

Ref	NR/PS/SIG/11757
Issue	I
Date	December 2000

A.C. Phase Sensitive Track Circuits (formerly RT/E/PS/11757)

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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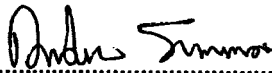


RAILTRACK LINE PRODUCT SPECIFICATION

A.C. PHASE SENSITIVE TRACK CIRCUITS

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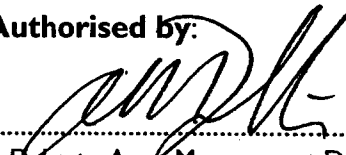
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Railtrack plc
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Euston Square
LONDON
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Summary

This Line Specification states the minimum requirements for a.c. phase sensitive track circuits. It includes lifecycle requirements from design, safety and environmental to installation, testing and maintenance.

Issue/Revision Record

Issue	Date	Comments
1	December 2000	New Specification. The contents are based on Railway Group Codes of Practice GK/RC0757, GK/0758 and GK/RC0759 which are to be transferred to Railtrack Line in February 2001.

Implementation

The requirements of this Specification shall apply to all a.c. phase sensitive track circuits supplied for use on Railtrack controlled infrastructure on or after 3 February 2001. It shall also apply to the alteration and maintenance of existing a.c. phase sensitive track circuits from the same date. The following documents are superseded:

Superseded Documents

GK/RC0757, Issue 1, Dec 98 - 50Hz A.C. Track Circuits

GK/RC0758, Issue 1, Dec 98 - 83 $\frac{1}{3}$ Hz A.C. Track Circuits

GK/RC0759, Issue 1, Dec 98 - VTI (SP) A.C. Track Circuits

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I INTRODUCTION

I.1 PURPOSE

This Product Specification gives details of best practice in respect of a.c. phase sensitive track circuits in order to achieve the requirements of RT/E/S/I 1752.

I.2 SCOPE

The contents of this Product Specification apply to a.c. phase sensitive track circuits, and shall be read in conjunction with RT/E/S/I 1752. The following forms of a.c. track circuit are included:

- 50Hz a.c. track circuit,
- $83\frac{1}{3}$ Hz a.c. track circuit,
- VTI (SP) track circuit.

It does not include non-frequency selective a.c. track circuits, such as the quick release type.

I.3 INTRODUCTION

50Hz a.c. track circuits are used where immunity from only d.c. traction current interference is required.

In areas where immunity from both d.c. and 50Hz a.c. traction currents is required, the $83\frac{1}{3}$ Hz track circuit may be used, but other options include reed, TI.2I and HVI track circuits. See RT/E/S/I 1752, Part H, for choice of track circuit types.

Other frequencies of a.c. track circuit, such as $33\frac{1}{3}$ Hz, 75Hz or 125Hz, give limited immunity to 50Hz, but these shall not be installed in connection with new schemes on Railtrack controlled infrastructure. The principles of operation are similar to those of the $83\frac{1}{3}$ Hz track circuit.

The VTI (SP) a.c. track circuit has been designed to replace standard single rail 50Hz a.c. track circuits in limited situations where compatible electric traction units have been authorised to run (e.g. class 373 trains). These track circuits give immunity from d.c. traction current interference only.

I.4 FEATURES

The principle feature of the a.c. track circuit is the double element vane relay and its operational characteristics which are described in section 3.1.

1.4.1 50Hz Track Circuits

50Hz a.c. track circuits can be used in either single rail or double rail configuration as required by the track layout and traction return current arrangements.

1.4.2 $83\frac{1}{3}$ Hz Track Circuits

The first types of $83\frac{1}{3}$ Hz a.c. track circuits operated from a two phase $83\frac{1}{3}$ Hz supply, one phase (phase U) being unscreened and the other (phase S) being screened. A phase difference of 90° existed between the two.

The $83\frac{1}{3}$ Hz a.c. supply was generated by central motor generator sets. The unscreened phase was generated at 650V and fed through unscreened cables to the lineside equipment housings where it was stepped down to 110V before being fed to the track and then to the control coil of the relay. The screened phase was generated at 110V and fed to the local coil of the relay. In all cases, the power supplies and track relays were situated in equipment buildings thereby confining the screened phase entirely to the building. This considerably reduced the likelihood of contamination of the phase by 50Hz interference.

Due to the impracticability associated with the original arrangement, in ensuring the long feed cables from a central supply point are free from 50Hz contamination and the widespread reliability implications of a single motor/generator failure, the $83\frac{1}{3}$ Hz a.c. supply is currently provided by a local static frequency inverter which operates from the general 50Hz a.c. signalling supply.

$83\frac{1}{3}$ Hz a.c. track circuits can be used in either single rail or double rail configuration as required by the track layout and traction return current arrangements. Single rail track circuits only are described in this Specification due to the absence of any known double rail installations.

1.4.3 VTI(SP) Track Circuits

VTI(SP) a.c. track circuits are approved for use in single rail configuration only. Where double rail track circuits are required, an alternative type of track circuit shall be used. The equipment can be installed as a completely new track circuit or as a conversion of an existing 50Hz a.c. single rail track circuit.

2 APPLICATION AND CONSTRAINTS

2.1 APPLICATION

The application of a.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.

2.2 CONSTRAINTS

The following constraints apply to the use of a.c. track circuits, in addition to the general restrictions given in RT/E/S/11752:

2.2.1 General

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

- 50Hz a.c. track circuit,
- $83\frac{1}{3}$ Hz a.c. track circuit,
- VTI (SP) track circuit.

A.C. track circuits may be used in single or double rail configuration. However, VTI (SP) track circuits are only approved for use in single rail configuration.

The following general restrictions apply:

- a) A.C. track circuits shall only be provided in jointed form and arranged so that trains usually run on to the relay end first. On bi-directional lines, any predominance of direction shall be taken into account. However, staggering rules take precedence (see section 3.3).
- b) There are no special restrictions when abutting with other types of track circuit, apart from the need for IRJs on both rails.
- c) 50Hz and $83\frac{1}{3}$ Hz 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 Part F of RT/E/S/11752 for interface delay requirements between adjacent track circuits. The special requirements for interfacing with FS2600 track circuits are given in RT/E/S/11760.

- d) Due to their very slow to pick-up characteristics, VTI (SP) track circuits have special interface delay requirements and limitations on minimum length (see section 3.4.2). This also applies to a conventional a.c. track circuit abutting a VTI (SP) track circuit.
- e) A.C. track circuit bonding shall not be wired in series with track circuit interrupters. A separate relay circuit shall be provided in accordance with RT/E/S/11764.

