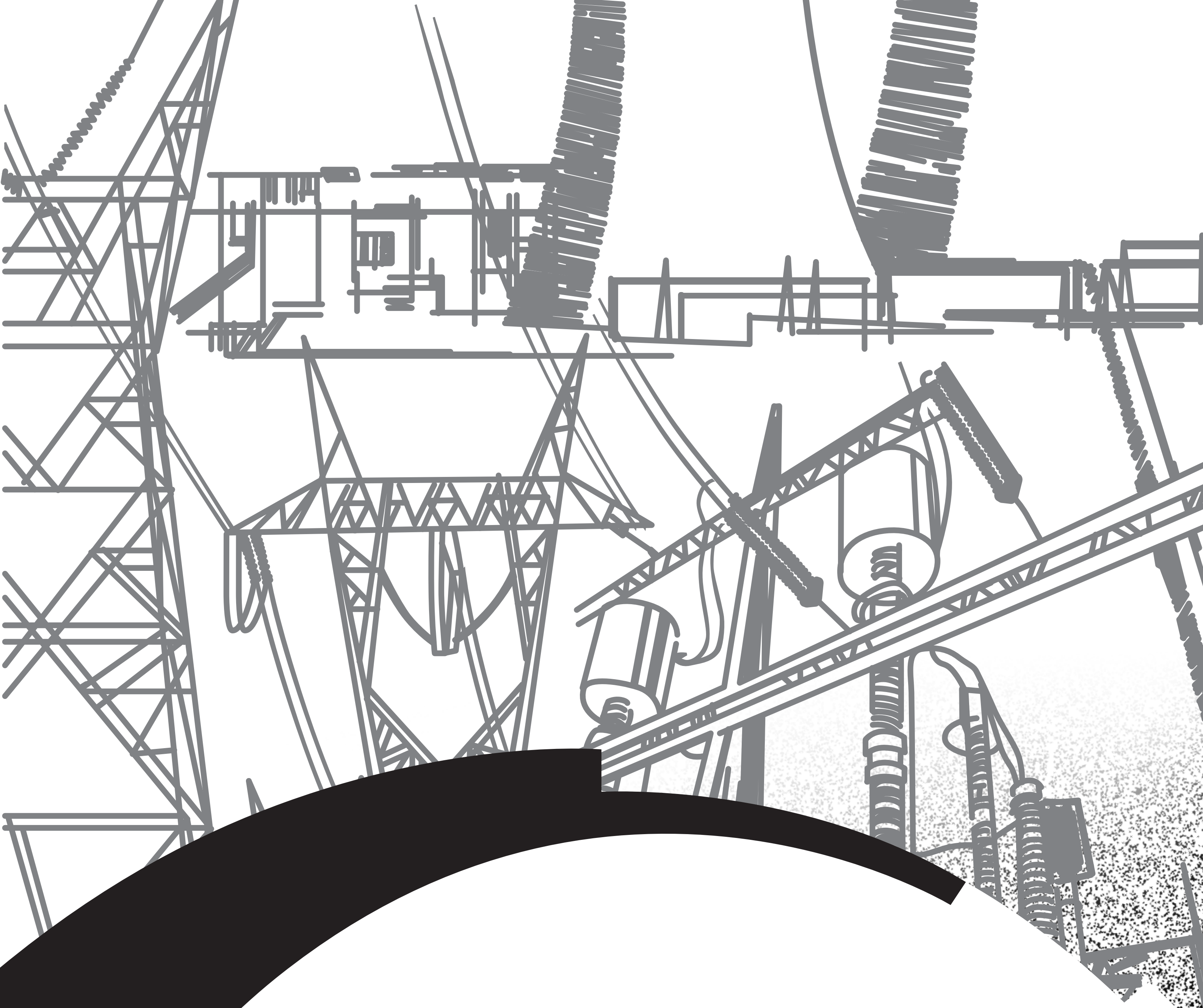


Service Manual

Type LFCB102
Digital Current Differential Relay

ALSTOM

Service Manual

Type LFCB102
Digital Current Differential Relay

HANDLING OF ELECTRONIC EQUIPMENT

A person's normal movements can easily generate electrostatic potentials of several thousand volts. Discharge of these voltages into semiconductor devices when handling electronic circuits can cause serious damage, which often may not be immediately apparent but the reliability of the circuit will have been reduced.

The electronic circuits of ALSTOM T&D Protection & Control Ltd products are immune to the relevant levels of electrostatic discharge when housed in their cases. Do not expose them to the risk of damage by withdrawing modules unnecessarily.

Each module incorporates the highest practicable protection for its semiconductor devices. However, if it becomes necessary to withdraw a module, the following precautions should be taken to preserve the high reliability and long life for which the equipment has been designed and manufactured.

1. Before removing a module, ensure that you are at the same electrostatic potential as the equipment by touching the case.
2. Handle the module by its front-plate, frame, or edges of the printed circuit board. Avoid touching the electronic components, printed circuit track or connectors.
3. Do not pass the module to any person without first ensuring that you are both at the same electrostatic potential. Shaking hands achieves equipotential.
4. Place the module on an antistatic surface, or on a conducting surface which is at the same potential as yourself.
5. Store or transport the module in a conductive bag.

More information on safe working procedures for all electronic equipment can be found in BS5783 and IEC 60147-0F.

If you are making measurements on the internal electronic circuitry of an equipment in service, it is preferable that you are earthed to the case with a conductive wrist strap.
Wrist straps should have a resistance to ground between 500k – 10M ohms. If a wrist strap is not available, you should maintain regular contact with the case to prevent the build up of static. Instrumentation which may be used for making measurements should be earthed to the case whenever possible.

ALSTOM T&D Protection & Control Ltd strongly recommends that detailed investigations on the electronic circuitry, or modification work, should be carried out in a Special Handling Area such as described in BS5783 or IEC 60147-0F.

ALSTOM

SAFETY SECTION

This Safety Section should be read before commencing any work on the equipment.

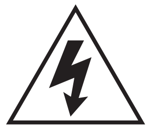
Health and safety

The information in the Safety Section of the product documentation is intended to ensure that products are properly installed and handled in order to maintain them in a safe condition. It is assumed that everyone who will be associated with the equipment will be familiar with the contents of the Safety Section.

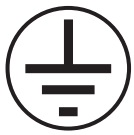
Explanation of symbols and labels

The meaning of symbols and labels which may be used on the equipment or in the product documentation, is given below.

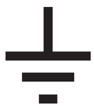
Caution: refer to product documentation



Caution: risk of electric shock



Protective/safety *earth terminal



Functional *earth terminal.
Note: this symbol may also be used for a protective/safety earth terminal if that terminal is part of a terminal block or sub-assembly eg. power supply.

*Note: The term earth used throughout the product documentation is the direct equivalent of the North American term ground.

Installing, Commissioning and Servicing

Equipment connections

Personnel undertaking installation, commissioning or servicing work on this equipment should be aware of the correct working procedures to ensure safety. The product documentation should be consulted before installing, commissioning or servicing the equipment.

Terminals exposed during installation, commissioning and maintenance may present a hazardous voltage unless the equipment is electrically isolated.

If there is unlocked access to the rear of the equipment, care should be taken by all personnel to avoid electric shock or energy hazards.

Voltage and current connections should be made using insulated crimp terminations to ensure that terminal block insulation requirements are maintained for safety. To ensure that wires are correctly terminated, the correct crimp terminal and tool for the wire size should be used.

Before energising the equipment it must be earthed using the protective earth terminal, or the appropriate termination of the supply plug in the case of plug connected equipment. Omitting or disconnecting the equipment earth may cause a safety hazard.

The recommended minimum earth wire size is 2.5 mm^2, unless otherwise stated in the technical data section of the product documentation.

Before energising the equipment, the following should be checked:

Voltage rating and polarity;

CT circuit rating and integrity of connections;

Protective fuse rating;

Integrity of earth connection (*where applicable*)

Equipment operating conditions

The equipment should be operated within the specified electrical and environmental limits.

Current transformer circuits

Do not open the secondary circuit of a live CT since the high voltage produced may be lethal to personnel and could damage insulation.

External resistors

Where external resistors are fitted to relays, these may present a risk of electric shock or burns, if touched.

Battery replacement

Where internal batteries are fitted they should be replaced with the recommended type and be installed with the correct polarity, to avoid possible damage to the equipment.

Insulation and dielectric strength testing

Insulation testing may leave capacitors charged up to a hazardous voltage. At the end of each part of the test, the voltage should be gradually reduced to zero, to discharge capacitors, before the test leads are disconnected.

Insertion of modules and pcb cards

These must not be inserted into or withdrawn from equipment whilst it is energised, since this may result in damage.

Fibre optic communication

Where fibre optic communication devices are fitted, these should not be viewed directly. Optical power meters should be used to determine the operation or signal level of the device.

Older Products

Electrical adjustments

Equipments which require direct physical adjustments to their operating mechanism to change current or voltage settings, should have the electrical power removed before making the change, to avoid any risk of electric shock.

Mechanical adjustments

The electrical power to the relay contacts should be removed before checking any mechanical settings, to avoid any risk of electric shock.

Draw out case relays

Removal of the cover on equipment incorporating electromechanical operating elements, may expose hazardous live parts such as relay contacts.

Insertion and withdrawal of extender cards

When using an extender card, this should not be inserted or withdrawn from the equipment whilst it is energised. This is to avoid possible shock or damage hazards. Hazardous live voltages may be accessible on the extender card.

Insertion and withdrawal of heavy current test plugs

When using a heavy current test plug, CT shorting links must be in place before insertion or removal, to avoid potentially lethal voltages.

Decommissioning and Disposal

Decommissioning: The auxiliary supply circuit in the relay may include capacitors across the supply or to earth. To avoid electric shock or energy hazards, after completely isolating the supplies to the relay (both poles of any dc supply), the capacitors should be safely discharged via the external terminals prior to decommissioning.

Disposal: It is recommended that incineration and disposal to water courses is avoided. The product should be disposed of in a safe manner. Any products containing batteries should have them removed before disposal, taking precautions to avoid short circuits. Particular regulations within the country of operation, may apply to the disposal of lithium batteries.

Technical Specifications

Protective fuse rating

The recommended maximum rating of the external protective fuse for this equipment is 16A, Red Spot type or equivalent, unless otherwise stated in the technical data section of the product documentation.

Insulation class:	IEC 61010-1: Class I EN 61010-1: Class I	1990/A2: 1993/A2:	1995 1995	This equipment requires a protective (safety) earth connection to ensure user safety.
Installation Category (Overvoltage):	IEC 61010-1: Category III EN 61010-1: Category III	1990/A2: 1993/A2:	1995 1995	Distribution level, fixed installation. Equipment in this category is qualification tested at 5kV peak, 1.2/50μs, 500Ω, 0.5J, between all supply circuits and earth and also between independent circuits.
Environment:	IEC 61010-1: Pollution degree 2 EN 61010-1: Pollution degree 2	1990/A2: 1993/A2:	1995 1995	Compliance is demonstrated by reference to generic safety standards.
Product safety: CE	73/23/EEC			Compliance with the European Commission Low Voltage Directive.
	EN 61010-1: EN 60950:	1993/A2: 1992/A11:	1995 1997	Compliance is demonstrated by reference to generic safety standards.

