

REQUIRED OPERATIONAL CAPABILITY FOR AXLE COUNTER SYSTEMS FOR THE USE IN PASSANGER RAIL AGENCY OF SOUTH AFRICA (PRASA)

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Updated by:	Andile Rasmeni		2019-07-18	
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1. BACKGROUND

The purpose of an axle counter system is to provide the interlocking with an indication of whether a train occupies a track section or not. This is done by accurately counting the train wheels in all sections under its control. The section occupancy information passes to the interlocking system to enable train operation. All functions, and operation of the axle counter system, must be done fail-safely. This means that the system should return to a safe state in the event of a fault occurring in the system. A "safe state" for the axle counter is to indicate all sections affected by the fault as being undefined/Disturbed/Not monitored.

The axle counter system normally consists of outdoor wheel detection units, communication links, and one or more indoor evaluation units. The wheel detection units should give an indication of passing axles, and the direction of travel, via a communication link to the evaluator unit. By using this information, the evaluator can keep count of the axles in each section.

2. MISSION

2.1. Operational Requirements

The impulses formed by the passage of a wheel as well as the counting shall be effected by electronic means. The section status (clear/occupied/Undefined) should be reported via serial fail safe data interface (FSDT – SIL4) compatible with the electronic interlocking system.

The axle counter system must have the following operational capabilities:

2.1.1. Wheel detector:

- 2.1.1.1 Ability to detect wheels in a fail-safe manner. - (SIL4 according to CENELEC EN50126 standard).
- 2.1.1.2 Ability to detect wheels of trains travelling at speeds of up to 200 km/hr.
- 2.1.1.3 Ability to detect wheels with the wheel surfaces 20 mm above the rail surface.
- 2.1.1.4 Ability to detect wheels with minimum flange dimensions – See Figure B1 in Appendix C.

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2.1.2. Evaluator:

2.1.3. Detection of axles:

- 2.1.3.1 It must be able to count axles of trains moving at speeds of up to 200 km/h over all of its wheel detectors simultaneously, with a minimum permissible track section length of 20 m.
- 2.1.3.2 The Axle Counter Evaluator shall send 3 section status information to the interlocking Module via a serial FSDT:
- a) Occupied
 - b) Unoccupied
 - c) Un-defined/Disturbed
- 2.1.3.3 The Axle Counter Evaluator shall be able to be interface to the External interlocking Module via parrallel input/output onboard in order to send 3 section status information :
- 2.1.3.4 Reset Restriction active or not inactive indication shall be reported to the interlocking Module and indicated to the HMI.
- 2.1.3.5 The In-count Inhibit Indication/Reset Restriction Indication – IIK – Red rectangular frame around Mnemonic of section:
- a) When the Reset Restriction on a section is active in the axle counter evaluator it is not communicated to the IM/MMI – Indication rectangular red frame around Mnemonic not displayed.
The Reset Restriction is active on a section when:
 - i) The last axle was counted into the section.
 - ii) When section in the “Disturbed State” because of one or more of the wheel-detectors associated with the section was/were faulty or the communication to one or more of the wheel-detectors associated with the section was lost and there has not been an outcount out of the section after the fault to wheel-detector/s has/have been repaired.
 - iii) The Section was put into the “Disturbed State” because of a fault and there has not been an outcount out of the section after the fault has been repaired.

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iv) When the Section was put into the “Disturbed State” after the shuttle tolerance was exceeded over one of the wheel-detectors associated with the section and there has not been an outcount out of the section after shuttle move exceeded limit.

2.1.3.6 Emergency Reset Restriction removal command performed by 2 Train Control Operators Password shall be implemented to remove Reset Restriction through the Interlocking Module via HMI.

2.1.3.7 Emergency Axle counter section reset command performed by 2 Train Control Operators Password shall be implemented to reset a section through the Interlocking Module via HMI.

2.1.4. Accounting for wheels entering or leaving a section

2.1.4.1 The accounting for wheels entering or leaving a section, and determining of section occupation, must be done fail-safely (SIL 4).

2.1.4.2 When the number of axles that have entered a section does not concur with the number of axles that have left it, the section must be indicated as being occupied, irrespective of whether the number that has entered or left is the most. If the number of axles that have left is most, i.e., section count being negative, then that particular section may not be cleared, unless a manual reset is performed, or if it can be proven fail-safely that the section is indeed void of any axles.

2.1.4.3 During shunting operations, it is possible that a wheel may leave a section directly after entering it. The system must be able to cope with these situations in a fail-safe and reliable manner without miscounting.

2.1.4.4 The axle counter shall not miscount during shuttling operations over the wheel detectors (see Appendix A for the description of 14 x shuttle moves).