2.2.2 Single Rail Track Circuits

- a) All track circuits less than 100m in length should generally be designed as single rail track circuits, due to adjustment difficulties associated with short double rail track circuits (but see section 2.2.4.b).
- b) Single rail track circuits must not exceed 200m without the agreement of the Infrastructure Controller except in terminal platforms where a maximum length of 300m is permitted.
- c) In electrified areas, 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).
- d) Single rail track circuits are not generally acceptable over level crossings due to the effects of road debris and salt on ballast resistance. Pre-fabricated crossing units can also cause unpredictable variations in operating values.
- e) In electrified areas, double rail reed or TI.2I track circuits must not be allowed to be surrounded by an area of a.c. single rail track circuits, e.g. on a loop line, as described in the appropriate Track Circuit Product Specification.
- f) Where 50Hz a.c. track circuits are used through S&C equipped with electric point heaters, the heaters must be fed from a d.c. supply, or separate isolated a.c. supplies to an approved design.
- g) In conductor rail electrified areas, protection boarding shall be fitted where specified in RT/E/S/11752, Part C.
- h) The VTI (SP) relay and delay unit must be fed only from the 110V a.c. signalling supply.

- i) A maximum of three $83\frac{1}{3}$ Hz track circuits may be operated from one inverter provided that they are not all of maximum length. As a general guide, the total feed capacitance connected to one inverter should not exceed 45 μ F. All track relays that are fed from a common inverter shall be contained in the same location.
- j) In a.c. electrified areas, the traction return rail shall, wherever practicable, be positioned on the cess side to enable structure bonds to be kept short.

2.2.3 Double Rail Track Circuits without Impedance Bonds

The provisions for single rail type apply, except that the track circuit is fully isolated with IRJs and there is no common rail. The length restriction does not apply, but this configuration is not suitable for use in S&C.

This design of track circuit is used in the following situations:

- in fourth rail d.c. electrified areas (but not for interrunning of third and fourth rail trains, where single rail track circuits are used, with the common rail bonded to the traction return fourth rail),
- where a d.c. electrified area abuts a non-electrified area, requiring a d.c. immunity zone of at least 800m. Part F of RT/E/S/I 1752 explains that IRJs on both rails are required throughout the immunity zone,
- in non-electrified areas (but note restrictions with lightweight vehicles in section 2.2.5.b).

2.2.4 Double Rail Track Circuits with Impedance Bonds

- a) Except for the situations described in section 2.2.3, impedance bonds are always required for double rail track circuits in electrified areas. 50Hz track circuits are not permitted for use in a.c. or dual electrified areas. General track circuit restrictions in electrified areas are given in Part F of RT/E/S/I 1752.
- b) Track circuits using double rail series bonding should be the first choice on plain line for track circuits longer than 100m (see section 2.2.2.b). However, if a shorter double rail track circuit is necessary, a single rail feed transformer should be used in reverse mode, i.e. with the low voltage winding feeding the track.
- c) Double rail a.c. track circuits are not suitable for use in S&C.
- d) Careful attention shall be given to traction current balance by equalising rail resistance in cases of curves and check rails (see RT/E/S/I 1765).

- e) Traction return cross bonding and the siting of impedance bonds shall be in accordance with RT/E/S/11765.
- f) It has been found that particular combinations of relay type and impedance bond type are inherently more difficult to set up correctly and shall be avoided, as they are likely to be more susceptible to traction interference. In particular, the combination of G4 relay and either type 2 or type 3 impedance bonds **must not** be used (see RT/E/S/11765).
- g) Two impedance bonds in the same track circuit less than 100m apart must be avoided where possible, since resonance between the two impedance bonds makes adjustment of the track circuit very difficult.
- h) Due to the difficulties in co-ordinating adjustment at various locations along the track, a.c. double rail track circuits are to be limited to 1800m in length, with a maximum of 2 intermediate impedance bonds, although existing designs may be found up to 2475m.
- i) In a.c. electrified areas with double rail track circuits, structure bond connections shall be made to impedance bonds.

2.2.5 Compatibility with Types of Traction Unit

a) Electric Traction

50Hz and VTI (SP) track circuits give immunity to d.c. traction, but are not permitted in a.c. or dual electrified areas. $83\frac{1}{3}$ Hz track circuits may be used in all electrified areas.

However, the introduction of traction units incorporating a.c. asynchronous, three phase and inverter drives, e.g. Networker, Class 373, Class 323 and Class 92, has created new track circuit interference risks arising from the wide frequency spectrum over which such units are capable of generating interfering current. The possibility of false operation of the track relay by 50Hz traction interference is greatly reduced by the use of VTI (SP) track circuits. See section 6.3 on traction immunity.

General restrictions for use in electrified areas are given in RT/E/S/11752.

b) Lightweight Vehicles and Others Susceptible to Poor Train Shunt

A.C. phase sensitive track circuits are not generally permitted on non-electrified lines used by lightweight vehicles in Classes 14X to 16X or other modern rolling stock designated as susceptible. However, these types of track circuit may be used in the following circumstances:

- on uni-directional lines,

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- where sequential track circuit proving is provided, or
- where an assessment shows that all susceptible vehicles permitted to use the line are fitted with Track Circuit Assisters (TCAs).

3 FUNCTIONAL REQUIREMENTS

3.1 PRINCIPLES OF OPERATION

3.1.1 Double Element Vane Relay

The relay is comprised of a thin aluminium vane which is pivoted on a spindle and able to rotate. Buffer stops are provided to limit the travel in either direction and a mechanical linkage enables the electrical contacts to operate in sympathy with the vane rotation.

A counterbalance action ensures that the vane and contacts assume the track circuit occupied position in the absence of any torque on the vane i.e. the back contacts are made.

The general arrangement of vane and contact assembly is shown in Figure 1.

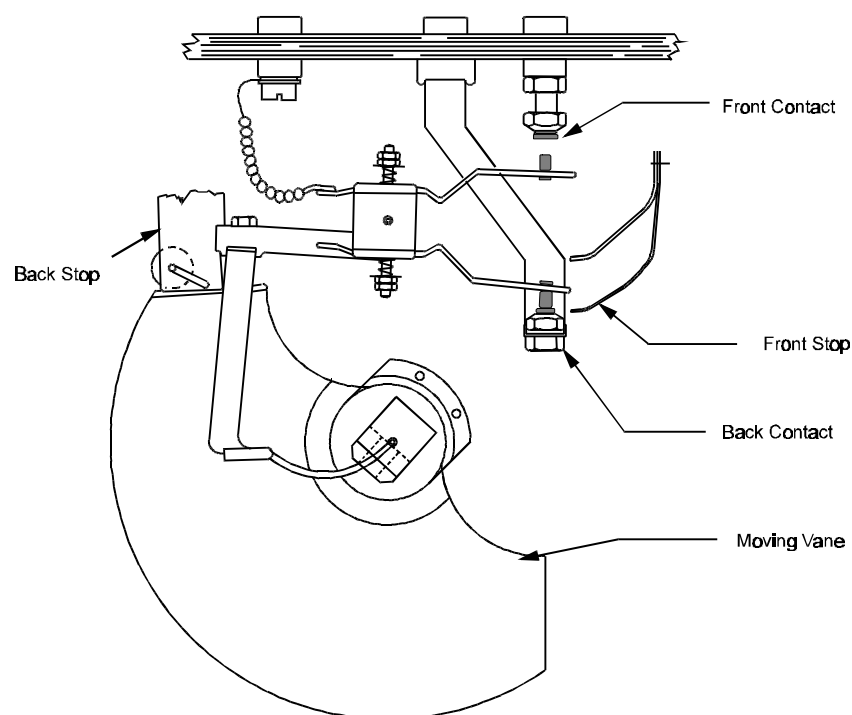


Figure 1 - Double Element Vane Relay Assembly

Torque to rotate the vane to the energised position is provided by the interaction of two coils whose a.c. magnetic fields (Φ_L & Φ_C) induce eddy currents in the vane.