Digital Current Differential Relay Type LFCB 102

Chapter 1
General Description

Publications R4054 and R6090 included

Section 1. PRESENT PRACTICE AND TREND

Biased pilot wire schemes are most common for current differential protection of transmission lines and feeders. They require a continuous metallic circuit between line ends for the communication of a 50/60Hz replica signal of the primary line current. A limiting factor is the cost of providing metallic pilots between line ends. Economic considerations make it desirable to keep down the number of wire conductors used in the pilot circuit. Summation current transformers (CT) were therefore devised to produce a single phase relaying signal from three phase line current inputs. This however causes the relay sensitivity to vary for different fault types and the design is not suitable for single-pole tripping applications. In the case of three-ended applications, the choice of operating and bias quantities for the summation CT approach is more critical due to the multitude of current distributions that can occur due to different source impedance's, fault position, fault types, CT saturation etc. It is known that some schemes do not perform adequately for certain types of fault, in that failures to operate for some internal faults and maloperations for some external faults can occur.

Due to the series impedance and shunt capacitance of pilot wires, pilot wire schemes are limited to circuits having a length of up to about 30km. Another disadvantage of pilot wire protection is its susceptibility to electrical interference induced by parallel power circuits carrying load or fault currents, or rise of earth potential due to local power system fault currents flowing through the ground. Adequate measures such as electrical screening, isolation and good earthing practice must be adopted.

When privately owned pilot circuits are not available, metallic circuits, normally of speech type, have to be rented from a telecommunication company. However with the extensive use of electronic signal repeating and multiplexing equipment in modern telecommunication systems, direct signalling of power frequency signals over rented circuits is becoming less feasible. There is a need therefore for a new generation of current differential relays suitable for longer line application and designed to follow the trends in the telecommunication industry towards digital communications.

Recently schemes based on frequency modulation techniques have been introduced to enable conventional pilot wire relays to operate over voice frequency telecommunication channels or dedicated optical fibre links. A voltage-frequency converter unit converts the 50/60Hz relaying quantity to a frequency modulated signal. The instantaneous value of line currents is represented by the instantaneous frequency of the modulated signal. These schemes enable conventional analogue relays to work with modern communication links and so help to overcome some of the earlier limitations. Whilst they represent a step forward in the field of current differential protection, an entirely new digital approach will be able to exploit more fully the benefits offered by modern digital communication systems.

Digital Current Differential Relay Type LFCB 102

Chapter 2
Application Notes

Section 1. GENERAL

This section covers the application of the LFCB 102 relay for the protection of two-ended lines. The settings of the relay and the line current transformer (CT) requirements are discussed. Additional intertrip facilities are provided by the relay and a few typical schemes of their use are described. Finally the usage of opto-isolated status inputs and contact outputs are discussed.

Section 2. SETTINGS

The relay has three basic groups of settings:

- Protection settings
- Communication settings
- Auxiliary settings

2.1 Protection settings

The protection settings are divided into two functional groups, these being the current differential settings and the permissive intertrip setting.

2.1.1 Current differential protection settings

The LFCB relay current differential protection function has a dual slope percentage bias characteristic which is defined by four settings:

I_{S1} – The basic differential current setting.

k_1 – The percentage bias setting used when the bias current is below I_{S2}.

I_{S2} – The bias current threshold setting above which a higher percentage bias k_2 is used.

k_2 – The percentage bias setting used when the bias current exceeds I_{S2}.

These settings affect both the relay sensitivity and line CT requirement. To simplify the selection of settings, we recommend three of them to be set to:

I_{S2} = 2.0 x In

k_1 = 30% (or twice the CT mismatch if the mismatch is larger than 15%)

k_2 = 150%

These settings results in a relay characteristic suitable for most applications.
It leaves only the I_{S1} setting to be determined by the user.

The minimum operating current of the relay is related to the I_{S1} and k_1 settings and the level of through load current. Under no load conditions, the minimum operating current is $\frac{I_{S1}}{(1 - 0.5\,k1)}$

The I_{S1} setting should generally be set to above 2.5 times the value of the steady state line charging current. This allows for transient in-rush current during line energization and for increases in capacitive charging current caused by overvoltages during normal load and external fault conditions.

In a limited number of special applications, settings different from those stated above may have to be used. Please consult ALSTOM T&D Protection & Control Ltd for assistance.

2.1.2 Permissive intertrip setting

The permissive intertrip facility is equivalent to destabilizing the current differential protection in order to intertrip circuit breakers at the remote end. It works on an interlocked overcurrent basis. The current setting uses the same IS1 setting.
The only setting required is a time setting which governs the definite time delay for the relay to operate after receiving a permissive intertrip command from the remote end.

The timer should be set to allow normal fault clearance by circuit breakers at the line end initiating the permissive intertrip command. It should include the breaker operating and arc extinguishing times. Allowance should be made for the time taken for the signalling and security checking of the permissive intertrip command. This takes typically 25ms (50Hz) or 21ms (60Hz).

2.1.3 Scheme logic settings

There are two settings which control the operating modes of the trip and block auto-reclose outputs.

The 'Block Auto-Reclose' setting is used to select auto-reclose blocking on permissive intertrip only, or on either permissive intertrip or three phase trip.

The 'Tripping Mode' setting is used to select single-pole or three-pole tripping. The Trip A, Trip B and Trip C output contacts will close simultaneously on any trip conditions if three-pole tripping is selected.

2.2 Communication settings

There are two communication settings. Although they are mainly concerned with communication supervision, they do have some effect on the protection scheme. The two settings are the channel propagation delay tolerance and the communication failure time.

The propagation delay tolerance is the maximum difference in the measured channel propagation delay time between consecutive messages that the relay will tolerate before rejecting the messages. This causes the relay to ignore messages that may be invalid due to system disturbances or channel change-over.

This setting is factory set to the minimum value of 250µs. It should be increased to a suitable value if the propagation delay time is expected to vary considerably such as in the case of a microwave link with multiple repeaters.

The communication failure time is the time during which communication errors must be continuously detected before the channel is declared failed. This governs the implementation of the 'Communication Supervision' alarm and the 'Protection Scheme Inoperative' alarm. The setting is normally set to the maximum of 9.9 seconds so that the two alarms will not be affected by short bursts of noises or interruptions. The communication fail time setting however may be set to a lower value of say 200 or 300ms if the alarm contacts are to be used for enabling standby protection (Figure 1), or to signal a change-over to reserve communication facilities should the communication link become noisy or fails completely.

2.3 Auxiliary settings

These settings are not protection related but pertain to the operation of the user interface. The settings concerned are:

(1) Serial port baud rate and bit framing

(2) Clock synchronising period

(3) Remote port access level

(4) User identifier

Refer to see Chapter 7 for details of these settings.

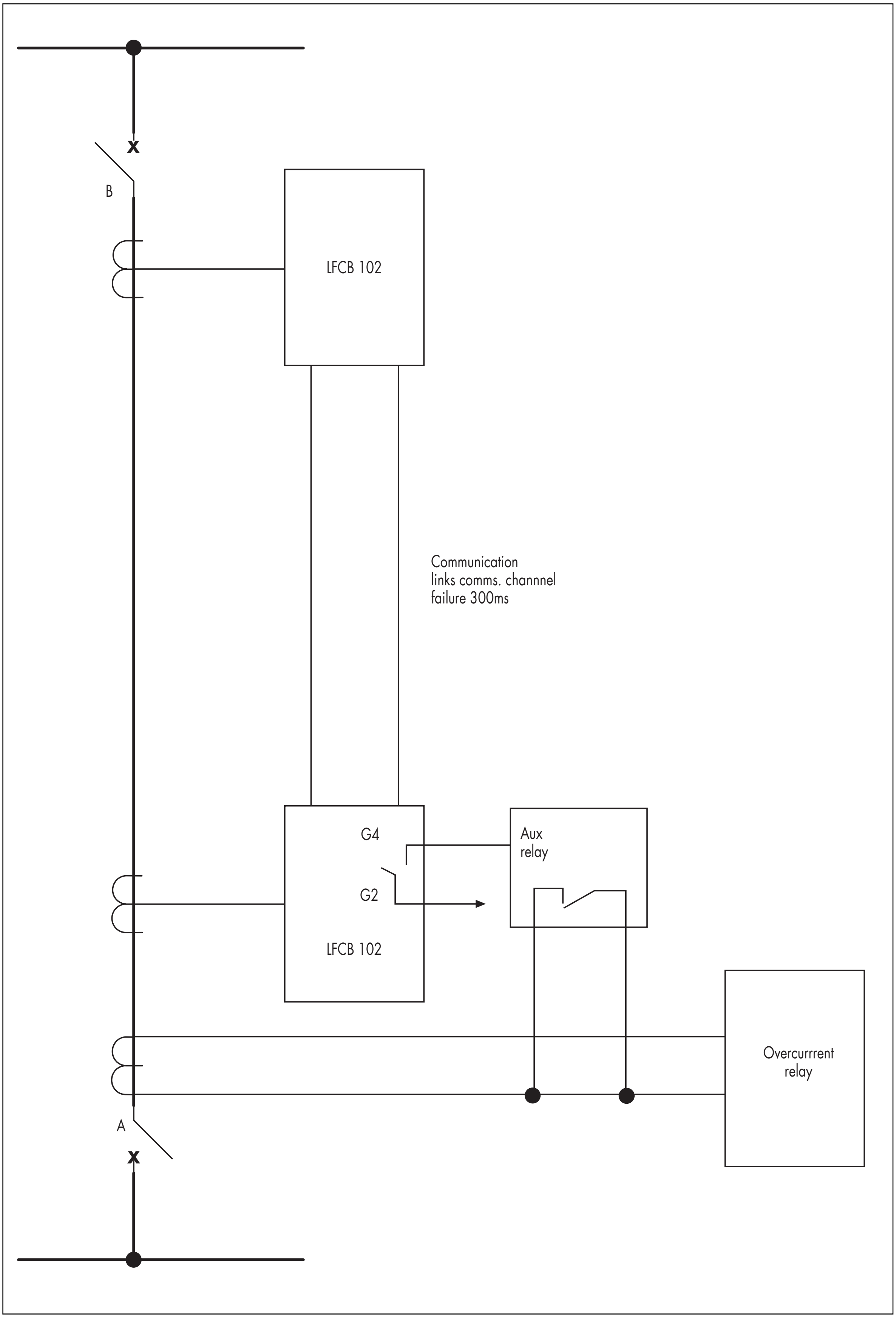


Figure 1: Using the protection scheme inoperative alarm output to enable stand-by overcurrent protection.

