Level Crossing Interface

Railway Interface Unit Design

Roads and Traffic Authority

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Revision history

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1 Introduction

1.1 Purpose

The purpose of this document is to define how railway interface unit (RIU) operates. The RIU can be used to interface to level crossings operated by any rail authority involved (RailCorp, ARTC, RIC, etc).

1.2 Scope

This document covers all aspects of the railway interface unit hardware. There is no software on the railway interface unit.

Within this document it is assumed that there are no other inputs or outputs being used. Ie, this document assumes usage of external detector inputs 1 to 7 and non signal group outputs 1 to 3. In practice at a specific intersection these may be used for other purposes and the actual identification numbers of the external detector inputs and non signal group outputs used for the RIU may differ.

It does not cover the operating principles or design considerations of the railway-road interface. This information can be found in Level Crossing Interface – Concept of Operations, [2] and Level Crossing Interface – Traffic Signal Design Guidelines, [3].

The installation and testing of the RIU in a traffic signal controller and connection to the railway level crossing can be found in Level Crossing Interface – Installation and Testing [4].

1.3 Definitions and abbreviations

Term	Meaning
ARTC	Australian Rail Track Corporation
RailCorp	Rail Corporation New South Wales
RIC	Rail Infrastructure Corporation
RIU	Railway Interface Unit
RTA	Roads and Traffic Authority of NSW
TD	Train Demand – an indication from the level crossing to the traffic signal controller indicating a train is approaching. (This signal ends when the train has cleared the crossing.) It is inferred from the TDNC and TDNO signals.
TDNC	The half of the train demand signal which is normally closed when there is no train demand.
TDNO	The half of the train demand signal which is normally open when there is no train demand.
TDRT	Train Demand Response Time – the advance warning time required by the traffic signal controller of an approaching train prior to the level crossing commencing to operate.
TLR	Traffic Light Response – indication from the traffic signal controller to the level crossing indicating that the traffic signal controller is ready for the level crossing to commence operating. (This signal remains active while the Train Demand signal is present.)
TLRFB	Traffic Light Response Feedback – an indication from the level crossing to the traffic signal controller confirming that the level crossing has received the Traffic Light Response indication.

Term	Meaning
TLRH	Traffic Light Response High relay
TLRL	Traffic Light Response Low relay
TMB	Traffic Management Branch
TSC	Traffic Signal Controller
TSC/4 Controller	A TSC that complies with the Control Equipment for Road Traffic Signals specification [6].
XE	Crossing Operating – indication from the level crossing to the traffic signal controller indicating the level crossing flashing lights are operating. It is inferred from the XENC and XENO signals.
XENC	The half of the crossing operating signal which is normally closed when the crossing is not operating.
XENO	The half of the crossing operating signal which is normally open when the crossing is operating.

1.4 References

[1] RailCorp – Roads & Traffic Authority, Level Crossing – Traffic Light Design Interface Agreement, 30 May 2008

[2] LX-CO-001, Level Crossing Interface – Concept of Operations

[3] LX-DG-001, Level Crossing Interface – Design Guidelines

[4] LX-IP-001, Level Crossing Interface – Railway Interface Unit Installation and Testing

[5] Traffic Signal Design, Section 15 – Special Situations

[6] Equipment Specification No. TSC/4, Control Equipment for Road Traffic Signals, December 1999

2 General Description

A description of the operating principles of the interface between the railway signalling system and the traffic signal controller is given in Level Crossing Interface – Concept of Operations, [2].

The railway interface unit (RIU) consists of two distinct parts. The first part conveys indications from the rail authority system to the RTA traffic signal controller and the second part of the RIU provides an indication from the RTA traffic signal controller to the railway signalling system.

2.1 Train Demand

Train demand is derived from the state of the TDR relay in the railway signalling system. This relay is normally energised, and releases when the train is detected. There are two voltage free circuits comprising the contacts of the TDR relay:

- Train Demand Normally Closed circuit. This contact is normally closed and opens when the train is detected.
- Train Demand Normally Open circuit. This contact is normally open and closes when the train is detected.

TDNC relay (RL4) monitors the state of the normally closed contact of the railway signalling system TDR relay. The TDNC relay is energised when there is no train demand.

TDNO relay (RL3) monitors the state of the normally open contacts of the same railway signalling system TDR relay. The TDNO relay is not energised when there is no train demand.

By monitoring both contacts the interface board and traffic signal controller have a double check on the condition of the railway signalling system TD relay contacts, so that if these contacts are not in the reverse state of each other under steady conditions, then the traffic signal controller has an indication of a failure of the train detection circuitry. In addition, the double contacts provide monitoring of the interface cable, the relays on the RIU, the contacts of the relays on the RIU and the traffic signal controller inputs.

2.2 Level Crossing Operating

Crossing operating is derived from the state of the two relays CSER and SSER in the railway signalling system. Both relays are normally energised and if either (or both) is released, the level crossing is operating. There are two voltage free circuits comprising contacts of the CSER and SSER relays:

- Crossing operating normally closed circuit. This circuit is normally closed and opens when the level crossing is operating.
- Crossing operating normally open circuit. This circuit is normally open and closes when the level crossing is operating.

XENC relay (RL2) monitors the state of the normally closed circuit of the level crossing warning lights. The XENC relay is energised when the level crossing warning lights are inactive.

XENO relay (RL1) monitors the state of the normally open circuit of the level crossing warning lights. The XENO relay is not energised when the level crossing warning lights are inactive.

By monitoring both contacts the interface board and traffic signal controller have a double check on the condition of the railway signalling system relay contacts, so that if these contacts are not in the reverse state of each other under steady conditions, then the traffic signal controller has an indication of a failure of the crossing operating circuitry.

2.3 Traffic Light Response

When the traffic signal controller has the intersection signals in a condition where it is safe for the level crossing warning light to start flashing it provides a Traffic Light Response (TLR) indication. TLR is a normally open circuit which is closed to provide the indication.

The output facilities provided by a traffic signal controller differ dependent on the manufacturer and the type of traffic signal controller. In general, two methods are employed:

- use of special facility outputs; and
- use of WAIT outputs.

These two methods are explained in the following sub-sections.

2.3.1 Special Facility Outputs

The TLR circuit is closed by energising the TLRL and TLRH relays (RL5 and RL6) using the special facility outputs (OUT 1 and OUT 3) of the traffic signal controller.

TLRL and TLRH provide a double cut circuit which completes the rail authority circuits and provides the redundancy required by railway signalling systems. These relays are powered from the traffic signal controller special facility output supply and are switched, as mentioned above, by the active low operation of the special facility outputs. TLRL is energised by the first traffic signal controller special facility output while TLRH is energised by the third special facility output.

The traffic signal controller monitors the TLR feedback signal. If the traffic signal controller observes a TLR feedback indication when TLR is not intended to be given (due to software or hardware fault) it can prevent TLRH from operating. TLRH is prevented from operating, and hence prevent the TLR indication being provided to the railway signalling system, by an active low operation of the second special facility output (OUT 2). The second special facility output (OUT 2) also protects against a traffic signal controller logic module hardware failure that puts all outputs low.

2.3.2 Wait Outputs

When the traffic signal controller has the intersection signals in a condition where it is safe for the level crossing warning light to start flashing it provides a Traffic Light Response (TLR) indication. TLR is a normally open circuit which is closed to provide the indication. It is closed by energising the TLRL and TLRH relays (RL5 and RL6) using the "WAIT" outputs (COUT 1 and COUT 3) of the traffic signal controller.

