



ELM V2

EARTH LEAKAGE PROTECTION RELAY

User Manual

Revision: 1, JULY/2018
Designed and manufactured in Australia by Ampcontrol Pty Ltd



WARNING!



The **warning** symbol highlights a potential risk of **injury or death**.
Please share these warnings with other operators.

CAUTION!



The **caution** symbol highlights a potential risk of **damage to equipment**.
Please share these cautions with other operators.

NOTE



The **note** symbol highlights **key information**.
Please share these notes with other operators.

ENVIRO



The **enviro** (environmental) symbol highlights areas which may have an impact on the surrounding **fauna and/or flora**.

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Before You Begin

Thank you for purchasing the Ampcontrol ELM V2 Relay.

WARNING!



In the interests of **safety and correct equipment operation**, please take the time to read and understand the content in this manual.

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1 SAFETY AND OTHER WARNINGS

For safety reasons, the ELM must be installed, operated and serviced only by competent personnel. Please read and understand this instruction manual completely before installing, operating or servicing this equipment. Failure to install or operate this instrument in accordance with the instructions contained in this manual may create hazardous operating conditions.

1.1 Safe Use of Equipment

The equipment supplied has been designed and manufactured to ensure safe operation. The equipment must only be used within the design parameters.

The instructions within this manual must be observed as an aid towards achieving the safest possible installation.

Persons responsible for installation, maintenance, or operation, must observe the following instructions:

1.1.1 Changes to Equipment

Changes in the design and modifications to the equipment are not permitted. Unauthorised changes made to the hardware or operating firmware will void the manufacturer's warranty, and may compromise the integrity of the system into which it is installed and other connected equipment.

1.1.2 Equipment Knowledge

Experience with, or understanding of, this equipment is essential for the safe installation and removal of the equipment. Therefore, please read and understand this manual prior to use. Competency based training courses are recommended and are available on request.

1.1.3 Manual Handling

Precautions have been taken to ensure all equipment is safe to handle and free from sharp edges. However care should always be taken when handling enclosures and gloves should be worn.

1.1.4 Installation

Correct operation and safety depend on the relay and associated equipment being installed correctly. Mechanical and or electrical installation and maintenance of plant and equipment must only be carried out by appropriately qualified personnel and must be tested thoroughly prior to operation.

1.1.5 Operation

As safety depends on the relay functioning correctly it is highly recommended that all safety functions of the relay be periodically tested to ensure correct operation.

2 RECEIVING AND STORAGE

2.1 Receiving

All possible precautions are taken to protect the equipment against damage or losses during shipment, however before accepting delivery, check all items against the packing list or bill of loading. If there is evidence of physical damage, notify Ampcontrol immediately.

Notify Ampcontrol immediately in case of any discrepancies to the packing list. Keep a record of any claims and correspondence. Photographs are recommended.

Where practicable do not remove protective covers prior to installation unless there are indications of damage. Boxes opened for inspection and inventory should be carefully repacked to ensure protection of the contents or else the parts should be packaged and stored in a safe place. Examine all packing boxes, wrappings and covers for items attached to them, retain and store any approval documentation for your safety file as applicable prior to wrapping being discarded.

2.2 Inspection

Equipment that is found to be damaged or has been modified away from its published specification must not be used. Please contact Ampcontrol if the equipment is suspected to be different than that ordered or if it does not match the published specifications.

2.3 Storage after Delivery

When the equipment is not to be installed immediately, proper storage is important to ensure protection of equipment and validity of warranty.

All equipment should be stored indoors between 0-40°C, preferably on shelves and protected from moisture and sunlight.

2.4 Unpacking of Equipment

The method of packing used will depend on the size and quantity of the equipment. The following cautions should be interpreted as appropriate.

CAUTION!



Take care when unpacking crates as the **contents may have shifted during transport.**

ENVIRO



The disposal of packaging materials, replaced parts, or components must comply with environmental restrictions without polluting the soil, air or water.

Ensure that any timber and cardboard used as **packaging is disposed of in a safe and environmentally responsible manner.**

Where possible, dispose of all waste products i.e. oils, metals, plastic and rubber products by using an approved recycling service centre.

3 PRODUCT OVERVIEW

3.1 ELM V2 Earth Leakage Relay

The Amcontrol ELM V2 Earth Leakage Relay is electronic in design and is based on microprocessor technology. The earth fault current is measured using a toroid, with the trip time and trip threshold being able to be independently adjusted using selectors on the relay fascia.

When a fault occurs and the trip level and time delay is exceeded the relay's trip function is activated. A trip will de-energise the trip contacts connected in the system control circuit. The trip condition is latched in non-volatile memory and requires operation of the reset input to clear the trip condition. An internal reset is also provided on the fascia of the relay.

A ten-segment LED bar graph indicates the percentage of leakage level being detected. This reading can be remotely monitored/displayed using the 4-20mA output of the relay. When the relay measures currents with frequencies much greater than 50Hz, the bar graph LED fast flashes (5Hz) instead of being steady. Should the high frequency current persist until the time delay is exceeded the relay will trip and the 'Har.Trip' LED (Harmonic Trip) will be illuminated.

The ELM V2 Earth Leakage Relay is housed in a stainless steel case and can be either 'DIN Rail' or 'Panel' mounted through a 69 x 39mm cut out. When panel mounted the front of the relay is designed to provide IP56 ingress protection. There is provision to prevent unauthorised adjustment of the trip settings by sealing the post (in front of the knurled nut) with a lead seal or the use of a padlocked cover (see the equipment list for part number), thus inhibiting the unauthorised removal of the front fascia cover.

An internal switch mode power supply allows the ELM V2 to operate from 24VAC to 110VAC or 24VDC to 150VDC



Figure 3.1: Amcontrol ELM V2 Earth Leakage Relay

The ELM V2 is suitable for both core balance and series neutral methods of protection.

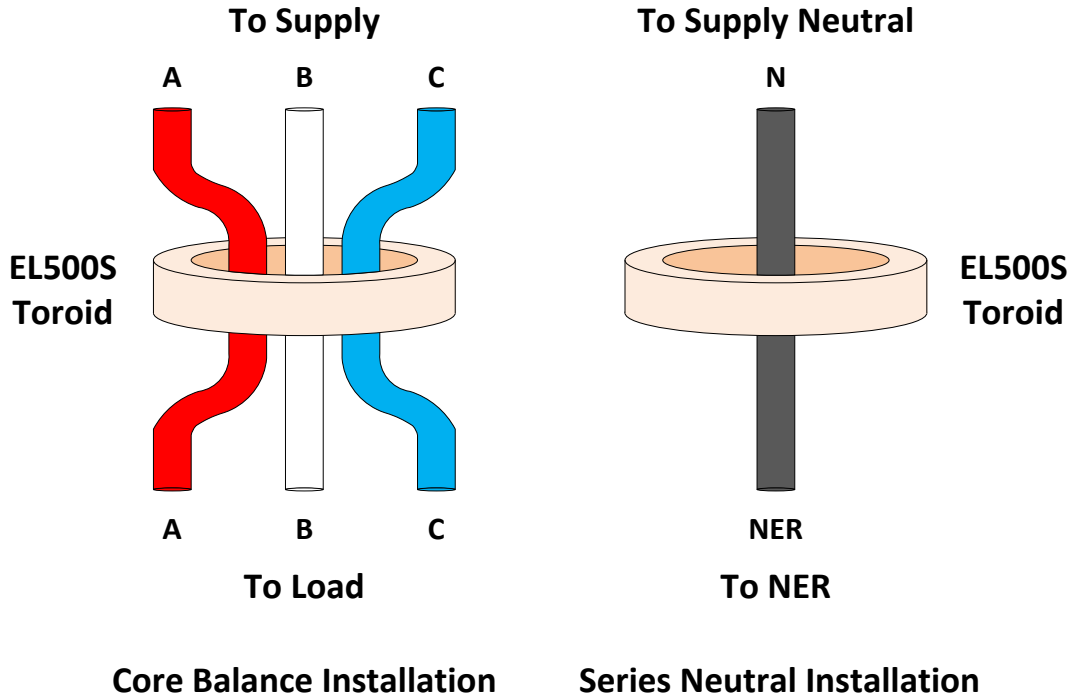


Figure 3.2: Core Balance and Series Neutral Installation Types

The ELM V2 Relay has been designed and tested for use on fault-limited systems. To ensure maximum protection the earth leakage system should be used in conjunction with the other protection systems covered by AS/NZS 2081. The collective systems are designed to limit touch and step potentials.