Section 3. LINE CURRENT TRANSFORMER REQUIREMENTS

For line current transformer requirements refer to Chapter 5.

Section 4. INTERTRIP FACILITIES

See also Chapter 5 for more details of the intertrip facilities.

4.1 Differential intertrip

An internal fault normally results in simultaneous operations of the relays at both ends irrespective of whether the fault current is fed from both ends or from one end only. For marginal fault conditions however, there may be a long delay between the operation of relays at the two line ends or the second relay may not operate at all if the fault current is single end fed from the operated end. To guarantee simultaneous operation at both line ends, the LFCB relay sends a 'Differential Intertrip' command to the relay at the other end once it reaches a trip decision.

4.2 Direct intertrip

This is an auxiliary signalling facility provided by the LFCB relay. The activation of the 'Initiate Intertrip' opto-isolated status input of the relay at one end will cause the independent 'Intertrip' output contacts of the remote relay to close. The facility may be used for direct transfer tripping or any user-assigned signalling functions.

Examples of the use of this are:

(a) Direct intertrip due to remote busbar faults

For a two-ended line, the circuit breaker at the remote line end may be intertripped directly following a busbar fault at one end. This can be done using the direct intertrip facility instead of the Permissive Intertrip.

The trip contact of the busbar relay at end B should then be connected to the 'Initiate Intertrip' status input of relay B instead of the 'Initiate Permissive Intertrip' input and the Intertrip output contacts of relay A should be connected for tripping circuit breaker A.

(b) Transformer feeder intertrip

Figure 2 depicts a transformer feeder. The line section of the transformer feeder is protected by LFCB relays and the transformer is protected by a separate transformer protection system. In the absence of a circuit breaker at the end of the line section, the circuit breaker at end A must be intertripped when a transformer fault occurs. This can be achieved using the direct intertrip facility of the LFCB relay.

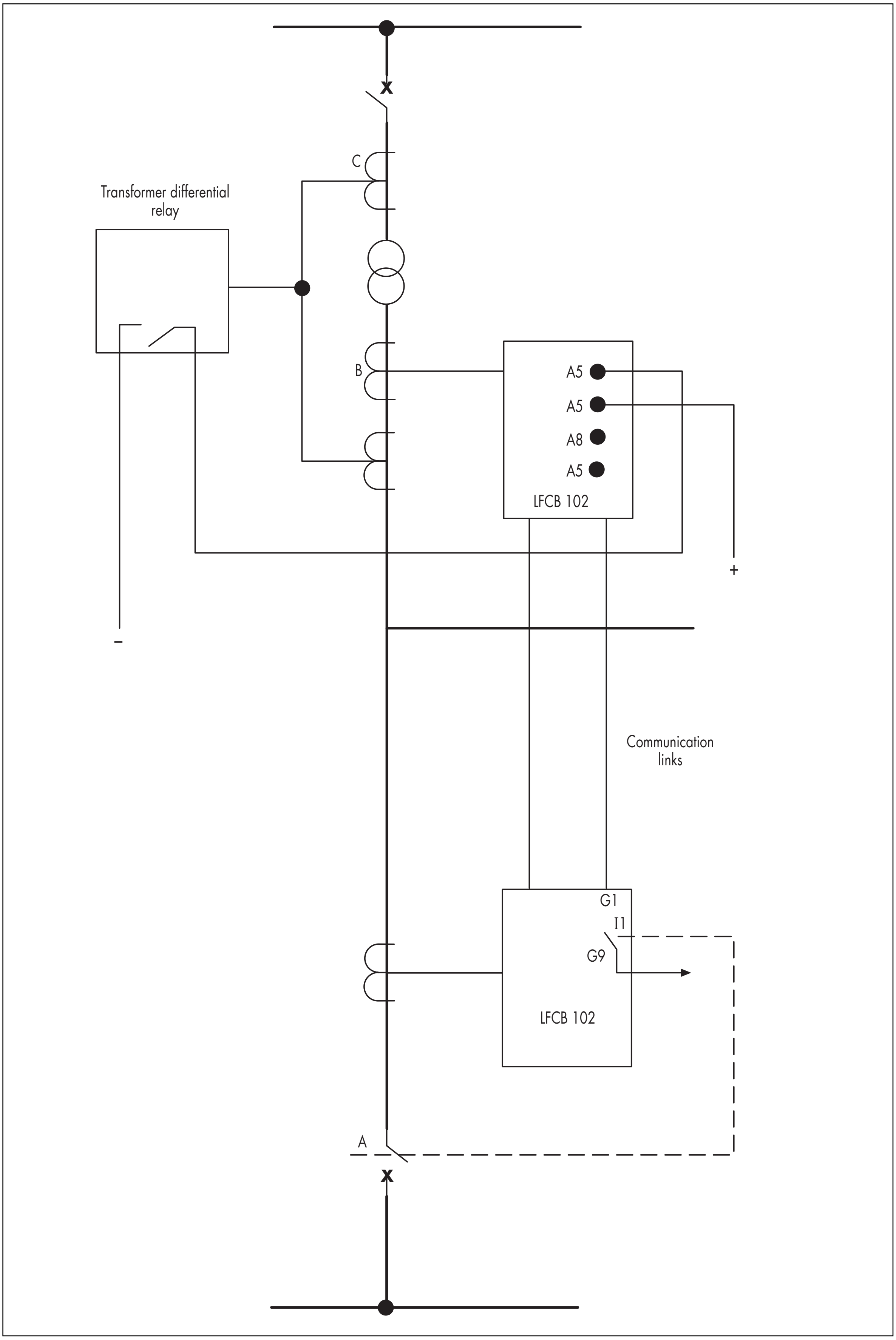


Figure 2: Transformer feeder intertrip

4.3 Permissive intertrip

This is a facility provided to intertrip circuit breakers at the remote end.
The activation of the 'Initiate Permissive Intertrip' status input of the relay at one end will cause the Trip A, Trip B, Trip C and Any Trip output contacts to close after a specified time delay if the line current at the initiating end exceeds I_{S1}.

An example of the use of this is:

(a) Permissive intertrip due to remote busbar faults

A busbar zone fault is normally cleared by the tripping of all circuit breakers connected to the faulted zone. As shown in Figure 3, for a busbar fault at end B, it is necessary to intertrip the circuit breaker at end A in cases of:

(1) circuit breaker B fails to trip; or

(2) the busbar zone fault occurs between the circuit breaker B and the line CT.

A trip contact of the busbar relay at end B can be used to activate the 'Initiate Permissive Intertrip' status input of relay B. This causes relay B to send a permissive intertrip command to relay A. Relay A will then trip the circuit breaker at end A if the line current level at end B still exceeds I_{S1} after the specified permissive intertrip delay time.

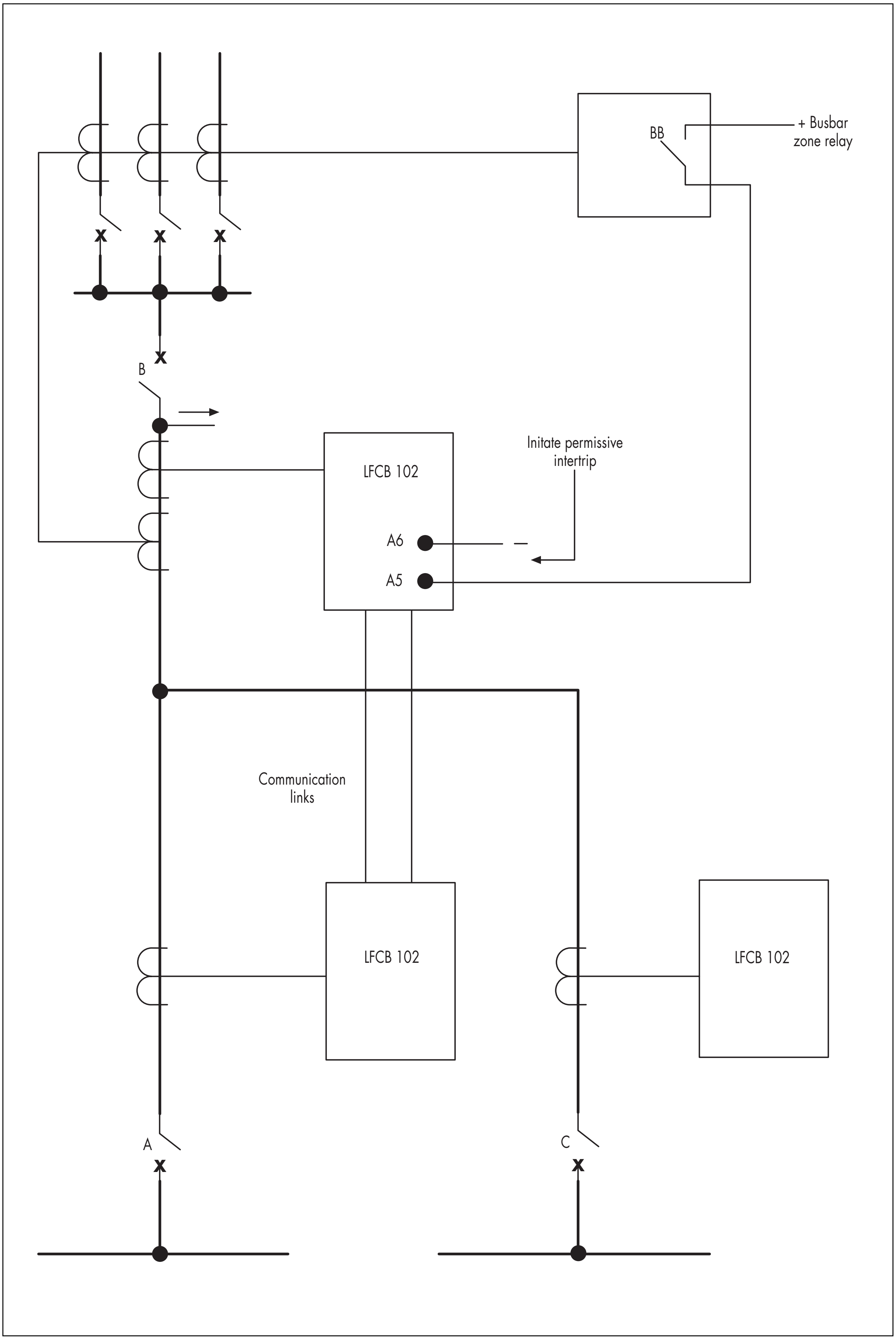


Figure 3: Permissive intertrip due to remote busbar faults

Section 5. STATUS INPUTS

The relay has six opto-isolated status inputs. Five of the inputs are used and given the following functions:

- Inhibit trip/alarm outputs
- Initiate intertrip
- Initiate permissive intertrip
- Reset indication and alarms
- Time sync

All these functions are activated when the corresponding status input is energised by connecting the specified auxiliary dc voltage Vx(2) across its input terminals.