- a) Axle counter systems must be configurable to allow or not allow shuttle moves per wheel-detector.
- b) Some can be configured per wheel-detector to allow or disallow shuttle moves and even allow towards the one and not the other of the two sections associated with a wheel-detector.
- c) When the overall shuttle moves results in a full axle count any shuttle occupancy flag, that may have been set during this or a previous shuttle move on this particular wheel-detector, is reset.
- d) When a normal count takes place over a wheel-detector on which a shuttle occupancy flag has been set by a previous shuttle move this

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flag is reset.

- e) When only one half of wheel-detector is influenced by a shuttle move the adjacent vacant section will become occupied while influenced but will become vacant again when not influenced. When this happens a second time a shuttle occupancy flag will be set that will keep the adjacent section occupied.
- f) When both halves of wheel-detector is influenced by a shuttle move the adjacent vacant section will become occupied while either influenced but will become vacant again when not influencing either. When this happens three consecutive times the adjacent section will become occupied while either influenced but will become vacant again when not influencing either. When this happen a fourth time a shuttle occupancy flag will be set that will keep the adjacent section occupied.
- g) When configured not to allow shuttling with any shuttle move a shuttle occupancy flag will be set that will keep the adjacent section occupied – a normal count will reset this shuttle occupancy flag.

- 2.1.4.5 In multi-section axle counters, at adjacent axle counter controlled sections, a wheel will leave one section and enter the next one simultaneously. The evaluator must be able to handle this situation without miscounting.
- 2.1.4.6 The maximum length of a section to be controlled by an axle counter is 160 km. In case of repeaters being used to relay information over the longer distances, the distance between repeaters must not be less than 15 km.
- 2.1.4.7 The shortest and longest trains to be detected by means of axle counters are respectively 2 and 2000 axles long.
- 2.1.4.8 The axle counter must be able to handle situations with long trains and short sections where it is possible for a train entering the section at one end, to be leaving it at the opposite end simultaneously.
- 2.1.4.9 It must also cater for more than one train entering a section at opposite ends, in the case where shunting movements from opposite ends are allowed.

2.1.5. System integrity:

- 2.1.5.1 The design must be such that the equipment shall continuously detect the presence of the wheel detectors, the absence of short circuits in the cables, failure of power supplies as well as the continuous supervision of

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the correct functioning of the electronic components.

- 2.1.5.2 Cyclic self-test procedures must be implemented in computer-based evaluators to ensure fault free operation of all internal sub-systems. These test procedures should also validate all interfaces, including data transfers, especially the output interface to the interlocking system. The “Self-tests” must always be done, including during on-line operation of the axle counter.
- 2.1.5.3 Within 2 seconds of any component failure or fault that affects the safety of the system, the affected sections must be indicated as being occupied. If this fault occurs in a computer channel, the affected channel should be taken out of operation and a fault message must be sent to the maintenance personnel. Functional faults do not affect the safety of the system should also be reported to the maintenance personnel.
- 2.1.5.4 In computer-controlled evaluators, at least two independent channels must give correlating section unoccupied/occupied outputs. When a channel discrepancy is detected controlled sections must be indicated as being occupied. The system may then perform a reset in an attempt to restore operation. If this attempt fails, the system must shut down.
- 2.1.5.5 In a two out of three system the affected channel could reset to restore operation. If this is unsuccessful the evaluator may continue operation with the existing two channels, but the fault should be reported to the maintenance personnel. In this mode of operation, any channel fault must shut down the evaluator, until the third channel is repaired.
- 2.1.5.6 If a new channel is switched in, due to repair or a successful reset, the new channel should synchronise and do a self-test in less than 3 minutes. The current data must also be transferred within 1 second. Normally this should be done when there is no movement over the wheel detectors. If an axle is detected in this time, then the relevant sections must be shown as occupied and the normal manual reset should be performed.

2.1.6. Occupancy information:

- 2.1.6.1 Only when a section is unoccupied and the axle counter system is functioning correctly, that is to say if it is capable of detecting wheels that enter or leave from either end of the section, a serial FSDT (SIL4) interface with information about the section status shall be used sent status to be read by the electronic interlocking.
- 2.1.6.2 The axle counter system is responsible to ensure that the status information is in the correct state and functioning properly as well as the proper information is sent via serial FSDT (SIL4) interface. When there is a malfunction, safety functions must ensure that the affected section/s

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is/are taken to a fail-safe state – undefined state for axle counter systems to ensure that safety is maintained.