The local coil (TQ) is permanently connected to a 110V a.c. supply whilst the control coil (TR) receives its energy from the track circuit itself (1V to 3V a.c. depending on type).

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The local coil (TQ) induces continuous eddy currents in the vane, but no mechanical torque results if the control coil remains de-energised. The counterbalance action of the vane ensures that the relay remains on its backstop.

The arrangement is shown in Figure 2.

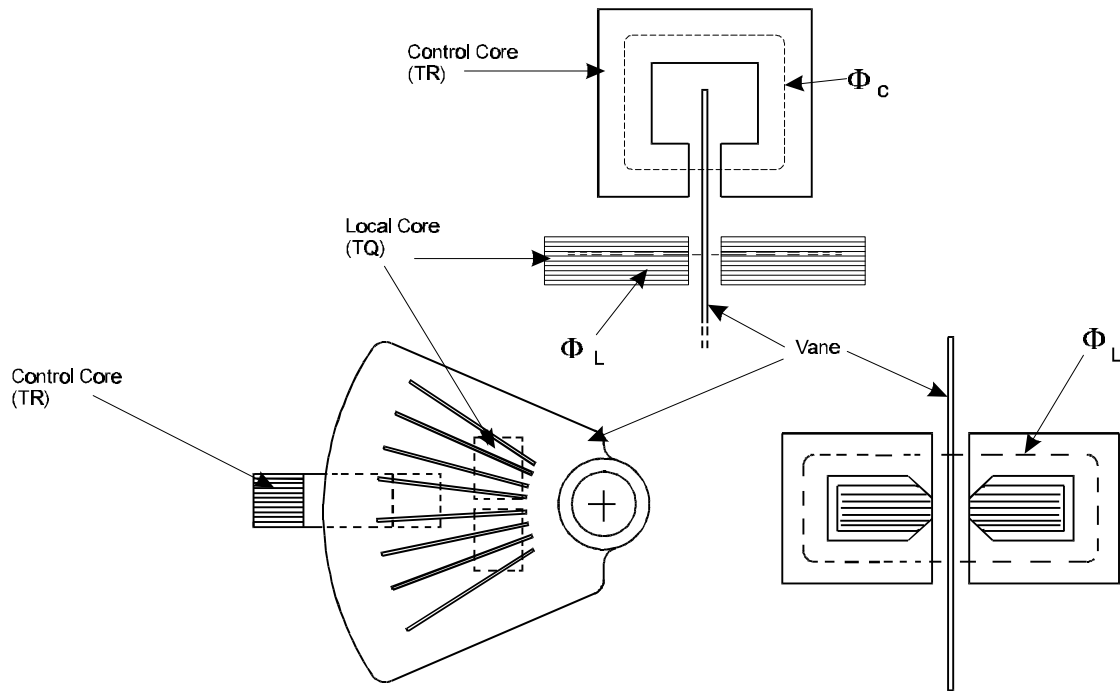


Figure 2 - Double Element Vane Relay Coil Arrangement

When the second a.c. voltage is applied to the control coil (TR) by the track circuit, a steady mechanical torque is applied to the vane if the frequency is identical to that on the local coil and there is a suitable phase difference between the two. The torque is proportional to:

Local Voltage x Control Voltage x Sin (Local-Control Phase Angle).

Thus the torque reaches a maximum when there is a phase difference of 90° between the two voltages and falls to zero when the voltages are in-phase or anti-phase. The direction of any torque will depend upon whether the control voltage lags or leads the local voltage.

When used within a track circuit, due to leakage of current through the ballast and the inductance of rails, it is not practicable to achieve a 90° phase angle. To improve the operation of the track circuit, most designs of relay presently in use, incorporate an internal tuning capacitor connected across the control coil, or across a third (tertiary) winding to partially compensate for this effect. The value of the capacitor is selected to achieve parallel resonance with the control or tertiary coil inductance at the track circuit operating frequency. This results in an apparent increase in control coil impedance and also reduces the effect of phase shift due to track inductance and ballast leakage.

To compensate for the reduction to a more achievable phase angle of 70° - 75° , a working control voltage of approximately 25% above nominal must be applied. This raised voltage, associated with a good phase angle also allows for mains frequency and/or voltage variations.

The maximum applied voltage must not exceed 60% above the nominal value.

Note: The track circuit feed supply must be derived from the same lineside power supply as that applied to the local coil in order to maintain a constant phase angle.

3.2 BONDING REQUIREMENTS

The limits of a.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 RT/E/S/11752, the following being applicable to a.c. track circuits:

The preferred configuration is double rail, implemented with series bonding on both rails to traction standards.

Only where the double rail configuration is impractical, such as in S&C or short track circuits, the single rail mode may be used. This shall preferably be 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.

3.3 ELECTRICAL STAGGER

When designing the bonding for a new scheme or modifying an existing scheme, the correct electrical stagger of the track circuits, so as to detect IRJ failures where necessary, must be considered. It is normally impracticable for the designer to pre-determine the phase relationship between adjacent track circuits and it is therefore necessary for the commissioning engineer to check for effective electrical stagger and correct where necessary. However, the designer shall check a layout to minimise the number of occasions where correct stagger may be unachievable.

In order to assist commissioning staff when setting the correct stagger in complicated areas, designers shall make use of the arrangements shown in Figure 3 wherever necessary. These are shown for single rail track circuits (for double rail track circuits, a transposition within one track circuit can be used to ensure correct stagger at each end).

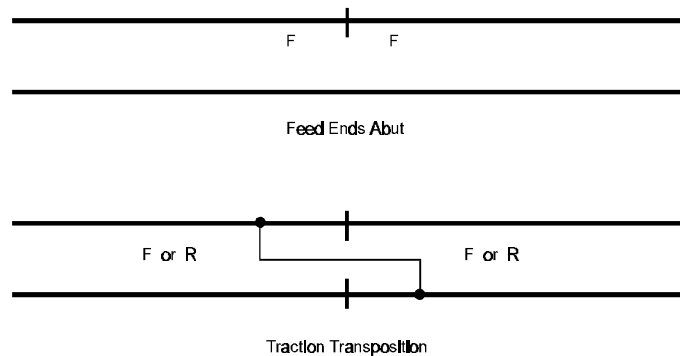


Figure 3 - Arrangements for Electrical Staggering

At any location where correct stagger cannot be achieved, feed ends must abut. This takes precedence over the aim to ensure that trains usually run on the relay end first.