Activation of the 'Inhibit Trip/Alarm Outputs' status input blocks all trip and alarm contact operations of both the local and remote relays. The function is therefore useful during injection tests and other test conditions. Activation of the 'Initiate Intertrip' and the 'Initiate Permissive Intertrip' inputs causes corresponding intertrip operation at the remote relay. The 'Reset Indication and Alarms' function can be used for remote reset of relay indication and alarms following tests or normal operations. The 'Time Sync' input allows the relay internal calendar clock to be synchronised to an external clock reference.

The user may opt to use only some of these functions. If not used, the input terminals of the corresponding status input should be left either unconnected or preferably shorted together.

See Chapter 5 for more information about the status inputs.

Section 6. OUTPUT CONTACTS

The relay has 27 output contacts:

Trip A	4 NO
Trip B	4 NO
Trip C	4 NO
Any Trip	2 NO
Intertrip	4 NO
Protection Operated A	1 NO
Protection Operated B	1 NO
Protection Operated C	1 NO
Block Auto-Reclose	2 NO
Communication Supervision Alarm	1 NO
Protection Scheme Inoperative Alarm	1 NO
Relay Inoperative Alarm	1 NC
Power Supply Failure Alarm	1 NC

If the single-pole tripping mode is selected, the Trip A, Trip B and Trip C outputs operate individually for single phase faults but operate all together for two phase and three phase faults. The outputs can be used for direct single-pole tripping, or can be connected in parallel for three-pole tripping. Together with the Any Trip output, the number of contacts provided should be sufficient for most applications for tripping circuit breakers, to initiate breaker failure protection, to initiate auto-reclose and for trip annunciation.

When the three-pole tripping mode is selected, the Trip A, Trip B and Trip C outputs operate as the Any Trip output and close for any trip condition. A total of 14 trip output contacts are then available for various uses. One slight disadvantage is that it is no longer possible to distinguish between single-phase faults and multi-phase faults from the trip outputs.

For single-pole tripping, two circuit breaker schemes, it may be necessary to repeat the Trip A, Trip B and Trip C contacts externally, eg.

Trip A (1) – Trip CB1

Trip A (2) – Trip CB2

Trip A (3) – Initiate auto-reclose

Trip A (4) – To external repeat relay for:

Initiate breaker fail 1

Initiate breaker fail 2

Trip annunciation

The time settings of the breaker fail relays must be adjusted accordingly to compensate for the extra time delay introduced by the repeat relay.

The three 'Protection Operated' outputs indicate which phases of the current differential protection function have operated and so may be used as inputs to fault locators or for fault type annunciation. In contrast to the Trip A, Trip B and Trip C outputs, only the outputs corresponding to the faulty phases will operate for a two phase fault. Therefore it is possible to distinguish a three phase fault from two phase ones using these outputs. The Protection Operated outputs also serve to distinguish a current differential protection trip from a permissive intertrip.
The permissive intertrip function shares the same trip outputs with the current differential protection function but does not operate the Protection Operated outputs. The permissive intertrip always trips three poles.

The Protection Operated outputs may be used instead of the trip outputs to initiate auto-reclose for single-pole tripping schemes. The auto-reclose relay however needs to be able to action a three-pole reclosure when only two of the Protection Operated outputs operate for a two phase fault. Also the Protection Operated outputs pick-up times are 6ms slower than the trip outputs.

The Block Auto-Reclose output can be selected to block auto-reclose on permissive intertrip only, or on either permissive intertrip or three phase trip. The contacts are kept closed for a further 100ms (ie. a delay on drop-off) after all block auto-reclose conditions have been removed.

All the trip outputs, including the Intertrip and the Protection Operated outputs remain closed for a minimum 60ms following.

Digital Current Differential Relay Type LFCB 102

Chapter 3
Installation and Handling

Section 1. RECEIVING

Remove the relay from the container in which it is received and inspect for obvious damage. If damage has been sustained in transit, a claim should be made immediately to the transport company concerned and a report sent to ALSTOM T&D Protection & Control Ltd.

Section 2. HANDLING

The relay in its case is extremely robust and no special precautions are necessary. However, to prevent the ingress of dirt, it is strongly advised that modules are not removed from the case.

CAUTION: HANDLE WITH CARE - THIS EQUIPMENT CONTAINS HEAVY AC INPUT MODULES.

Section 3. STORAGE

If not required for immediate use, return the relay to its original wrapper and carton and store in a clean dry place. The silica gel unit supplied with relays delivered outside the United Kingdom should be heated at 60 – 70°C for one hour before being replaced.

Section 4. INSTALLATION

Relays should be installed in a location free from excessive vibration. The relay cases can be supplied for either rack or panel mounting.

4.1 Rack mounting

Relays for rack mounting are supplied in cases designed for housing in standard 483 mm racks to IEC 60297.

4.2 Panel mounting

Relays can be supplied for flush or semi-projecting panel mounting. Panels should be vertical to within 5°. Dimensions, fixing details and cut-out sizes for the cases are shown in the relevant case outline drawing GM0008.

Flush mounted relays are inserted from the front into the panel cut-out and secured by means of the M5 screws provided.

When installation is complete the relay must be set up and commissioned as described in Chapter 8.

Section 5. EARTHING

The relay case earthing terminal on the rear of the relay case must be connected to earth (ground).

Section 6. SPECIAL HANDLING PRECAUTIONS AGAINST ELECTROSTATIC DISCHARGE

A person's normal movements can easily generate electrostatic potentials of several thousand volts. Discharge of these voltages into semiconductor devices when handling electronic circuits can cause serious damage, which often may not be immediately apparent but the reliability of the circuit will have been reduced.

The electronic circuits of ALSTOM T&D Protection & Control products are completely safe from electrostatic charge when housed in the case. Do not expose them to the risk of damage by withdrawing modules unnecessarily.

Each module incorporates the highest practicable protection for its semiconductor devices. However, if it becomes necessary to withdraw a module, the following precautions should be taken to preserve the high reliability and long life for which the equipment has been designed and manufactured:

(1) Before removing a module, ensure that you are at the same electrostatic potential as the equipment by touching the case.

(2) Handle the module by its front-plate, frame, or edges of the printed circuit board. Avoid touching the electronic components, printed circuit track or connectors.

(3) Do not pass the module to any person without first ensuring that you are both at the same electrostatic potential. Shaking hands achieves equipotential.

(4) Place the module on an anti static surface, or on a conductive surface which is at the same potential as yourself.

(5) Store or transport the module in a conductive bag.
More information on safe working procedures for all electronic equipment can be found in BS5783 and IEC 60147-0F.

If you are making measurements on the internal electronic circuitry of an equipment in service, it is preferable that you are earthed to the case with a conductive wrist strap. Wrist strap should have a resistance to ground between 500k to 10M ohms. If a wrist strap is not available, you should maintain regular contact with the case to prevent the build up of static. Instrumentation which may be used for making measurements should be earthed to the case whenever possible.

ALSTOM T&D Protection & Control Ltd strongly recommends that detailed investigations on the electronic circuitry, or modification work, should be carried out in a Special Handling Area such as described in BS5783 or IEC 60147-0F.

Digital Current Differential Relay Type LFCB 102

Chapter 4
Hardware Description

Section 1. RELAY IDENTIFICATION

The LFCB relay is constructed using the ALSTOM T&D Protection & Control Ltd M4 multi-modular hardware. The following identification system is used.

1.1 Cases

The complete identification for a case or subrack (a subrack is a single tier housing) is a 14 character coding. The first 4 characters are letters and the next 3 are digits. These 7 characters form the equipment reference. Together with the 8th and 9th characters, which indicate the type of mounting, they describe the case assembly completely. The rest of the coding is a 4-digit sequential number and a design issue letter.

L	FCB	102	S1	nnnn	A

- L: M4 Multi-modular hardware
- FCB: Digital current differential relay
- 102: For 2 ended lines
- S1: S1-Flush mounted / S5-Rack mounted
- nnnn: Rating and other variations
- A: Design issue letter

The case terminals and their functions are shown on the external connection diagram or application diagram. These are specified by a drawing number of the form 10 WXYZnnn mm, where 10 indicates external connection diagram and WXYZnnn is the equipment reference. For example, the external connection diagrams for the LFCB102 relay are numbered as L10LFCB102mm.

1.2 Schemes

Where an auxiliary subrack forms part of a more complex scheme, ie. in conjunction with other ALSTOM T&D Protection & Control equipments, a coding comprising 2 letters and 10 numbers is used. The related scheme or system diagrams are coded 12 L00 000 000 or 14 L00 000 000. Two digits 12 and 14 denote 'tender' or 'contract' diagram respectively. The 4th letter denotes the type of relay casing used. 'L' represents the M4 multi-modular case system. This and the digits following the coding are required for complete identification of the scheme.

1.3 Modules

Modules are identified by a 10 character code. This coding, which is known as a 2 alpha coding, is of the form:

GM nnnn mmm A

The identifier is marked on a strip fitted into the lower front extrusion of the module. The first two characters are always 'GM' for the M4 multi-modular hardware.

Together with the next 4 digits they specify the type of the module.

The next 3 characters represent a sequential number and vary according to minor variations such as the rating of the module. The last letter is a design suffix letter.

The position of a module in a subrack is designated by a number. Module 1 in an equipment is the module at the left-most position of the the top subrack, viewing from the front of the equipment. The rest of the modules are numbered sequentially from left to right, and then from top to bottom of the case. The module number is marked on a strip fitted into the top front extrusion of the module. The case also has numbered strips fitted which indicate the position of each module.

Section 2. MECHANICAL LAYOUT

Relevant drawings:

GM0008	sht 1	Outline and mounting details of 4U modular case – rack mounting.
	sht 2	Outline and mounting details of 4U modular case – panel mounting.
GM0054	003	LFCB102 arrangement diagram (G.703) – rack mounting.
GM0054	009	LFCB102 arrangement diagram (optical) – rack mounting.
GM0055	003	LFCB102 arrangement diagram (G.703) – panel mounting.
GM0055	009	LFCB102 arrangement diagram (optical) – panel mounting.

The LFCB relay is housed in a single tier, 4U (178mm) high, rack or panel mounting case. The case has been particularly designed for adequate screening of high speed electronic circuitry. The whole case including the front cover is made in steel. The relay is of modular design and modules are located in grooves. Interposed between the plastic grooves and the outer case are two full size upper and lower aluminium plates which are insulated from the outer case.

Each module has a complete aluminium side plate which provides both mechanical strength and electrical screening to the electronic circuitry.

The side plates are electrically connected to the upper and lower plates by means of spring clips. This internal screen is connected to the case at a single earthing point at the top of a terminal block. The arrangement gives a Faraday cage within the outer case. The purpose is to divert all electromagnetic noise and interference from intermodule coupling via a low impedance path to a single earthing point.

