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Level 2

Signalling Design: Module B3 - Circuits - General

Endorsement and Authorisation

For endorsement and authorisation, please refer to
NR/L2/SIG/11201

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Issue record

Issue	Date	Comments
4	June 2011	Modularisation of handbook and guidance notes, contains content of former NR/GN/SIG/11600 Part D.
5	03/09/2011	Amended references due to withdrawal of NR/L3/SIG/30018
6	06/09/2014	LOI320 incorporated

Compliance

This Module is mandatory and shall be complied with by Network Rail and its contractors if applicable from 06/09/2014.

When this standard is implemented, it is permissible for all projects that have formally completed GRIP Stage 3 (Option Selection) to continue to comply with the issue of any relevant Network Rail standards current when GRIP Stage 3 was completed and not to comply with requirements contained herein, unless stipulated otherwise in the scope of this standard.

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1 ELECTRICAL CIRCUITS

1.1 INTRODUCTION

This module applies to the design of electrical circuits associated with:

- a) electro-mechanical signalling systems;
- b) electro-pneumatic signalling systems;
- c) relay based signalling systems; and
- d) electronic signalling systems.

It applies to both internal and external circuits, commencing on the load side of the final busbar.

1.2

It does not apply to wiring associated with the power supply side of the final busbar, which is covered in [NR/L2/SIG/30050](#), nor to circuits associated with signaller's voice communication systems, which are covered in [NR/L2/TEL/30002](#), [NR/L2/TEL/30031](#), [NR/L2/TEL/30032](#) & [NR/L2/TEL/30143](#).

For the presentation and use of circuit diagrams within the design process see [NR/L2/SIG/11201, Module A2 & A15](#). Relay and circuit nomenclature, as well as symbols, are defined in [NR/L2/SIG/11201, Module A19](#).

1.3

Where it entirely addresses the situation under consideration, the use of this Standard is an alternative to an approved risk-based assessment. However, where the particular application or intended environment for the system introduces additional risks, these should be subject to separate assessment.

The Design Principles in Section 2 give the minimum requirements that need to be addressed, even when a risk-based approach is used. These principles are mandated in [NR/L2/SIG/11201](#).

1.4

The following guidelines and specifications should satisfy the principles encompassed within the standard:

- a) guidelines on fusing and looping in [NR/L2/SIG/11201, Module B4](#);
- b) guidelines on the electromagnetic compatibility of electronic equipment in [NR/L2/SIG/11201, Module B5](#);
- c) guidelines on protection of conductors for occupational safety, in [NR/L2/SIG/11201, Module B6](#);
- d) guidelines on the application of different types of circuit in the relevant parts of this standard;
- e) the typical circuits listed in [NR/GN/SIG/CAT005](#); and
- f) the relay specifications listed in [NR/LS/CAT006](#).

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2 DESIGN PRINCIPLES

These principles are mandated in [NR/L2/SIG/11201](#).

2.1 GENERAL

Circuits should be provided, as necessary:

- a) to interlock the signalling functions in accordance with the control tables;
- b) to operate the trackside and on-track signalling equipment and prove that operation;
- c) to control the signalling functions from the signalbox and to indicate their state; and
- d) to monitor the system to warn of failures or operating irregularities.

Consistency in the operating and proving circuits associated with any interlocking should be maintained, irrespective of whether the trackside and on-track equipment is directly or indirectly fed from the interlocking. Where it is necessary to house the controlling relays at the interlocking, the same type of circuitry should be used, as far as practicable, as if the relays were remote.

2.2 SAFETY INTEGRITY

The use of fail-safe circuits and components should be commensurate with the levels of safety and availability required. The following areas should be considered:

- a) safety-critical systems and components to fail safe, such that no foreseeable failure mode can introduce a hazard within the signalling system that was not present before the failure;
- b) safety-related systems and components that are not safety-critical to fail safe wherever reasonably practicable;
- c) the possible failure modes of each component of a safety-related system and the implications of a fail safe circuit component failing in its predetermined mode (such as a relay failing to energise, or overcurrent protective device operating);
- d) circuits to be designed to prevent feedback from current taking an unintended path, both under ordinary and failure conditions (care should be taken when interfacing with electronic equipment where outputs could be conductive even when nominally de-energised);
- e) circuits to be designed to take all transient conditions into account, i.e. concurrent changes in other circuits (care should be taken to consider any fleeting outputs from electronic equipment that could occur under either normal or failure conditions);
- f) circuit faults to be self-revealing and rapidly detectable, to reduce the risk of a subsequent fault, in combination with the first fault, leaving the system in an unsafe state;

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- g) circuit components that do not fail safe (e.g. diodes, relays with non-safety contacts, and electronic flashers), and cannot be otherwise proved, to be used only where a hazardous failure cannot arise;
- h) secondary protection, or proving, to be provided for safety-critical functions (even at a lower safety integrity level) such that, if a wrong side failure were to occur, a hazardous event would be unlikely to follow;
- i) warnings to the signaller or train driver in the event of a failure of safety-related functions; and
- j) the use of a probabilistic approach with complex systems.

