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Date	December 2000

DC Track Circuits (formerly RT/E/PS/I 1755)

This temporary front sheet facilitates change to the new Network Rail Standards referencing nomenclature.

The Ref above will be formally allocated to this standard when it is next changed in the meantime the contents, date and issue number of this Network Rail Standard are **UNCHANGED and with immediate effect it should be referred to as “(new ref) formerly (old ref)”.**

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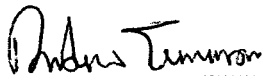


RAILTRACK LINE PRODUCT SPECIFICATION

DC TRACK CIRCUITS

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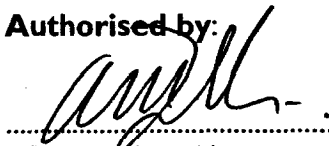
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Summary

This Line Specification states the minimum requirements for d.c. track circuits. It includes life-cycle requirements from design, safety and environmental through to installation, testing and maintenance.

Issue/Revision Record

Issue	Date	Comments
1	December 2000	New Specification. The contents are based on Railway Group Code of Practice GK/RC0755 which is to be transferred to Railtrack Line in February 2001.

Implementation

The requirements of this Specification shall apply to all d.c. track circuits supplied for use on Railtrack controlled infrastructure on or after 3 February 2001. It is not retrospective. The following document is superseded:

Superseded document

GK/RC0755, Issue 2, December 1998

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I INTRODUCTION

I.1 PURPOSE

This Product Specification gives details of best practice in respect of d.c. track circuits in order to achieve the requirements of RT/E/S/11752.

I.2 SCOPE

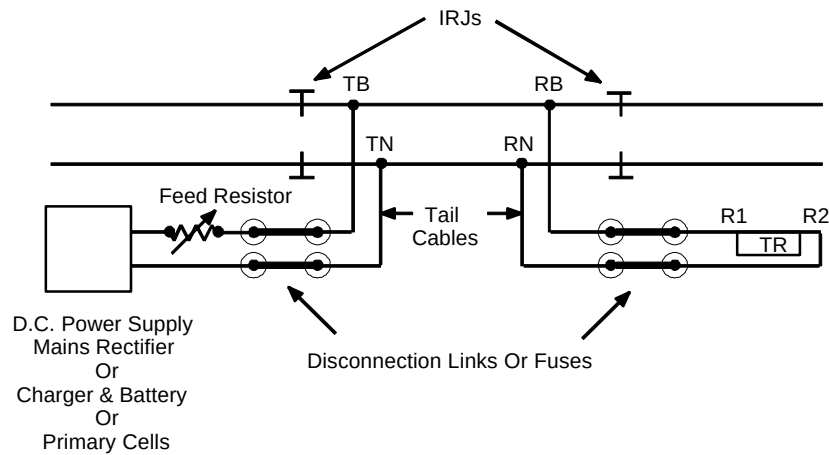
The contents of this Product Specification apply to both new and existing d.c. track circuit installations, and shall be read in conjunction with RT/E/S/11752. The following types of track circuit are included:

- low voltage non-immune,
- low voltage a.c. immune,
- medium voltage non-immune,
- medium voltage a.c. immune,
- medium voltage a.c. immune/d.c. tolerant,
- diode.

I.3 INTRODUCTION

D.C. track circuits are the simplest, least costly and most reliable type of track circuit and are therefore the natural first choice for other than d.c. electrified areas. However, the geographical limits of each section must be defined by insulated rail joints (IRJs) and the cost of these may influence choice towards jointless designs, especially on main lines where the whole life cost of IRJ installation and maintenance is a larger factor.

In the basic form of d.c. track circuit, power is applied to the rails at one end of the section and is transmitted via the rails to a d.c. track relay at the other end as shown in Figure 1.

**Figure 1**

The d.c. power supply, obtained from a mains transformer / rectifier, trickle charged secondary battery or a primary battery, is fed through a feed resistor to the rails. The resistor is necessary to limit the current drawn from the feed unit when the track circuit is shunted by the train, and to permit the track circuit sensitivity to be adjusted. The performance of d.c. track circuits is determined by:

- the required minimum drop shunt;
- the drop away rail voltage (to tolerate d.c. interference and rail contamination);
- the minimum ballast resistance at which the track circuit remains functional;
- the need or otherwise for a.c. immunity (a.c. traction, a.c. point heater, train heating shore supply or other a.c. source induced).