The relay is also suitable for industry where equipment or system earth leakage protection is required. The relay is not suitable for personal protection, which requires trip levels of 20-30mA, with instantaneous operation (refer to AS/NZS 3190).

The relay continually monitors the toroid and if the connection is lost the relay will trip and flash the 'CT Fault' LED.

3.2 Accessories

3.2.1 DIN Rail Mounting Kit (101399)

The Elm V2 is designed to be panel mounted, however a DIN rail mounting kit can be separately purchased.

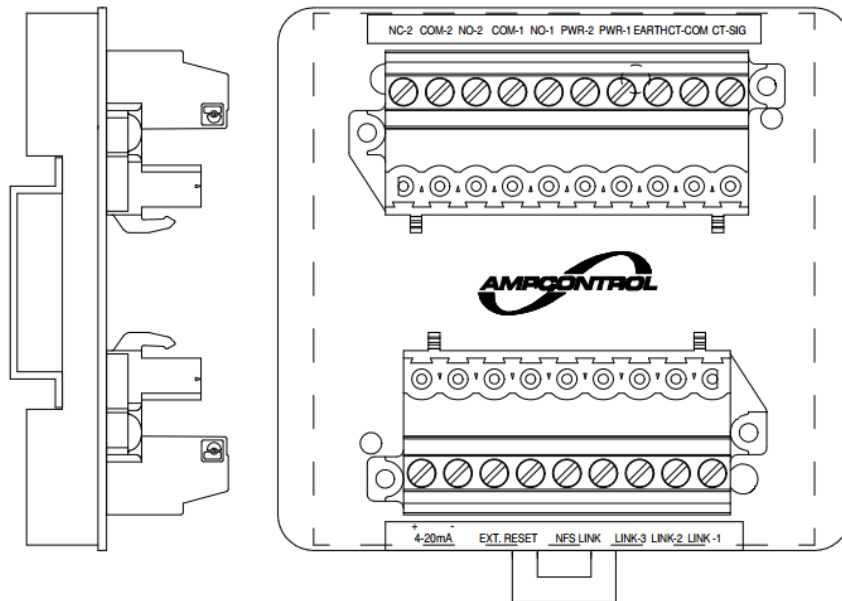


Figure 3.3: DIN Rail Mounting Kit (Suit ELM / ELD / ELV)

3.2.2 Lockable Cover (164672)

A separately purchasable Lockable Cover is available to install over the fascia of the ELM V2 relay. This can be used to prevent earth leakage resets being performed by unauthorised personnel.

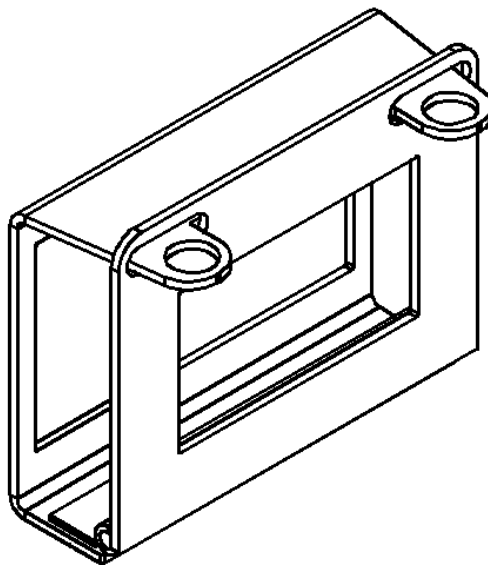


Figure 3.4: Lockable Cover (Suit ELM / ELD / ELV)

3.2.3 ELCF Adaptor (120255)

This accessory allows users of the obsolete ELCF earth leakage relay to upgrade to Ampcontrol's next generation of earth leakage relays. The ELCF Adaptor seals the larger hole left by the ELCF relay and provides a mounting point for the ELM V2 relay.

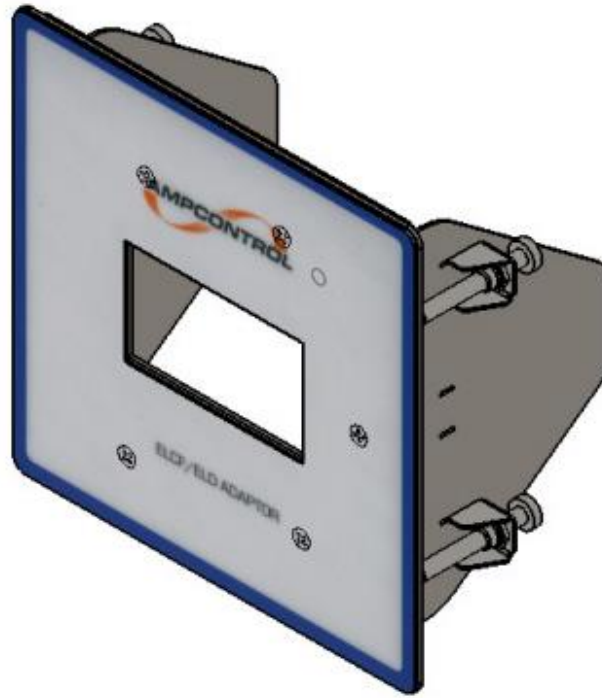


Figure 3.5: ELCF Adaptor (Suit ELM / ELD / ELV)

3.2.4 ELD / ELV / ELM Service Kit (179513)

This kit includes all loose components used in the ELD / ELV / ELM relays.

- 1x Clear Front Window Cover
- 2x Window Thumb Nuts
- 2x Mounting Clips with Screws
- 1x Facia Gasket

3.2.5 Bramco ELF Adaptor (175279)

This adaptor kit allows users of the Bramco ELF and ELF2 relays to transfer to Ampcontrol's next generation of earth leakage relays. The ELF Adaptor seals the larger hole (90x90mm) left by the ELF relay and provides a mounting point for the ELM V2 relay.

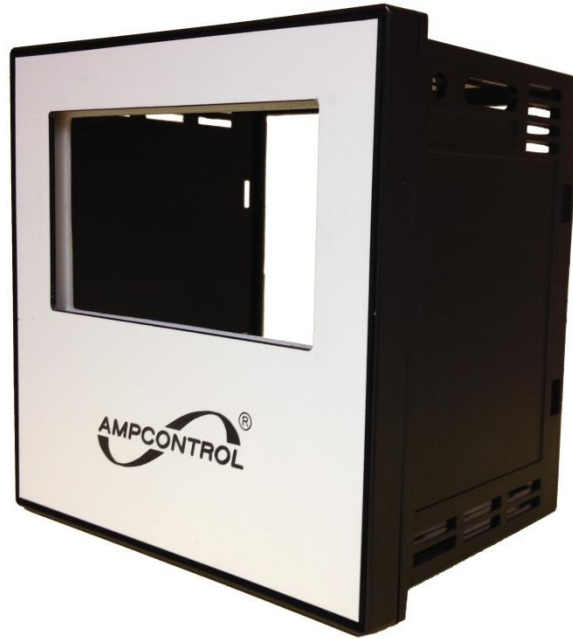


Figure 3.6: ELF Adaptor (Suit ELM / ELD / ELV)

4 INSTALLATION

4.1 General Warnings

These instructions have been designed to assist users of the ELM V2 relay with installation.