- 2.1.6.3 Within 200ms of the physical occupation of the section, the relevant information occupation information shall be, ready to be sent to Interlocking Module via the serial FSDT.
- 2.1.6.4 The axle counts of all sections controlled by the axle counter system must be clearly displayed.
- 2.1.6.5 To avoid interface problems with other systems, e.g., track circuits, the track free indication must be delayed by at least 350ms after the physical vacation of the track. This time limit must be adjustable to 1s.
- 2.1.6.6 Track occupied and free indications must occur in the same sequence as the physical train movements.

2.1.7. Fault correction:

- 2.1.7.1 Where fault correction algorithms are employed to improve system performance, this must be done in a fail-safe manner.
- 2.1.7.2 The fault correction sub-system must be able to detect faulty wheel detectors as well as incorrect counts from a specific wheel detector.
- 2.1.7.3 Fault correction should only be made if at least two corresponding counts (1 count before and 1 after, or 2 counts after the faulty counting point) can be found.

2.1.8. Section reset function

- 2.1.8.1 The interlocking output for a section reset shall be serial FSDT (SIL4) interface to the Axle counter evaluator.
- 2.1.8.2 When a traditional override section reset is executed any previous wheel count in that section must be returned to zero and the affected section must be indicated as being unoccupied, unless:
 - a) All wheel detectors from specific section are not connected correctly to the evaluator and it was not functioning correctly with the last wheel that traversed it.
 - b) Some of the wheel-detectors from the specific section are being influenced.
 - c) The last count at a wheel-detector, associated with this specific

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section, was not an out-count but an in-count (in-count inhibit).

- d) There is a fault in the axle counter system affecting the specific section.
- e) The section was not occupied.
- f) There shall be an emergency in-count inhibition/restriction reset command via HMI through the interlocking to the evaluator that has the function of changing the direction of the last axle counted.

2.1.8.3 When preliminary/preparatory reset is configured, the reset should put the section in a preliminary/preparatory-reset mode.

- a) After the reset the section is not set clear but the number of axles in the section is set to zero.
- b) This section may be shown as unoccupied only when a train has been authorised through the section or dummy wheel been swiped and corresponding "in" and "out" counts of an/ axle/s, involving at least two separate wheel detectors (for sections based on two or more wheel detectors), were performed by the passage of a train through the section or the swiping of the dummy wheel.
- c) This train movement described before must ensure that the whole axle counter section is covered before the section is shown as unoccupied. With herringbone layouts, this requirement may require that a train be sent through several different routes or a specific route to ensure coverage of the entire section.

2.1.8.4 The reset facility must be done with high integrity at least SIL 3. The initiation of the traditional override reset on a specific axle counter, must be with the same integrity level as the emergency override functions to an electronic interlocking. The initiation of the preliminary/preparatory-reset mode need not be fail-safe but at least SIL 2.

2.1.8.5 After a system start-up, a complete system self-test should be performed to establish a fault free state. This test should not take longer than 3 minutes.

2.1.8.6 A configuration must be available to choose to force or not a section to occupied when a reset is done on this section when unoccupied.

2.1.8.7 All relevant sections must be shown as occupied when configured for preliminary/preparatory reset and already placed in the preliminary/preparatory reset mode, so that a command train may be

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used to clear all sections, starting from an outer section, and clearing sections in succession.

2.1.9. Adaptability to existing equipment:

2.1.9.1 The standard power supply in the relay room and for outside use is 110 V $\pm 10\%$, 50 Hz AC. All equipment must therefore use this supply as their primary power supply. A battery supported standby supply is normally available to back up the standard power supply. When the evaluators are distributed in the station a local UPS must be supplied at the evaluator housings.

2.1.9.2 Any communication must be capable of functioning over any of the following mediums:

- a) Multi-core signal cable, 0.9 or 1.6 mm diameter.
- b) Open wire routes.
- c) Radio channels with carrier frequencies from VHF to microwave band.
- d) Carrier equipment.
- e) Fibre optical cables.

All communications using any of the above mentioned mediums must comply with the CCITT specifications for multi-channel carriers and multi-core cables.

2.1.9.3 Any communication system between evaluators and detector points must uniquely identify each evaluator and/or detector point, in a fail-safe manner (SIL4).

2.1.9.4 The axle counter must be able to run with the following interlocking designs:

Spoorplan Mk1, 1a, 1b, 1c, II, M, T; NFG; NX; HR92; HR97; HRS.

2.1.10. Equipment maintenance:

2.1.10.1 A sophisticated diagnostic system should be supplied to support the maintenance activity:

- a) By indicating FSDT communication link failures to other evaluators or an electronic interlocking.