Within the limitations imposed by basic operating principles and commissioning methods, d.c. track circuit equipment can be designed to fulfil any required performance. A variety of types have been used in the past and many of these continue in service. In the interests of standardisation, it is necessary to limit new installations to certain preferred options.

D.C. Track Circuits

When track circuits had to be powered by primary batteries, the conservation of power was of utmost importance; early designs, therefore, had low values of everything; feed voltage, feed resistance, rail voltage and relay resistance and operating values. The availability of mains power led to new designs with less emphasis on power conservation. Designs became available which required no feed adjustment, whilst rail voltages could be raised to improve detection with poorer vehicles and / or poorer rail surfaces. Designs were adapted to achieve immunity to a.c. interference and to enhance tolerance to d.c. interference.

.....

2 APPLICATION AND CONSTRAINTS

2.1 APPLICATION

The application of d.c. track circuits fulfils the basic requirement for continuous train detection.

Where additional integrity is required, e.g. for the operation of automatic level crossings (not locally monitored), they shall be used in conjunction with some other type of train detection device.

Where reduced integrity is sufficient, e.g. for the operation of automatic level crossings locally monitored by the train driver, certain requirements may be relaxed (see section 10.1 on Residual Interference Voltage Tests).

2.2 CONSTRAINTS

The following constraints apply to the use of d.c. track circuits, in addition to the general restrictions given in Part F of RT/E/S/I 1752:

2.2.1 Designs for New Work

Only the following designs provide the required integrity for new work:

- medium voltage a.c. immune,
- medium voltage a.c. immune/d.c. tolerant,
- diode.

2.2.2 Track Circuit Length

The maximum operational lengths are dependent upon the configuration used and minimum ballast resistance that can be expected. In a.c. electrified areas, there are additional length restrictions to limit the traction interference.

Full details are given in section 4.

There is no special restriction on minimum length, other than that given in RT/E/S/I 1752.

2.2.3 Switches and Crossings (S&C)

Diode track circuits shall not be used in S&C, as they are not suitable for single rail configuration.

Other types of d.c. track circuit may be used in either single rail or double rail mode.

2.2.4 Point Heater Restrictions

D.C. track circuits shall not be installed through S&C fitted with d.c. electric point heaters.

Only a.c. immune designs shall be used through S&C equipped with a.c. electric point heaters unless the heaters on each rail are supplied from separate isolated power supplies to an approved design.

2.2.5 Residual Interference Voltage

A d.c. track circuit shall not be used where the track condition is such that residual interference voltage presents an unacceptable hazard to train operations. Further details are given in section 6.2 on Immunity from D.C. Interference and in section 10, Testing Procedures.

Significant improvement may be achieved, where practicable, by the use of double rail rather than single rail configuration. Where this is not practicable, a feed end relay may be introduced to obviate any restriction on use.

Where new d.c. track circuits without feed end relays are to be introduced on insulated concrete sleepers, it is important that the general condition of those insulations be verified some time before commissioning, since failure to do so could result in an inability to commission due to excessive d.c. residual voltage interference.

For the same reason d.c. track circuits are unsuitable for use on track which uses concrete sleepers that are not insulated from the rails, or steel sleepers.

2.2.6 Lightweight Vehicles and Others Susceptible to Poor Train Shunt

On non-electrified lines used by lightweight vehicles in Classes 14X to 16X or other modern rolling stock designated as susceptible, unless they are fitted with Track Circuit Assisters (TCAs), the only generally permitted types are:

- medium voltage a.c. immune,
- medium voltage a.c. immune/d.c. tolerant,
- diode.

Low voltage d.c. track circuits (see section 3.5.2) may also be used, provided they are adjusted for high sensitivity, but only in the following circumstances:

- on uni-directional lines, or
- where sequential track circuit proving is provided.

However, all types of d.c. track circuit may be used where an assessment shows that all susceptible vehicles permitted to use the line are fitted with TCAs.

2.2.7 D.C. and Dual Electrified Areas

D.C. track circuits shall not be installed on d.c. and dual electrified lines. However, the d.c. medium voltage a.c. immune/d.c. tolerant type may be used on a.c. electrified lines in the vicinity of dual electrified lines, even if the traction return systems cannot be isolated, subject to an immunisation evaluation exercise.