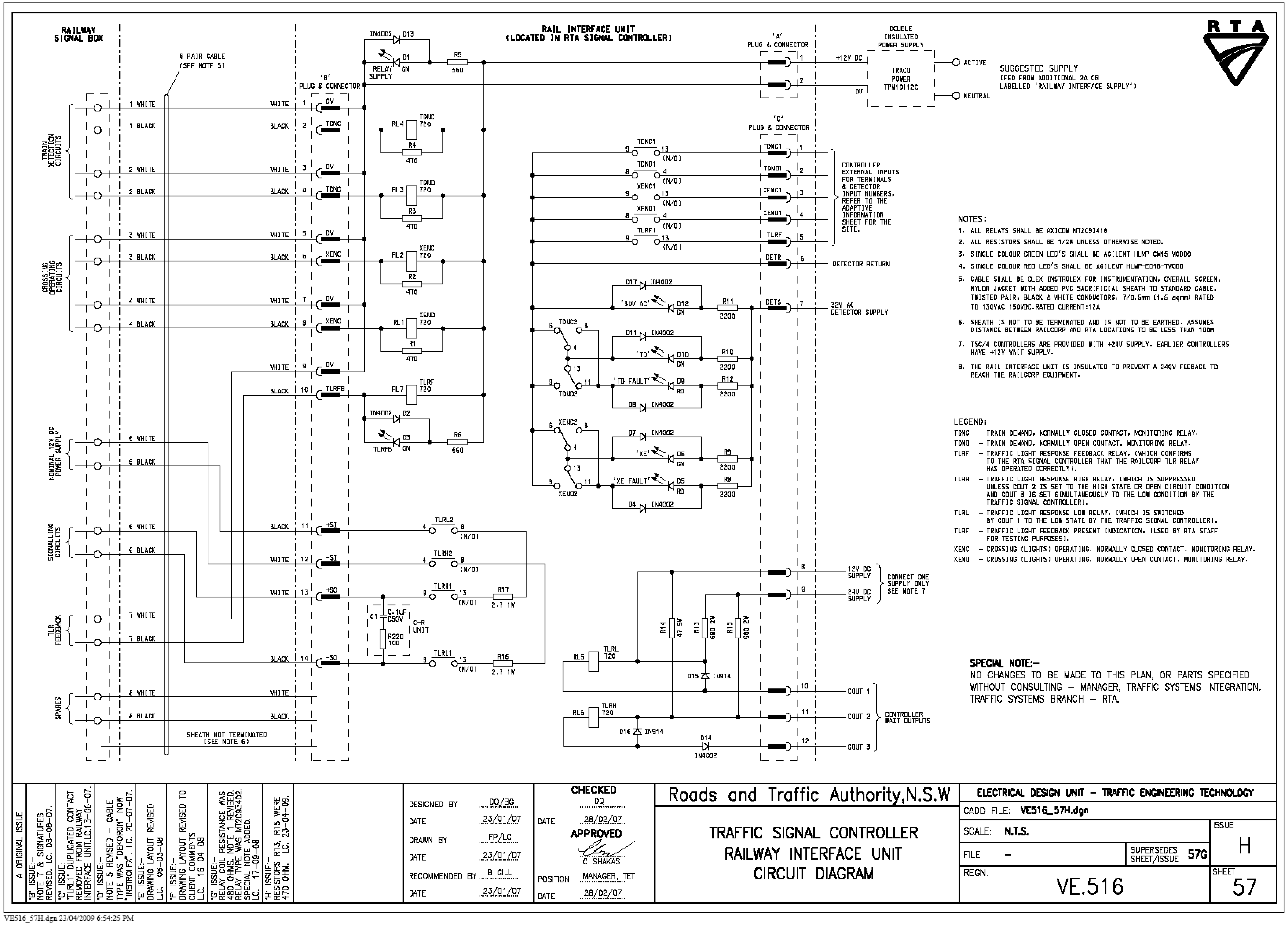
TLRL and TLRH provide a double cut circuit which completes the rail authority circuits and provides the redundancy required by railway signalling systems. These relays are powered from the traffic signal controller "WAIT" supply voltage and are switched, as mentioned above, by the active low operation of the "WAIT" outputs. TLRL is energised by the first traffic signal controller "WAIT" output while TLRH is energised by the third "WAIT" output.

The traffic signal controller monitors the TLR feedback signal. If the traffic signal controller observes a TLR feedback indication when TLR is not intended to be given (due to software or hardware fault) it can prevent TLRH from operating. TLRH is prevented from operating, and hence prevent the TLR indication being provided to the railway signalling system, by an active low operation of the second "WAIT" output (COUT 2). The second "WAIT" output (COUT 2) also protects against a traffic signal controller logic module hardware failure that puts all outputs low.

2.4 Traffic Light Response Feedback

The TLRFB relay (RL7) monitors a contact in the rail authority system, which confirms, (for the interface and traffic signal controller), that the rail authority system has received the Traffic Light Response (TLR) from the RTA traffic signal controller.

3 Railway Interface Unit Circuit Diagram



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4 Explanation

This section describes:

- the connections between the RIU and the railway signalling system;
- the connections between the RIU and the traffic signal controller;
- the electrical signals and indications on the RIU, including the states the indications can take;
- the design principles of the RIU.

4.1 Connections to the Railway Signalling System

The RIU provides for eight circuit connections to the railway signalling system providing four indications. These connections generally provide the following indications:

- Train demand, TD (Two circuits - one normally open TDNO and one normally closed TDNC when there is no train demand. Normally both circuits change state when a train demand is present, however change in state of either circuit is treated as a valid train demand. A fault is registered if only one circuit changes state.)
- Crossing operating, XE (Two circuits - one normally open and one normally closed circuit when the crossing is not operating. Normally both circuits change state when the crossing is operating, however change in state of either circuit is treated as the crossing is operating. A fault is registered if only one circuit changes state.)
- Signalling circuits used for traffic light response, TLR (normally open, closed when the traffic signal controller is ready for the crossing to operate)
- Traffic light response feedback, TLRF (normally open, closed when the rail authority has received the TLR signal)
- Nominal 12v DC power supply (provided by the rail authority)
- Spare

4.2 Connections to the Traffic Signal Controller

The RIU provides for the following connections to the Traffic Signal Controller:

- 32v AC detector power supply from the TSC for detecting TD, XE and TLRF indications
- Nominal 12v DC power supply from the TSC for TD, XE and TRLF circuits
- 12v DC or 24v DC power supply from the TSC for providing TLR indications[1]
- 5 outputs to the TSC providing TD, XE and TLRF indications
- Detector return to the TSC
- 3 inputs from the TSC to drive the TLRL and TLRH relays for providing TLR indications

4.3 Signals and Indications

The following section provides a simple description of each LED's function when the RIU has been correctly installed and the traffic signal controller has been installed and commissioned on site.

LED	Status	Indication
30v AC Grn (D12) →	Lit	Power is present

[1] TSC/4 controllers are provided with +24v supply, earlier controllers have +12v wait supply.

LED		Status	Indication
	→	Unlit	Power is not present
TD Grn (D10)	→	Lit	Train Demand is present, either or both TDNO or TDNC has changed state
	→	Unlit	Train Demand is not present, TDNO is open and TDNC is closed
TD Fault Red (D9)	→	Lit	TDNC and TDNO are not in agreement
	→	Unlit	TDNC and TDNO are not in agreement
XE Grn (D6)	→	Lit	Level crossing is operating, either or both XENO or XENC has changed state
	→	Unlit	Level crossing is not operating, XENO is closed and XENC is open
XE Fault Red (D5)	→	Lit	XENC and XENO are not in agreement
	→	Unlit	XENC and XENO are in agreement
Relay Supply (D1)	→	Lit	Power is present
	→	Unlit	Power is not present
TLRFB Gn (D3))	→	Lit	TLR is being received by railway signalling system
	→	Unlit	TLR is not being received by railway signalling system

4.4 Components

The following section describes the components of the RIU and their purpose.

Component	Function
Relay 1	Provides isolation and indication of XENO from rail authority to TSC inputs
Relay 2	Provides isolation and indication of XENC from rail authority to TSC inputs
Relay 3	Provides isolation and indication of TDNO from rail authority to TSC inputs
Relay 4	Provides isolation and indication of TDNC from rail authority to TSC inputs
Relay 5	Provides isolation and indication of TLR from TSC output to rail authority, must work in conjunction with relay 6 otherwise indication is not provided
Relay 6	Provides isolation and indication of TLR from TSC output to rail authority, must work in conjunction with relay 5 otherwise indication is not provided
Relay 7	Provides isolation and indication of TLRF from rail authority to TSC inputs
Diode 1	Provides green LED indication 'Relay supply' of 12v DC to rail authority indication circuits
Diode 2	Provides path to dissipate the energy from the collapsing magnetic field for relay TLRF de-energising to prevent reverse breakdown of 'TLRFB' LED
Diode 3	Provides green LED indication 'TLRFB' of TLRF circuit being active
Diode 4	Provides path for 32v AC negative half cycle around 'XE Fault' LED to prevent reverse breakdown of 'XE fault' LED
Diode 5	Provides red LED indication 'XE fault'
Diode 6	Provides green LED indication 'XE' – crossing is operating
Diode 7	Provides path for 32v AC negative half cycle around 'XE' LED to prevent reverse breakdown of 'XE' LED

