this clause.

3.1.1 event recorder: On-board device/system with crashworthy, nonvolatile memory, which records data to support accident/incident analysis.

3.1.2 galvanic isolation: A method of electrical isolation where neither the signal nor the common of the output of the isolator is dc coupled to the signal or common of the input of the isolator, except for low-level leakage associated with nonideal components.

3.1.3 health: Summary information regarding the current ability of a system or subsystem to perform its intended function.

3.1.4 sampling rate: The frequency with which the event recorder regularly monitors an input channel to determine its value.

3.1.5 storage rate: The frequency with which sampled signals are recorded in crashworthy nonvolatile memory. The event recorder may store any signal less often than it samples.

3.2 Abbreviations and acronyms

ACSES	advanced civil speed enforcement system
ATC	automatic train control
ATP	automatic train protection
ATS	automatic train speed
CBTC	communications-based train control
CFR	Code of Federal Regulations
FRA	Federal Railroad Administration
GPS	global positioning system
IEC	International Electrotechnical Commission
ITS	intelligent transportation systems
LED	light emitting diode
MDS	monitoring and diagnostic system

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4. Rail transit vehicle event recorders

This standard describes the requirements for rail transit event recorders. The function of a rail transit event recorder is to record and preserve data to be used in the investigation of an accident or incident, and to allow more effective determination of the cause(s).

There shall be at least one event recorder for each basic operating unit that gathers information from the operating cab of the basic operating unit.

The event recording may be implemented functionally as part of an IEEE P1482/D699[3] compliant monitoring and diagnostics system (MDS) or as a stand-alone system, as long as the requirements of this standard are met.

4.1 Inputs

Rail transit event recorders shall capture the signals listed in the second column of Table 1.

Signals shall be extracted from either the source of the signal or the system monitoring the source of the signal. Measured signals are preferred over calculated or derived signals. If signals are transmitted over networks, it shall be possible to determine from the record if and when a network failed. All records shall be date and time stamped.

Table 2 shows a list of potential additional signals for a rail transit event recorder. These signals are for consideration only and may be applied in addition to the signals described in Table 1.

For Table 1 and Table 2, the listed inputs apply only if the vehicle in question is equipped with the relevant system or component (e.g., track brakes do not always apply to rail transit equipment).

4.2 Sampling and storage rate(s)

The event recorder shall be capable of sampling signals at a maximum of 20 ms intervals (minimum 50 samples per second) to ensure that changes that affect operation are detected.

Signals shall be processed and stored to ensure that changes that affect operation are captured. Repetitive samples of identical information reflecting no state change may be stored at a lower storage rate than other signals. The storage rate depends on the individual rate of change under operating or failure conditions for each signal. Thresholds, ranges, and durations for defining state changes shall be determined for each signal. Signals shall be stored at least once per second.

To conserve memory, stored data more than 10 hours old may be reprocessed to eliminate data samples that reflect no change from consecutive samples to a minimum storage rate of one sample per 15 seconds.

Crashworthy nonvolatile memory shall preserve a minimum of 48 hours worth of data.

[3]Information on references can be found in Clause 2.

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Table 1—Required event recorder signals

Input #	Event recorder required signals	Corresponding Federal Railroad Administration (FRA) requirement (see Note)	Typical input
1	Time including date (YYYY:MM:DD:HH:MM:SS), correctable to a time standard	Time	Internal frequency
2	System/subsystem time(s) (any time(s) originated by systems generating required signals) [a]		Digital
3	Master controller braking commands, including emergency commands	Brake applications and operations (include train brake, independent brake)	Analog or digital
4	All other emergency or automatic brake application commands initiated in the cab		Analog or digital
5	Track brake activation signal		
6	Brake pipe pressure		Analog
7	Brake cylinder pressure (at least 1 cylinder)		Analog
8	Dynamic brakes enabled	If so equipped, dynamic brake applications and operations	Digital
9	Traction motor torque signal		Analog current or derived torque
10	Master controller propulsion commands, including coast	Throttle position	Analog or digital
11	Speed sensor input	Train speed	Frequency /coded
12	Other speed input (GPS, radar, etc.): at least 1 in addition to input 11		Analog or digital
13	Odometer	Distance [0.3048 m (1 ft) resolution]	Analog
14	Reverser position	Direction of motion	Digital
15	Direction of actual movement		Derived from several digital
16	Active cab (make-up relay)		Digital
17	Cab signal aspects	Cab signal aspects	Digital
18	Communication-based train control (CBTC) control signals		
19	Advanced civil speed enforcement system (ACSES) status		
20	Doors closed summary train line		
21	Doors locked summary training		

NOTE—The input signals described in the third column of Table 1 are quoted from the FRA regulations in 49 CFR Part 229 [B1]. At the time this standard was drafted, the Code of Federal Regulations (CFR) was in effect for some potential users of this standard. Therefore, the corresponding FRA signals were considered of interest to the organizations intending to use this standard. The second column of Table 1 lists actual signals that can meet the intent of the FRA requirements. The fourth column lists examples of signal types typical of those available on rail transit vehicles.