2.3 PROVING

Where necessary to reduce risks to an acceptable level, proving should be used to confirm equipment is in a safe state before another operation can be carried out. Proving should automatically disable a potentially conflicting operation.

Proving is generally provided for safety-critical functions, as in the following situations, but this list is not exhaustive:

- a) to verify the state of trackside and on-track equipment, in accordance with control tables (lamp proving, point detection, etc.);
- b) to verify correspondence between outputs from systems duplicated by diversity;
- c) to verify that certain safety-critical relays, repeat relays, latched relays, contactors and timers have reverted to the de-energised or released position (down proving);
- d) to verify the removal of a bridge path in certain locking levels;
- e) to verify that two mutually exclusive safety-critical functions are not operated at the same time (cross proving);
- f) to verify that certain safety-critical events have occurred in the correct sequence (sequence proving); and
- g) to verify that certain lever locks are effective (lock proving contacts).
- h) The application of proving is considered further in Section 9.

2.4 FAULT MONITORING

Where necessary to achieve the required availability level, monitoring should be provided to warn the signaller or maintainer of a failure, by means of an audible and/or visual alarm. The result of monitoring functions that directly affect train operations should be communicated to the signaller as an alarm, but other alarms need only inform the maintainer. Details of interlocking monitoring requirements are given in [NR/L2/SIG/11201, Module B7](#) and the signaller's display in [TI 157](#).

Where circuit components or cables are duplicated to provide continued availability in the event of a single failure, a facility should be provided to permit the independent

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monitoring, either manual or automatic, of both elements, for example disconnection links for duplicated tail cables.

2.5 MAINTAINABILITY

Circuits should be designed to facilitate preventive and corrective maintenance, minimise failure potential and the consequences of failure, and simplify testing.

Where a risk to train operations is presented by the resetting of equipment following a failure, a means of isolation to enable out-of-service resetting and testing by the maintainer prior to restoration by the signaller should be provided, in accordance with [GK/RT0028](#).

2.6 POWER SUPPLY CONSIDERATIONS

The voltage drop within a circuit should not generally exceed 10%, unless the design specifically caters for it, e.g. with long block circuits. In addition, the circuit should be capable of operating correctly under all conditions of power supply fluctuation. For a public supply, a variation of $\pm 1\%$ on the declared frequency and $\pm 10\%$ on the declared voltage is permitted under the Electricity Supply (Amendment) Regulations 1992, as amended, and referenced in [BS EN 50160](#).

Circuits should be designed such that systems revert to a safe state in the event of a power failure. Where this is impracticable, or there is no safe state, a secure power supply should be provided.

Where necessary to achieve the required availability level, the state of safety-critical interlocking functions should be stored by a means that will remain secure in the event of a total failure of all power supplies.

Circuits should be designed to prevent an unsafe state occurring during power supply failure or restoration, including momentary loss. Where the state of safety-critical information is not, or cannot be stored, e.g. in the case of electronic interlocking systems, processes should be provided to reset or refresh the system to correspond to the state of the railway before being restored to use.

Wherever practicable, circuits should function in their usual manner following power supply loss and restoration without having to be manually reset by a maintainer, unless a safe state cannot otherwise be provided.

See also [NR/L2/SIG/30052](#) for power supply requirements.

2.7 ELECTRICAL SAFETY

Appropriate measures should be taken to comply with the Electricity at Work Regulations 1989.

The main requirements are as follows:

- Protection from direct contact. See Section 3.1 and [NR/L2/SIG/11201, Module B6](#).
- Protection from indirect contact. See Sections 3.2 and 6.6, and [NR/L2/SIG/11201, Module B6](#).
- Provision of a single earth. See [NR/L2/SIG/11201, Module B6](#).

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- d) Use of appropriate equipment. See Section 6.
- e) Overcurrent protection. See Section 3.3 and [NR/L2/SIG/11201, Module B4](#).
- f) Ability to disconnect the supply. See Section 3.4.
- g) Sufficient working space. See [NR/GN/SIG/11821](#).
- h) Competent staff. See [NR/L1/CTM/001](#).
- i) Accurate documentation. See [NR/L2/SIG/11201, Module A2](#).