The relay consists of 6 modules and a hinged front panel:

Module Number	Function
1	Power supply unit
2	Output module 1
3	Output module 2
4	Communications
5	Microcomputer
6	Analogue/status input module
Front panel	Operator interface

The arrangement diagrams show the relative positions of the modules within the case. External connections for CT, output contacts and status inputs are made via standard 28-way MIDOS connectors mounted on the rear of the relay, CT shorting switches are fitted where required. There are also an interface connector for the communication module and a 25-way D-type female connector which provides serial RS232 communication with the microcomputer module. The communication module interface connector is either an optical connector or a 15-way D-type female connector depending on the type of digital communication interface used.

There is no back plane wiring in the back of the relay. All intermodule wiring is done by means of a 64-way ribbon cable bus (the I/O bus) behind the hinged front panel. By this means all the electronic signals and internal power rails between modules are spaced as far as possible from the incoming wiring.
As shown in Figure 1, the I/O bus runs along the front of modules and is terminated at the front panel assembly.

Connections are made to the modules by two part insulation displacement connectors (IDC). Modules are locked in position by an aluminium screen mounted on the rear of the front plate.

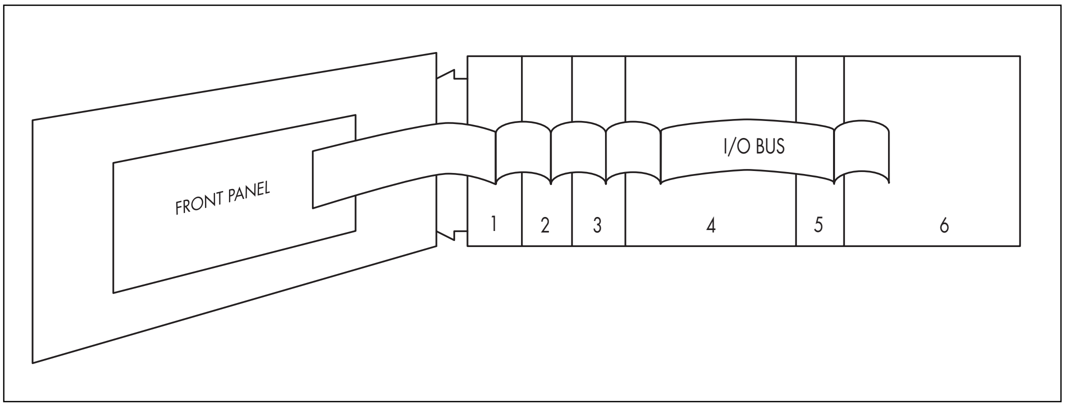


Figure 1: LFCB relay hardware configuration

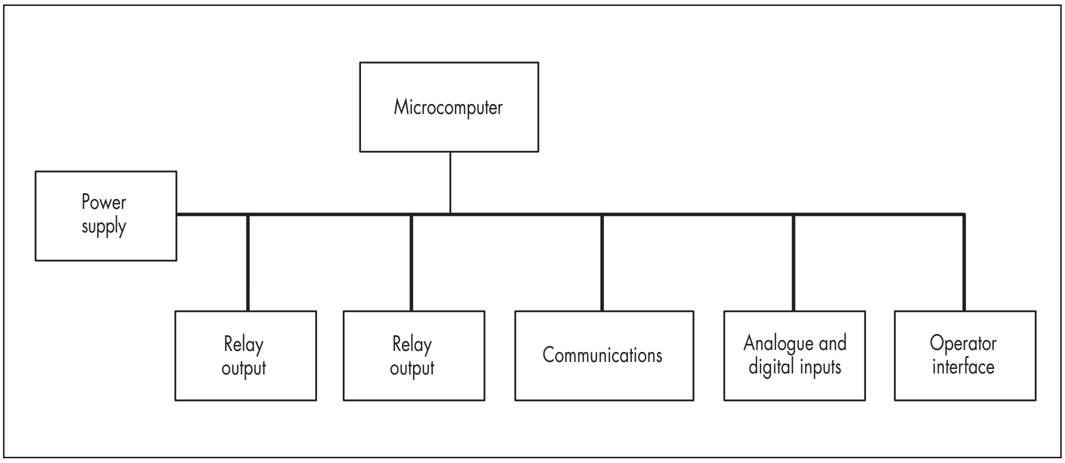


Figure 2: LFCB relay hardware architecture

The hardware architecture is shown in Figure 2. The microprocessor module controls all the modules on the I/O bus.

Section 3. MODULE DESCRIPTION

3.1 Power supply

Model No :	GM0026	24V, 30V & 50V
	GM0097	110V & 220V
Circuit diagram :	01 GM0026 01	24V, 30V & 50V
	01 GM0097 01	110V & 220V
PCB No :	ZH0805	24V, 30V & 50V
	ZH0999	110V & 220V
Versions :	Five versions are available covering the following dc supply voltages	

Nominal	Operative range
24/27V	19.2 – 32.4V
30/34V	24 – 40.8V
48/54V	38.4 – 64.8V
110/125V	88 – 150V
220/250V	176 – 300V

The power supply module (Figure 3) is a size 2 module containing one printed circuit board.

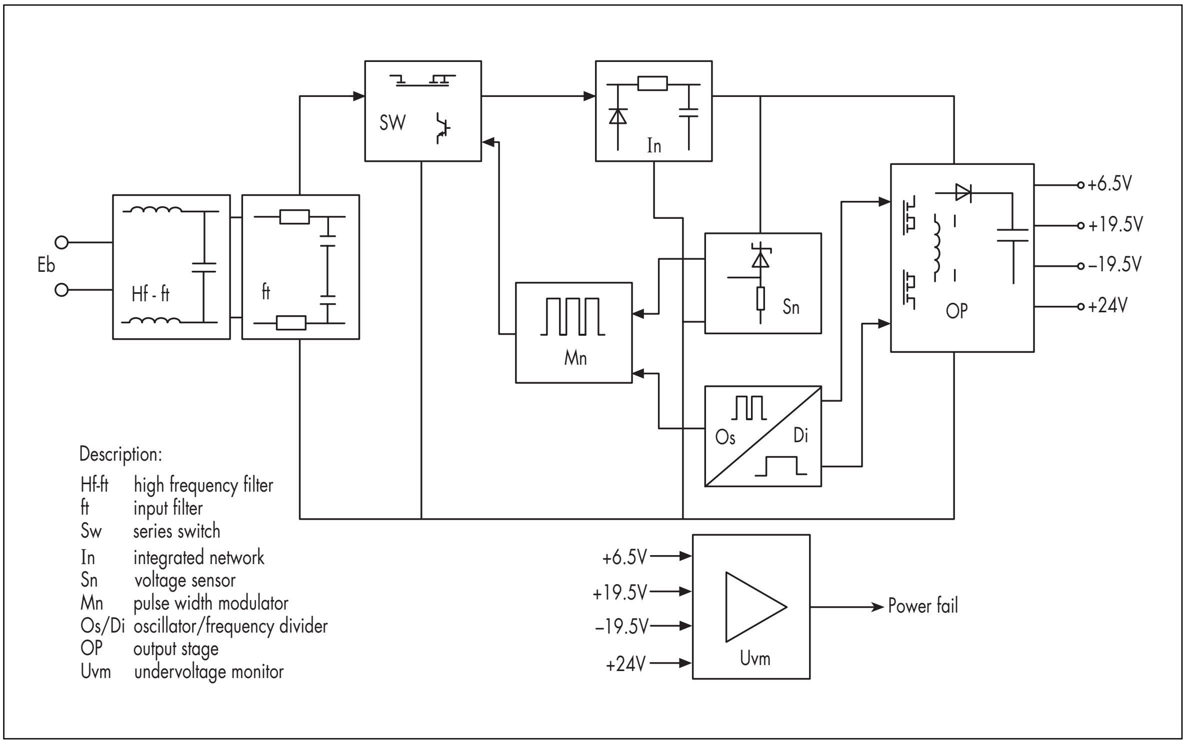


Figure 3: Power supply module

The function of the module is to supply four internal dc voltage rails from the single auxiliary dc input supply. It is a switched mode power supply design and the output rails are fully isolated from the input.

External connections are made via a 28-way MIDOS connector. The power supply output rails are distributed to the other modules in the equipment via the I/O bus. The four internal voltage rails are +6.5V, +19.5V, –19.5V and +24V. +6.5V rail is regulated to +5V locally in each of the input/output modules to power the logic circuitry. ±19.5V rails are regulated in respective modules where necessary to ±15V for analogue circuitry, or to ±12V for RS232 interface and some fibre-optic devices. The +24V rail is used unregulated to switch the output relays.

An under-voltage monitoring circuit is employed within the power supply module. If the voltage on any rail is out of tolerance, a power supply fail signal is asserted on the I/O bus to disable the relay. An alarm output relay inside the power supply module is also de-energised. The alarm output relay has one normally open contact and one normally closed contact which are brought out to the MIDOS connector.

The terminal allocation of the power supply module is shown in Table 1, also see the LFCB102 relay external connection diagram (No. 10LFCB102) for specific connection details.

Terminal Block H

Terminal number	Function number
1	Protective Earth
3	Power Supply Failure
4	Alarm (No)
5	Power Supply Failure
6	Alarm (n.c.)
13	Vx (1) aux input (+ve)
14	Vx (1) aux input (–ve)

Table 1: Terminal allocation of the power supply module

3.2 Relay output

Model No : GM0032.nnn

Circuit diagram : 1GM0032

PCB No : ZH0929

Versions : One

The Relay Output module is a size 2 module and contains one printed circuit board (Figure 4).

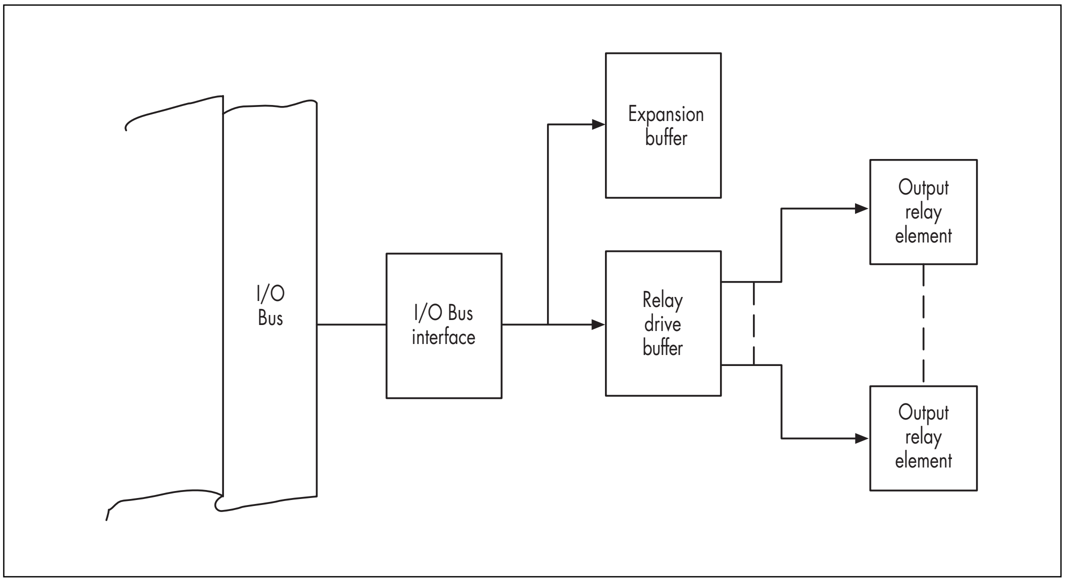


Figure 4: Relay output module

Each module has eight PCB mounted miniature hinged armature relays.
Two change-over and eleven normally closed contacts are wired to a 28-way MIDOS connector for external connection (see Table 2).