Component	Function
Diode 8	Provides path for 32v AC negative half cycle around 'TD Fault' LED to prevent reverse breakdown of 'TD fault' LED
Diode 9	Provides red LED indication 'TD fault'
Diode 10	Provides green LED indication 'TD' – there is a train demand
Diode 11	Provides path for 32v AC negative half cycle around 'TD' LED to prevent reverse breakdown of 'TD' LED
Diode 12	Provides green LED indication '30v AC' of 32v AC to rail authority indication circuits
Diode 13	Provides alternative path to dissipate the energy from the collapsing magnetic field for relays 1, 2, 3, 4 or 7 de-energising to prevent reverse breakdown of 'Relay supply' LED
Diode 14	Ensures that relay 6 can only be operated if COUT3 is low
Diode 15	Provides path to dissipate the energy from the collapsing magnetic field for relay 5 de-energising
Diode 16	Provides path to dissipate the energy from the collapsing magnetic field for relay 6 de-energising
Diode 17	Provides path for 32v AC negative half cycle around '30v AC' LED
Resistor 1	Provides path to dissipate the energy from the collapsing magnetic field for Relay 1 de-energising, and ensures wetting current at the rail authority's contacts is within an acceptable band
Resistor 2	Provides path to dissipate the energy from the collapsing magnetic field for Relay 2 de-energising, and ensures wetting current at the rail authority's contacts is within an acceptable band
Resistor 3	Provides path to dissipate the energy from the collapsing magnetic field for Relay 3 de-energising, and ensures wetting current at the rail authority's contacts is within an acceptable band
Resistor 4	Provides path to dissipate the energy from the collapsing magnetic field for Relay 4 de-energising, and ensures wetting current at the rail authority's contacts is within an acceptable band
Resistor 5	Regulates current drawn by LED diode 1
Resistor 6	Provides path for to dissipate the energy from the collapsing magnetic field Relay 7 de-energising, and ensures wetting current at the rail authority's contacts is within an acceptable band, and regulates current drawn by LED diode 3
Resistor 8	Regulates current drawn by LED diode 5
Resistor 9	Regulates current drawn by LED diode 6
Resistor 10	Regulates current drawn by LED diode 10
Resistor 11	Regulates current drawn by LED diode 12
Resistor 12	Regulates current drawn by LED diode 9
Resistor 13	Provides load to reduce voltage across relay 5 when 24v supply is used
Resistor 14	Provides load to ensure voltage is dropped across it and none across relay 6 when COUT2 is switched to active low (with 12 v supply used)
Resistor 15	Provides load to reduce voltage across relay 6 when 24v supply is used, and ensures voltage is dropped across it and none across relay 6 when COUT2 is switched to active low

Component	Function
Resistor 16	Limits current inrush through relay 5 contacts 9 and 13 caused by interface cable capacitance
Resistor 17	Limits current inrush through relay 6 contacts 9 and 13 caused by interface cable capacitance
LC Unit	Capacitor and resistor pair to absorb any back emf generated by the Rail Authority's TLR relay coil

5 Fault Identification at Site

The information provided in this section assumes that the traffic signal controller is on and working correctly.

Repairs to the RIU should not be attempted on site. The technician should only establish that there is a fault with the RIU and not the connections or external signals.

5.1 LED Indications

The following tables provide combinations of LED indications, their interpreted meaning and possible causes.

LED		Status	Possible causes
Relay Supply (D1)	→	Unlit	12v DC power supply not connected 12v DC power supply failure D1 LED failure Resistor R5 failure (open circuit)
30v AC (D12)	→	Unlit	32v AC power supply not connected 32v AC power supply failure D12 LED failure Resistor R11 failure (open circuit)
TLRF (D3)	→	Unlit	TLR is not used at the site. Where used: There is no TLR indication to the railway signalling system There is no TLRF indication from the railway signalling system D3 LED failure Resistor R6 failure (open circuit)

LED	Possible causes
TD (D10) and TD Fault (D9) are both lit (with no train demand)	Relay 3 is in its energised state because: relay 3 has failed in this state; or the relay is kept energised by an incorrect TDNO signal from the Rail Authority; or short in interface cable; or there is an electrical short on RIU. Relay 3, contact 9 failed to break or contact 11 failed to make. Relay 4 in its energised state because: relay 4 has failed in this state; or the relay is kept energised by an incorrect TDNC signal from the Rail Authority; or short in interface cable; or there is an electrical short on RIU. Relay 4, contact 8 failed to break or contact 6 failed to make. The appearance of a Train Demand would cause the TD Fault LED to go off.

LED	Possible causes
TD (D10) and TD Fault (D9) are both lit (with a train demand)	Relay 4 in its de-energised state because: relay 4 has failed in this state; or the TDNC signal has not been given by the Rail Authority; or open circuit in interface cable; or there is an electrical open circuit on RIU. Relay 4, contact 6 failed to break or contact 8 failed to make. Relay 3 in its de-energised state because: relay 3 has failed in this state; or the TDNO signal has not been given by the Rail Authority; or open circuit in interface cable; or there is an electrical open circuit on RIU. Relay 3, contact 11 failed to break or contact 9 failed to make. The removal of the Train Demand would cause the TD Fault LED to go off.
XE and XE Fault are both lit (with no crossing operating)	Relay 1 is in its energised state because: relay 1 has failed in this state; or the relay is kept energised by an incorrect XENO signal from the Rail Authority; or short in interface cable; or there is an electrical short on RIU. Relay 1, contact 9 failed to break or contact 11 failed to make. Relay 2 in its energised state because: relay 2 has failed in this state; or the relay is kept energised by an incorrect XENC signal from the Rail Authority; or short in interface cable; or there is an electrical short on RIU. Relay 2, contact 8 failed to break or contact 6 failed to make. The appearance of a Crossing Operating indication would cause the XE Fault LED to go off.
XE and XE Fault are both lit (with a crossing operating)	Relay 2 in its de-energised state because: relay 2 has failed in this state; or the XENC signal has not been given by the Rail Authority; or open circuit in interface cable; or there is an electrical open circuit on RIU. Relay 2, contact 6 failed to break or contact 8 failed to make. Relay 1 in its de-energised state because: relay 1 has failed in this state; or the XENO signal has not been given by the Rail Authority; or open circuit in interface cable; or there is an electrical open circuit on RIU. Relay 1, contact 11 failed to break or contact 9 failed to make. The removal of a Crossing Operating indication would cause the XE Fault LED to go off.

5.2 Traffic Signal Controller Detection

The following table provides fault states that can be detected by the traffic signal controller if the correct coding of the Personality has been considered, Level Crossing Interface – Design Guidelines [3].

A technician will need a hand held terminal to observe the state of the signals described below, access to the traffic signal controller information sheet to establish the signals and which detector or WAIT/special facility output it is mapped to.

Fault states	Possible causes
TDNC1 & TDNO1 are both closed (with no train demand)	Relay 3 is in its energised state because: relay 3 has failed in this state; or the relay is kept energised by an incorrect TDNO signal from the Rail Authority; or short in interface cable; or there is an electrical short on RIU. Relay 3, contact 8 failed to break or contact 6 failed to make.
TDNC1 & TDNO1 are both closed (with a train demand)	Relay 4 in its energised state because: relay 4 has failed in this state; or the relay is kept energised by an incorrect TDNC signal from the Rail Authority; or short in interface cable; or there is an electrical short on RIU. Relay 4, contact 9 failed to break or contact 11 failed to make.
TDNC1 & TDNO1 are both open (with a train demand)	Relay 3 in its de-energised state because: relay 3 has failed in this state; or the TDNO signal has not been given by the Rail Authority; or open circuit in interface cable; or there is an electrical open circuit on RIU. Relay 3, contact 6 failed to break or contact 8 failed to make.
TDNC1 & TDNO1 are both open (with no train demand)	Relay 4 in its de-energised state because: relay 4 has failed in this state; or the TDNC signal has not been given by the Rail Authority; or open circuit in interface cable; or there is an electrical open circuit on RIU. Relay 4, contact 11 failed to break or contact 9 failed to make.
XENC1 & XENO1 are both closed (with no train demand)	Relay 1 is in its energised state because: relay 1 has failed in this state; or the relay is kept energised by an incorrect XENO signal from the Rail Authority; or short in interface cable; or there is an electrical short on RIU. Relay 1, contact 8 failed to break or contact 6 failed to make.
XENC1 & XENO1 are both closed (with a train demand)	Relay 2 in its energised state because: relay 2 has failed in this state; or the relay is kept energised by an incorrect XENC signal from the Rail Authority; or short in interface cable; or there is an electrical short on RIU. Relay 2, contact 9 failed to break or contact 11 failed to make.
XENC1 & XENO1 are both open (with a train demand)	Relay 1 in its de-energised state because: relay 1 has failed in this state; or the XENO signal has not been given by the Rail Authority; or open circuit in interface cable; or there is an electrical open circuit on RIU. Relay 1, contact 6 failed to break or contact 8 failed to make.