Before the relay can be installed, there are a number of things that need to be considered and understood to prevent incorrect or unsafe operation of the relay or the system into which it is installed.

Along with relevant competence, and an understanding of the target application, the following points should be considered:

4.1.1 Ensure that the information provided in this user manual is fully understood.

It is extremely important that the limitations and functionality of the relay are understood to prevent incorrect installation and use from creating a potentially dangerous risk. If in doubt as to the nature of the limitations or their implication, consult a competent authority such as a supervisor or Ampcontrol technical representative.

4.1.2 Ensure that the application into which the relay is being installed has been properly defined, designed and approved.

Any system intended to mitigate the risk of injury needs to be properly designed and implemented. Such a system must be the result of structured risk analysis with the outcomes used to define the system requirements. These requirements, in turn, will guide the choice of instrumentation, logic solvers and actuators needed to implement the system. Understanding the needs of the system will ensure proper selection of equipment.

4.1.3 Ensure that the relay will properly perform the required functions within the system design.

It is important to understand how the relay is intended to interact with other equipment within a system. For safe and reliable use, it is crucial that neither the ELM V2 logical operation nor its signalling be compromised by incompatibilities with connected equipment.

4.1.4 Modifications of any form to the EL relay are prohibited.

The relay as supplied has been designed and manufactured to comply with the requirements of protection standards. If modifications of any form are made to the relay, the equipment may no longer be fit for use. If any modifications or damage to the relay is evident, do not use the equipment and contact Ampcontrol for advice.

4.2 Mandatory Installation Practices

The following information must be adhered to when installing the relay. Failure to adhere to this information may give rise to unsafe operation.

Using the relay in a manner that exceeds its electrical, functional or physical specifications, or in a way that is contrary to its operating restrictions, may create risks to personnel and/or equipment resulting in injury or death.

- The relay must be powered within the specified voltage range.
- The voltage and current ratings of the relay's output contacts must be observed.
- The 4-20mA Output Signal circuit must adhere to the parameters stated in the specifications
- The installation of the relay must be carried out by suitably trained and qualified personnel.
- Identification labels fixed to the relay must not be damaged, removed or covered before, during or after installation.
- The installation is to be in accordance with the relevant installation Standards/Codes of Practice.

- Modifications must not be made to any part of the relay. As supplied, the unit is built to, and complies with the relevant standards. Modifications to its construction will render the unit non-compliant.
- Complete and accurate records of the installation must be kept as part of the site installation.

4.3 ELM V2 Mechanical Installation Information

The relay is housed in a plastic and stainless steel enclosure and is rated as IP20. The enclosure is designed to be either DIN rail or Panel mounted. The dimensions are shown in Figure 4.1 below.

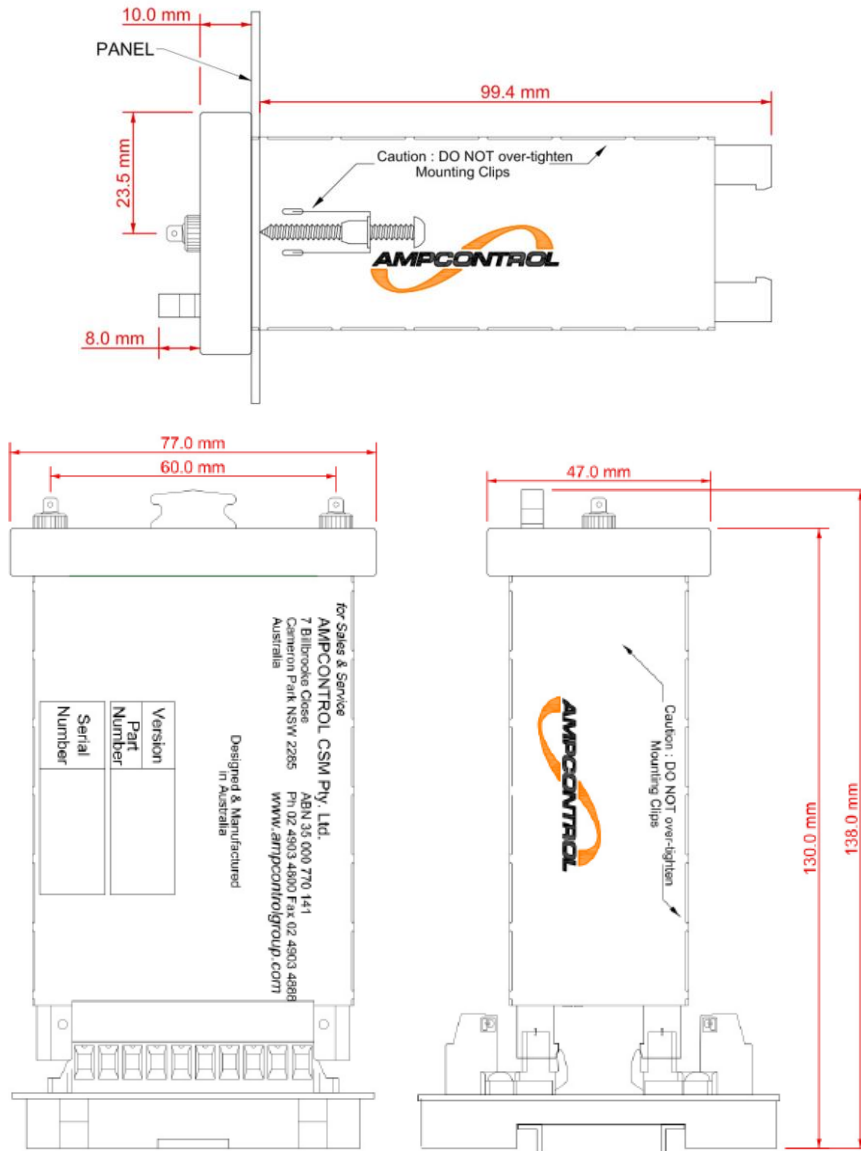


Figure 4.1: EL Range Enclosure Dimensions – Panel Mounted (Top) and DIN Rail Mounted (Bottom)

4.3.1 Panel Mounting

The required cut out for panel mounting is 69w x 39h (mm).

When panel mounted correctly using the supplied gasket, the relay will have a fascia IP rating of IP56.

4.3.2 DIN Rail Mounting

A separately purchasable mounting kit is available for mounting the relay onto a DIN rail. See the equipment list in Section 0.

4.4 Toroid Mechanical Installation Information

The ELM V2 uses the EL500 100:1 toroid range for earth leakage current detection. These toroids are available in three window sizes: 25mm, 60mm, 85mm & 112mm. These allow trip settings from 30mA to 2.5A.

4.4.1 EL500S/25 (Item Number 115438)

The EL500S/25 toroid has a 25mm window and is DIN rail mounted.

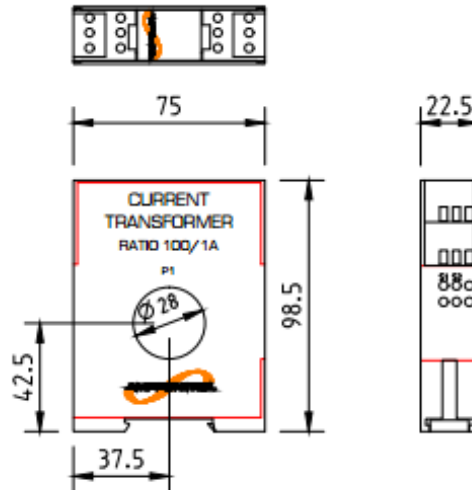


Figure 4.2: EL500S/25 Toroid (115438) Dimensions

4.4.2 EL500/60 (Item Number 115439)

The EL500/60 toroid has a 60mm window and is panel mounted.