Each module has an address which is set by the positions of jumper links JM1 and JM2 on the PCB. The states of the output relays are controlled by an 8-bit data latch. Data is written into the data latch when the address of the module is selected and a strobe signal asserted by software on the I/O bus.

The module takes the +6.5V and +24V supplies from the I/O bus. The +6.5V is regulated to +5V for logic circuitry on the board. The +24V is used to drive the output relays.

All the output relays are held de-energised during power failure or hardware reset conditions. This prevents incorrect contact operations during power-up, power-down and reset conditions.

The output contact ratings are:

Make and carry:	7500VA for 0.2s with maixima of 30A and 300V ac or dc.
Carry continuously:	5A ac or dc
Break:	ac 1250VA
	dc 50W resistive
	25W L/R = 0.04s
	with maxima of 5A and 300V

Two relay output modules are fitted in the LFCB relay (terminal blocks F and G). Please see the external connection drawing 10LFCB102 and Chapter 5 for details of output contact functions.

Output relay no.	Terminal no.	Contact type	Pick-up speed	Drop-out speed
0	1	n.o.		
	3	common	8ms	8ms
	5	n.c.		
1	2	n.o.		
	4	common	8ms	8ms
	6	n.c.		
2	7	n.o.	8ms	8ms
	8			
3	9	n.o.	2ms	2ms
	11			
	10	n.o.	2ms	2ms
	12			
4	13	n.o.	2ms	8ms
	15			
	14	n.o.	2ms	8ms
	16			
5	17	n.o.	2ms	8ms
	19			
	18	n.o.	2ms	8ms
	20			
6	21	n.o.	2ms	8ms
	23			
	22	n.o.	2ms	8ms
	24			
7	25	n.o.	2ms	8ms
	27			
	26	n.o.	2ms	8ms
	28			

Table 2: Terminal allocation of the relay output module

3.3 Communication

This is a size 4 module designed for high-speed data communication. It contains two PCB's. The communication controller board and the interface board (Figure 5). The two boards are interconnected by a 20-way idc ribbon cable. The module is connected to the I/O bus through the communication controller board.

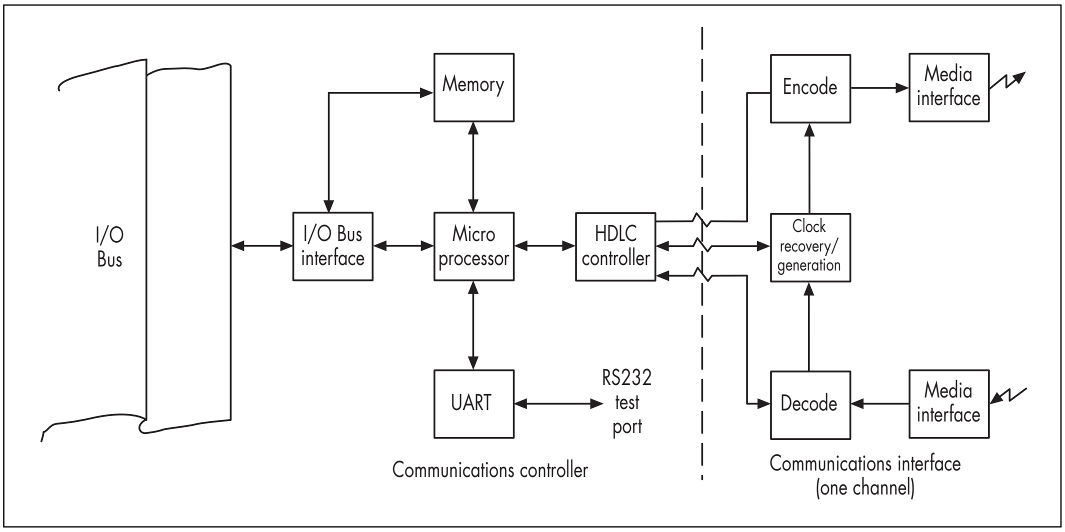


Figure 5: Communication module

The communication controller board works as an intelligent I/O device for the microcomputer module. Central to the communication controller board is a highly integrated 16-bit microprocessor (the communication processor) and a dedicated HDLC protocol controller intergrated circuit There are 48kbytes of memory (32kbytes EPROM, 16kbytes RAM) and an RS232 serial port (this serial port is intended for testing purposes only and is not available to the user).

Data transfer between the microcomputer module and the communication module is achieved using part of the communication processor's local memory as a common data area and allowing the microcomputer to access this using a standard HOLD/HOLD ACKNOWLEDGE protocol. The main processor asserts a HOLD signal to request the use of the common data memory. The communication processor signals a HOLD ACKNOWLEDGE signal after it relinquishes its local bus. Data transfer between the microcomputer module and the common data area then takes place. The HOLD and HOLD ACKNOWLEDGE signals are reset at the end of each data transfer.

The communication interface board provides a transmit and a receive timing signal for clocking data into and out of the communication controller board. The clock signals may be generated within the interface, or may be recovered from the incoming signals. The transmit and receive data and clock signals are encoded and decoded by the interface board. The board also contains the circuitry of interface drivers and receivers.

The module can support two independent communication channels. Only one of the channels is used by the LFCB102 relay. The module is capable of operating at data rates of up to 1Mbits/s. It is however normally set to operate at 64kbits/s.

The communication module is required to work with different types of communication links. Communication can be on a dedicated link or on a multiplexed one. It can be of the fibre-optic type or based on conventional metallic or microwave media. Only the communication interface board needs to be varied to meet the different interface requirements.

Please see Chapter 5 for more detailed discussions on communication interfaces.

The module is powered from the +6.5V and ±19.5V rails of the I/O bus.

3.3.1 Communications processing module

Module No :	GM0052.nnn	
Circuit diagram :	01 ZH0944 01 ZH1011	
PCB No :	ZH0944 ZH1011	Communications Processor PCB Optical Interface PCB
Versions:	Four versions are available.	
Module No:	GM0052.02n	
Circuit diagram:	01 ZH1019 01 ZG1090 01 ZH1011	
PCB No.	ZH1019 ZG1090 ZH1011	Communications Processor PCB Communications Daugtherboard Optical Interface PCB
Versions:	Four versions are available.	

3.3.2 Fibre optic interface for 850nm

Module No :	GM0051.nnn	
Circuit diagram :	01 ZH0944 01 GM0051 01	
PCB No :	ZH0944 ZH0932	Communications Processor PCB G.703 Interface PCB
Versions:	Two versions are available.	
Module No.	GM0051.01n	
Circuit diagram :	01 ZG1090 01 ZH1019 01 GM0051 01	
PCB No :	ZH1019 ZG1090 ZH0932	Communications Processor PCB Communications Daugtherboard G.703 Interface PCB
Versions:	Two versions are available.	

Short haul

Wavelength:	850nm
Transmitter type:	LED
Minimum Tx output level:	–18dBm
Receiver type:	PIN
Rx sensitivity	–18dBm to 32dBm
Optical budget:	0 – 14dB

Medium haul

Transmitter type:	LED
Typical transmit output level:	–18dBm
Receiver type:	PIN
Maximum receive level:	–18dBm
Receive sensitivity:	–37dBm
Optical budget:	19dB

Long haul

Transmitter type:	LED
Typical transmit output level:	–18dBm
Receiver type:	PIN
Receive sensitivity:	–44dBm
Optical budget:	26dB

Note: The Tx output levels given are power launched into 1m of 50/125μm fibre.

All three versions are based on 850nm wavelength optical devices. Optical attenuation at this wavelength is typically 3dB/km. The module can be used to drive a dedicated optical link. If a multiplexed link is used and the PCM multiplexer is remote from the relay, then the short haul optical interface can also be used to connect the relay to the multiplexer via optical cables. A type MITZ interface unit is needed on the multiplexer side for optical to electrical signal conversion.

The optical transmitter and receiver devices are mounted on a small PCB (the optical device board) fixed to the back plate of the case. SMA 9mm type connectors are used for optical fibre connections. Electrical connections to the communication interface board are made through a two part DIN connector. The communication module can be withdrawn without disturbing the optical connections.

*** **CAUTION** *** (Applies PRE 0010A relays only)

The metal shell of the optical connectors of the medium haul and long haul versions are bonded to an internal +6V voltage and are insulated from the case ground.

DO NOT CONNECT ANYTHING OTHER THAN YOUR OPTICAL CABLES TO THESE CONNECTORS.

The internal +6V supply is short circuit protected. If the connectors are earthed accidentally, no damage will be caused but the optical circuitry will not function properly.

3.3.3 Fibre optic interface for 1300nm

Model No :	GM0114.nnn
Circuit diagram :	L1ZG7086
PCB No :	ZH1087
Versions:	Four versions are available

Two versions of the 1300nm optical interface are available. The first one is suitable for single-mode applications and the second is avcailable for multi-mode applications.

Single-mode interface

Transmitter type:	VCSEL
Typical Transmit output level at +25°C : [3.3.4.1]	–8.2dBm
Receiver type:	PIN
Receiver sensitivity:	–38.2dBm
Maximum guaranteed optical budget:	30dB

Multi-mode interface

Transmitter type:	VCSEL
Typical transmit output level at +25°C : [3.3.4.2]	–8.2dBm
Receiver type:	PIN
Receiver sensitivity:	–38.2dBm
Maximum guaranteed optical budget:	30dB

Notes:

3.3.4.1 The single-mode transmit output levels given are power launched into 1m of 9/125μm fibre.

3.3.4.2 The multi-mode transmit output levels given are power launched into 1m of 50/125μm fibre.

Optical attenuation at the 1300nm wavelength is typically 0.55dB/km for single-mode fibres or 1.1dB/km for multi-mode fibres. The maximum guaranteed optical budget for both of the 1300nm optical interfaces is 30dB. However, the lower attetuation of single-mode fibre will provide better performance, making it suitable for long distance applications.

The 1300nm interfaces are suitable for use on dedicated optical links only. They cannot be used with type MITZ interface units since such units exploit 850nm optical components which are not compatible with 1300nm components.

The optical transmitter and receiver devices are mounted on a small PCB (the optical device board) fixed to the back plate of the case. 'FC' or 'ST' type connections are used for optical fibre connections. Electrical connections are made through a two part DIN connector. The communications module can be withdrawn without disturbing the optical connections.