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- b) By indicating FSDT communication link failures to wheel-detectors, when applicable.
- c) By indicating shuttle move occupation flags on wheel-detectors and sections forced to occupied by the flag.
- d) By indicating faulty pluggable cards.

- 2.1.10.2 If computer software is used in the maintenance action, then the man-machine interface should be in English.
- 2.1.10.3 All indications must be clearly marked and all generated reports should be in English.
- 2.1.10.4 Remote diagnosis, which includes system and operational status reports, should be possible. This is due to the wider influence that the system status may have on train operation. All faults should be logged to be accessed by the maintenance personnel.

2.2. Performance characteristics:

The axle counter system must have the following performance characteristics:

2.2.1. Wheel detector

- 2.2.1.1 It must be fail-safe (SIL4). A section occupied signal should be sent to the evaluator in the event of failure. The safety function detecting and forcing the section to occupied should do this with a SIL4 probability of failing to do so.
- 2.2.1.2 Should any one of the detector heads drop off the track to a position where it is not able to detect a wheel, a section occupied signal should be sent to the evaluator.

2.2.2. Evaluator

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- 2.2.2.1 It must be fail-safe. In the event of a failure, the affected section must be indicated as being occupied within 2 seconds of the occurrence of the failure.
- 2.2.2.2 An accurate figure of axle counts must be held and be displayed for all sections controlled by the axle counter system.
- 2.2.2.3 If auto correction algorithms are used to correct miscounts, this must be based on correct counts from at least two different wheel detection points.
- 2.2.2.4 Multi section axle counters must have an uninterrupted power supply. This is due to the high demands for reliability and availability and the widespread effect that a power failure would have on train operations. These systems must also be immune to minor fluctuations in power supply.

2.3. Physical characteristics:

The axle counter system must have the following physical characteristics:

2.3.1. Wheel detector:

- 2.3.1.1 The wheel detector must be able to fit on all rail profiles used in the country.
- 2.3.1.2 The largest mounting hole to be drilled in the neutral axis of a 60 kg/m chrome manganese rail has a dimension of 13 mm. Should any equipment be mounted to the rail, the track maintenance personnel must be able to remove it easily for the purpose of maintenance.
- 2.3.1.3 The positioning and functioning of rail attached equipment must not be influenced by the geographical rail layout or by the surrounding Civil layout (e.g., bend, curves, gradient, cuttings, tunnels, railway sleeper material, etc.).
- 2.3.1.4 The rail-mounted equipment must be protected from gear that might be hanging from carriages.
- 2.3.1.5 It must be possible to mount associated modules excluding rail attached equipment in a standard apparatus case. The dimensions of the apparatus case and racks as well as the limits on the equipment to be mounted therein can be found in plans CSE Q6-20 and CSE Q6-23.

2.3.2. Evaluator:

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2.3.2.1 It must be possible to mount the axle counter evaluator in any relay room.

2.3.2.2 The evaluator must interface to the following:

- a) Electronic interlocking with serial communication (FSDT)
- b) Hybrid and Relay interlocking with voltage free contacts for section clear and 60 Volt inputs for reset functions.
- c) Evaluators of the same design with FSDT.
- d) All current and subsequent wheel detectors of the same manufacturer
- e) Diagnostic equipment over ether-net link.

2.4. Availability factors:

2.4.1. Failure rates:

2.4.1.1 For single section:

- a) MTBF > 2 months
- b) MTBFF > 3 months
- c) MTBEF > 4 years

2.4.1.2 For evaluator:

- a) MTBSF > 100 years

2.4.1.3 Definitions:

- a) MTBF (Mean Time Between Failures): This is the time permitted between two failures. These failures will not necessarily affect train operation in redundant systems.
- b) MTBFF (Mean Time Between Functional Failures): This is the time permitted between failures that influences the safety of part of the system. A failure of this nature will cause one or more of the sections not to return to the unoccupied state when it is vacant. A section reset will correct this state.
- c) MTBEF (Mean Time Between Equipment Failures): This is the same as the MTBFF with one difference. Some of the equipment will have to be repaired before a section reset can return the system to the normal operating mode.
- d) MTBSF (Mean Time Between System Failures): This is the time permitted between failures that causes the whole system to crash. The result will be a total system restart, which may include some repairs to the system (2003 system).

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The availability rates for multi-section axle counters should equal or better that of track circuits to make their use viable.

2.4.1.4 Repair times:

- a) MDT (no system failure) < 8 hours
- b) MDT (system failure) < 3 hours
- c) MRT (no system failure) < 30 minutes
- d) MRT (system failure) < 2 hours

2.4.1.5 Definitions:

- a) MDT (Mean Down Time): This is the average time permitted for the system or part of the system to be inoperative.
- b) MRT (Mean Repair Time): This is the average time permitted for repair of the system or sub system.