At any location where two abutting track circuits are fed from separate power sources or a power source arrangement which cannot guarantee a stable phase relationship, the feed ends must abut.

Where abutting $83\frac{1}{3}$ Hz track circuits are fed from the same inverter, correct stagger shall be ascertained by carrying out the appropriate IRJ shorting test as described in section 10, Testing Procedures. Where abutting track circuits are fed from different inverters, correct stagger cannot be guaranteed due to the possibility of frequency drift and the joints shall be treated as unstaggered.

The arrangements for unstaggered joints must be in accordance with Part F of RT/E/S/11752.

3.4 ALTERNATIVE CONFIGURATIONS

3.4.1 $83\frac{1}{3}$ Hz Track Circuit Static Frequency Invertor

The main differences with the $83\frac{1}{3}$ Hz track circuit occur due to the generation and distribution of the $83\frac{1}{3}$ Hz supply.

The static frequency invertor is designed to produce two isolated in-phase outputs of $83\frac{1}{3}$ Hz a.c. at 110V.

The complete invertor is split into three separate units for ease of transport and maintenance:

- Control Transformer Chassis.
- Local Transformer Chassis
- Electronics Chassis.

The three units are electrically interconnected by means of plugs and sockets.

The control transformer chassis and local transformer chassis contain the 50Hz input circuits and all other transformers associated with the control and local phases respectively.

The electronics chassis contains the semi-conductor devices for the control and local phases, the timing and driver units, three style "R" proving relays and a style "S" pulsing relay.

The units are mounted as shown in Figure 4.

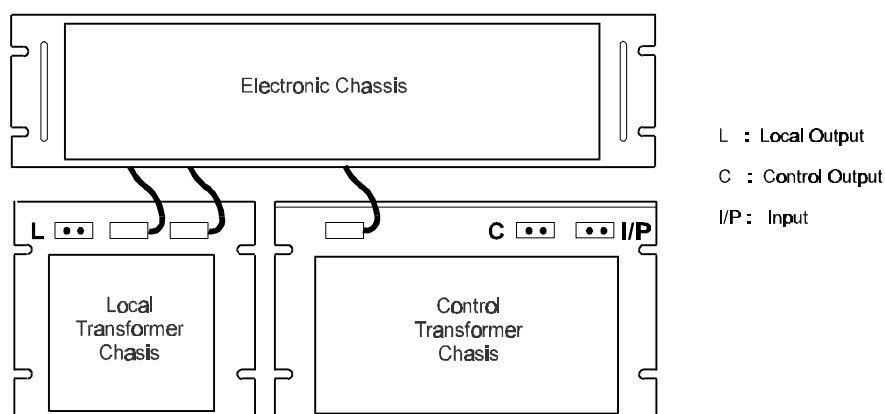


Figure 4 - Static Frequency Invertor Mounting

3.4.2 VTI(SP) Track Circuit Operation

The VTI(SP) a.c. track circuit uses the same principles of operation as the 50Hz a.c. vane relay type track circuit but with two main differences:

- The introduction of a delay of at least 2 seconds before the track circuit clears after removal of the train shunt;
- De-sensitisation of the track circuit by an increased rail voltage and the introduction of series resistance at the relay end.

These features are achieved by re-wiring or replacing the feed transformer (when converting an existing 50Hz a.c. track circuit) and by the installation of the following equipment:

- VTI(SP) Relay;
- VTI(SP) Delay Unit;
- 60 μ F Feed Capacitor;
- Relay End Resistor.

The VTI(SP) a.c. track circuit does not fall within the standard group of operating characteristics due to its very slow to pick up and medium to drop away operating times. To overcome the problem of abutment with other types, two tables have been produced to enable the calculation of the minimum length of track circuit following a VTI(SP). In each of the tables, the minimum track circuit length can be obtained by multiplying the time given by the permissible speed for the route in metres per second (i.e. mph x 0.447). The table in Figure 5 shows comparisons of speeds in mph and m/s.

mph	m/s		mph	m/s
10	4.5		70	31.3
20	8.9		80	35.8
30	13.4		90	40.2
40	17.9		100	44.7
50	22.4		110	49.2
60	26.8		120	53.6

Figure 5 - Speed Conversion Table

The table in Figure 6 is applicable to Free-Wired, Westpac and GEC Geographical Interlockings.

		Times for Starting TC Type		
Timing Category	Following TC Type	VTI(SP)	VTI(SP)+1 TPR	VTI(SP)+2 TPRs
A	TI.2I	3.3s	3.9s	4.5s
#	VTI*	Banned	Banned	Banned
B	VTI+1 TPR	4.6s	5.2s	5.8s
B (with C)	VTI + 2 TPRs	4.0s	4.6s	5.2s
C	HVI + 2 TPRs	4.1s	4.7s	5.3s
#	VTI(SP)	3.3s	3.9s	4.5s
#	VTI(SP) + 1 TPR	No Restriction	3.3s	3.9s
#	VTI(SP) + 2 TPRs	No Restriction	No Restriction	3.3s

* Banned in all circumstances.

Not within a Timing Category.

Figure 6 - Operating Characteristics for Relay-Based Signalling System

An example calculation of minimum track circuit length is shown below:

Assuming a route speed of 80mph in a free-wired interlocking area, the minimum track circuit length of a TI.2I track circuit when preceded by a VTI(SP) track circuit with one TPR, can be obtained by multiplying the appropriate time from Figure 6 (3.9s) by the route speed in m/s from Figure 5 (35.76) i.e. minimum length of track circuit is $3.9 \times 35.76 = 139.464\text{m}$, say 140m.

The table in Figure 7 is used in the same way for areas with SSI Interlocking.

		Times for Starting TC Type	
Timing Category	Following TC Type	VTI(SP)	VTI(SP) + Extra Delay
A	TI.2I	No Restriction	4.9s
B	VTI*	Banned	Banned
B (with C)	VTI + extra delay	4.8s	5.8s
C	HVI + extra delay	4.9s	5.9s
#	VTI(SP)	3.9s	4.9s
#	VTI(SP) + extra delay	No Restriction	3.9s

* Banned in all circumstances.

Not within a Timing Category.

Figure 7 - Operating Characteristics for Solid State Interlocking

3.4.3 Track Relay Converted for Use as Stagework Repeater Relay

When it is necessary to operate a track relay as a stagework TPR, the appropriate circuit as indicated in Figure 8 must be used. An allowance of 25VA loading shall be made for each. Where line circuits result, they must be double cut.