3.3.4 Fibre optic interface for 1550nm

Model No :	GM0114.nnn
Circuit diagram :	L1ZG7086
PCB No :	ZH1087
Versions:	Twor versions are available

The 1550nm optical interface is only suitable for single-mode applications

Single-mode interface

Transmitter type:	VCSEL
Typical transmit output level at +25°C : [3.3.4.1]	–8.2dBm

Receiver type:	PIN
Receiver sensitivity:	–38.2dBm
Maximum guaranteed optical budget:	30dB

Notes:

3.3.4.1 The single-mode transmit output levels given are power launched into 1m of 9/125µm fibre.

Optical attenuation at the 1550nm wavelength is typically 0.3dB/km for single-mode fibres.

The 1550nm optical interface is suitable for use on dedicated optical links only. It cannot be used with type MITZ interface units since such units exploit 850nm optical components which are not compatible with 1550nm components.

The optical transmitter and receiver devices are mounted on a small PCB (the optical device board) fixed to the back plate of the case. 'FC/PC' or 'ST' type connections are used for optical fibre connections. Electrical connections are made through a two part DIN connector. The communications module can be withdrawn without disturbing the optical connections.

3.3.5 G.703 Co-directional interface

This interface is no longer available.

3.4 Microcomputer

Model No :	GM0024.nnn
Circuit diagram :	1GM0024
PCB No :	ZH0794
Versions :	One

The module is a size 2 module and contains one printed circuit board.

As shown in Figure 6 the module incorporates a powerful 16-bit microprocessor (Intel 80186) featuring integrated on-chip peripherals. These peripherals include a timer unit with three programmable timers, a direct memory access (dma) unit, a programmable interrupt controller unit (icu), and an address decoder unit.

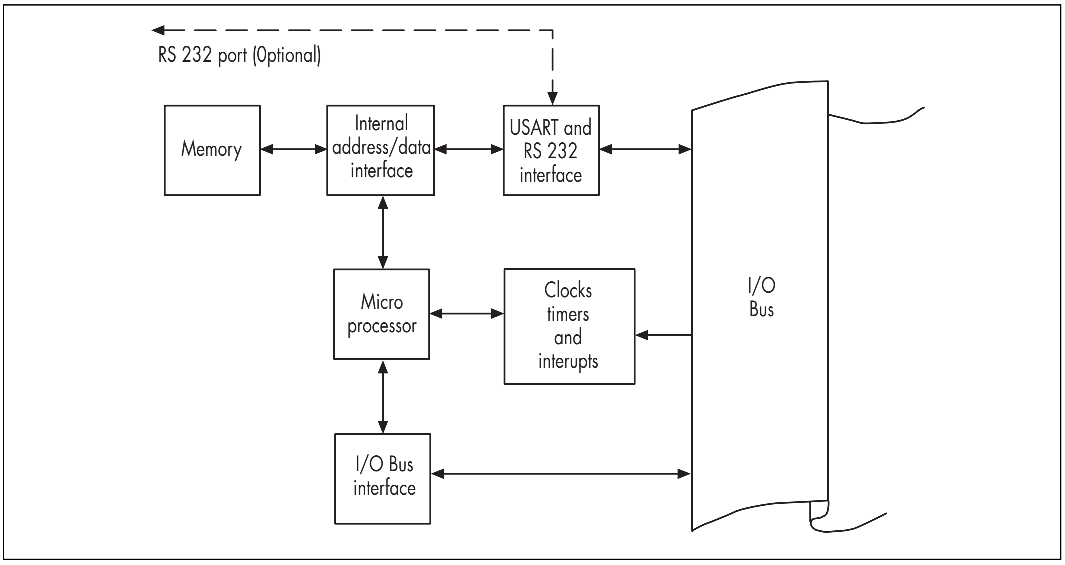


Figure 6: Microcomputer module

Eight 28-pin JEDEC memory sockets are provided. For the LFCB relay, the memory sockets are populated with RAM, EEPROM, and EPROM giving a total of 112kbytes of memory. The module incorporates a watchdog timer to ensure an orderly restart in the unlikely event of a system crash. An RS232 compatible serial interface controlled by a universal synchronous/asynchronous receiver transmitter (usart) allows serial communication with the microprocessor. The interface is normally brought out to a 25-way D-type female connector at the front panel for easy access. For more permanent connections to modems etc., the interface can be directed to a second 25-way D-type female connector mounted on the rear of the case. This is done by moving the position of a jumper link on the printed circuit board. See Table 5 for the pin connections of the rear mounted connector. The pin-outs of the front panel serial connector are given in Table 7.

The interface cable should be of 24AWG gauge and shielded. The cable should be provided with metal or metal-impregnated connector hoods.

We recommend that the cable shield is connected to the frame (protective) ground of the connecting terminal. There is no electrical isolation on the serial port.
An external isolation barrier with transient suppressers should be used if the communication is to be over a long distance or if the earth potential of the connected equipment can differ from that of the relay.

The microcomputer module controls the I/O bus. All modules connected to the bus work as slave I/O modules to the microcomputer module. The module is powered from the +6.5V and ±19.5V rails of the I/O bus.

Pin no.	Function	Direction
1	Protective ground	–
2	Transmitted data	Out
3	Received data	In
4	Request to send	Out
5	Clear to send	In
6	Data set ready	In
7	Signal ground	–
9	+12V	–
10	–12V	–
20	Data terminal ready	Out

Notes (1) The protective ground is connected to the case.

(2) Pins 5 and 6 are internally pulled up to +12V through 3.9k ohm resistors.

(3) The ±12V supplies brought out to pins 9 and 10 can be used to power an external RS232/optical converter or a line driver. The current drain however should be kept to within 50mA.

(4) Other pins on the 25-way connector are not connected.

Table 5: Pin-out table for the rear mounted RS232 serial connector

3.5 Analogue and status input

Model No : GM0036.nnn

Circuit diagram : 1ZH0793

PCB No : ZH0793

Versions : Two versions of CT are available: 1A, 5A.

The following auxiliary voltages are available for both CT versions.

Nominal	Operating range
24/34V	19.0V – 37.5V
48/54V	37.5V – 60.0V
110/125V	87.5V – 137.5V
220/250V	175.0V – 275.0V

The input module of the LFCB relay has 3 CT and 6 status inputs. The module is a size 4 module and contains one printed circuit board. As shown in Figure 7 the module features both analogue and digital status inputs. Interfacing CTs are used to scale down the levels of incoming current signals and to provide isolation. Opto-isolated couplers are used for status inputs.

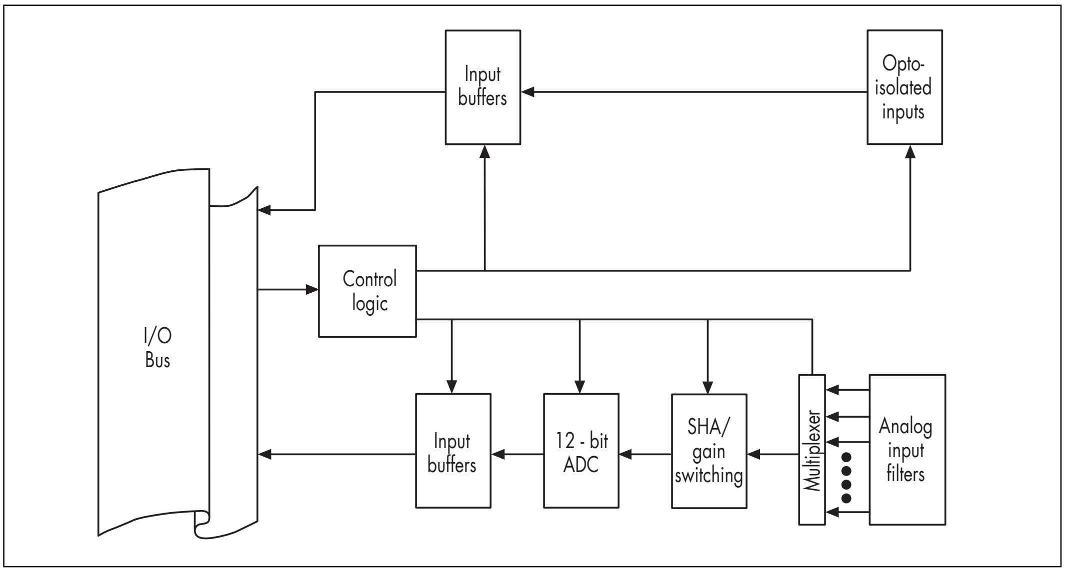


Figure 7: Analogue and status input module

Analogue signals from the interfacing CT are filtered by single-pole low pass filters and then multiplexed by an analogue multiplexer to a sample and hold amplifier (SHA). Data conversion is performed by a 12-bit analogue to digital converter (ADC). The typical conversion cycle time is 35µs. The 12-bit converted data is 2's complemented and sign-extended to 16 bits before being transferred by DMA to the microcomputer module.

The multiplexer, SHA, ADC and the transfer of converted data are all controlled by software running in the main processor of the microcomputer module.

A software controlled gain switching circuit is provided in the feedback loop of the SHA to extend the dynamic range of the ADC under low level input signal conditions. The feature however is not used by the LFCB relay.

Six opto-isolated digital status inputs are provided which are rated at the auxiliary dc supply voltage Vx(2). To reduce power dissipation caused by current flowing in the opto-input circuitry, a strobing technique is adopted which only allows current to flow into the opto-input circuitry when the status inputs are being read.

Connections to external wirings are made via a 28-way MIDOS connector which provides CT shorting facility for the CT inputs. Terminal allocation of the input module is given in Table 6. See the LFCB102 relay external connection diagram 10LFCB102 for details of input function assignment.

The module is powered from the +6.5V and ±19.5V rails of the I/O bus.

Terminal No.	Function	
1 2	Status Input 0	(+ve) (–ve)
3 4	Status Input 1	(+ve) (–ve)
5 6	Status Input 2	(+ve) (–ve)
7 8	Status Input 3	(+ve) (–ve)
9 10	Status Input 4	(+ve) (–ve)
11 12	Status Input 5	(+ve) (–ve)
21 22	CT Input 1	(start) (end)
23 24	CT Input 2	(start) (end)
25 26	CT Input 3	(start) (end)

Table 6: Terminal block A – allocation of the analogue and status input module

3.6 Front panel operator interface

Model No : GM0025.nnn

Circuit diagram : 1GM0025

PCB No : ZH0797

Versions : One

The operator interface (Figure 8) is mounted in the hinged front panel. It consists of a 2 row x 16 character alpha numeric LCD and a 7-key keypad. With the glass cover in position, only two of the seven push-button keys are accessible.
Also included in the front panel operator interface are four indication LEDs and two 25-pin D-type sockets.