2.2.8 A.C. Electrified Areas

Only a.c. immune designs shall be used in a.c. electrified areas. Track circuits on a.c. electrified lines are subject to particular length restrictions (see section 4.2.1.4). Diode track circuits are not A.C. immune.

- a) Traction return cross bonding must be provided at all insulated rail joints (IRJs) in the traction return rail. The traction return rails in adjacent terminal platforms shall also be bonded together at the buffer stop end (see RT/E/S/11752).
- b) The traction return rail shall, wherever practicable, be positioned on the cess side to enable structure bonds to be kept short.
- c) Double rail reed or TI.21 track circuits must not be allowed to be surrounded by an area of d.c. single rail track circuits, e.g. on a loop line, as described in the appropriate Track Circuit Product Specification.

2.2.9 Interfacing with Other Types of Track Circuit

The relay end of a non a.c. immune d.c. track circuit is not permitted to abut a HVI track circuit. A.C. immune types are not restricted.

The relay/feed end of a diode track circuit is not permitted to abut a reed or HVI track circuit (i.e. the permitted interface is at the diode end).

No style of d.c. track circuit is permitted to abut a FS2600 track circuit, or the transmitter end of an Aster type U or SFI5 track circuit.

There are no other special restrictions when adjoining other types of track circuit, apart from the need for IRJs on both rails. Since the sharing of a common rail with other types of track circuit is thereby precluded, interfaces within S&C layouts are not achievable.

However, special precautions shall be taken where low voltage d.c. track circuits abut to higher voltage d.c. track circuits, as follows:

- Track circuits of dissimilar design shall not share a common rail.
- With double rail IRJ abutment between dissimilar d.c. track circuits, correct electrical staggering must be achieved.
- Where the difference between their clear rail voltages can exceed the rail voltage at which the lower voltage relay can pick up, the lower voltage track circuit shall be fitted with a feed end relay, to guard against IRJ failure.

2.2.10 Operating Category and Interface Delay Requirements

D.C. track circuits are categorised as Operating Category B, requiring one slow to pick-up track repeat relay (TPR) in relay based signalling systems, or standard track circuit data in Solid State Interlocking (SSI) and the equivalent in other data driven systems. Reference shall be made to the appropriate part of RT/E/S/11752 for interface delay requirements between adjacent track circuits.

3 FUNCTIONAL REQUIREMENTS

3.1 THEORETICAL OPERATION

The general operation of d.c. track circuits can be understood by reference to the equivalent circuit shown in Figure 2.