Relay Type	Figure
WSL Style G2 or G4	9 or 11
WSL Style VT1	10 or 11
SGE Style CE 391	12

Figure 8 - Stagework Circuits for Different Relays

Figure 9 shows the circuit when using WSL Style G2 or G4 track relays

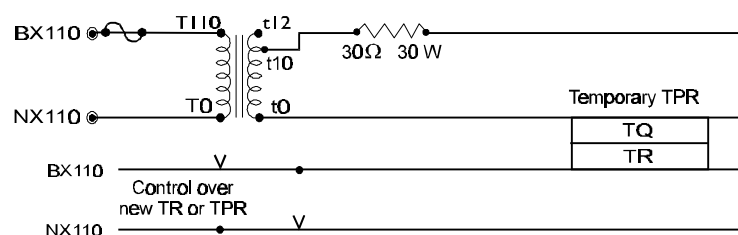


Figure 9 - Stagework Circuit for WSL Style G2 or G4 Track Relay

The components used are as follows:

- 30 W, 30W Resistor, Railway Catalogue No. 54/84734
- 110/12V 35VA Transformer, Railway Catalogue No. 54/89710

Note: A redundant signal head transformer may be used to avoid ordering new equipment.

The resistor is to be mounted in a fuse clip.

Should a group of track relays in the same equipment building or lineside apparatus housing require conversion to stageworks TPRs, a common transformer of suitable rating may be used, with a separate resistor to each relay.

Figure 10 shows the circuit when using WSL Style VT1 track relays.

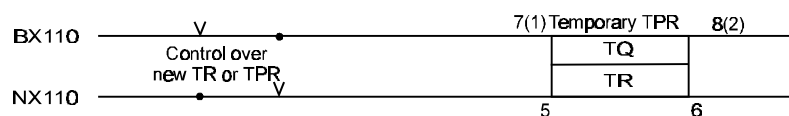


Figure 10 - Stagework Circuit for WSL Style VTI Track Relay

The VTI relay used must be fitted with an internal capacitor.

An alternative arrangement to those shown in Figures 9 and 10 is shown in Figure 11. This arrangement may be used for short periods not to exceed 6 weeks.

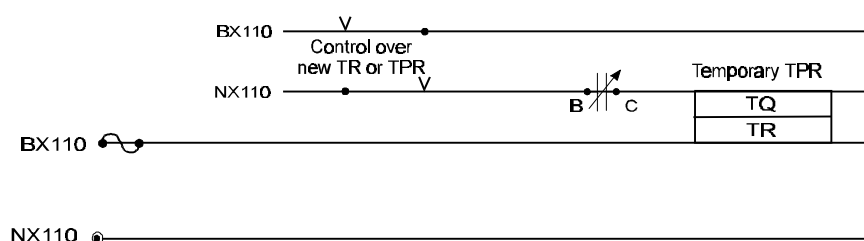


Figure 11 - Short Term Stagework Circuit

The capacitor used is the 20 μ F variable capacitor set to give the track relay a good action with readings similar to those of a single rail track circuit.

Figure 12 shows the circuit when using SGE Style CE 391 track relays.

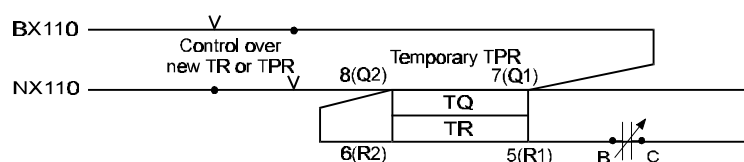


Figure 12 - Stagework Circuit for SGE Style CE391 Track Relay

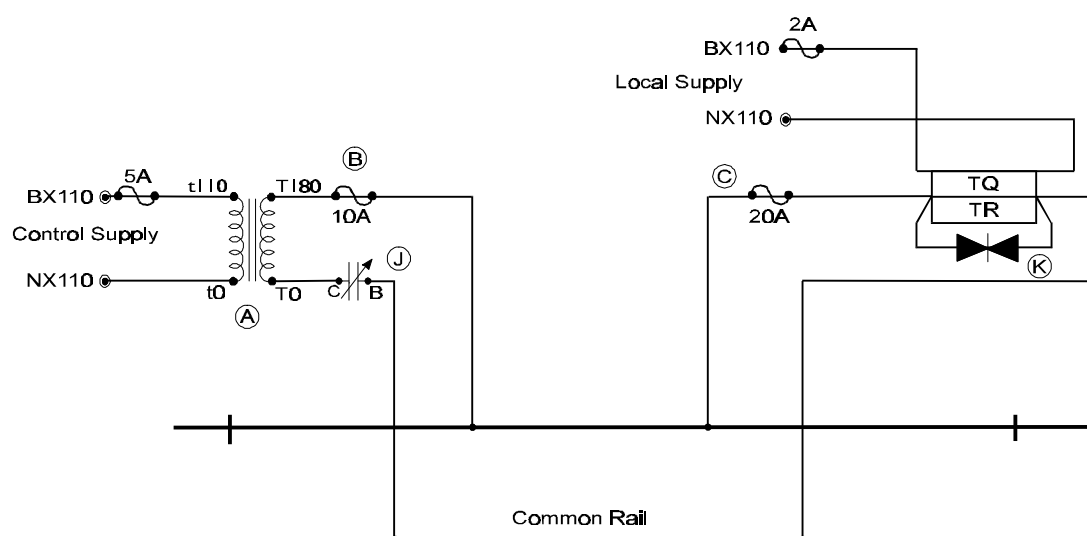
The capacitor used is 12.3 μ F variable, capacitor adjusted to approximately 10 μ F.

4 PHYSICAL REQUIREMENTS

4.1 EQUIPMENT AND CIRCUITRY

4.1.1 Single Rail 50Hz Track Circuits

The typical arrangement of a single rail a.c. track circuit is shown in Figure 13.



Note: track cable terminations not shown (see section 7.2.1).

Figure 13 - Single Rail 50Hz Track Circuit

A feed transformer (A) isolates the track circuit and provides initial voltage step up and adjustment. The supply is fed to the rails via a traction rated 10A fuse (B) and a 20μF adjustable feed capacitor (J).

The capacitor (J) in the track feed circuit ensures that the control current in the rails leads the 110V local supply voltage by approximately 90°; (inductance of the rail and track cables causes a modest reduction).

The voltage from the rails is fed to the control coil (TR) via a traction rated 20A fuse (C) and is out of phase with the local supply voltage applied to the local coil (TQ) by approximately 90°. Therefore, torque is created in the vane and the relay energises if the control coil voltage is high enough.

A stabilising rectifier (K) is connected across the control coil of the relay to provide suppression of transient voltages. See the section 6.3 on Immunity from Traction Interference.

The connections to the rails at both the feed and relay end must be in the same phase relationship. The connections may be reversed to amend the electrical stagger of the track circuit, in which case, the reversal of connections must be carried out at both ends of the track circuit to maintain the phase relationship between the rail voltage and the supply to the local coil of the relay. The wiring shall be reversed at the secondary of the transformer and at the control coil of the relay. A reversal at only one end will cause the relay vane to attempt rotation in the wrong direction, forcing it against its back stop.

Single rail track circuits are arranged so that trains usually run on to the relay end first. On bi-directional lines, any predominance of direction shall be taken into account.

4.1.2 Double Rail 50Hz Track Circuits without Impedance Bonds

The circuitry and equipment is identical to single rail track circuits except that they are fully isolated with IRJs and there is no common rail.