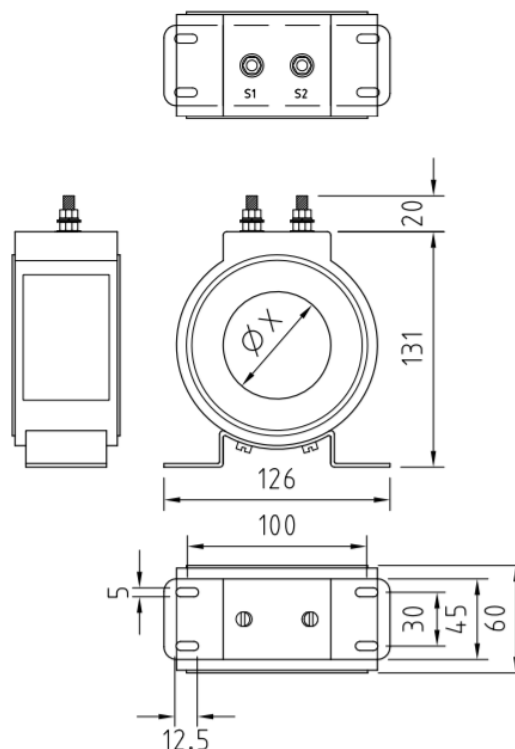
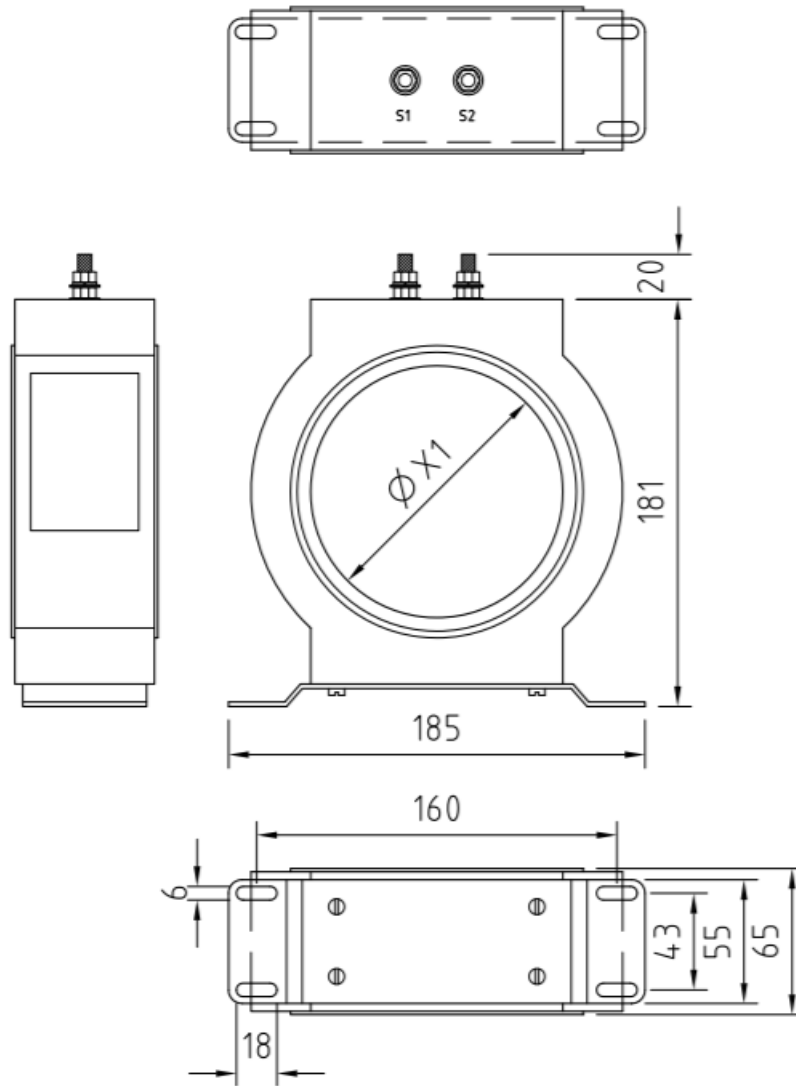


Figure 4.3: EL500/60 Toroid (115439) Dimensions

4.4.1 EL500/85 (Item Number 115440) & EL500/112 (Item Number 115441)

The EL500/85 and EL500/112 toroids have a 85mm and 112mm window respectively and is panel mounted.



EL500/85 - 115440

EL500/112 - 115441

$\phi X1 = \phi 85 / \phi 112$

Figure 4.4: EL500//85 & EL500/112 Toroid Dimensions

4.5 Electrical Installation Information

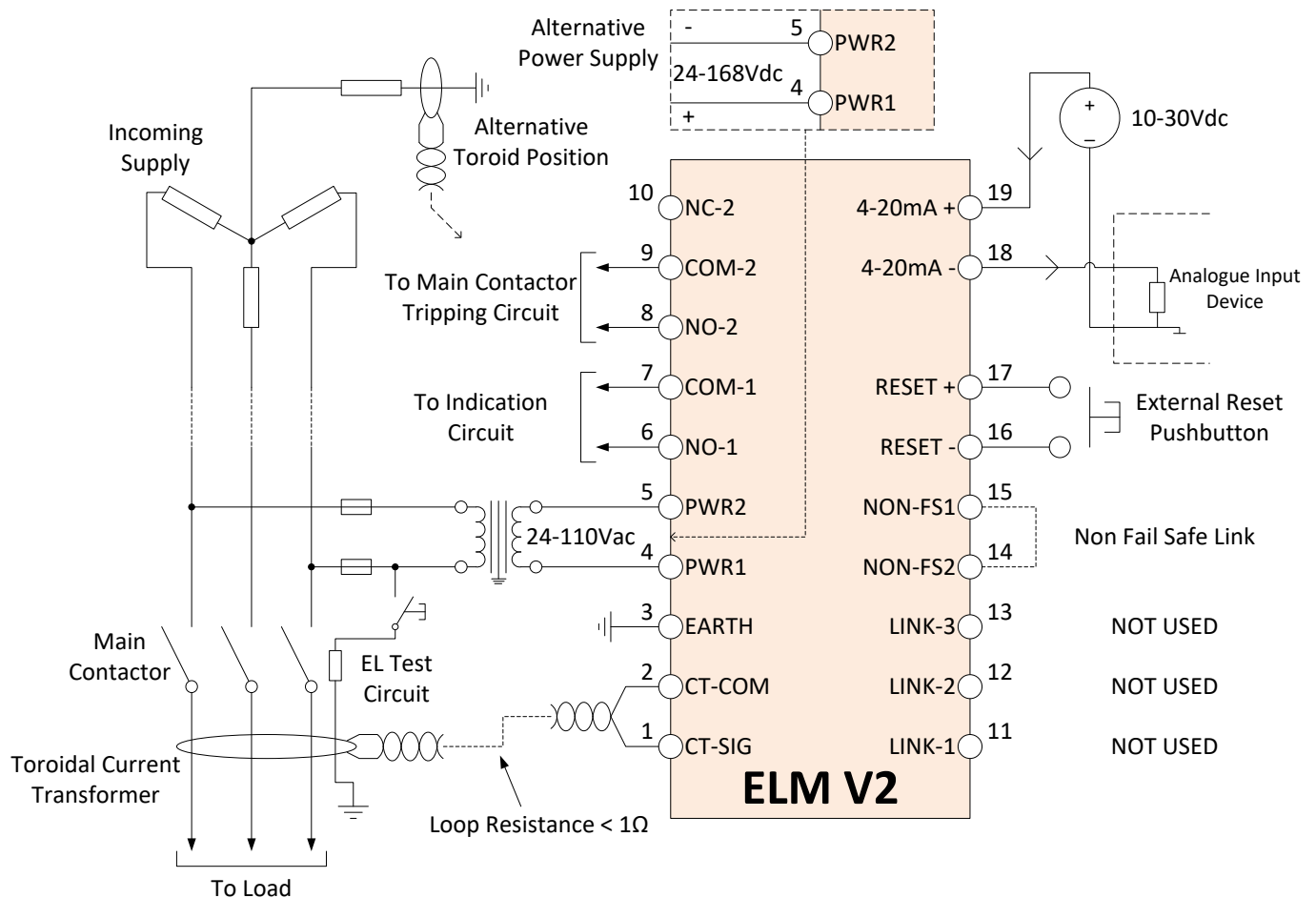


Figure 4.5: ELM V2 Typical Connection Diagram

4.5.1 CT-SIG & CT-COM Connections (Terminals 1 & 2)

These terminals are for the earth leakage toroid connection.