Fault states	Possible causes
XENC1 & XENO1 are both open (with no train demand)	Relay 2 in its de-energised state because: relay 2 has failed in this state; or the XENC signal has not been given by the Rail Authority; or open circuit in interface cable; or there is an electrical open circuit on RIU. Relay 2, contact 11 failed to break or contact 9 failed to make.
TLRF1 closed with no TLR indication	Relay 5, contacts 8 & 9 failed to break and Relay 4, contacts 8 & 9 failed to break. Relay 5 and Relay 4 both energised incorrectly due to COUT1 and COUT3 both shorted to earth. Short in interface cable.
TLRF1 open with TLR indication	Capacitor C1 failed (short circuit) Diode 14 failed (open circuit) Diode 15 failed (reverse breakdown) Diode 16 failed (reverse breakdown) Resistor 6 failed (short circuit) Resistor 13 failed (open circuit) – 24v DC supply Resistor 14 failed (open circuit) – 12v DC supply Resistor 15 failed (open circuit) – 24v DC supply Resistor 16 failed (open circuit) Resistor 17 failed (open circuit) Relay 5 failed: to energise contact 6 failed to break or contact 8 failed to make contact 11 failed to break or contact 13 failed to make Relay 6 failed: to energise contact 6 failed to break or contact 8 failed to make contact 11 failed to break or contact 9 failed to make Rail Authority has not provided TLR Feedback indication Relay 7 failed: to energise contact 11 failed to break or contact 9 failed to make Open circuit in interface cable. Open circuit on RIU.

Appendix A FMEA

In the following where reference is made to WAIT outputs, these also cover special facility outputs where used.

No.	Item	Component	Failure Mode	Local Effects	Next Level	External Effects	External Influences	Detection Method	Notes	Assumption
1	R1	Relay - XENO	Contact 6 welded	Fails to switch over when XE applied	XENO1 latching does not register in TSC	TSC reverts to normal operation when TD removed. TSC will log a fault with the XE indication as XENO and XENC do not correspond. As long as XENC operates, on next TD applied TSC will "see" TD and XE go "on" together and react appropriately.	Crossing operating present	By TSC seeing XENO1 low when XENC1 is low.	Possibly caused by R8 or R9 shorting	Relay contacts are not Forced-guided contacts, ie one can change while the other does not.
1.1			Contact 8 welded	Fails to switch over when XE removed	XENO1 latching does not register in TSC	TSC reverts to normal operation when TD removed. TSC will log a fault with the XE indication as XENO and XENC do not correspond. As long as XENC operates, on next TD applied TSC will "see" TD and XE go "on" together and react appropriately.	NO Crossing operating present	By TSC seeing XENO1 high when XENC1 is high	Possibly caused by R8 or R9 shorting	Relay contacts are not Forced-guided contacts, ie one can change while the other does not.
1.2			Contact 9 welded	Fails to switch over when XE removed	XENO2 latching does not register in TSC	None	NO Crossing operating present	By technician observing 'XE fault' LED lit and 'XE' LED lit	Possibly caused by R8 or R9 shorting	Relay contacts are not Forced-guided contacts, ie one can change while the other does not.
1.3			Contact 11 welded	Fails to switch over when XE applied	XENO2 latching does not register in TSC	None	Crossing operating present	By technician observing 'XE fault' LED lit and 'XE' LED lit	Possibly caused by R8 or R9 shorting	Relay contacts are not Forced-guided contacts, ie one can change while the other does not.
1.4			Unable to energise - Contacts 6 & 11 effectively welded	Fails to switch over when XE applied	XENO1 and XENO2 latching does not register in TSC	TSC reverts to normal operation when TD removed. TSC will log a fault with the XE indication as XENO and XENC do not correspond. As long as XENC operates, on next TD applied TSC will "see" TD and XE go "on" together and react appropriately.	Crossing operating present	By TSC seeing XENO1 low when XENC1 is low By technician observing 'XE fault' LED lit and 'XE' LED lit	Relay coil open cct. XENO indication - open cct.	Relay contacts are not Forced-guided contacts, ie one can change while the other does not.
1.5			Unable to de-energise - Contacts 8 & 9 effectively welded	Fails to switch over when XE removed	XENO1 and XENO2 latching does not register in TSC	TSC reverts to normal operation when TD removed. TSC will log a fault with the XE indication as XENO and XENC do not correspond. As long as XENC operates, on next TD applied TSC will "see" TD and XE go "on" together and react appropriately.	NO Crossing operating present	By TSC seeing XENO1 high when XENC1 is high By technician observing 'XE fault' LED lit and 'XE' LED lit	Excessive current welds contacts. XENO continuously applied.	Relay contacts are not Forced-guided contacts, ie one can change while the other does not.
2	R2	Relay - XENC	Contact 6 welded	Fails to switch over when XE removed	XENC2 latching does not register in TSC	None	NO Crossing operating present	By technician observing 'XE fault' LED lit and 'XE' LED lit	Possibly caused by R10 or R12 shorting	Relay contacts are not Forced-guided contacts, ie one can change while the other does not.
2.1			Contact 8 welded	Fails to switch over when XE applied	XENC2 latching does not register in TSC	None	Crossing operating present	By technician observing 'XE fault' LED lit and 'XE' LED lit	Possibly caused by R10 or R12 shorting	Relay contacts are not Forced-guided contacts, ie one can change while the other does not.
2.2			Contact 9 welded	Fails to switch over when XE applied	XENC1 latching does not register in TSC	TSC assumes there is a XE present, but will a log a fault as XENC does not match.	Crossing operating present	By TSC seeing XENC1 high when XENO1 is high	Possibly caused by R10 or R12 shorting	Relay contacts are not Forced-guided contacts, ie one can change while the other does not.
2.3			Contact 11 welded	Fails to switch over when XE removed	XENC1 latching does not register in TSC	TSC assumes there is a XE present, but will a log a fault as XENC does not match.	NO Crossing operating present	By TSC seeing XENC1 low when XENO1 is low	Possibly caused by R10 or R12 shorting	Relay contacts are not Forced-guided contacts, ie one can change while the other does not.
2.4			Unable to energise - Contacts 6 & 11 effectively welded	Fails to switch over when XE removed	XENC1 and XENC2 latching does not register in TSC	TSC assumes there is a XE present, but will a log a fault as XENC does not match.	NO Crossing operating present	By TSC seeing XENC1 low when XENO1 is low By technician observing 'XE fault' LED lit and 'XE' LED lit	Relay coil open cct. XENC indication - open cct.	Relay contacts are not Forced-guided contacts, ie one can change while the other does not.