4.1.3 Double Rail 50Hz Track Circuits with Impedance Bonds

On double rail track circuits, the traction current by-passes the IRJs via impedance bonds, while the track circuit current is contained within the limits of the track circuit by the IRJs.

Double rail track circuits are arranged so that trains usually run on to the relay end first. On bi-directional lines, any predominance of direction shall be taken into account.

A typical wiring diagram is shown in Figure 14:

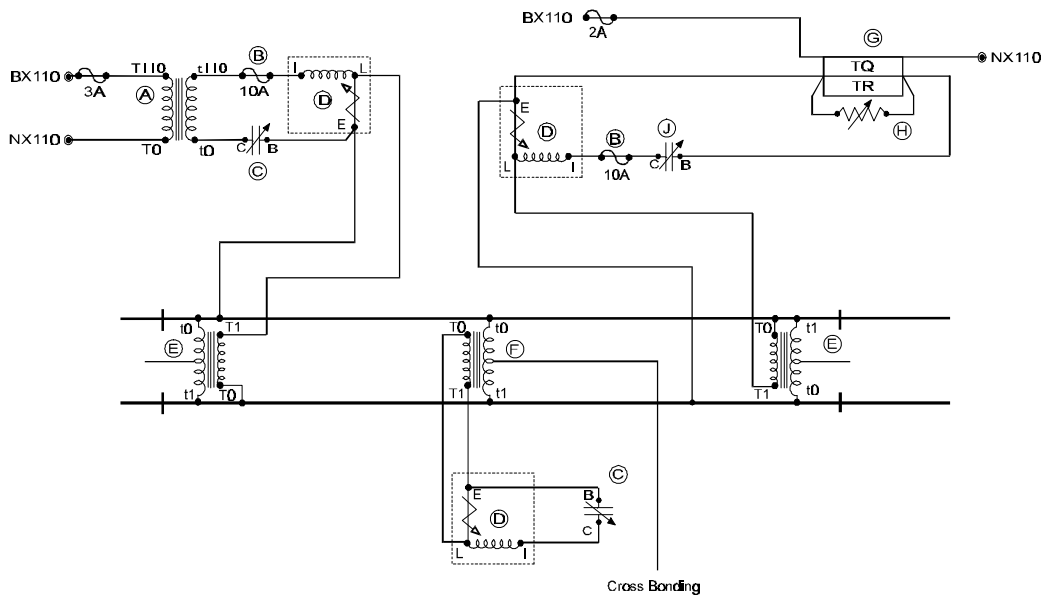


Figure 14 - Double Rail 50Hz Track Circuit with Impedance Bonds

At the feed end, the supply transformer (A) and the adjustable 12.3 μ F capacitor (C) are connected to the impedance bond (E) via a 10A traction rated fuse (B) and a surge arrester (D). The impedance bond is configured as an auto transformer and the capacitor is adjusted to achieve series resonance.

WARNING: Voltages over three times greater than the supply voltage will appear across the capacitor and the windings of the impedance bond. Due to the low number of turns on the traction winding, a small proportion of the enhanced voltage appears across the rails.

An intermediate impedance bond (F) may be provided in connection with traction cross bonding. It is tuned to parallel resonance by a 12.3 μ F adjustable capacitor (C) connected across the auxiliary winding via a surge arrester (D).

At the relay end, the impedance bond (E) is connected as an auto transformer via a surge arrester (D) to the track relay control coil (G) via a 10A traction rated fuse (B) and a 20 μ F adjustable capacitor (J) which is provided to control the phase angle of the voltage applied to the relay. A variable resistor (H) is connected across the control winding in order to facilitate adjustment of the voltage and change the drop shunt, without significantly affecting its phase angle.

Where the apparatus housing is remote from the track connections, the surge arrester must be located at the tail cable terminations nearest to the rail connections.

4.1.4 Single Rail $83\frac{1}{3}$ Hz Track Circuits

Figure 15 shows the typical arrangement for a single rail $83\frac{1}{3}$ Hz track circuit in an a.c. electrified area. For fusing arrangements on d.c. electrified areas, refer to section 4.3.

A.C. Phase Sensitive Track Circuits

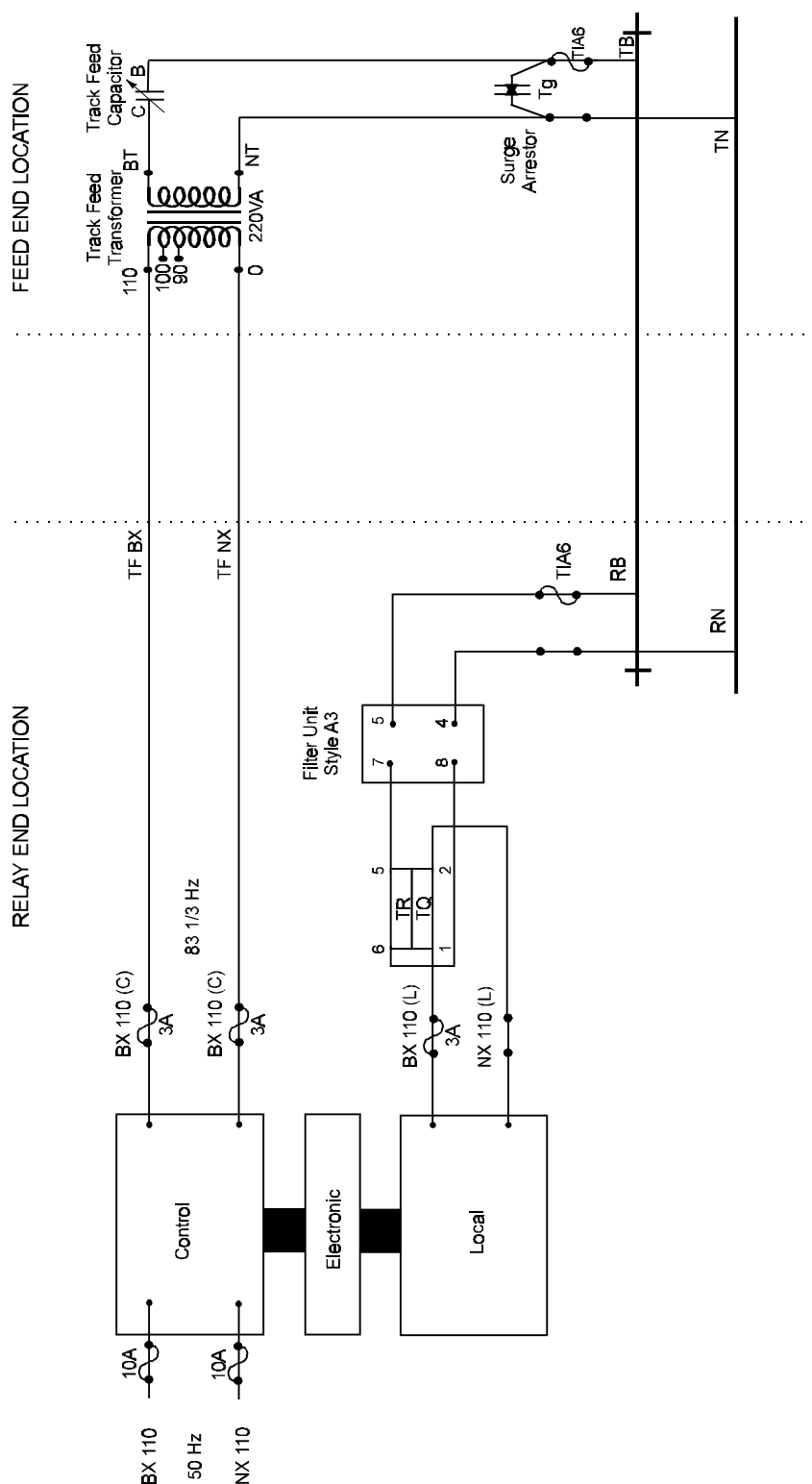
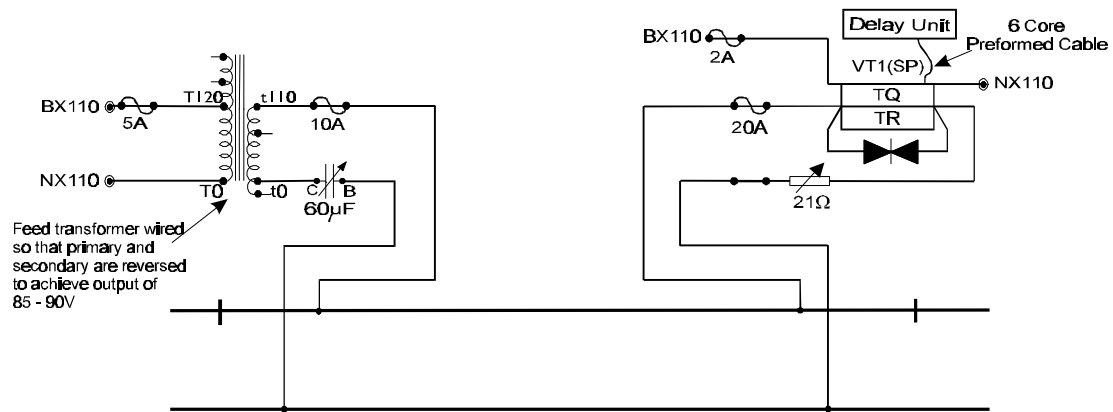