CAUTION!

The wires connecting the ELM V2 and the earth leakage toroid should be run in a **twisted pair** and must have a **loop resistance of less than 1Ω**.

4.5.2 Earth Connection (Terminal 3)

This terminal is for the connection of the power supply earth.

4.5.3 PWR1 & PWR2 Connections (Terminals 4 & 5)

These terminals are for the connection of the control power supply.

The relay is able to operate across both AC and DC voltages ranges. The supply voltage can be 24-110VAC +/- 20% at 50Hz, or 24-168VDC +/- 10%.

4.5.4 NO-1 & COM-1 Connections (Terminals 6 & 7)

These terminals provide a normally open contact that can be wired into control or indication circuits.

The output relay will be energised (closed) whilst the relay is healthy and will de-energise when in the

tripped state.

4.5.5 NO-2, COM-2 & NC-2 Connections (Terminals 8, 9 & 10)

These terminals provide a changeover contact that can be wired into control or indication circuits.

The output relay will be energised whilst the relay is healthy and will de-energise when in the tripped state.

4.5.6 LINK-1, LINK-2 & LINK-3 Connections (Terminals 11, 12 & 13)

These terminals are **not used** and are not to be connected.

4.5.7 NON-FS1 & NON-FS2 Connections (Terminals 14 & 15)

These terminals are used to change the relay between Fail-safe and Non-Fail-Safe modes of operation by shorting these two terminals.

4.5.8 RESET- & RESET+ Connections (Terminals 16 & 17)

These terminals are for the connection of the external reset pushbutton.

If an external reset is used, it is recommended that a twisted pair be used between the N/O contact and the reset input.

4.5.9 4-20mA- & 4-20mA+ Connections (Terminals 18 & 19)

These terminals provide a 4-20mA analogue output that indicates the earth leakage current as a percentage of the trip level.

The current output of 4mA represents an earth leakage current of 0% of the trip level (no earth leakage) and the current output of 20mA represents an earth leakage current of 120% of the trip level. At 100% the current will be 17.33mA.

$$\text{Maximum Loop Resistance} = [V_s^* - 10] \times 50,$$

*where V_s must be greater than 10VDC and less than 30VDC

The 4-20mA output should be wired as per Figure 4.5.

5 COMMISSIONING AND CALIBRATION

Prior to being put into service, the electrical protection system must be correctly commissioned. This manual does not cover system commissioning; the full scope of commissioning tests should be determined during the risk assessment or FMEA covering the design of the electrical protection system.

The following test can provide guidance on checking the correct operation of the ELM V2 during commissioning. This is not intended to provide an exhaustive commissioning checklist, but should be considered to be a minimum set of tests.

5.1 Earth Leakage Test

Inject a test current at 120% of the trip level setting through the toroid, as shown in Figure 5.1. Verify that the ELM V2 relay trips as expected.

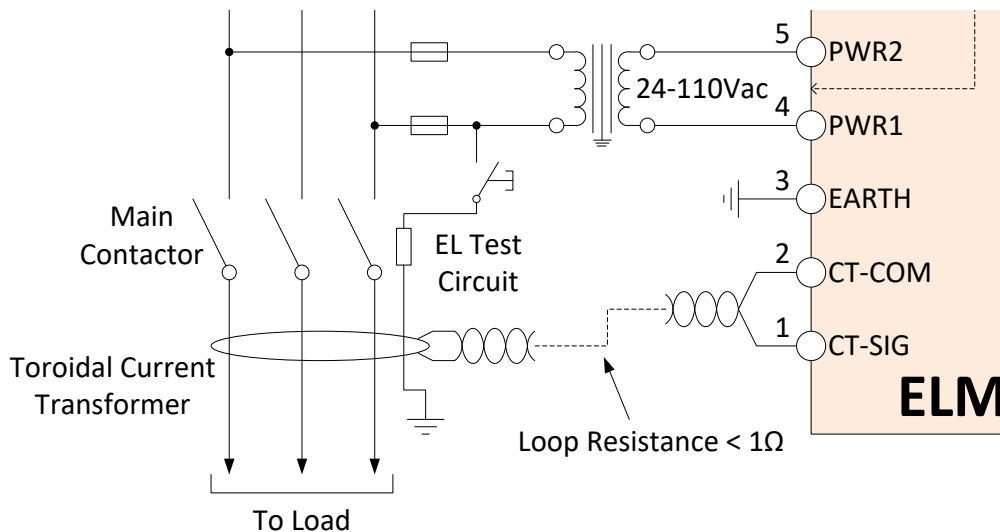


Figure 5.1: Earth Leakage Test Circuit

6 PRODUCT OPERATION

The following subsections will detail the operation of the ELM V2 relay. This includes the operation of the earth leakage protection, rotary switches, output relays and indication LEDs.

6.1 Configuration of Trip Level and Trip Time

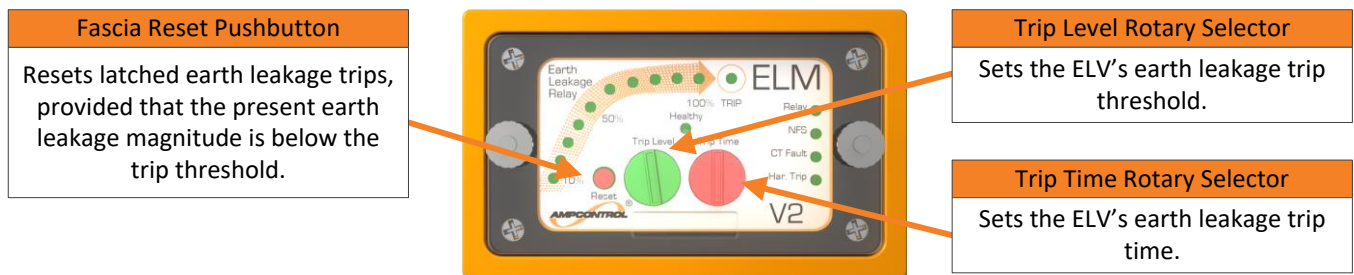


Figure 6.1: ELM V2 Fascia Operators

The trip settings are configured using the rotary selectors on the fascia of the ELM V2 relay. The trip level is configured using the green rotary selector and the trip time is selected using the red rotary selector.

The trip level represents the threshold of current measured by the earth leakage toroid, above which a trip occurs. The trip level is selectable from 100mA to 2.5A.

The trip time represents the delay after which a fault condition has occurred when the ELM V2 relay will de-energise. Time Delay settings are selectable from 50ms to 3000ms.