No.	Item	Component	Failure Mode	Local Effects	Next Level	External Effects	External Influences	Detection Method	Notes	Assumption
2.5			Unable to de-energise - Contacts 8 & 9 effectively welded	Fails to switch over when XE applied	XENC1 and XENC2 latching does not register in TSC	TSC assumes there is a XE present, but will a log a fault as XENC does not match.	Crossing operating present	By TSC seeing XENC1 high when XENO1 is high By technician observing 'XE fault' LED lit and 'XE' LED lit	Excessive current welds contacts. XENC continuously applied.	Relay contacts are not Forced-guided contacts, ie one can change while the other does not.
3	R3	Relay - TDNO	Contact 6 welded	Fails to switch over when TD applied	TDNO1 latching does not register in TSC	TSC assumes there is a TD present, but will a log a fault as TDNC does not match.	Train Demand present	By TSC seeing TDNO1 low when TDNC1 is low.	Possibly caused by R10 or R12 shorting	Relay contacts are not Forced-guided contacts, ie one can change while the other does not.
3.1			Contact 8 welded	Fails to switch over when TD removed	TDNO1 latching does not register in TSC	TSC assumes there is a TD present, but will a log a fault as TDNC does not match.	NO Train Demand present	By TSC seeing TDNO1 high when TDNC1 is high By technician observing 'TD fault' LED lit and 'TD' LED lit	Possibly caused by R10 or R12 shorting	Relay contacts are not Forced-guided contacts, ie one can change while the other does not.
3.2			Contact 9 welded	Fails to switch over when TD removed	TDNO2 latching does not register in TSC	None	NO Train Demand present	By technician observing 'TD fault' LED lit and 'TD' LED lit	Possibly caused by R10 or R12 shorting	Relay contacts are not Forced-guided contacts, ie one can change while the other does not.
3.3			Contact 11 welded	Fails to switch over when TD applied	TDNO2 latching does not register in TSC	None	Train Demand present	By technician observing 'TD fault' LED lit and 'TD' LED lit	Possibly caused by R10 or R12 shorting	Relay contacts are not Forced-guided contacts, ie one can change while the other does not.
3.4			Unable to energise - Contacts 6 & 11 effectively welded	Fails to switch over when TD applied	TDNO1 and TDNO2 latching does not register in TSC	TSC assumes there is a TD present, but will a log a fault as TDNC does not match.	Train Demand present	By TSC seeing TDNO1 low when TDNC1 is low By technician observing 'TD fault' LED lit and 'TD' LED lit	Relay coil open cct. TDNO indication - open cct.	Relay contacts are not Forced-guided contacts, ie one can change while the other does not.
3.5			Unable to de-energise - Contacts 8 & 9 effectively welded	Fails to switch over when TD removed	TDNO1 and TDNO2 latching does not register in TSC	TSC assumes there is a TD present, but will a log a fault as TDNC does not match.	NO Train Demand present	By TSC seeing TDNO1 high when TDNC1 is high By technician observing 'TD fault' LED lit and 'TD' LED lit	Excessive current welds contacts. TDNO continuously applied.	Relay contacts are not Forced-guided contacts, ie one can change while the other does not.
4	R4	Relay - TDNC	Contact 6 welded	Fails to switch over when TD removed	TDNC2 latching does not register in TSC	None	NO Train Demand present	By technician observing 'TD fault' LED lit and 'TD' LED lit	Possibly caused by R10 or R12 shorting	Relay contacts are not Forced-guided contacts, ie one can change while the other does not.
4.1			Contact 8 welded	Fails to switch over when TD applied	TDNC2 latching does not register in TSC	None	Train Demand present	By technician observing 'TD fault' LED lit and 'TD' LED lit	Possibly caused by R10 or R12 shorting	Relay contacts are not Forced-guided contacts, ie one can change while the other does not.
4.2			Contact 9 welded	Fails to switch over when TD applied	TDNC1 latching does not register in TSC	TSC assumes there is a TD present, but will a log a fault as TDNC does not match.	Train Demand present	By TSC seeing TDNC1 high when TDNO1 is high	Possibly caused by R10 or R12 shorting	Relay contacts are not Forced-guided contacts, ie one can change while the other does not.
4.3			Contact 11 welded	Fails to switch over when TD removed	TDNC1 latching does not register in TSC	TSC assumes there is a TD present, but will a log a fault as TDNC does not match.	NO Train Demand present	By TSC seeing TDNC1 low when TDNO1 is low	Possibly caused by R10 or R12 shorting	Relay contacts are not Forced-guided contacts, ie one can change while the other does not.
4.4			Unable to energise - Contacts 6 & 11 effectively welded	Fails to switch over when TD removed	TDNC1 and TDNC2 latching does not register in TSC	TSC assumes there is a TD present, but will a log a fault as TDNC does not match.	NO Train Demand present	By TSC seeing TDNC1 low when TDNO1 is low By technician observing 'TD fault' LED lit and 'TD' LED lit	Relay coil open cct. TDNC indication - open cct.	Relay contacts are not Forced-guided contacts, ie one can change while the other does not.
4.5			Unable to de-energise - Contacts 8 & 9 effectively welded	Fails to switch over when TD applied	TDNC1 and TDNC2 latching does not register in TSC	TSC assumes there is a TD present, but will a log a fault as TDNC does not match.	Train Demand present	By TSC seeing TDNC1 high when TDNO1 is high By technician observing 'TD fault' LED lit and 'TD' LED lit	Excessive current welds contacts. TDNC continuously applied.	Relay contacts are not Forced-guided contacts, ie one can change while the other does not.
5	R5	Relay - TLRL	Contact 6 welded	Fails to switch over when WAIT 1 applied	Fails to provide continuity for TLR indication	Rail Authority has to wait until complete TDRT period has expired before applying XE.	Train Demand present	By TSC seeing no TLRF when TLR indication given By technician observing detector inputs and WAIT outputs via HHT		Relay contacts are not Forced-guided contacts, ie one can change while the other does not.
5.1			Contact 8 welded	Fails to switch over when WAIT 1 applied	Fails to provide continuity for TLR indication	Rail Authority has to wait until complete TDRT period has expired before applying XE.	Train Demand present	By TSC seeing no TLRF when TLR indication given By technician observing detector inputs and WAIT outputs via HHT		Relay contacts are not Forced-guided contacts, ie one can change while the other does not.

No.	Item	Component	Failure Mode	Local Effects	Next Level	External Effects	External Influences	Detection Method	Notes	Assumption
5.2			Contact 9 welded	Fails to switch over when WAIT 1 applied	Fails to provide continuity for TLR indication	Rail Authority has to wait until complete TDRT period has expired before applying XE.	Train Demand present	By TSC seeing no TLRF when TLR indication given By technician observing detector inputs and WAIT outputs via HHT		Relay contacts are not Forced-guided contacts, ie one can change while the other does not.
5.3			Contact 11 welded	Fails to switch over when WAIT 1 applied	Fails to provide continuity for TLR indication	Rail Authority has to wait until complete TDRT period has expired before applying XE.	Train Demand present	By TSC seeing no TLRF when TLR indication given By technician observing detector inputs and WAIT outputs via HHT		Relay contacts are not Forced-guided contacts, ie one can change while the other does not.
5.4			Unable to energise - Contacts 6 & 11 effectively welded	Fails to switch over when WAIT 1 applied	Fails to provide continuity for TLR indication	Rail Authority has to wait until complete TDRT period has expired before applying XE.	Train Demand present	By TSC seeing no TLRF when TLR indication given By technician observing detector inputs and WAIT outputs via HHT		Relay contacts are not Forced-guided contacts, ie one can change while the other does not.
5.5			Unable to de-energise - Contacts 8 & 9 effectively welded	Fails to switch over when WAIT 1 applied	Fails to break continuity for TLR indication	No effect if TLRH is working correctly	NO Train Demand present	None		Relay contacts are not Forced-guided contacts, ie one can change while the other does not.
6	R6	Relay - TLRH	Contact 6 welded	Fails to switch over when WAIT 3 applied	Fails to provide continuity for TLR indication	Rail Authority has to wait until complete TDRT period has expired before applying XE.	Train Demand present	By TSC seeing no TLRF when TLR indication given By technician observing detector inputs and WAIT outputs via HHT		Relay contacts are not Forced-guided contacts, ie one can change while the other does not.
6.1			Contact 8 welded	Fails to switch over when WAIT 3 applied	Fails to provide continuity for TLR indication	Rail Authority has to wait until complete TDRT period has expired before applying XE.	Train Demand present	By TSC seeing no TLRF when TLR indication given By technician observing detector inputs and WAIT outputs via HHT		Relay contacts are not Forced-guided contacts, ie one can change while the other does not.
6.2			Contact 9 welded	Fails to switch over when WAIT 3 applied	Fails to provide continuity for TLR indication	Rail Authority has to wait until complete TDRT period has expired before applying XE.	Train Demand present	By TSC seeing no TLRF when TLR indication given By technician observing detector inputs and WAIT outputs via HHT		Relay contacts are not Forced-guided contacts, ie one can change while the other does not.
6.3			Contact 11 welded	Fails to switch over when WAIT 3 applied	Fails to provide continuity for TLR indication	Rail Authority has to wait until complete TDRT period has expired before applying XE.	Train Demand present	By TSC seeing no TLRF when TLR indication given By technician observing detector inputs and WAIT outputs via HHT		Relay contacts are not Forced-guided contacts, ie one can change while the other does not.
6.4			Unable to energise - Contacts 6 & 11 effectively welded	Fails to switch over when WAIT 3 applied	Fails to provide continuity for TLR indication	Rail Authority has to wait until complete TDRT period has expired before applying XE.	Train Demand present	By TSC seeing no TLRF when TLR indication given By technician observing detector inputs and WAIT outputs via HHT		Relay contacts are not Forced-guided contacts, ie one can change while the other does not.
6.5			Unable to de-energise - Contacts 8 & 9 effectively welded	Fails to switch over when WAIT 3 applied	Fails to break continuity for TLR indication	No effect if TLRL is working correctly	NO Train Demand present	None		Relay contacts are not Forced-guided contacts, ie one can change while the other does not.
7	R7	Relay - TLRF	Contact 6 welded	Not used	None	None	None	None		Relay contacts are not Forced-guided contacts, ie one can change while the other does not.
7.1			Contact 8 welded	Not used	None	None	None	None		Relay contacts are not Forced-guided contacts, ie one can change while the other does not.
7.2			Contact 9 welded	TLRF indication provided continuously	None	None	None	By TSC seeing TLRF when no TLR indication given By technician observing detector inputs and WAIT outputs via HHT		Relay contacts are not Forced-guided contacts, ie one can change while the other does not.
7.3			Contact 11 welded	TLRF indication never provided	None	None	None	By TSC seeing no TLRF when TLR indication given By technician observing detector inputs and WAIT outputs via HHT		Relay contacts are not Forced-guided contacts, ie one can change while the other does not.