Figure 15 - Single Rail 83 $\frac{1}{3}$ Hz Track Circuit

4.1.5 Single Rail VT1(SP) Track Circuits

Figure 16 shows a typical VT1(SP) a.c. track circuit.



Note: track cable terminations not fully shown (see section 7.2.1).

Figure 16 - Single Rail VT1(SP) Track Circuit

Figure 17 shows the connection details of the VT1(SP) relay and delay unit.

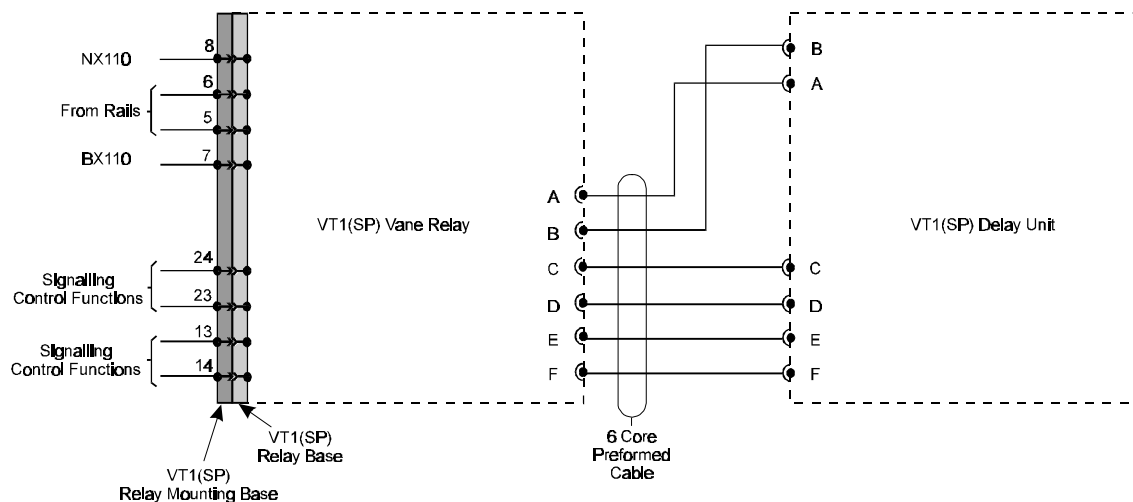


Figure 17 - VT1(SP) Relay and Delay Unit Wiring

The VT1(SP) relay is a development of the VT1 track relay and replaces it when the track circuit is converted from an existing 50Hz a.c. track circuit. The unit consists of a modified VT1 relay and contains a constant voltage transformer and a rectifier giving a 50V d.c. output which is fed to the VT1(SP) delay unit via a track relay front contact. The VT1(SP) relay is mounted on a modified VT1 relay base.

Note: The delay unit does not affect the pick up or drop away time of the VTI(SP) relay itself and therefore signalling control functions must not be fed directly over the relay contacts.

The VTI(SP) delay unit comprises a sealed case containing two BR930 style relays with internal wiring arranged so that their operation times are cumulative. These relays (one QSRA5 type and one twin QNNSI type) are selected as a matched pair during manufacture of the unit and are not interchangeable. The delay unit requires additional space equivalent to two adjacent BR930 style relays and is mounted directly onto the racking or a backboard by means of a mounting kit.

The delay unit provides a connection between VTI(SP) pins 13 & 14 and between pins 23 & 24 only when the VTI(SP) relay has been energised for a time exceeding 2 seconds. At all other times, there is an open circuit between these pairs of pins. Pins 13/14 and 23/24 are used for the control of the TPR or other signalling functions.

The VTI(SP) relay is connected to the delay unit by a preformed 6 core interconnecting cable with a connector at each end, which provides all electrical connections to the delay unit. The cable is available in lengths of up to 20m to allow for siting of the unit in an adjacent housing when necessary.

A 30 μ F - 60 μ F variable capacitor is used at the feed end to allow more current to flow through the track circuit and develop a higher rail to rail voltage. This capacitor replaces the 20 μ F feed capacitor of an existing 50Hz a.c. track circuit and is shown in the typical circuit in Figure B1. The feed capacitor is the same size as a 20 μ F track circuit feed capacitor (and replaces it when the installation is a conversion from a 50Hz a.c. track circuit). It is designed for vertical fixing to a rack or backboard in the feed end apparatus housing.

The resistance of the relay end circuit is increased by the inclusion of a 21 Ω 15W variable resistor. Its purpose is to de-sensitise the relay end circuit and reduce the relay voltage to 1.5V $\pm$ 0.5V. The resistor is fixed to a base plate for standard rack mounting at the relay end apparatus housing. It occupies the same space as a BR930 style relay. The resistor is shown in Figure B1.