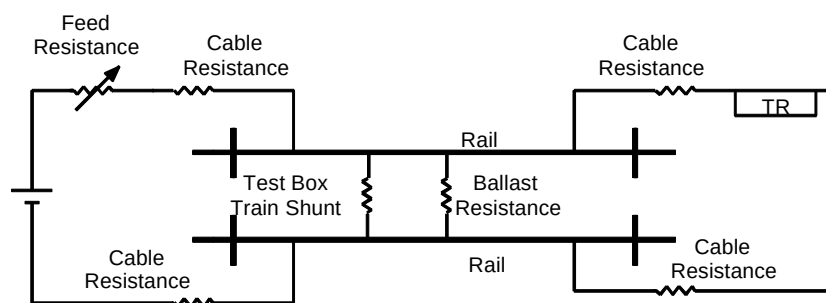


Figure 2

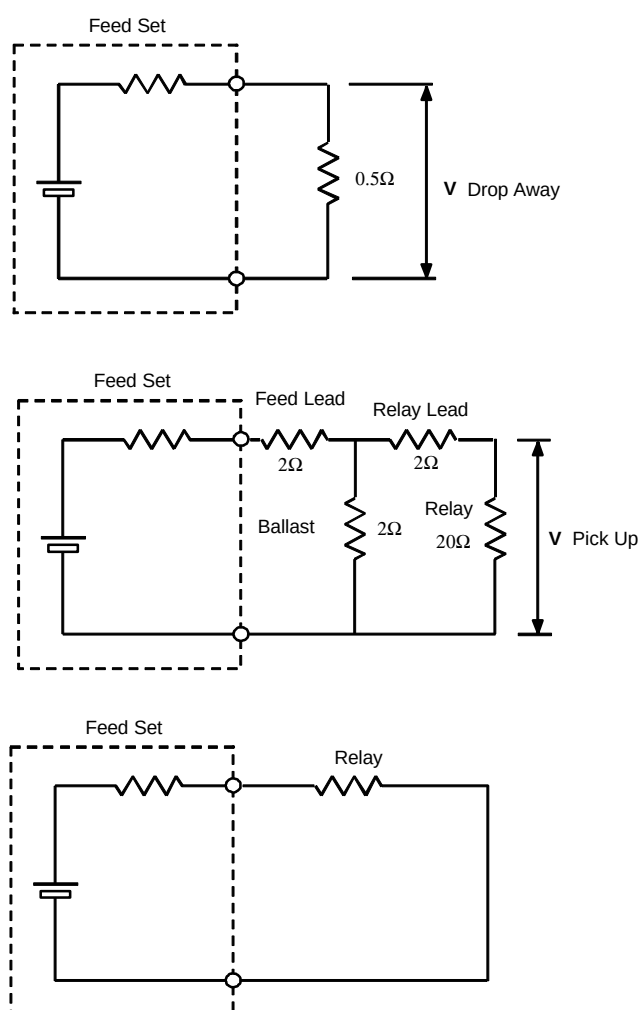
At first sight, it would appear possible to design a workable d.c. track circuit of any feed voltage whatsoever, as long as the other circuit components are chosen to complement that voltage decision. There are, however, a number of constraints which serve to limit design options:

- The track is very leaky and the ballast resistance of a clear track circuit often forms the principal load. Higher rail voltages can only be attained at the expense of excessive amounts of power dissipated in the ballast. This suggests that rail voltage must be kept as low as possible.
- If the track circuit is to function over a wide range of ballast resistance, weather induced changes in ballast resistance should have a minimal effect on rail voltage. This suggests that the feed resistance should be as small as possible.
- The feed resistance limits the current drawn from the supply when the track is occupied. If that current is to be kept low, the source voltage must also be kept as low as possible.
- The minimum operating voltage at the relay must be sufficiently greater than any d.c. interference voltage so as to avoid wrong side failures of the track circuit.

- e) When conducting a drop shunt test, the relay will drop away at a particular value of the effective resistance comprising the ballast and drop shunt resistances in parallel. Therefore, a rise in ballast resistance will reduce the value of the drop shunt, and vice versa.
- f) For any given adjustment, a reduction in ballast resistance (e.g. in wet weather) will increase the feed current and reduce the rail voltage, ultimately resulting in a right side failure.
- g) After re-adjustment to compensate for wet weather, an increase in ballast resistance as the track dries out will reduce feed current and increase rail voltage.

3.1.1 Non-adjustable D.C. Track Circuit

Reconsideration of Figure 2 shows that by specifying the relay, the maximum lead resistance and the minimum operational ballast resistance, it is possible to select values of feedset voltage and resistance which render adjustment unnecessary. The critical requirements are shown in Figure 3.

**(a) Minimum Drop Shunt**

The lowest value of drop shunt will occur when the ballast resistance is infinite and short leads offer zero resistance. Thus, when the minimum drop shunt is connected across the feedset output terminals, its terminal voltage should fall to the minimum relay drop-away voltage. Any finite ballast resistance will then give a higher drop shunt.

(b) Minimum Operational Ballast Resistance

This occurs when both feed and relay leads have maximum permitted resistance. Thus, when the depicted resistive load is applied to the feedset terminals, the relay voltage must equate to maximum pick up.

(c) Relay Power Dissipation

Maximum power is applied to the relay when the ballast resistance is infinite and the leads have zero resistance. Thus, when the relay is connected directly across the feedset terminals, the power injected into the relay must not exceed its design maximum.

Figure 3

Conditions (a) and (b) give simultaneous equations which can be solved to give the required combination of feedset voltage and resistance. It is important to understand that the (a) / (b) solution applies to a particular design of relay, as does condition (c). Therefore, the non-adjustable feedset can only be operated in conjunction with its designated relay type.

3.2 BONDING REQUIREMENTS

The limits of d.c. track circuits shall be defined by IRJs in at least one rail. In single rail mode, IRJs are provided in the insulated rail. In double rail mode, IRJs are provided in both rails. General details of bonding arrangements are contained in Part F of RT/E/S/I 1752, the following being applicable to d.c. track circuits:

3.2.1 A.C. Electrified Lines

Single rail configuration shall be used, implemented with Standard series bonding on the insulated rail and parallel Yellow traction bonding on the common rail (i.e. the traction return rail). In this mode, it shall be accepted that the traction rail bonding precludes detection of rail breakage in the common rail. The special requirements for long spurs are given in RT/E/S/11752, Part F, section 4.5.3.