No.	Item	Component	Failure Mode	Local Effects	Next Level	External Effects	External Influences	Detection Method	Notes	Assumption
7.4			Unable to energise - Contacts 6 & 11 effectively welded	TLRF indication never provided	None	None	None	By TSC seeing no TLRF when TLR indication given By technician observing detector inputs and WAIT outputs via HHT		Relay contacts are not Forced-guided contacts, ie one can change while the other does not.
7.5			Unable to de-energise - Contacts 8 & 9 effectively welded	TLRF indication provided continuously	None	None	None	By TSC seeing TLRF when no TLR indication given By technician observing detector inputs and WAIT outputs via HHT		Relay contacts are not Forced-guided contacts, ie one can change while the other does not.
8	D1	Grn LED Diode - 'Relay Supply'	Open Cct	Fails to light when relay power supply is connected	None	None	None	By technician observing 'Relay Supply' LED as unlit and checking that relay supply is actually connected.		
8.1			Short Cct	Fails to light when relay power supply is connected	None	None	None	By technician observing 'Relay Supply' LED as unlit and checking that relay supply is actually connected.		
9	D2	Diode	Open Cct	Fails to provide back emf path for relay 7 de-energising	None	None	None	None		Alternate de-energising route via diode D13 available
9.1			Short Cct	TLRFB' LED may fail to light	No indication to the maintainer that TLF indication is being given.	None	None	By technician observing 'TLRFB' LED unlit. Would also need to observe detector inputs via HHT		
10	D3	Grn LED Diode - 'TLRF'	Open Cct	Fails to light when TLRF indication from rail authority	None	None	None	By technician observing 'TLRFB' LED unlit. Would also need to observe detector inputs via HHT		
10.1			Short Cct	Fails to light when TLRF indication from rail authority	None	None	None	By technician observing 'TLRFB' LED unlit. Would also need to observe detector inputs via HHT		
11	D4	Diode	Open Cct	Fails to provide reverse path for 32v AC negative half cycle around 'XE fault' LED	Reverse breakdown of 'XE fault' LED likely	No visual indication of a XE fault	None	None		
11.1			Short Cct	May result in 'XE fault' LED not lighting when there is a fault with XE.	Fault in XE not visually indicated to Technician	None	Must be a fault in XE	None		Provides a least resistance path around 'XE fault' LED
12	D5	Red LED Diode - 'XE fault'	Open Cct	Fails to light when there is an XE fault	Fault in XE not visually indicated to Technician	None	Must be a fault in XE	None		
12.1			Short Cct	Fails to light when there is an XE fault	Fault in XE not visually indicated to Technician	None	Must be a fault in XE	None		
13	D6	Grn LED Diode - 'XE'	Open Cct	Fails to light when there is an XE indication	XE indication not visually given to the Technician	None	Crossing Operating present	By technician observing 'XE' LED unlit when crossing operating or observing detectors via HHT.		
13.1			Short Cct	Fails to light when there is an XE indication	XE indication not visually given to the Technician	None	Crossing Operating present	By technician observing 'XE' LED unlit when crossing operating or observing detectors via HHT.		
14	D7	Diode	Open Cct	Fails to provide reverse path for 32v AC negative half cycle around 'XE' LED	Reverse breakdown of 'XE' LED likely	No visual indication of a XE - crossing operating	None	None		
14.1			Short Cct	May result in 'XE' LED not lighting when XE - crossing operating signal is present.	XE - Crossing operating not visually indicated to Technician	None	Crossing Operating present	By technician observing 'XE' LED unlit when crossing operating or observing detectors via HHT.		Provides a least resistance path around 'XE' LED

No.	Item	Component	Failure Mode	Local Effects	Next Level	External Effects	External Influences	Detection Method	Notes	Assumption
15	D8	Diode	Open Cct	Fails to provide reverse path for 32v AC negative half cycle around 'TD fault' LED	Reverse breakdown of 'TD fault' LED likely	No visual indication of a TD fault	None	None		
15.1			Short Cct	May result in 'TD fault' LED not lighting when there is a fault with TD.	Fault in TD not visually indicated to Technician	None	Must be a fault in TD	None		Provides a least resistance path around 'TD fault' LED
16	D9	Red LED Diode - 'TD fault'	Open Cct	Fails to light when there is an TD fault	Fault in TD not visually indicated to Technician	None	Must be a fault in TD	None		
16.1			Short Cct	Fails to light when there is an TD fault	Fault in TD not visually indicated to Technician	None	Must be a fault in TD	None		
17	D10	Grn LED Diode - 'TD'	Open Cct	Fails to light when there is an TD indication	TD indication not visually given to the Technician	None	Train Demand present	By technician observing 'TD' LED unlit and observing detectors via HHT.		
17.1			Short Cct	Fails to light when there is an TD indication	TD indication not visually given to the Technician	None	Train Demand present	By technician observing 'TD' LED unlit and observing detectors via HHT.		
18	D11	Diode	Open Cct	Fails to provide reverse path for 32v AC negative half cycle around 'TD' LED	Reverse breakdown of 'TD' LED likely	No visual indication of a TD - Train demand	None	None		
18.1			Short Cct	May result in 'TD' LED not lighting when TD - Train demand signal is present.	TD - Train demand not visually indicated to Technician	None	Train Demand present	By technician observing 'TD' LED unlit and observing detectors via HHT.		Provides a least resistance path around 'TD' LED
19	D12	Grn LED Diode - '30v AC'	Open Cct	Fails to light when detector supply is connected	None	None	None	By technician observing '30v AC' LED as unlit and checking that detector supply is actually connected.		
19.1			Short Cct	Fails to light when detector supply is connected	None	None	None	By technician observing '30v AC' LED as unlit and checking that detector supply is actually connected.		
20	D13	Diode	Open Cct	Fails to provide alternate back emf path for relays 1, 2, 3, 4 and 7 de-energising	None	None	None	None		Main de-energising route available for relays 1, 2, 3, 4 and 7
20.1			Short Cct	Relay Supply' LED may fail to light	No indication to the maintainer that Relay Supply is connected being given.	None	None	By technician observing 'Relay Supply' LED as unlit and checking that relay supply is actually connected.		
21	D14	Diode	Open Cct	Loss of TLRH circuit continuity	TLRH relay cannot be activated	No TLR indication to rail authority, TDRT maximum always used.	Train Demand present	By TSC seeing no TLRF when TLR indication given By technician observing detector inputs and WAIT outputs via HHT		
21.1			Short Cct	Relay TLRH can be operated by COUT2 going low.	Incorrect TLRH activation	None if TLRL operating correctly	COUT2 must be driven low incorrectly	None		
22	D15	Diode	Open Cct	Fails to provide back emf path for relay 5 de-energising	High voltage spike occurs	Possible arcing and damage to TSC WAIT output components	Removal of TLR	None		
22.1			Short Cct	Loss of TLRL circuit continuity	TLRL relay cannot be activated	No TLR indication to rail authority, TDRT maximum always used.	Train Demand present	By TSC seeing no TLRF when TLR indication given By technician observing detector inputs and WAIT outputs via HHT		