2.4.2. Maintainability factors:

- 2.4.2.1 The installation, adjusting procedure as well as first line maintenance must be possible using a multi meter with similar specifications as the FLUKE model 8060A or special tools to be delivered by producer.
- 2.4.2.2 The modules must be plug-in type, so that repairs can be performed at a central workshop. If any specialised test instrument (digital store oscilloscope excluded) or computers and software is needed in the workshop to facilitate repairs to the system, then it must be supplied as a module with the system.
- 2.4.2.3 Visual indications to assist in fault finding and maintenance should include at least the following:
 - axle detection
 - wheel counting
 - count direction
 - axle counts in section
 - system integrity
 - occupancy information
 - type of fault
 - module affected by fault
 - cause of fault (if possible)

This information must be displayed for each of the wheel-detectors connected to the evaluator and all sections controlled by the axle counter system.

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- 2.4.2.4 In computer controlled evaluators a facility must exist to store and display deviations from the normal operating procedures for at least 72 h.
- 2.4.2.5 The remote diagnostic system should automatically transmit fault reports to the maintenance personnel and allow operational and fault queries.
- 2.4.2.6 It must be possible for the system to be tested on-line by the maintenance team.
- 2.4.2.7 The system must provide test points with which the functionality of each module can be confirmed.
- 2.4.2.8 Components and modules must be easily accessible to facilitate testing.
- 2.4.2.9 The modules must be repairable.
- 2.4.2.10 Only standard components which are readily available may be used, and the availability of components and modules must be guaranteed for at least 20 years.
- 2.4.2.11 Plug-in modules must be provided with protective containers in which the modules can be transported over rugged dirt roads using light delivery vehicles.

3. ENVIRONMENT:

3.1. Wheel detector:

- 3.1.1. The equipment mounted onto the track must be able to operate in a GRADE E environment as specified in document CSE-1154-001 Category E48.
- 3.1.2. Other outdoor equipment mounted in apparatus cases must be able to operate in a GRADE C environment as specified in document CSE-1154-001 Category E48.
- 3.1.3. Attention is drawn to the severe lightning conditions pertaining in the country and adequate lightning protection must be provided. The system must be capable of withstanding the following discharges in the area:
 - 3.1.3.1 Transversal and longitudinal voltage spikes of 10 kV peak, 20 μ s wide with a rise time of 8 μ s between cores and on single cores respectively, leading from the equipment.

3.2. Evaluator:

- 3.2.1. The evaluator equipment mounted in the relay room must be able to operate in a

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GRADE B environment as specified in document CSE-1154-001 Category E48.

- 3.2.2. All parts connected to the axle counter system must show isolation to earth with a test voltage of 2500 V, 50 Hz, and test duration of 1 minute.

4. CONSTRAINTS:

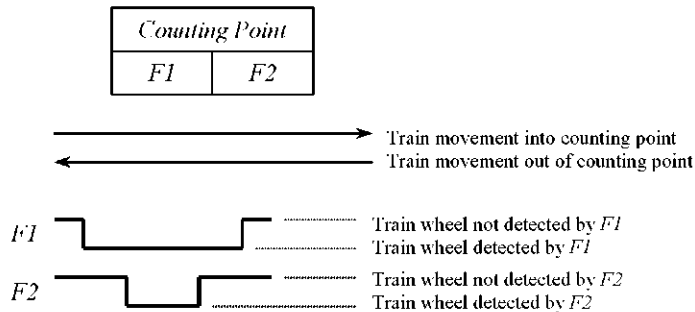
- 4.1. Any costs for changes / enhancements to modules / switches required as a result of permits and safety test are to be borne by the contractor.
- 4.2. Should any of the components or modules, etc., be declared unsuitable due to technical faults, then any changes made by the developer must again undergo the necessary approval procedures.
- 4.3. The following documentation should be provided:
 - 4.3.1. Planning and design documents
 - 4.3.2. Full description of the system
 - 4.3.3. Installation manual
 - 4.3.4. Maintenance manual containing at least:
 - fault finding trees
 - precautionary measures
 - transportation procedures
 - adjustment procedures
 - maintenance schedules
- 4.4. The presentation of the required approval documentation must be handed, by the developer, to the Spoornet authority responsible for approval. The developer must bear the costs involved in acquiring the proof of safety certificates, and the approval for application in the Spoornet environment.
- 4.5. Subsequent development of the axle counter system must ensure compatibility or the capability to interact with the existing equipment.
- 4.6. When replacing existing axle counter units the existing cabling should be used to minimise cost.