3.2.2 Non-electrified Lines

The preferred configuration is double rail, implemented with Standard series bonding on both rails.

Only where the double rail configuration is impractical, generally at S&C (unless C&P, etc.), the single rail mode may be used. This shall preferably be implemented with Standard series bonding on both rails, although in complex S&C the common rail may need to be parallel bonded. The series bonded rails shall be fitted with Standard bonding and only the parallel bonded rail with Yellow Standard bonding. The special requirements for long spurs are given in RT/E/S/11752, Part F, section 4.5.3. In parallel bonded mode, it shall be accepted that the bonding precludes detection of rail breakage in the common rail.

Any proposal to convert series bonding to parallel bonding (i.e. to add Yellow bonding), perhaps to improve a residual voltage problem, shall consider the safety implications of losing broken rail detection.

3.2.3 Track Circuit Interrupters

Track circuit interrupters may be wired in series with d.c. track circuit bonding, subject to all the following conditions:

- a) The interrupter bonding carries no traction current.
- b) The interrupter bonding is of the opposite polarity to that of the rail on which the interrupter is situated, to prevent a wrong side failure from insulation breakdown (or contact with the rail after operation).
- c) The interrupter is cut into the relay end of the track circuit rather than the feed end, to prevent any residual voltage holding up the track relay if the interrupter were struck.
- d) All signals reading over the track circuit concerned are, where practicable, replaced by the track circuit becoming occupied.

- e) The operation of the one track circuit, where practicable, places or maintains at danger the necessary signals on all the adjacent lines.

Where it is not practicable to fulfil conditions d) and e), e.g. in the case of mechanically operated signals, the signals concerned shall be prevented from clearing when the track circuit associated with the interrupter is occupied.

If any of the above conditions are not fulfilled, the interrupter shall instead be provided with its own track circuit interrupter relay, which, in turn, is cut into the TPR circuit.

The general requirements for the installation and use of track circuit interrupters are contained in RT/E/S/11764.

3.3 ELECTRICAL STAGGER

The bonding layout shall be arranged so that a change of electrical polarity across all IRJs is created, the intention being that a failure of the IRJ will not create a potential wrong side failure due to the feed of one interfering with the relay of the other. The opposing voltages are meant to cancel out with the result that both track circuits fail right side.

However, where this cannot be achieved, lack of change of electrical polarity across an IRJ is permitted where the feed end of adjacent track circuits abut. In this case, the two track circuits concerned shall be of the same type and power. Any lack of correct staggering shall be recorded on the bonding plan.

Where neither polarity stagger or feed end abutment can be arranged, both track circuits shall be fitted with feed end relays.

It should be appreciated that if one track circuit has a significantly higher rail voltage than its neighbour (e.g. a BR867 and a low voltage type), the IRJ failure permits the higher voltage track circuit to swamp its neighbour. Both track circuits continue to function although the low voltage relay is operating with opposite polarity to that normally applied by its legitimate feed. The low voltage track circuit is then at risk of wrong side failure due to a single bonding disconnection.

3.4 COMMON RAIL BALANCE

Where a group of track circuits share a common rail, it is necessary to achieve an approximate balance whereby the aggregate current flowing from the common rail into the ballast approaches zero.

The requirement for electrical stagger tends to also fulfil the requirement for common rail balance, provided that all track circuits are of similar voltage / power characteristics. However, where there is a conflict, other bonding safety rules take precedence over balancing the common rail.

3.5 ALTERNATIVE CONFIGURATIONS

3.5.1 Feed End Relays TR(F)

Within reasonable limits, d.c. interference on a d.c. track circuit does not cause a malfunction provided that the bonding remains intact. It may, however, cause a wrong side failure when a single bonding disconnection occurs.

If a second track relay is separately connected across the rails at the feed end, the ability of a bonding disconnection to cause that unsafe failure is eliminated. Whilst a feed end relay can be applied to any d.c. track circuit variant, the additional load imposes a reduction in maximum permitted length and reduces the life of primary cells where fitted.