No.	Item	Component	Failure Mode	Local Effects	Next Level	External Effects	External Influences	Detection Method	Notes	Assumption
23	D16	Diode	Open Cct	Fails to provide back emf path for relay 6 de-energising	High voltage spike occurs	Possible arcing and damage to TSC WAIT output components	Removal of TLR	None		
23.1			Short Cct	Loss of TLRH circuit continuity	TLRH relay cannot be activated	No TLR indication to rail authority, TDRT maximum always used.	Train Demand present	By TSC seeing no TLRF when TLR indication given By technician observing detector inputs and WAIT outputs via HHT		
24	D17	Diode	Open Cct	Fails to provide reverse path for 32v AC negative half cycle around '30v AC' LED	None	None	None	None		
24.1			Short Cct	May result in '30v AC' LED not lighting when detector supply connected.	No indication to the maintainer that 32v AC supply is connected being given.	None	None	By technician observing '30v AC' LED as unlit and checking that 32v AC supply is actually connected.		
25	R1	Resistor 1	Open Cct	Causes current in XENO circuit to drop from 42mA to ≈ 17mA	None	None - minimum wetting current for Rail Authority relay contacts is 10mA.	None	None		
25.1				Fails to provide back emf path for relay 1 de-energising	High voltage spike occurs	Possible arcing and damage to Rail Authority components	Removal of XE	None		
25.2			Short Cct	Causes current in XENO circuit to climb from 42mA to unacceptable levels	Relay 1 by passed. Therefore not energised when XE present	High current may cause Rail Authority relay contacts to become welded causing XENO to become permanently closed.	Crossing Operating present	By TSC seeing XENO1 high when XENC1 is also high		
25.3							NO Crossing Operating present	By TSC seeing XENO1 high when XENC1 is also high By technician observing 'XE fault' LED lit and 'XE' LED lit		
25.4			Drift ± 50%	None	None	None	None	None		
26	R2	Resistor 2	Open Cct	Causes current in XENC circuit to drop from 42mA to ≈ 17mA	None	None - minimum wetting current for Rail Authority relay contacts is 10mA.	None	None		
26.1				Fails to provide back emf path for relay 2 de-energising	High voltage spike occurs	Possible arcing and damage to Rail Authority components	Application of XE	None		
26.2			Short Cct	Causes current in XENC circuit to climb from 42mA to unacceptable levels	XENC1 - permanently high	High current may cause Rail Authority relay contacts to become welded causing XENC to become permanently closed.	Crossing Operating present	By TSC seeing XENC1 high when XENO1 is also high By technician observing 'XE fault' LED lit and 'XE' LED lit when there is no train demand		
26.3							NO Crossing Operating present	By TSC seeing XENC1 high when XENO1 is also high		
26.4			Drift ± 50%	None	None	None	None	None		
27	R3	Resistor 3	Open Cct	Causes current in TDNC circuit to drop from 42mA to ≈ 17mA	None	None - minimum wetting current for Rail Authority relay contacts is 10mA.	None	None		
27.1				Fails to provide back emf path for relay 3 de-energising	High voltage spike occurs	Possible arcing and damage to Rail Authority components	Removal of TD	None		

No.	Item	Component	Failure Mode	Local Effects	Next Level	External Effects	External Influences	Detection Method	Notes	Assumption
27.2			Short Cct	Causes current in TDNC circuit to climb from 42mA to unacceptable levels	TDNO1 - permanently high	High current may cause Rail Authority relay contacts to become welded causing TDNO to become permanently closed.	Train Demand present	By TSC seeing TDNO1 high when TDNC1 is also high		
27.3							NO Train Demand present	By TSC seeing TDNO1 high when TDNC1 is also high By technician observing 'TD fault' LED lit and 'TD' LED lit		
27.4			Drift ± 50%	None	None	None	None	None		
28	R4	Resistor 4	Open Cct	Causes current in TDNC circuit to drop from 42mA to ≈ 17mA	None	None - minimum wetting current for Rail Authority relay contacts is 10mA.	None	None		
28.1				Fails to provide back emf path for relay 4 de-energising	High voltage spike occurs	Possible arcing and damage to Rail Authority components	Application of TD	None		
28.2			Short Cct	Causes current in TDNC circuit to climb from 42mA to unacceptable levels	TDNC1 - permanently high	High current may cause Rail Authority relay contacts to become welded causing TDNC to become permanently closed.	Train Demand present	By TSC seeing TDNC1 high when TDNO1 is also high By technician observing 'TD fault' LED lit and 'TD' LED lit when there is no train demand		
28.3							NO Train Demand present	By TSC seeing TDNC1 high when TDNO1 is also high		
28.4			Drift ± 50%	None	None	None	None	None		
29	R5	Resistor 5	Open Cct	Voltage supply to 'Relay Supply' LED halted.	None	None	Power connected	By technician observing 'Relay Supply' LED unlit.		
29.1			Short Cct	Voltage through 'Relay Supply' LED rises to the extent that 'Relay Supply' LED is blown	None	None	Power connected	By technician observing 'Relay Supply' LED unlit.		
29.2			Drift 50% original	Current rises to ≈ 30mA	Relay Supply' LED intensity rises to 100%	None	None	None		
29.3			Drift twice original	Current falls to ≈ 8mA	Relay Supply' LED intensity falls ≈ 50%	None	None	None		
30	R6	Resistor 6	Open Cct	Voltage supply to 'TLRFB' LED halted.	None	None	TLR is present	By technician observing 'TLRFB' LED unlit. Would also need to observe detector inputs via HHT		
30.1				Fails to provide back emf path for relay 7 de-energising	High voltage spike occurs	Possible arcing and damage to Rail Authority components	Removal of TLR	None		
30.2			Short Cct	Voltage through 'TLRFB' LED rises to the extent that 'TLRFB' LED is blown	TLRFB' LED fails to light	None	TLR is present	By technician observing 'TLRFB' LED unlit. Would also need to observe WAIT outputs and detector inputs via HHT		
30.3				Would allow less resistive path and therefore bypass TLRF relay (RL7)	TLR feedback relay would not energise. No feedback to TSC of TLR being received	None	TLR is present	By technician observing 'TLRFB' LED unlit. Would also need to observe WAIT outputs and detector inputs via HHT		
30.4			Drift 50% original	Current rises to ≈ 30mA	Relay Supply' LED intensity rises to ≈ 125%	None	None	None		
30.5			Drift twice original	Current falls to ≈ 8mA	Relay Supply' LED intensity falls ≈ 50%	None	None	None		

No.	Item	Component	Failure Mode	Local Effects	Next Level	External Effects	External Influences	Detection Method	Notes	Assumption
31	R8	Resistor 8	Open Cct	Voltage supply to 'XE fault' LED halted.	Fault diagnosis lost	None	Crossing Operating present & fault with XE signal	By technician observing 'XE fault' LED unlit. Would also need to observe detector inputs via HHT		
31.1			Short Cct	Voltage through 'XE fault' LED rises to the extent that 'XE fault' LED is blown and possible welding of relay 1 & relay 2 (XENO & XENC) contacts	Fault diagnosis lost	None	Crossing Operating present & fault with XE signal	By technician observing 'XE fault' LED unlit. Would also need to observe detector inputs via HHT		
31.2			Drift 50% original	Current rises to ≈ 27mA	XE Fault' LED intensity rises to ≈ 125%	None	None	None		
31.3			Drift twice original	Current falls to ≈ 7mA	XE Fault' LED intensity falls ≈ 40%	None	None	None		
32	R9	Resistor 9	Open Cct	Voltage supply to 'XE' LED halted.	Fault diagnosis lost	None	Crossing Operating present	By technician observing 'XE' LED unlit.		
32.1			Short Cct	Voltage through 'XE' LED rises to the extent that 'XE' LED is blown and possible welding of relay 1 & relay 2 (XENO & XENC) contacts	Fault diagnosis lost	None	Crossing Operating present	By technician observing 'XE' LED unlit.		
32.2			Drift 50% original	Current rises to ≈ 26mA	XE' LED intensity rises to ≈ 110%	None	None	None		
32.3			Drift twice original	Current falls to ≈ 6mA	XE' LED intensity falls ≈ 40%	None	None	None		
33	R10	Resistor 10	Open Cct	Voltage supply to 'TD' LED halted.	Fault diagnosis lost	None	Train Demand present	By technician observing 'TD' LED unlit.		
33.1			Short Cct	Voltage through 'TD' LED rises to the extent that 'TD' LED is blown and possible welding of relay 3 & relay 4 (TDNO & TDNC) contacts	Fault diagnosis lost	None	Train Demand present	By technician observing 'TD' LED unlit.		
33.2			Drift 50% original	Current rises to ≈ 26mA	TD' LED intensity rises to ≈ 110%	None	None	None		
33.3			Drift twice original	Current falls to ≈ 6mA	TD' LED intensity falls ≈ 40%	None	None	None		
34	R11	Resistor 11	Open Cct	Voltage supply to '30v AC' LED halted.	None	None	Power connected Train Demand present	By technician observing '30v AC' LED unlit while 'TD' lit.		
34.1			Short Cct	Voltage through '30v AC' LED rises to the extent that '30v AC' LED is blown	None	None	Power connected Train Demand present	By technician observing '30v AC' LED unlit while 'TD' lit.		
34.2			Drift 50% original	Current rises to ≈ 26mA	30v AC' LED intensity rises to ≈ 110%	None	None	None		
34.3			Drift twice original	Current falls to ≈ 6mA	30v AC' LED intensity falls ≈ 40%	None	None	None		
35	R12	Resistor 12	Open Cct	Voltage supply to 'TD fault' LED halted.	Fault diagnosis lost	None	Train Demand present & fault with TD signal	By technician observing 'TD fault' LED unlit. Would also need to observe detector inputs via HHT		