Trip Level Rotary Selector		Trip Time Rotary Selector	
Switch Position	Trip Level (mA) ±5%	Switch Position	Time Delay (ms)
0	100	0	50
1	150	1	100
2	200	2	150
3	250	3	200
4	300	4	250
5	350	5	300
6	400	6	350
7	450	7	400
8	500	8	450
9	750	9	500
A	1000	A	750
B	1250	B	1000
C	1500	C	1500
D	1750	D	2000
E	2000	E	2500
F	2500	F	3000

Table 6.1: Trip Level and Trip Time Settings

6.2 Resetting the ELM V2

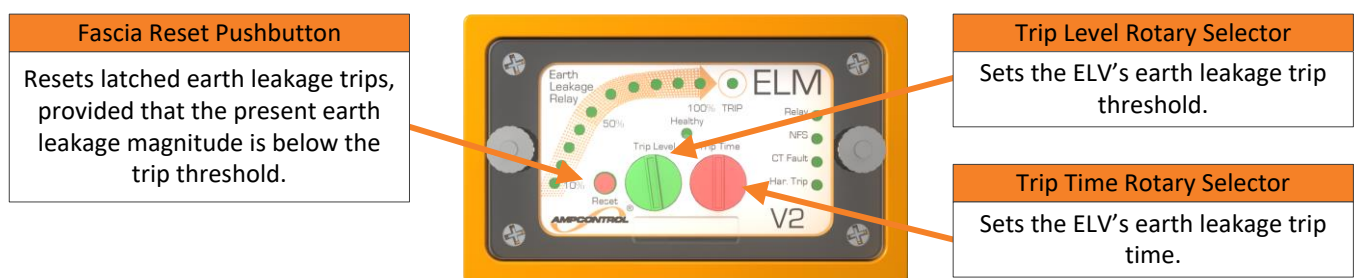


Figure 6.2: ELM V2 Fascia Operators

The ELM V2 can be reset using the pushbutton on the fascia of the relay, or by bridging the two RESET terminals on the relay using a normally open (NO) pushbutton or relay contact connected to the terminals labelled “Ext Reset” (see Figure 4.5 for connection information).

Initiating a reset will clear a latched earth leakage or CT fault trip, provided that these faults are not still present or have been cleared.

The reset button is also used to access the memory of the processor to view the maximum level of leakage since the previous trip. A section of the bar graph will slow flash (2Hz) indicating the peak level while the reset button is held closed, and will continue to flash for 2 second after the reset button is released.

6.3 ELM V2 Indicators

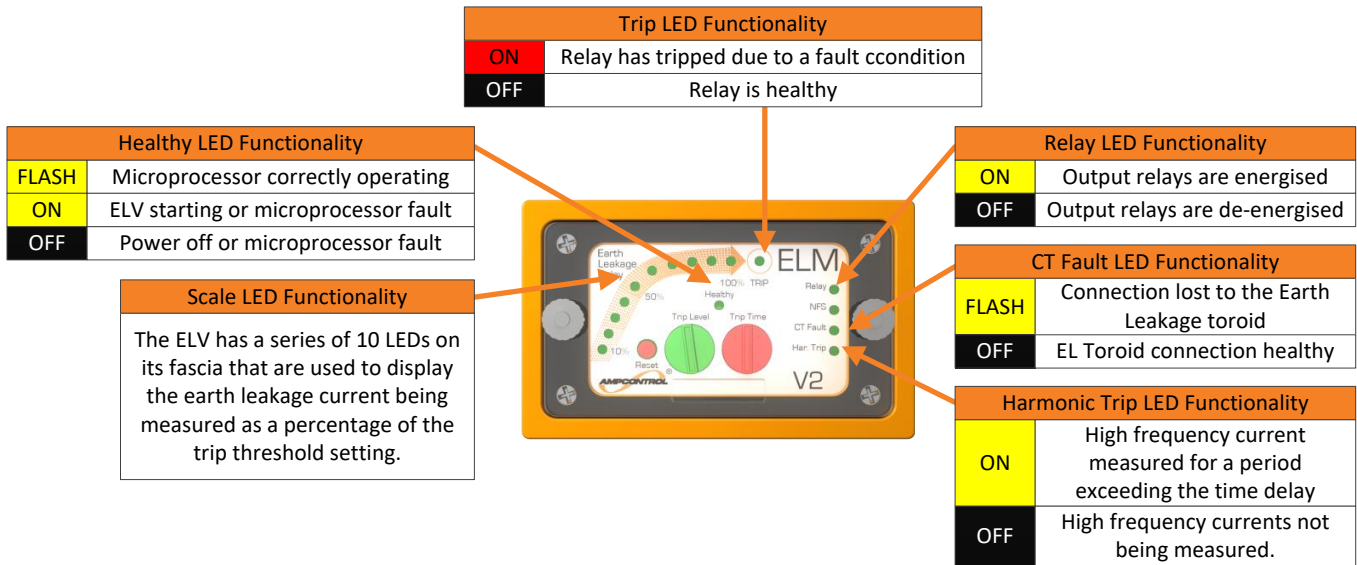



Figure 6.3: Functionality of ELM V2 Indicator LEDs

6.4 CT Fault Protection

The ELM V2 continually monitors the connection to the earth leakage toroid to ensure that it has not been disconnected. If the relay fails to detect the earth leakage toroid, it will initiate (and latch) a CT Fault trip which will de-energise the output relays.

A CT Fault trip can be reset using either the fascia reset pushbutton or the external reset contact.



CAUTION! The loop impedance of the connection to the earth leakage toroid is continually monitored by the ELM. To prevent a CT Fault trip, **the loop resistance of the wiring between the relay and the toroid must be kept below 1Ω.**

6.5 Fail Safe Operation

The ELM V2 can be operated in fail-safe and non-fail-safe mode of operation.

Fail-Safe Mode: This mode is the default and preferred method, where the relay drops out on fault or loss of power. Power to the relay is from the line side of the isolating device or from an independent supply

Non-Fail-Safe Mode: In this mode of operation the relay picks up on fault. This method should only be used when the supply to the relay is only available from the load side of the isolating device. To select this mode link the 'NFS' input terminals ('NFS' LED is 'On' when this mode is selected).

Note1: To restore power following a trip condition the reset needs to be held while re-closing the circuit breaker.

7 SERVICE, MAINTENANCE & DISPOSAL

7.1 Equipment Service

A number of external system based checks should be completed on a regular basis. These 'routine inspections' must be carried out by suitably trained people with knowledge of the relay and the systems into which it is fitted. Routine inspections may take the form of either visual-only checks, or visual and 'hands-on' checks.

7.1.1 Visual Only Inspections

A basic visual inspection focuses on looking at the installation for signs of physical damage, water or dust ingress and the condition of cables and labels. This type of inspection may involve opening cabinets to gain access to the relay and other equipment. This level of inspection may also include cleaning display windows that have become obscured by dirt.

Observations would typically be:

- Check that equipment enclosures, cable trays, conduits, etc. are in good order with no physical damage.
- Check that sealed wall boxes are free from water and dust ingress internally. Door seals are in good condition.
- Check that connected cables are free from cuts, abrasions and obvious signs of damage. Cable restraints are in good order and correctly fitted.
- Check that labels on equipment, wall boxes and cables are present and in good condition (especially certification labels).
- Check that no modifications have been carried out to installed equipment.

7.1.2 Hands-On (Detailed) Inspections

A more detailed inspection would include all of the elements of a visual inspection, plus some checks that cover the integrity of connections, fixtures and fittings.

In addition to basic visual observations, more detailed integrity checks would involve:

- Verify that equipment housings, wall boxes and other mechanical fixtures are secured in place. This includes terminal box lids, tightness of cable glands, integrity of wall-box mountings, security of equipment fixing to walls/DIN rails etc.
- Verify all electrical connections are secure with no loose screw terminals or DIN rail terminals not fitted to rails etc.

7.2 Equipment Maintenance

WARNING!



The ELM V2 has no user-serviceable parts.

All repairs must be carried out by Ampcontrol only.

If a fault develops, return the relay to Ampcontrol for repair. It is essential that **no attempt be made to repair the relay** as any attempt to dismantle or repair the relay can **seriously compromise the safety of the unit and voids product warranty.**

It is recommended that the electrical protection system incorporating the ELM V2 be subject to regular functional tests at intervals determined by risk assessment or FMEA. These intervals typically coincide with periodic maintenance checks and will cover (but not limited to) tests such as:

- Inject a test current at 120% of the trip level setting through the toroid, as shown in Figure 5.1. Verify that the relay trips as expected.