Where such a relay is fitted, the following shall apply:

- The feed end relay shall be to the same specification as the track relay (TR).
- The feed end relay shall be connected across the rails at the same position as the feed, although its connections to rail shall be independent of those used for the feed.
- Both relays shall independently control the track repeat relay (TPR) or, in the case of Solid State Interlocking (SSI) schemes, return separately to the interlocking and be combined in the data.
- There shall never be more than two track relays on one track circuit.

3.5.2 Relay End Adjustment Resistance to Increase the Sensitivity of Low Voltage Track Circuits (not for new work)

As explained in Part F of RT/E/S/11752, the ability to detect vehicles on poor rail surfaces is related to the rail voltage at which the relay drops away.

Inserting additional resistance in series with a track relay will raise the rail voltage at which it operates and therefore reduce the significance of any interference voltages present across the rails. The legitimate power fed into the track circuit will, however, have to be increased, thus imposing a reduction in maximum permitted length.

Older designs of track circuit using such as the BS 1659 (9Ω) shelf type or BR 938 (4Ω) plug-in relay directly across the rails, operate at a drop-away rail voltage below 0.3V and are therefore susceptible to loss of trainshunt under adverse conditions. They are classified as low voltage.

Low voltage d.c. track circuits can have their poor trainshunt characteristics improved by insertion of additional resistance in series with the relay, as shown in Figure 4. The rail voltage at relay drop-away is increased in sympathy with the ratio of total resistance to relay resistance.

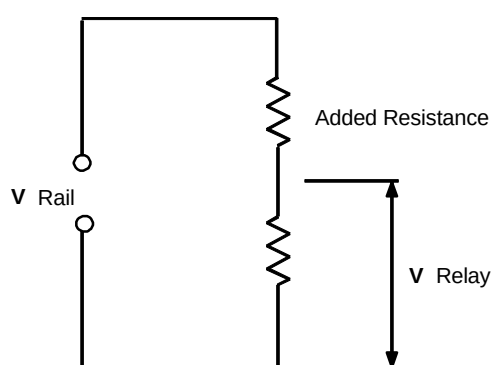


Figure 4

Inserting such a resistance raises the minimum operational ballast resistance unless more power is fed to the track. This is done by first reducing the feed resistance to a point where the feed arrangement is supplying its maximum rated current during track occupied short circuit conditions; the relay end resistance is then set to a maximum, consistent with reliable operation.

The extent of sensitivity improvement achievable by this method is limited by the output power available from the particular design of feed arrangement. Similar performance to the medium voltage relay types will not be attained unless a value of additional resistance at least equal to the relay resistance itself is achievable.

Note: The a.c. immune track relays to BR 939 (20Ω), BR 966 F2 (9Ω) and BR 966 F9 (60Ω) have drop-away values in excess of 0.7V, and have been found to operate satisfactorily under the degree of contamination typically experienced on running lines. They are classified as medium voltage.

Note: Track circuits using the BS 1659 (2.25Ω) relay are incapable of improvement in this manner.

3.5.3 Diode Track Circuit

In this design, both relay and feed are located at one end of the track circuit whilst a diode is placed across the rails at the opposite end, as shown in Figure 5. Although the design uses an a.c. immune relay, the track circuit itself is not a.c. immune and can only be used in non-electrified areas. It requires an a.c. power supply, making it more difficult to provide a standby. Its use is usually restricted to level crossing controls in rural areas, where the avoidance of lineside power distribution away from the crossing presents a significant saving.

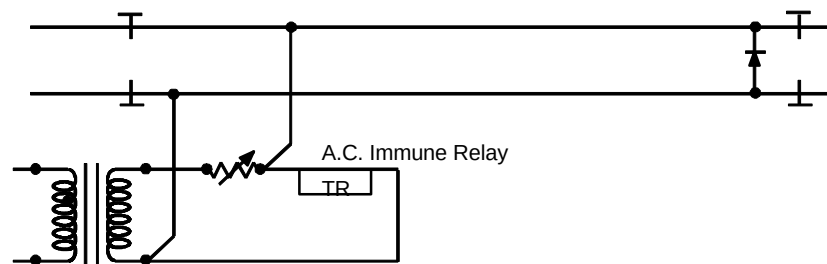


Figure 5

Power is supplied to the rails via a transformer and series adjustable feed resistance with a BR 966 F2 a.c. immune track relay connected across the feed leads.