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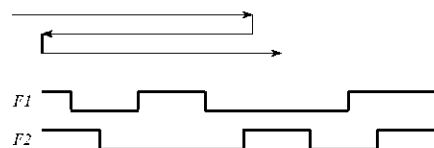
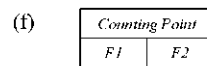
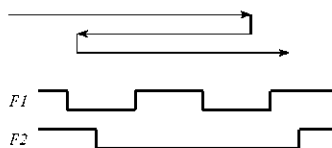
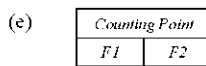
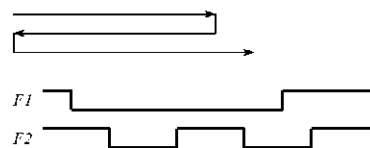
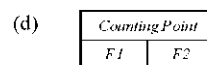
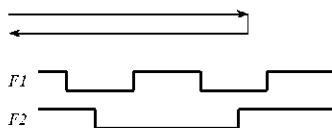
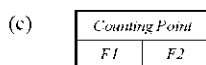
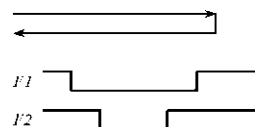
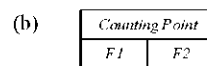
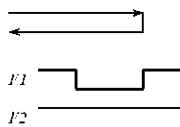
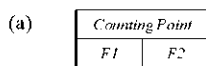
Appendix A:

The following series of fixed test cases depict possible shuttling moves of a train over a wheel detection point (counting point). *F1* and *F2* represent the receiver system of the counting point. The example below shows the direction of train movement as well as the detection by *F1* and

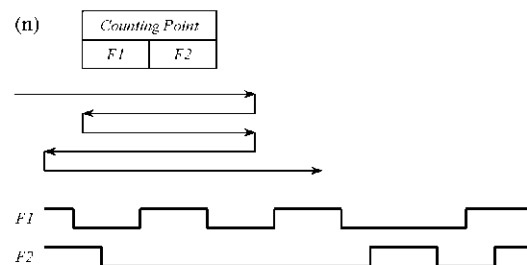
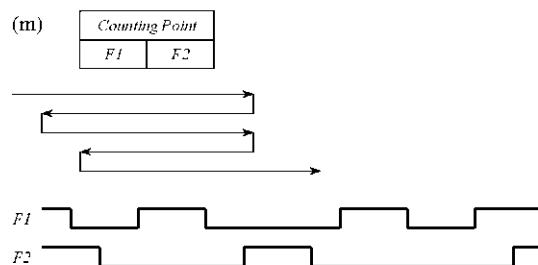
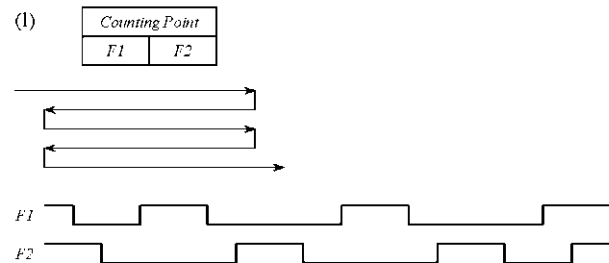
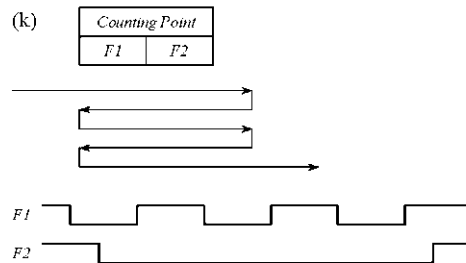
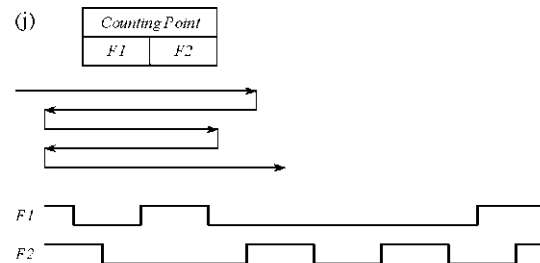
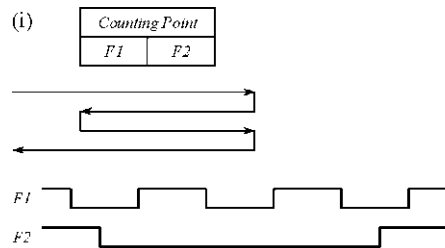
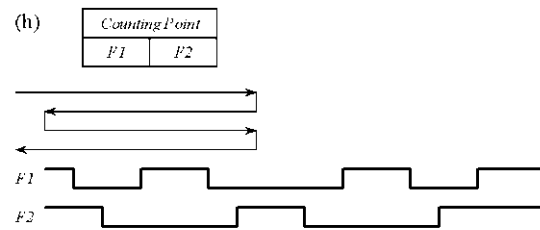
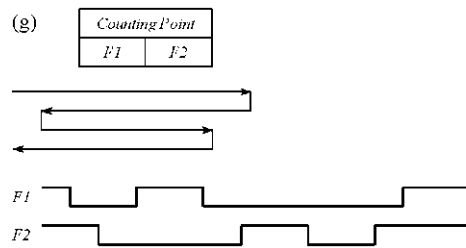
F2. Example:



Fixed test cases:



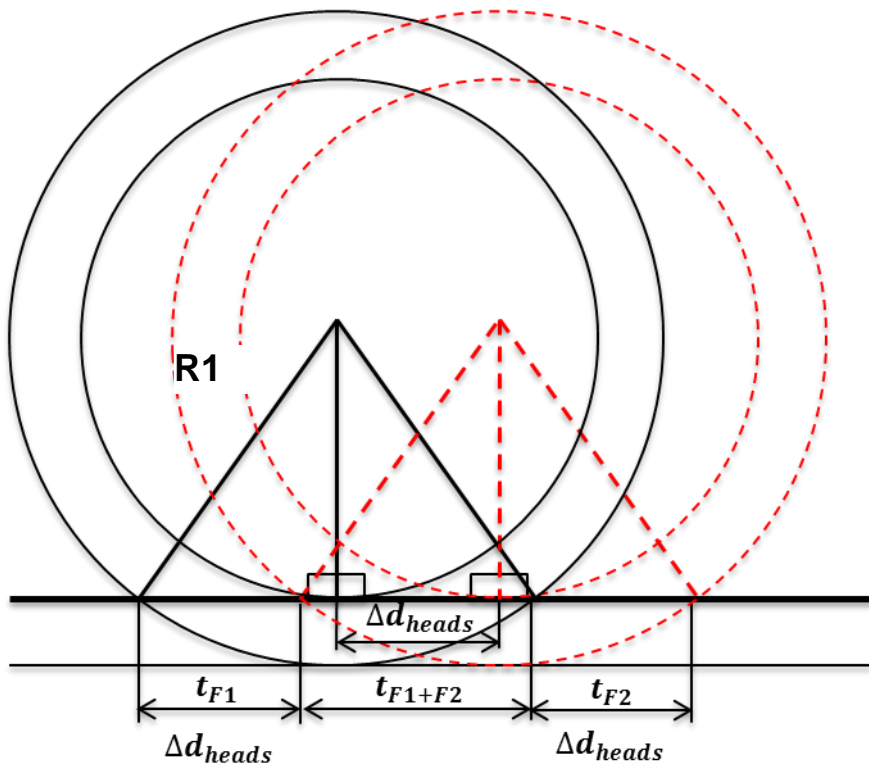
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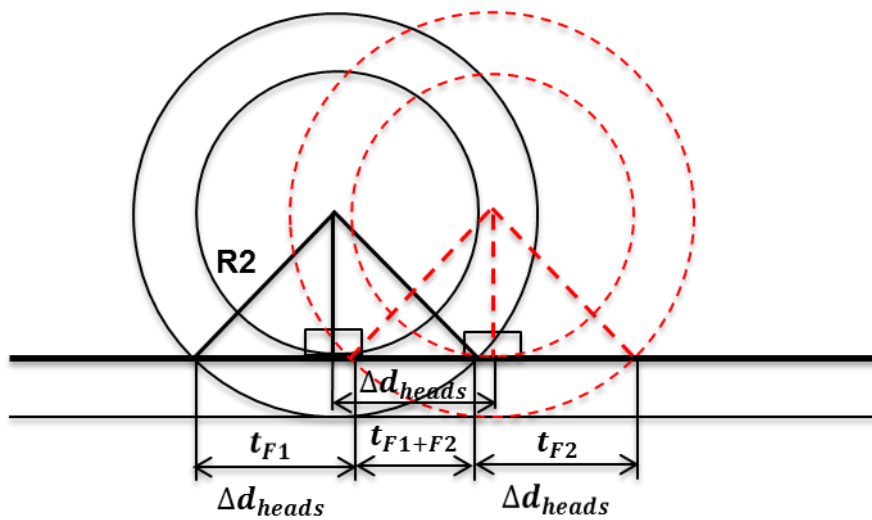
Appendix B:

Measuring train speed with an axle counter wheel detector.
Independent of train wheel diameter R1 or R2:



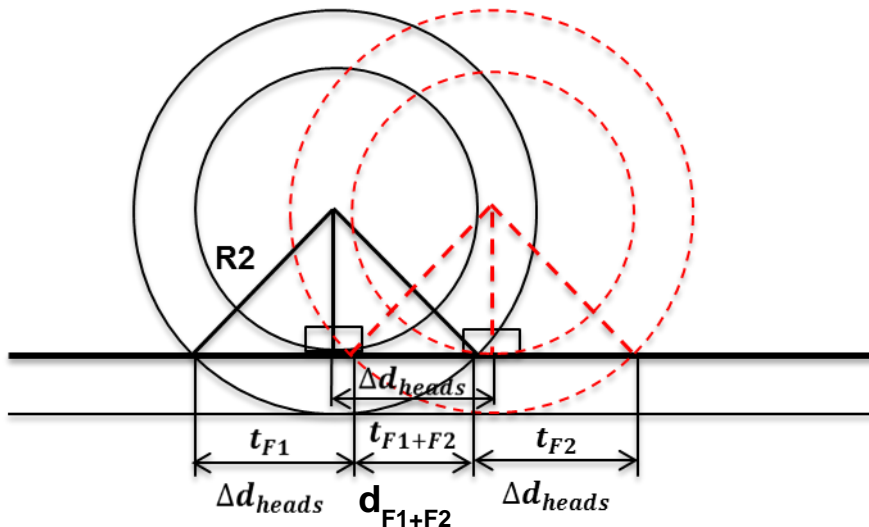
$$Speed = \frac{\Delta d_{heads}}{t_{F1}} = \frac{\Delta d_{heads}}{t_{F2}} \quad R1 > R2$$

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Minimum detectable train-wheel diameter – small diameter maximum detectable train speed reduced:



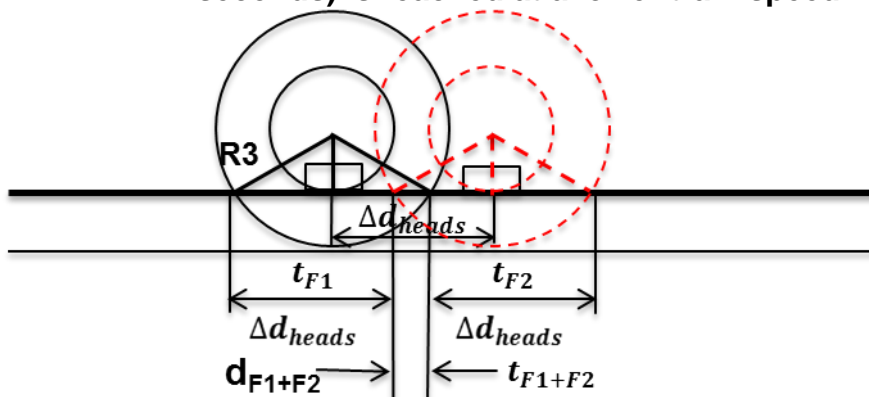
d_{F1+F2} = Overlap distance becomes smaller with reduced wheel diameter R.

$t_{F1 + F2}$ = Minimum detectable value must be for example > 3 milliseconds.

Δd_{heads} = Larger distance between heads causes a bigger minimum detectable wheel diameter R.

d_{F1+F2} = Overlap distance becomes zero (no overlap distance) with reduced wheel diameter R – no counting possible – section/s will still show occupied.

$t_{F1 + F2}$ = With smaller wheel diameter R the minimum detectable overlap time (3 milliseconds) is reached at a lower train speed.



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Appendix C

Maximum diameter of wheels: 1219mm Minimum

diameter of wheels: 470mm

Protrusion of wheel flange (see figure B - 1): 29mm minimum - 35mm maximum

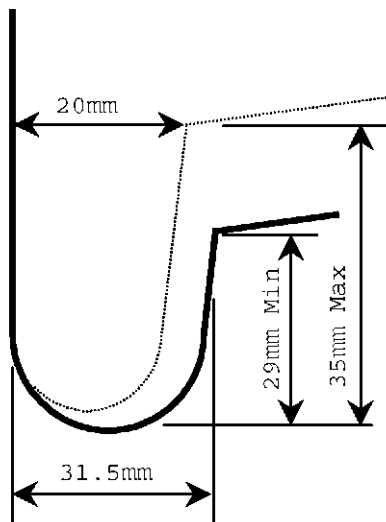


Figure B - 1: Wheel profile

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