[a]Matching the signal states with each other shall coordinate time stamping. If more than one event recorder is available in a consist, their time stamps shall be synchronized with each other. If an MDS survives an accident or if the MDS has radio capability and data radioed immediately before the accident is available, those time stamps shall also be synchronized.

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Table 2—Potential additional event recorder signals

Input #	Potential additional signal description
A1	Handbrake/parking brake status
A2	Snow brake status
A3	Brake cutout status
A4	Non-cab emergency brake activation signal(s)
A5	Automatic train control (ATC) penalty brake activation signal
A6	Trip cock brake activation signal
A7	Deadman or alerter penalty brake activation signal
A8	Wheel spin/slide activation
A9	Brake assurance accelerometer
A10	Brake apply summary train line
A11	Brake release summary train line
A12	Horn activated
A13	Bell activated
A14	Headlights on
A15	Crossing lights (on-board)/strobes/marker lights/ditch lights on
A16	End of train device active
A17	Uncouple switch activated
A18	Door close command (train line/local)
A19	Door open command (train line/local)
A20	End door open
A21	Crew door open
A22	Zero speed detection
A23	Door bypass (allowing train movement) (train line)
A24	Door cutouts (per panel)
A25	Door override (prevents doors from opening) (train line)
A26	Cab signal/ATC/ATP/ATS cutout
A27	Car number (from car wiring)

4.3 Electrical

4.3.1 Event recorder self-test requirements

The event recorder system shall perform self-tests on power-up and periodically, as defined below, to determine whether or not it is functioning correctly. The self-test feature shall evaluate processor operation on a continuous basis and shall employ recorded signals from train operations as the basis for evaluation of the entire event recorder system. For this purpose, test routines shall identify event recorder faults through diagnostic analysis.

a) *Program storage memory.* For program storage that only changes when new software is loaded, the program shall verify, at least once every 24 hours, that the contents of the program memory have not changed since the software was loaded. This shall also be performed after loading updated software if embedded software can be altered without removing the chip.

b) *Data memory.* For crashworthy nonvolatile memory used to store data, each write shall be read and verified.

c) *Other memory.* All other memory shall be checked at system start-up and at least once every 24 hours in a way that is assured not to interfere with stored data.

d) *Clocks.* System clocks shall be continuously checked to ensure that they are operating.

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e) *Processor exceptions.* Processor exceptions shall be trapped so that processor errors and memory failures resulting in processor exceptions will be detected and appropriate actions taken to prevent processor crashes.

f) *Watch dog timers.* Watch dog timers shall be provided to detect and interrupt program control flow errors.

g) *Controlled shutdown.* The system shall monitor power supply input voltage. When the voltage is outside of the acceptable range for normal operation (per IEEE P1476/D4.0 [B14])[4], the system shall take appropriate actions such as suspending recording and fault logging and performing a controlled shutdown. The system shall identify shutdown periods to avoid misinterpretation of recorded data when the power supply voltage is outside the acceptable range.

4.3.2 Error logging

The following error logging shall apply to event recorders:

a) Each time a self test or functional check detects an error, the time stamp and an annotation indicating the error shall be entered into memory as a fault.

b) A fault light interface shall cause an event recorder health status indicator to change per 4.4 if a fault is detected.

c) An event recorder fault shall be indicated if none of the input channels has detected a change in state in the preceding 92 day period.

d) Removal or loss of the event recorder memory shall cause an event recorder fault indication.

4.3.3 Software

In cases where processing is performed, software design practices and documentation shall conform to the appropriate IEEE software standards selected from the bibliography.

4.3.4 Embedded batteries

The following shall apply to event recorder batteries:

a) *Battery life.* Batteries shall have a predicted life in excess of five years in the application in which they are installed.

b) *Battery test.* A method of battery test, which does not require disassembly of any kind, shall be provided.

c) *Low battery fault.* A low battery shall be annunciated as a fault event.

d) *Low battery indicator.* Impending battery failure shall cause a visible indication (see 4.4).