With an open circuit diode or any other disconnection, an a.c. waveform is present on both rails / relay and the relay remains de-energised (see Figure 6).

On connection, the diode presents a near short circuit to alternate half cycles, increasing the feed instantaneous current and volt drop across the feed resistance. Thus, the rails and relay are presented with a half wave rectified waveform to which the relay responds.

The presence of a train or a short circuit failure of the diode, short circuits the relay and causes the feed power to be dissipated in the feed resistance.

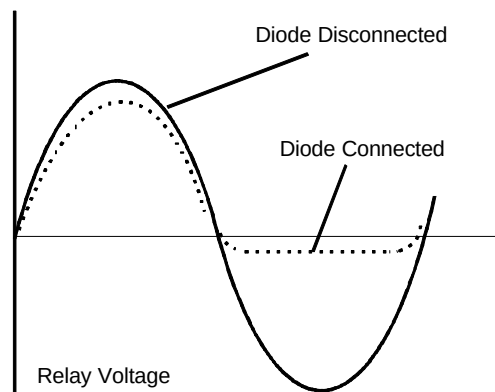


Figure 6

Note: The relay of the Diode Track Circuit does not count as a Feed End Relay, and a Feed End Relay cannot be incorporated into this design.

4 PHYSICAL REQUIREMENTS

4.1 FEED AND RELAY TAIL CABLE LEADS

All leads shall be single 2.5mm² flexible cable terminated to the rail with a moulded rubber connection; the leads may be duplicated for reliability. A disconnection box may also be utilised. If a disconnection box is used, only one track circuit may be terminated within each box. For duplicated leads, it is advisable to use a disconnection box as its use will enable continuity to the rail and renewal of cables to be accomplished without disconnection of the track circuit. A separate twin cable shall be provided from each track circuit disconnection box to the lineside apparatus housing or equipment building.

Track circuit leads are to be terminated on disconnection links at the lineside apparatus housing (using fully insulated BS 88 type carriers in electrified areas). The carriers shall be fitted with solid links, except for the insulated rail of single rail track circuits in electrified areas, which shall be fitted with 6A fuses to BS 88.

The loop resistances of tail cable leads between rail and lineside apparatus housing are not critical, although values greater than 2Ω will progressively degrade performance.

4.2 PREFERRED DESIGNS FOR NEW WORK

4.2.1 Standard A.C. Immune Track Circuit with Non-adjustable Feedset (Medium Voltage)

This track circuit uses the BR 867 feedset, which incorporates a feed resistor integral within a choke provided to achieve a.c. immunity. It shall be fed from a secure 110V 50Hz power supply and can be used in a number of different relay configurations as follows:

4.2.1.1 Basic Configuration

- See Figure 8
- Uses a single track relay complying with BR 939 20Ω
- Earlier installations used the BR 966 F2 9Ω relay but this shall not be used for future work, except where essential to retain design uniformity.

4.2.1.2 Basic & Feed End Relay

- See Figure 9
- An additional relay at the feed end obviates the need to comply with the residual interference voltage limitations.
- Both feed and relay end relays shall be of the same type.

4.2.1.3 Basic & Relay Adjustable Resistor

- See Figure 10
- BR 3000 Appendix 2 adjustable resistor in series with the relay improves tolerance to residual interference voltage as well as improving detection with poor vehicles and / or surfaces.

4.2.1.4 Basic (substituting 60Ω Relay)

- See Figure 8
- BR 966 F9 60Ω relay improves tolerance to d.c. traction interference.
- Useful on a.c. lines where d.c. interference is marginal.
- The rail voltage of all configurations is adequate for the detection of Class 14X - 16X lightweight vehicles.
- The maximum operational lengths are dependent upon the configuration used and minimum ballast resistance that can be expected as shown in Figure 7.

Configuration	Length (Timber)	Length (Concrete)
9Ω TR only	700 metres	1200 metres
9Ω TR & Feed End Relay	500 metres	750 metres
9Ω TR & Relay Adj. Resistor	350 metres	500 metres
20Ω TR only	700 metres	1200 metres
20Ω TR & Feed End Relay	600 metres	900 metres
20Ω TR & Relay Adj. Resistor	350 metres	500 metres
60Ω TR only	250 metres	350 metres

Figure 7

D.C. Track Circuits

Note: Where d.c. track circuits are fitted to a.c. electrified lines, additional length restrictions which limit the traction interference are applicable:

- Track circuits using 20Ω relays to BR 939, are to be a maximum of 1000m in length.
- Track circuits using 9Ω relays to BR 966 F2, are to be a maximum of 680m in length.
- Track circuits using any other type of track relay, are to be a maximum of 600m in length.