4.2 A.C. TRACK CIRCUIT POWER SUPPLIES

The feed must be derived from the same supply source as that which feeds the track relay local coil.

Care shall be taken where two power supply sources interface (see section 3.3 on Electrical Stagger).

The average power supply loading for a.c. track circuits is shown in Figure 18.

Item	VA	Phase Angle (° lead or lag)
Double Rail Feed	80	66 lead
Single Rail Feed	60	84 lead
Track Relay Local	30	72 lag
Double Rail Complete	60	45 lead
Single Rail Complete	35	60 lead

Figure 18 - Power Loading

4.3 FUSING

In d.c. or dual electrified areas, traction fuses rated at 750V to BS 88 must be used in the rail lead, as follows:

- A 20A fuse is used at the relay end of single rail track circuits in the track lead that connects to the insulated rail.
- A 10A fuse is used at the feed end of single rail track circuits in the track lead that connects to the insulated rail.
- A 10A fuse is used at the feed and relay ends of double rail track circuits in the track leads that connect to the impedance bond coils.

A 2A or 3A fuse generally in accordance with BS714 is used in the supply to the local coil of the track relay in both single and double rail track circuits.

Note: Although strictly outside the scope of BS714, where sufficient reliability can be achieved, the use of a 2A fuse gives improved discrimination.

In a.c. electrified areas, a 6A fuse to BS 88 is used in the track lead that connects to the insulated rail.

Fuses rated at 250V to BS714 may be used for all other applications.

4.4 TRACK LEADS

When positioning the associated equipment and lineside apparatus housings, the connecting cables must be kept as short as possible (see RT/E/S/I 1752). The maximum allowable loop resistance and cable lengths between equipment and rails is shown in Figure 19.

A.C. Phase Sensitive Track Circuits

Track Leads	Max Loop Resistance (Ω)	Max Lead Length (m)
Feed end (double and single rail)	2	120
Single rail track relay leads	5	300
Double rail track relay leads	10	610
Resonated bond capacitor leads:	10	610

Figure 19 - Maximum Track Lead Resistance

Wiring between the lineside apparatus housing and the rail connections or impedance bond shall be 2.5mm²(f) to RT/E/PS/00005 in accordance with RT/E/S/11752.

Feed, relay and resonated bond capacitor leads must not be run in multicore cables which contain other line circuits or designs of track circuit, although communication circuits for track circuit test purposes are permitted.

4.5 TRACK REPEAT RELAY CIRCUITS

Track repeat relay (TPR) circuits must comply with RT/E/S/11752.

If the track relay is a plug-in vane relay (WSL style VT1 8F4B or 2F2B, or SGE style CE391 4F2B), contacts 23/24 and 13/14 must be used for the TPR circuit.

5 PERFORMANCE REQUIREMENTS

5.1 MAINTAINABILITY

The use of preformed tail cables to GK/RT030I is preferred for ease of replacement.

5.2 INSTRUMENTATION

This section describes special instrumentation for a.c. track circuits, such as the direct reading phase angle meter for use in determining the relationship between the local and control coil voltages of the track relay.

Details of other test instruments are given in Part N of RT/E/S/I 1752.

5.2.1 Mark 4 Direct Reading Phase Angle Meter

The Mk 4 direct reading phase angle meter is the latest in a series of meters which have been developed for use on 50Hz vane type track circuits. Only the Mk4 unit will be described.

The instrument is illustrated in Figure 20.



Figure 20 - Mk 4 Direct Reading Phase Angle Meter

The instrument can be used to display the following:

- The phase angle relationship between the local and control coil voltages of the track relay. This is shown as the angle (0 - 180°) with the lead or lag indicated by red lights.
- The a.c. relay control voltage.

- The degree of electrical stagger between track circuits at IRJs.

Notes:

1. A 50 Hz filter is incorporated to eliminate spurious traction frequencies; voltage readings will therefore be slightly lower than those of a technicians multimeter which will read the 50Hz a.c. volts plus any harmonics present.
2. Only the Mk 4 phase angle meter will give a direct stagger reading.

To measure the relay phase angle and control coil voltage, connect the "local" and "control" leads to the appropriate windings of the relay. Ensure that the BX and NX markings are correct in relation to the relay terminals.

Refer to Figure 21 for terminal and relay base markings.

Relay	Local		Control	
	BX Red lead	NX Black lead	BX Red lead	NX Black lead
VTI	7 or 1	8 or 2	5	6
G2/G4	Q1	Q2	R1	R2
CE391	Q1 or 7	Q2 or 8	R1 or 5	R2 or 6
AB401/AB402	Q1	Q2	R1	R2
L4	Q1	Q2	R1	R2

Figure 21 - Meter Connections to Track Relays

All connections must be made at the relay terminals or plugboard to avoid the possibility of errors in the case wiring or where traction suppressors are fitted.

With the switch in the "phase angle" position the meter will display the phase angle in degrees together with a lead or lag display.

With the switch in the "volts" position, the instrument will read the relay control voltage.

The instrument will indicate phase angles between 0°-180° lead and lag.

The instrument measures the phase displacement directly.

Note: To preserve the life of the internal batteries, switch to PHASE (OFF) when readings are not being taken.

5.2.2 Meter Lead for $83\frac{1}{3}$ Hz Filter Unit

A meter lead has been designed for connecting a technicians multimeter to the plug in filter unit to monitor the control coil voltage. One end of the lead has a plug which fits the socket on the filter unit and the other has spade connectors for connecting to the technicians multimeter.

Details can be obtained from the manufacturer of the filter or a suitable lead may be made up on site.

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6 ENVIRONMENTAL REQUIREMENTS

6.1 ENVIRONMENTAL CONDITIONS

All equipment associated with a.c. track circuits shall conform to specification BR967, category D, and, in addition, track-mounted equipment shall conform to BR967, category F.

6.2 ENVIRONMENTAL RESTRICTIONS

Track circuit transformers must be positioned where ventilation is not impaired.

Equipment shall not be mounted under oil filled capacitors unless a drip tray is installed immediately below each capacitor.

6.3 IMMUNITY FROM TRACTION INTERFERENCE

General Information relating to Traction Interference can be found in RT/E/S/11752.

6.3.1 D.C. Interference

50Hz a.c. track circuits are inherently immune to false operation (wrong side failure) from the presence of d.c. traction currents flowing in the rails, although in some circumstances these can be of a magnitude sufficient to occasionally cause damage to equipment, or cause right side failure of the track circuit. The levels of d.c. interference that the track circuit is subjected to, can normally be sufficiently limited by well maintained bonding, track circuit length restrictions (single rail track circuits) and balance of traction currents between rails (double rail track circuits). There are however, a number of additional protective measures that can be employed when necessary.

6.3.1.1 Stabilising Rectifier

A stabilising rectifier can be fitted across the control winding of the track relay on single rail track circuits. See Figure 13.