7.3 Disposal

ENVIRO



The electronic equipment discussed in this manual **must not be treated as general waste.** By ensuring that this product is disposed of correctly you will be helping to prevent potentially negative consequences for the environment which could otherwise be caused by incorrect waste handling of this product.

8 SPECIFICATIONS

Supply Voltage	
<i>Voltage</i>	24-110VAC +/- 20%, 50Hz 24-168VDC +/- 10%
<i>Power Consumption</i>	< 3W
<i>Operating Temperature</i>	0 to 60°C
<i>Humidity</i>	Between 10% relative humidity and the dew point, non-condensing
Operating Frequency	
<i>Frequency</i>	50Hz
<i>Accuracy</i>	5% @ 50Hz
Relay Contacts	
<i>Contacts</i>	1 x NO / 1 x CO
<i>Ratings</i>	250V, 1.6A, 400VA
<i>Relay to Toroid</i>	< 1Ω
4-20mA Output	
<i>4-20mA Output</i>	The 'Loop Powered' current represents the leakage current as a % of the trip level. 4mA => 0% leakage, 20mA => 120% leakage (100% = 17.33mA)
<i>Loop Supply Voltage</i>	10 – 30VDC
<i>Max. Loop Resistance</i>	700Ω at 24V loop supply
<i>Accuracy</i>	+/- 2% of full scale
Mechanical	
<i>Dimensions (mm)</i>	77w x47h x116d
<i>IP Rating</i>	IP56 (when panel mounted)
<i>Cut Out Size (mm)</i>	69w x 39h
<i>Weight</i>	500g

9 SETTINGS QUICK REFERENCE GUIDE

Trip Threshold and Time Delay Settings		
<i>Switch Position</i>	<i>Trip Level mA (Accuracy +/- 5%)</i>	<i>Time Delay ms (Accuracy +0ms, -20ms)</i>
0	100	50
1	150	100
2	200	150
3	250	200
4	300	250
5	350	300
6	400	350
7	450	400
8	500	450
9	750	500
A	1000	750
B	1250	1000
C	1500	1500
D	1750	2000
E	2000	2500
F	2500	3000

10 EQUIPMENT LIST

10.1 Relay

<i>Part Number</i>	<i>Description</i>
179723	ELM V2 Earth Leakage Relay

10.2 Toroids

One toroid is required per installation. Order based upon required window size.

<i>Part Number</i>	<i>Description</i>
115438	Toroid – 25mm ID
115439	Toroid – 60mm ID
115440	Toroid – 85mm ID
115441	Toroid – 112mm ID

10.3 Accessories

The below accessories are optional.

<i>Part Number</i>	<i>Description</i>
179513	ELD, ELV, ELM Service Kit
101399	DIN Rail Mounting Kit (suit ELM / ELD / ELV)
120255	ELC/F Adapter Kit (suit ELM / ELD / ELV)
175279	ELF/ELF2 Adaptor Kit (suit ELM / ELD / ELV)
164672	Lockable Cover (suit ELM / ELD / ELV)
175279	Adaptor BRAMCO to ELD/ELV/ELM

APPENDIX A: EARTH LEAKAGE PROTECTION REQUIREMENTS

A1 Australian Standards for Earth Leakage (Mining Industry)

Earthing of electrical equipment, associated machinery and structures is a seemingly simple practice and is covered adequately by the various applicable sections of Australian Standards AS/NZS 3000 or AS/NZS 3007. However, in the mining industry earthing is somewhat more complex than normal domestic or commercial applications and requires other factors to be taken into consideration, particularly where trailing and/or reeling cables supply mobile electrical equipment.

The protection scheme that covers mobile and relocatable equipment used in mining and quarry operations is detailed in AS/NZS4871:2012, while the operating parameters for relays suitable for use in that distribution system are defined in AS/NZS2081:2011. Earth leakage function (as performed by the Ampcontrol EL Relays) is one of six separate functions that comprise an AS/NZS4871 distribution system protection scheme (EL, EC, EFLO, LOV/CF, NER, and NERM). A best practice protection scheme for an earth fault limited network is reliant on the interaction and operation of all six devices. Omitting a complementary device from the recommended scheme requires the protection system to be assessed by a competent person or authority.

The AS/NZS 4871 and AS/NZS 2081 standards are not independent. In conjunction with each other, these standards have been developed in coordination with:

- AS/NZS 3000 – Electrical installations (known as the Australian/New Zealand Wiring Rules)
- AS/NZS 1802, AS/NZS 1300 - Reticulation, trailing and reeling cables.
- AS/NZS 1299, AS/NZS 1300 - Plugs, adaptors, couplers and receptacles.
- AS/NZS 2067 – Substations and High Voltage Installations Exceeding 1kV A.C.
- AS/NZS 3007 – Electrical Equipment in Mines and Quarries - Surface Installations and Associated Processing Plant.
- AS/NZS 4871 – Electrical Equipment for Mines and Quarries.
- Internationally accepted voltage/time effects on the human body based on IEC60479.1 and IEC60479.2.
- Instructions for installation in accordance with accepted State and Federal Regulations.
- Equipment maintained in accordance with industry standards.

Earth fault protection systems designed for personnel protection must either limit the continuous touch potential to less than the extra low voltage limit (50VAC as per AS3000), or in applications where a higher touch voltages are generated under fault conditions have a total fault clearance time such that the probability of fibrillation is below an acceptable threshold.

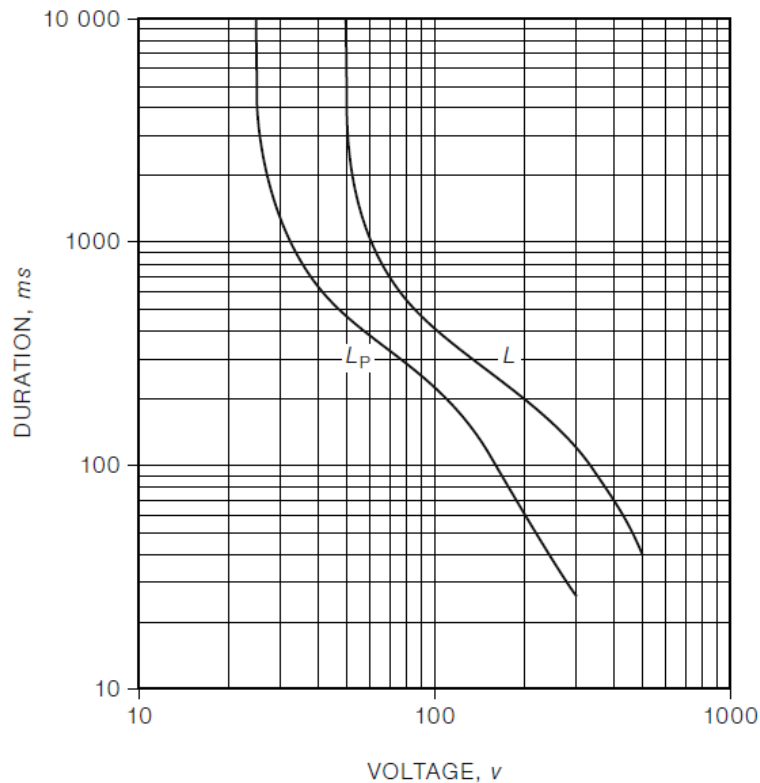
There are a number of standards that relate the maximum duration of human exposure to prospective touch voltages that do not usually result in harmful physiological effects on any person subjected to that touch voltage (i.e. 'an acceptable limit'). Figure 1 is extracted from AS/NZS4871.1:2012 and the same figure also appears in AS/NZS3000:2007.

This figure shows two curves:

- L – for normal conditions
- L_P – for wet conditions

Operating regions to the left of the designated curves are assumed to represent an 'acceptable' risk of fibrillation, although they are not necessarily as low as reasonably achievable in all instances.