2.8 CIRCUIT CONDUCTORS

The current carrying capacity of circuit conductors should be adequate for the design, considering its environment, range of ambient temperature, insulation and whether the current is continuous or intermittent. Conductors (including earth and equipotential bonding, where reasonably practicable) should be capable of carrying overload and short circuit currents to survive beyond the time necessary to operate the protective device(s). The insulation should be sufficient to withstand the operating temperature and provide adequate protection against the highest voltages present in the immediate vicinity of the conductor.

Conductors are considered further in [NR/L2/SIG/11201, Module B12](#).

2.9 CIRCUIT COMPONENTS

The continuous and intermittent rating of circuit components should be adequate for the design. Circuit switching devices should be sufficiently robust to make and break the highest current for which the circuit is designed, within its designed life-cycle, without sustaining damage. Components should be capable of carrying overload and short circuit currents to survive beyond the time necessary to operate the protective device(s).

Insulation should be effective to enable the equipment to withstand the applied voltage and any likely transient overvoltages.

A circuit component that presents a hidden or unexpected danger to staff should have a warning sign affixed indicating the specific danger, e.g. hazardous substance, hot surface, moving parts, etc.

Where circuit components are provided with plug-in connectors, measures should be taken to prevent a hazard being caused by a wrong component being plugged in, in accordance with [NR/L2/SIG/11630](#).

Components are considered further in Section 6.

2.10 ELECTROMAGNETIC COMPATIBILITY (EMC)

All electrical and electronic systems and equipment should be capable of demonstrating conformity to the following EMC protection requirements, in accordance with the Electromagnetic Compatibility Regulations 1992:

- I. the electromagnetic disturbance (a.c., d.c. or h.f.) it generates, by conduction or radiation, should not exceed a level allowing other equipment to operate as intended, unless the electromagnetic emission is a stated necessary function of operation; and

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- II. it should have a level of intrinsic immunity adequate to enable it to operate as intended.

It may be assumed that such equipment present in the electromagnetic environment is that which might reasonably be expected to be present. The manufacturer's declaration of conformity and associated Conformité Européene (CE) marking should only be used to demonstrate compliance for the particular application and in the particular environment specified by the manufacturer in the instructions supplied with the equipment.

Systems and equipment that are assembled from components that individually may, or may not, have CE markings should, nevertheless, be provided with a declaration of conformity and CE marking for the overall configuration. This also applies to existing systems that are altered to such an extent that their EMC characteristics are substantially changed, and to systems that are used in different applications or environments from those specified by the manufacturer.

Conformance may be demonstrated by application of experimental European Standards [BS EN 50121-1:2000](#) (for the railway system environment as a whole) and [BS EN 50121-4:2000](#) (for signalling and telecommunications apparatus within the railway system environment).

Protection of signalling equipment is required against:

- a) direct contact with traction current through rail connections;
- b) direct contact with earth or rails through insulation damage;
- c) high frequency (h.f.) contamination of power supplies; and
- d) induction from parallel a.c. or h.f. circuits;

so as to provide an appropriate level of system safety and dependability and safeguard staff from danger.

The application of these requirements is considered in Section 4.

3 CIRCUIT DESIGN FOR OCCUPATIONAL SAFETY

The Electricity at Work Regulations 1989, made under the Health and Safety at Work Act 1974, require both employers and employees to take precautions in respect of electrical systems, equipment and conductors, and activities on or near such equipment.

All electrical and electronic systems and equipment are required to comply with these regulations. They may generally be satisfied by following the IEE Wiring Regulations ([BS 7671](#)) and [BS EN 50122-1](#) for railway applications. Although [BS 7671](#) is not mandatory for railway signalling equipment, every area of protection addressed therein should be covered, either by compliance with [BS 7671](#), or by providing an equivalent degree of protection. Note that the use of an earth-free supply alone is not recognised as an adequate form of protection from direct contact or indirect contact with live parts.

Procedures and training for work on or near electrical equipment are outside the scope of this standard, but are covered in [NR/L2/SIG/10064](#), Part X.

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3.1 DIRECT CONTACT WITH LIVE PARTS

To comply with the Electricity at Work Regulations, all *live parts* of an *electrical installation* that could present danger to staff shall be provided with *basic insulation*, *barriers*, or *enclosures* with external warning signs affixed.