These limits will require reassessment where new types of rolling stock are introduced.

Prioritisation of retrospective action shall be on the basis of exposure to risk from transformer inrush currents or poor traction current collection due to high speed running or overhead line conditions (see section 6.2 on Immunity from D.C. Interference).

However, on main lines where the track has been well maintained and this can be foreseen to continue, it may be possible to operate track circuits over greater distances. In a.c. electrified areas, any such length extension shall also be compatible with traction interference requirements.

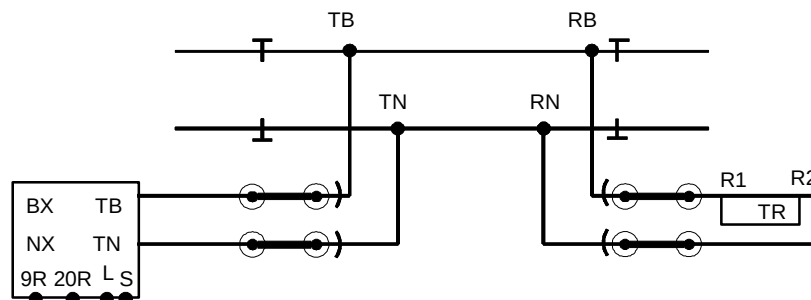


Figure 8

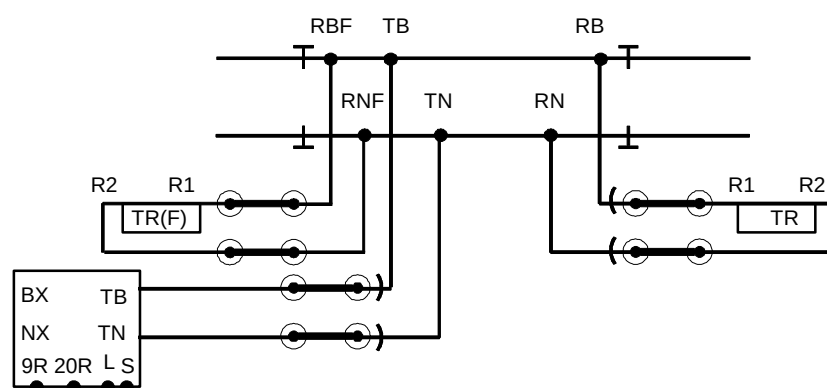


Figure 9

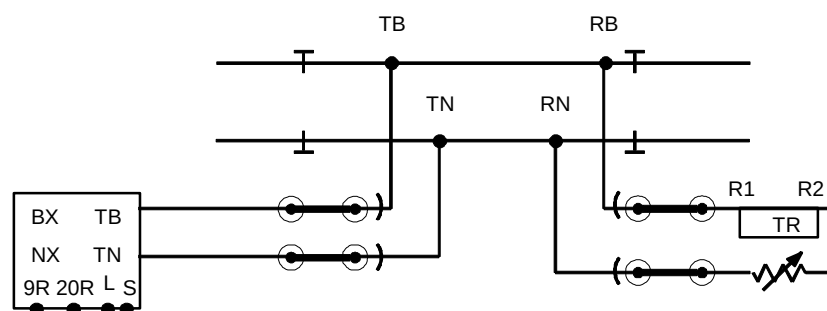


Figure 10

Note: In a.c. electrified areas, the links in the insulated rail legs are replaced with 6A fuses (type TIA6).

4.2.2 Standard A.C. Immune Track Circuit with Battery Standby (Medium Voltage)

This design uses the BR 939 20Ω relay but with a 12V battery charger / cells for the power supply. The same choke as fitted to the BR 867 feedset is used for a.c. immunity together with a BR 3000 Appendix I adjustable feed resistor.

It is suitable in non-electrified areas without secure power supply, either generally or where there is a localised risk of a.c. interference caused by point heaters or shore supplies for carriage heating.

4.2.2.1 Basic Configuration

- See Figure 12
- Uses a single track relay complying with BR 939 20Ω.