4.3.5 Sensor and input channel protection

The following requirements shall apply to signals that directly connect to the event recorder. For signals transmitted over data networks, the interface requirements shall be as specified in IEEE Std 1473-1999 and ST-ITS-TCIP-OB [B17]. Signal isolation shall ensure that the event recorder does not affect the systems it monitors under any operating or failure condition.

a) The input impedances for all channels shall be designed so that they do not influence the function, operations, and reliability of the circuit being monitored.

[4]The numbers in brackets correspond to those of the bibliography in Annex A.

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b) A failure of any component in the event recorder, including but not limited to the power supply, CPU, I/O components, and sensors, shall not affect the operation of any car system.

c) All input channels shall be isolated from each other (including signal returns) and from car body ground by at least 100 MΩ, with a voltage withstand capability of at least 1500 V dc. In addition, circuitry interfacing with measured signals shall be galvanically isolated from internal event recorder signal processing equipment (by opto-isolators, isolating amplifiers, etc.).

d) Power supply inputs, and any connected circuitry, shall be isolated from ground on both the positive and negative side of the low voltage supply by at least 100 MΩ, with a voltage withstand capability of at least 1000 V dc.

e) The event recorder shall be protected against reverse polarity input connections. All input channels (digital, analog, and frequency) connected to signals at battery voltage and above, and the power supply input circuits to the memory module shall be protected against damage or data loss from switching and other transients to ±4000 V peak with an energy content of 80 W-s. All other signals shall be protected from switching and other transients defined as permitted transients in IEC 60571:1998 [B2]. The entire event recorder system shall not be affected by other continuous or discontinuous electrical noise such as ripple and high-frequency hash.

f) The event recorder shall handle input signals up to 100 V. Input signals exceeding 100 V shall be conditioned to be less than 100 V prior to connection to event recorder input channels. The event recorder shall protect itself from inputs up to 150 V.

4.4 Outputs

A rail transit event recorder shall have the following minimum outputs:

a) Event recorder health status:
   1) A “go” or “OK” LED or other visual indication shall confirm that the recorder has passed the self-test. Faults detected during operation shall extinguish the indication.
   2) If the event recorder is not readily accessible or viewable within an equipment locker, the “go” or “OK” indication shall be displayed in the cab or on the exterior surface of the locker.
   3) If the event recorder is not physically part of the MDS, status shall be reported to the MDS, if present.

b) Data download:
   1) Portable test unit/laptop PC;
   2) PCMCIA [B16] memory flashcard or other portable medium; and/or
   3) Remote (by wireless and/or network).

Data download to an external storage medium such as flashcard/laptop computer shall be an image (exact copy) of the memory and shall not erase the data stored in the event recorder. The integrity of the image shall be verified.

4.5 Crashworthiness

The event recorder memory shall be capable of meeting the requirements in Table 3. The requirements may be met by the design of the data storage device(s), or by placing the device in a box meeting the requirement, or by judicious placement of the device within the car body envelope (e.g., to take advantage of the crashworthiness and fire-barrier properties of the car body), or by a combination of these approaches.

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Table 3—Crashworthiness requirements

Condition	Requirement
Fire	650 °C (1200 °F) for 30 minutes, followed by 300 °C (570 °F) for 60 minutes, followed by 100 °C (212 °F) for 5 hours.
Impact shock	55 g peak, 100 ms duration, 1/2 sine crash pulse, no less than 28 m/s velocity area under curve, separately in the direction of each of the three principal axes.
Penetration	23 kg (50 lb) weight with a protruding 6.4 mm (0.25 in) diameter steel pin dropped from a height of 1.5 m (5.0 ft).
Static crush	110 kN (25 000 lbf) for 5 minutes.
Fluid immersion	Immersion in any of the following individually for 48 hours: grade 1 and 2 diesel fuel, regular and salt water, and lubricating oil; and Immersion in fire-extinguishing fluids for 10 minutes, followed by 48 hours in a dry location without being otherwise disturbed.
Hydrostatic pressure	Immersion in salt water at a depth of 15 m (50 ft) for 2 days.

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Annex A

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[B1] CFR 49 Part 229, Transportation.[5]

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[B4] IEEE Std 828-1998, IEEE Standard for Software Configuration Management Plans.

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