Basic protection against *electric shock* under fault free conditions shall be provided for all *live parts* able to be raised to a potential exceeding 25V a.c. or 60V ripple-free d.c., or able to be supplied with a current exceeding 25A. These voltages are derived from equivalent situations quoted in [BS 7671](#).

The requirements for *basic protection* shall be satisfied by the use of *equipment* with *basic insulation* and IP2x terminals. Where this is not reasonably practicable, additional *enclosures* or additional *barriers*, to IP2x (IP4x on horizontal surfaces) shall be provided in order to prevent or deter unintentional contact with *live parts*. Such provision shall be shown as a permanent record on the design.

Enclosures and *barriers* (with the exception of portable shields) shall be removable only by use of a tool and shall carry a permanent warning label. They shall be arranged so that the removal of a *barrier* to permit one work activity will leave other *live parts* protected.

Where practicable, *enclosures* or *barriers* should be made of transparent material to reduce the need for removal.

Note: For the avoidance of doubt, these requirements are NOT satisfied solely by the provision of locked equipment housings.

Transient and likely fault conditions should be considered in assessing whether exposed *live parts* may be tolerated, using the transient values specified in [BS EN 50122-1](#) these relate to the steady state values of 60Va.c. and 120Vd.c..

See also Sections 3.1.2 and 4.3. Further details are given in [NR/L2/SIG/11201, Module B6](#)

Terms shown above in italics are defined in [BS 7671](#).

3.1.1 PRECAUTIONS TO BE TAKEN IN ELECTRIFIED AREAS

Danger from a.c. overhead line equipment is addressed in [GE/RT8024](#). Danger from induced voltages from parallel a.c. overhead lines should be avoided by following Section 4.3.

A special exemption from insulation or enclosure exists for live conductor rails. Danger should be reduced by the provision of warning notices, special training for staff and, where appropriate, barriers. On-track equipment should be positioned such that no lid, or other movable part, can make contact with the conductor rail. Where there is danger to maintainers working on such equipment, precautions should be taken to reduce the risk to be as low as reasonably practicable. The following options are in order of effectiveness:

- the conductor rail should be gapped;
- conductor rail protective boarding fitted; or
- staff provided with portable shields.

Further precautions are given in [GK/EH V609](#) and [GE/RT8000-DC](#).

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3.1.2 DANGER FROM TRACK CABLES IN ELECTRIFIED AREAS

In order to protect staff and signalling equipment in electrified areas from traction voltages under fault conditions, track circuit tail cables should be fully insulated, generally by terminating them on a pair of BS 88 fuse carriers and bases in the lineside apparatus housing nearest to the rail connections. The terminals of all track circuit equipment should be shrouded or enclosed, except when using the safety procedures for work on electrical equipment. Connections to impedance bonds and track circuit capacitors that are not at running rail potential could be charged at a dangerous voltage at any time.

A fuse is to be provided in one fuse carrier and a link in the other, as follows. Fuses in both legs would give unpredictable results.

- a) Single rail track circuits should be fused in the insulated rail leg.
- b) Double rail track circuits should be fused in the leg connecting to the impedance bond winding.

For double rail track circuits, a two electrode surge arrestor should generally be provided across the track circuit tail cable (on the external side of the fuse) in the apparatus housing nearest to the rail connections. It should not be connected to earth, unless precautions are taken to prevent a surge creating multiple earth faults.

Electrical isolation between track cables and the interlocking environment is desirable. Consequently, track relays and track feeds should generally be confined to lineside locations with repeat relays provided in interlockings.

The requirements of this section (3.1.2) do not apply to track circuits which are coupled to the rails by means of isolating transformers or tuning units adjacent to the track, such as HVI and TI.21 types. Detailed arrangements for individual types of track circuit are given in the [NR/L3/SIG/117XX](#) series.

3.1.3 DANGER FROM BACK ELECTROMOTIVE FORCE (EMF)

Inductive loads generate a back EMF when the current is broken, which is usually dissipated through the power supply unit. This applies particularly to AWS inductors, hydraulically powered trainstops and lever locks.

Precautions should be taken to guard against dangerous voltages occurring on the cable in the event of the disconnection links being removed.

These may take the form of:

- a) a reverse biased protection diode for back EMF suppression provided across the external side of the cable terminations;
- b) a voltage dependent resistor connected across the load (see [NR/L3/SIG/19272](#)); or
- c) fully insulated cables terminated on a pair of BS 88 fuse carriers fitted with links.

Suitable diodes are as follows: 1A, 400V for standard strength AWS inductors and suppressors, or 6A, 800V for high strength. The designer should include in the operation and maintenance documentation the need for the maintenance regime to regularly identify any diodes that have failed open-circuit.