No.	Item	Component	Failure Mode	Local Effects	Next Level	External Effects	External Influences	Detection Method	Notes	Assumption
35.1			Short Cct	Voltage through 'TD fault' LED rises to the extent that 'TD fault' LED is blown and possible welding of relay 3 & relay 4 (TDNO & TDNC) contacts	Fault diagnosis lost	None	Train Demand present & fault with TD signal	By technician observing 'TD fault' LED unlit. Would also need to observe detector inputs via HHT		
35.2			Drift 50% original	Current rises to ≈ 27mA	TD Fault' LED intensity rises to ≈ 125%	None	None	None		
35.3			Drift twice original	Current falls to ≈ 7mA	TD Fault' LED intensity falls ≈ 40%	None	None	None		
36	R13	Resistor 13	Open Cct	No voltage supply to TLRL	TLR indication not given to Rail authority	TDRT maximum always used.	TLR indication required to be given	By TSC seeing no TLRF when TLR indication given By technician observing detector inputs and WAIT outputs via HHT		
36.1			Short Cct	Voltage through TLRL would rise significantly	None	None	TLR indication required to be given	None	Currently specified relays (MT2C93418) can handle 24v adequately	
36.2			Drift 50% original	Voltage drop across relay 5 increases significantly.	None	None	TLR indication required to be given	None	Currently specified relays (MT2C93418) can handle 24v adequately	
36.3			Drift twice original	Voltage drop across relay 5 decreases significantly.	None	None	TLR indication required to be given	None	Currently specified relays (MT2C93418) can operate down to 7.8v (which would equate to a resistor drift of over 3 times original).	
37	R14	Resistor 14	Open Cct	No voltage supply to TLRH	TLR indication not given to Rail authority	TDRT maximum always used.	TLR indication required to be given	By TSC seeing no TLRF when TLR indication given By technician observing detector inputs and WAIT outputs via HHT		
37.1			Short Cct	Voltage through TLRH would rise marginally	None	None	TLR indication required to be given	None		
37.2			Drift 50% original	Voltage drop across relay 6 increases.	None	None	TLR indication required to be given	None		
37.3			Drift twice original	Voltage drop across relay 6 decreases.	None	None	TLR indication required to be given	None		
37.4			Short Cct	Shorts the TSC 12 v dc supply to the TSC WAIT outputs		May cause a problem for the TSC having the 12 v dc supply short to the active low TSC WAIT outputs	TLR indication is falsely being given (COUT1 and COUT3 are active low) & is required to be suppressed (COUT2 is active low)			
37.5			Drift 50% original	Marginal increase in current through circuit	None	None	None	None		
37.6			Drift twice original	Marginal decrease in current through circuit	None	None	None	None		
38	R15	Resistor 15	Open Cct	No voltage supply to TLRH	TLR indication not given to Rail authority	TDRT maximum always used.	TLR indication required to be given	By TSC seeing no TLRF when TLR indication given By technician observing detector inputs and WAIT outputs via HHT		

No.	Item	Component	Failure Mode	Local Effects	Next Level	External Effects	External Influences	Detection Method	Notes	Assumption
38.1			Short Cct	Voltage through TLRL would rise significantly	None	None	TLR indication required to be given	None	Currently specified relays (MT2C93418) can handle 24v adequately	
38.2			Drift 50% original	Voltage drop across relay 6 increases significantly.	None	None	TLR indication required to be given	None	Currently specified relays (MT2C93418) can handle 24v adequately	
38.3			Drift twice original	Voltage drop across relay 6 decreases significantly.	None	None	TLR indication required to be given	None	Currently specified relays (MT2C93418) can operate down to 7.8v (which would equate to a resistor drift of over 3 times original).	
39	R16	Resistor 16	Open Cct	TLR indication lost	TLR indication not given to Rail authority	TDRT maximum always used.	TLR indication required to be given	By TSC seeing no TLRF when TLR indication given By technician observing detector inputs and WAIT outputs via HHT		
39.1			Short Cct	Current would increase marginally over 'normal' operation in TLR circuit	None	None	TLR indication required to be given	None		
39.2			Drift 50% original	Current would increase marginally over 'normal' operation in TLR circuit	None	None	TLR indication required to be given	None		
39.3			Drift twice original	Current would decrease marginally over 'normal' operation in TLR circuit	None	None	TLR indication required to be given	None		
40	R17	Resistor 17	Open Cct	TLR indication lost	TLR indication not given to Rail authority	TDRT maximum always used.	TLR indication required to be given	By TSC seeing no TLRF when TLR indication given By technician observing detector inputs and WAIT outputs via HHT		
40.1			Short Cct	Current would increase marginally over 'normal' operation in TLR circuit	None	None	TLR indication required to be given	None		
40.2			Drift 50% original	Current would increase marginally over 'normal' operation in TLR circuit	None	None	TLR indication required to be given	None		
40.3			Drift twice original	Current would decrease marginally over 'normal' operation in TLR circuit	None	None	TLR indication required to be given	None		
41	R220	Resistor	Open Cct	Fails to provide back emf path for Rail Authority's TLR relay de-energising	High voltage spike occurs	Possible arcing and damage to TLRL and TLRH contacts	TLR indication required to be given	None		
41.1			Short Cct	Significant Increase in current on initial circuit activation (falls as capacitor charges). No affect once capacitor has fully charged.	Resistors 16 and 17 may act like a fuse.	None	TLR indication required to be given	None		
41.2			Drift 50% original	Current would increase over 'normal' operation in TLR circuit by ≈ 50%	Decrease in time for Capacitor to charge	None	TLR indication required to be given	None		
41.3			Drift twice original	Current would decrease over 'normal' operation in TLR circuit by ≈ 25%	Increase in time for Capacitor to charge	None	TLR indication required to be given	None		

No.	Item	Component	Failure Mode	Local Effects	Next Level	External Effects	External Influences	Detection Method	Notes	Assumption
42	C1	Capacitor	Open Cct	Fails to provide back emf path for Rail Authority's TLR relay de-energising	High voltage spike occurs	Possible arcing and damage to TLRL and TLRH contacts	TLR indication required to be given	None		
42.1			Short Cct	Fails to provide back emf path for Rail Authority's TLR relay de-energising	High voltage spike occurs	Possible arcing and damage to TLRL and TLRH contacts	TLR indication required to be given	None		
42.2				Would allow less resistive path and therefore bypass Rail Authority components	TLR indication not given to Rail authority	TDRT maximum always used.	TLR indication required to be given	By TSC seeing no TLRF when TLR indication given By technician observing detector inputs and WAIT outputs via HHT		
42.3				Resistor R220 is an active component continuously	Higher current through the circuit for longer	None	None	None		
42.4			Drift 50% original	≈ 50% decrease in time for Capacitor to charge	None	None	TLR indication required to be given	None		
42.5			Drift twice original	≈ 100% increase in time for Capacitor to charge	None	None	TLR indication required to be given	None		

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Roads and Traffic Authority

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