Operating regions to the right of the designated curves are assumed to represent an 'unacceptable' risk of fibrillation, even though they may be as low as reasonably achievable in some instances.



L for normal conditions touch voltage limit 50 V
 L_p for wet conditions touch voltage limit 25 V

NOTE: This curve is derived from AS/NZS 3000 and is based on a typical set of conditions and body resistance values.

Figure A1: Maximum Duration of Prospective 50Hz Touch Voltage (Source: AS/NZS 4871:2012)

It is generally assumed that the L_p curve (for wet conditions) is most applicable in coal mining applications, however the end user of the ELM must select the appropriate fibrillation curve set and commensurate clearance time for the generated touch potential given the environmental conditions of their specific application.

The ELM is able to accommodate clearance times for fibrillation curve sets given in AS/NZS3000, AS/NZS4871.1:2012, AS/NZS2067:2008, and AS/NZS3007:2004 and the majority of international standards.

A2 Overview of Protection Problems

Unless properly controlled the occurrence of an earth fault can be hazardous because it may cause:

- Frame to earth voltages dangerous to personnel.
- Electric arcing, which may initiate an explosion or fire when arcing occurs in an underground mining operation.

CAUTION!



The main purpose of earth fault protection is to safeguard personnel and electrical apparatus. However it is found that **relays designed to operate on fault limited systems are not suitable for direct contact protection**, i.e. users of portable drills, grinders etc., which require trip levels of 20-30mA, with instantaneous operation. (Refer AS/NZS 3190).

The most common apparatus faults in mining applications are cable faults. Cables are most susceptible to damage and are the major source of dangerous electrical incidents. This applies particularly to the flexible trailing cables supplying power to mobile mining machines.

Cable construction is such as to provide every phase conductor with an individual conductor screen so that crushing would cause a low single phase to earth fault current. The protective device, such as an Amcontrol ELM earth leakage relay, would then isolate the cable and contain the sparking within the cable before a heavy short circuit current due to a phase to phase fault occurs.

Earth fault protection has been applied with considerable success in limiting faults and providing quick disconnection of electrical apparatus from the supply in the event of earth fault situations.

A definite time operating characteristic is provided with adjustable trip sensitivity and time delay. Time delay between protective units is introduced to allow the unit close to the fault to isolate the faulty circuit without causing the healthy part of the system to be de-energised, hence providing discrimination.

A3 Earth Leakage Systems

Desirable though it may be it is impractical to provide automatic protection against electrocution as a result of direct contact with a live conductor, particularly where the electrical reticulation is exposed to a humid or damp atmosphere.

The table below (taken from IEC Standards) indicates the current values affecting human beings.

Current mA	Symptom
1 or less	Causes no sensation - not felt
1 to 8	Sensation of shock, not painful, individual can let go at will, as muscular control is not lost
8 to 15	Painful shock, individual can let go at will, as muscular control is not lost
15 to 20	Painful shock, muscular control of adjacent muscles lost, cannot let go
20 to 50	Painful, severe muscular contractions, breathing difficult
50 to 100 (possible) 100 to 200 (certain)	Ventricular fibrillation (a heart condition that may result in death)
200 and over	Severe burns, severe muscular contractions; so severe that chest muscles clamp the heart and stop it for the duration of the shock (this prevents ventricular fibrillation).

It can be seen from the previous table that the passage of a current of as low as 15mA through the human body can cause loss of muscular control to the extent of preventing the recipient from disengaging from the live conductor. Whereas a current in excess of 50mA is sufficient to produce a critical heart condition from which there is little or no chance of recovery.

It follows that as an effective safeguard against electrocution resulting from direct contact with a live conductor, it would be necessary to introduce earth leakage protection designed to operate with a fault current below 15mA, which in the majority of cases, would be impractical.

The automatic protection of circuits is not intended to take the place of sound installation practice and the regular maintenance and testing of electrical apparatus, so as to avoid direct contact scenarios.

Care must be taken in the selection and installation of all electrical equipment with due regard to its required duty and the conditions under which it may be called upon to operate.

Where automatic earth leakage protection has been installed it is essential that its operation be tested often, and to facilitate this, a means for testing is incorporated in all approved earth leakage relays.

A5 Methods of Earth Leakage Protection

There are two methods of protection used, Core Balance and Series Neutral earth leakage protection systems. A relay installed in Core Balance applications performs the primary protection in an installation, protecting the outlet supplying power to a machine. In this application the time delay is set at instantaneous. Series Neutral earth leakage provides backup protection for the installation and can have a time delay up to a maximum of 500ms (3000ms for AS/NZS2081 1988).

A5.1 Core Balance Protection

With this method all three phases of the cable are passed symmetrically through the toroid. If there is no earth fault present, the vector sum of the currents in a three-phase supply is zero. If current from any phase flows to earth the toroid flux becomes unbalanced. The toroid produces an output, which trips the relay.

A test current is injected through the window of the toroid to test the operation of the relay.

A5.2 Series Neutral Protection

With this method the neutral is passed through the toroid. An earth fault on any of the phase conductors causes an earth current which returns, through the toroid, to the star point of the transformer.

A test circuit can connect a test resistor between a phase and earth or inject a current through the toroid as previously described. The test resistor to earth method is recommended with this type of protection as this test also proves the neutral to earth connection.

A6 Earth Leakage Toroids

Toroids (current transformers) are not ideal devices and if correct procedures are not followed during installation, nuisance tripping can result. If, for example, we consider a single-phase earth leakage system where active and neutral pass through a toroid then at all times currents in the two wires are equal and opposite so that the net current through the toroid is zero. An ideal current transformer would have all of the flux from each wire contained in the core and so would accurately add the opposing fluxes to get a net result of zero. A real current transformer has “leakage fluxes”. This means that a very small proportion of the total flux from each cable is not contained in the core but in the space outside it and as a result it may link some turns but not others, depending on the positioning of the cables. The effect of this is that a small output may be obtained from the toroid where none would arise if the device were ideal.

The size of the error may vary from toroids of the same type because of slight differences in the core and the symmetry of the winding. Problems caused in this way increase as the toroid size increases, as currents increase and symmetry decreases. Nuisance tripping tends to occur when the total current rises, such as when a large motor is started. The following guidelines may help to avoid such problems.

A6.1 Toroid Selection

- i. Select the smallest internal diameter toroid, which will allow the cables to fit through. Avoid very large toroids (200mm) or toroids with square apertures.
- ii. The ELM has been designed for use with the Ampcontrol EL500 series of toroids. For ordering part numbers, refer to the Equipment List in Section 0.
- iii. Only use approved toroids specified by Ampcontrol as these have been designed for optimum performance.

A6.2 Toroid Installation Guidelines

- i. Keep cables as close to the centre of the toroid as possible. Do not tie them to one side of the toroid as this will reduce symmetry.
- ii. Do not bring the cables back within a diameter distance of the toroid. This will reduce cable symmetry.
- iii. Avoid placing the toroid near to any device which produces magnetic fields, for example busbars, transformers or other cables. Where possible maintain clearances in excess of several diameters distance from the toroid.
- iv. Multiple small cables may present more issues than larger cables. This should be considered in circuit design.
- v. Busbars cannot be passed through toroids used for core balance earth leakage protection.
- vi. To prevent possible nuisance tripping it is suggested that the conductor screen of the earth leakage toroid be earthed at the relay end only. If both ends are earthed there is a possibility that the shield may become an earth loop, injecting noise into the toroid leads.
- vii. To reduce noise pickup, install twisted pair cable between the protection device and the toroid.
- viii. The resistance between the protection device and the toroid must be kept as low as practicable to ensure that a trip on the protection device does not occur.

CAUTION!



The ELM V2 relay includes a circuit for continually testing the toroid connection. **The resistance of the wiring between the relay and toroid must be kept below 1Ω.** If this is not done then a “CT” fault will be detected and the relay will trip.