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Details of the protection of electronic devices from back EMF are given in [NR/L2/SIG/11201, Module B5](#).

3.2 SAFETY EQUIPOTENTIAL BONDING

The purpose of equipotential bonding is to protect against indirect contact with exposed-conductive-parts and extraneous-conductive-parts made live by an electrical fault. Earthed equipotential bonding within apparatus housings is associated with the signalling power supply system and is required where specified in [NR/L2/SIG/11201, Module B6](#).

Equipotential bonding of extraneous-conductive-parts that are not within apparatus housings is associated with external electrical systems, such as traction supply, and is required where specified in [NR/L2/SIG/11201, Module B12](#). In a.c. electrified areas and where overhead power distribution lines cross the track in non-electrified areas, equipotential bonding provides protection from dangerous touch potentials appearing between adjacent metalwork (and rail connections) in the event of a fault on the high voltage system. The connection of equipotential bonding to the traction return system facilitates the automatic disconnection of the traction supply if damaged overhead lines should make contact with structural metalwork.

However, in d.c. electrified areas, a greater danger would arise from large traction currents flowing to earth via the equipotential bonding, which consequently is not provided.

The designer should include in the operation and maintenance documentation the need for the maintenance regime to regularly identify any failure of safety equipotential bonding.

3.3 OVERCURRENT PROTECTION

An overcurrent protective device should be provided for each circuit or group of circuits, of sufficient rating to prevent damage from the current carrying capacity of a circuit conductor or circuit component being exceeded under failure or overload conditions and, where applicable, to make safe any exposed-conductive-parts or extraneous-conductive-parts made live by an electrical fault. Indirect contact protection is considered further in [NR/L2/SIG/11201, Module B6](#).

Protective devices should be selected by considering the following characteristics:

- a) nominal current of the device;
- b) speed of operation and sensitivity, depending on the type of load, e.g. highly inductive, starting or in-rush currents, or electronic equipment;
- c) voltage rating;
- d) discrimination between successive stages of protection (see [NR/L2/SIG/30050](#));
- e) suitability for the railway environment;
- f) reliability;
- g) whether fuses or circuit breakers;
- h) whether a monitoring facility is required;

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- i) whether required to be enclosed to provide protection from direct contact (see Section 3.1);
- j) whether required to provide disconnection facilities, e.g. fuse switches, (see Section 3.4); and
- k) whether required to provide isolation facilities, e.g. locking off, (see Section 3.4).

The nominal current of the device should be chosen to be greater than the design load of the circuit, but less than the current carrying capacity of the circuit conductors. Thus the device will operate before the conductors are exposed to a current greater than they can safely withstand (generally accepted as 1.45 times their current carrying capacity), or the insulation is subjected to an unacceptable rise in conductor temperature.

The design load should include any foreseeable peak load of a protracted nature. Where this excludes anticipated transients, such as motor starting currents or transformer inrush currents, it may be necessary to use reduced sensitivity or slow operation devices to avoid nuisance tripping.

Network Rail should be informed of any measures taken to avoid nuisance tripping and an appropriate note should be made on the design details.

The current rating of each circuit component shall be greater than the nominal current of the device.

Overcurrent protective devices should generally be provided in all non-earthed legs (only) of final circuits. However, for supplies with no earth connection that do not exceed 120V, protective devices may be provided in one leg only. For non-earthed supplies, it should be recognised that there is a risk of a return circuit conductor in an unfused leg of a low current circuit being unprotected, in the event of a double earth fault allowing a fault current from an adjacent high current circuit to flow in it.

All branches of a circuit (including both branches of a ring feed) should be connected to a single overcurrent protective device. Where practicable, every feed (phase 'BX', or positive 'B') device or terminal should have a corresponding return (neutral 'NX', or negative 'N') terminal or device.

Overcurrent protective devices should be arranged so as to minimise potential disruptions to train operations in the event of a fault. Discrimination between successive stages of protection should therefore be arranged, as described in [NR/L2/SIG/30050](#).

The standard arrangement for signalling circuits is given in [NR/L2/SIG/11201, Module B4](#).

3.4 ISOLATION AND EMERGENCY SWITCHING

Where necessary to prevent danger, each circuit should be capable of (a) emergency on-load switching and (b) isolation (fixing off).

Emergency switching and isolation devices should be clearly labelled, and their accessibility should be appropriate to the risks involved. Emergency switching and isolation facilities may be combined, and may be common to several items of