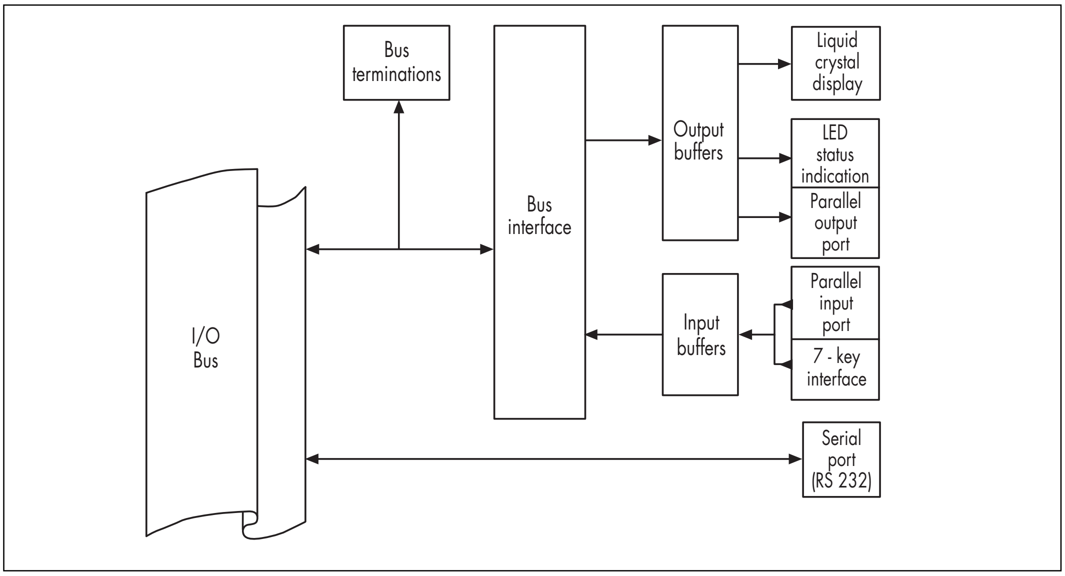


Figure 8: Front panel operator interface

One of the sockets marked 'SERIAL' is for RS232 serial communication with the relay. The pin-outs of the serial port (see Table 7) are configured for direct connection to data terminal equipment (DTE). No handshaking control signal is provided but XON/XOFF control is supported.

The other socket marked 'PARALLEL' is a parallel input/output port. It may be used to drive a parallel printer or to work as a test port for interfacing to a computer based injection testing equipment. Table 8 gives the pin-out information for both the parallel printer and test port connections. See Chapter 5 for more details about the printing and testing facilities.

The interface cables for the serial port and the parallel port should be of 24AWG gauge and shielded. The cables should be provided with metal or metal impregnated connector hoods. We recommend the cable shield to be connected to the frame (protective) ground of the connecting equipment. There is no electrical isolation on the serial port and the parallel port. An external isolation barrier with transient suppressers should be used if the communication is to be over a long distance or if the earth potential of the connected equipment can differ from that of the relay.

The front panel operator interface is powered by the +6.5V rail of the I/O bus.

Pin No.	Function	Direction
1	Protective ground	–
2	Received data	In
3	Transmitted data	Out
7	Signal ground	–

Notes (1) The protective ground is connected to the case.
(2) Other pins on the 25-way connector are not connected.
(3) Pins 4 and 5 are looped together at the connector.
(4) Pins 6, 8 and 20 are looped together at the connector.

Table 7: Pin-out table for the front panel RS232 serial connector

Pin No.	Parallel printer connection	Test port connection
1	Strobe	—Do Not Connect—
2	Data Bit 0	Protection Operated A
3	Data Bit 1	Protection Operated B
4	Data Bit 2	Protection Operated C
5	Data Bit 3	Block Auto-Reclose
6	Data Bit 4	Any Trip
7	Data Bit 5	Trip A
8	Data Bit 6	Trip B
9	Data Bit 7	Trip C
10	—Do Not Connect—	RESET Key
11	Busy	—Do Not Connect—
12	—Do Not Connect—	ACCEPT/READ Key
13	—Do Not Connect—	SET Key
14	—Do Not Connect—	=Key
15	—Do Not Connect—	[Key
16	—Do Not Connect—	–Key
17	—Do Not Connect—	+Key
18	—Do Not Connect—	+6.5V
19	—Do Not Connect—	+19.5V
20	—Do Not Connect—	–19.5V
21	—Do Not Connect—	+24V
22	Ground	Ground
23	Ground	Ground
24	Ground	Ground
25	Ground	Ground

Table 8: *Pin connections of the front panel parallel port for parallel printer and test port connections.*

Notes:
(1) Pins 1 – 9 are TTL outputs.
(2) Pins 10 – 17 are TTL inputs. Seven of which are connected in parallel with the front panel keypad.
(3) Pins 18 – 21 are connected to the internal voltage rails through 10k ohm resistors.
(4) The parallel printer connection is a sub-set of the IBM PC printer port. An IBM printer cable can be used by disconnecting the ‘Do not connect’ lines.
(5) No connections must be made to pins marked — Do not connect — above.

Section 4. LINK SETTINGS

The modules used in the LFCB relay are selected from a standard hardware range. Many of the modules have a number of jumper links which must be set to allow them to be used in particular applications.

The following section lists the link positions required in the LFCB relay.

All links must be fitted as shown with the exception of links marked with

'*** User Selectable ***' which may be set by the user to select a particular feature.

The following modules and boards do not have any jumper links:

(1)Power supply module

(2) Communication module – G.703 co-directional interface board

– all fibre optic device boards excluding pre 0010A long haul (850nm) versions 1300nm and 1550nm versions

4.1 Relay output module link positions

(1) Address Decode (Coarse)

JM2	No link	

(2) Address Decode (Fine)

Module at position No.2	Link	1–16
Module at position No.3	Link	2–15

See Figure 9 for the relay output module link positions

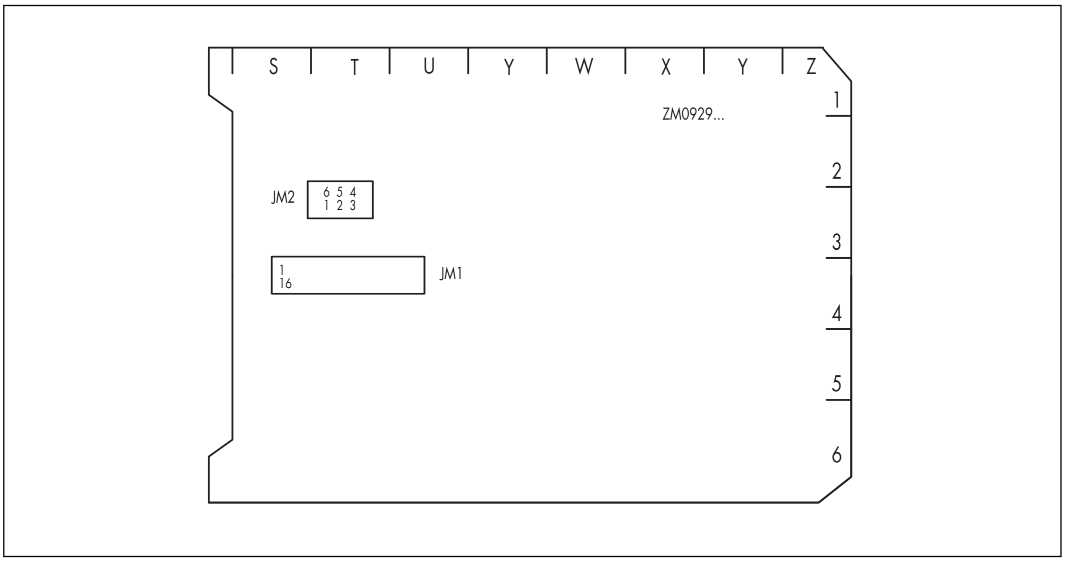


Figure 9: Relay output module link positions

4.2 Communication module link positions

4.2.1 Fibre optic interface board link positions

JM1	Link	2–3	LFCB terminal timing mode	
JM2	Link	2–3	LFCB terminal timing mode	
JM3	850nm Short haul		Link 5–6	64kb/s
	850nm Short haul		Link 11–12	56kb/s
	850nm Medium haul		Link 11–12	
	850nm Long haul		Link 11–12	
	1300nm & 1550nm		Link 5–6	
JM4	Link	1–4		
JM5	Link	1–4		

See Figure 10 for the fibre optic interface board link positions.

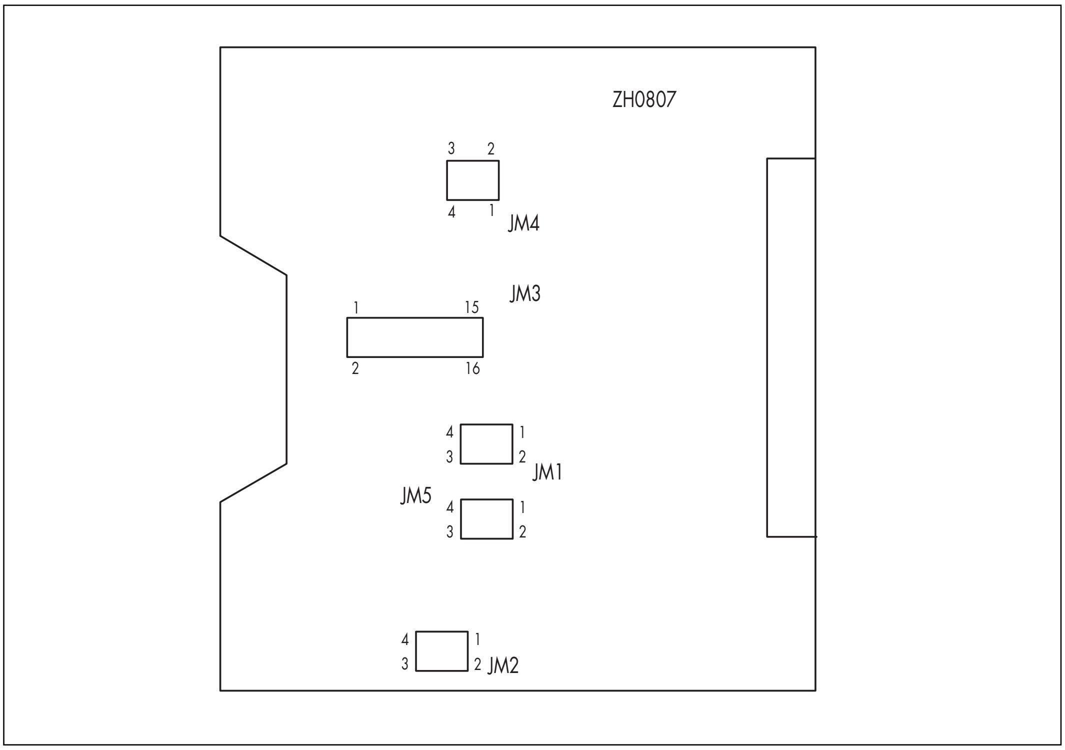


Figure 10: Fibre optic (850nm) interface board link positions

4.2.2 1300nm optical device board

JM1 Link 2–3 (default) (Link 1–2 for 2dB optical boost)

Note: PCB ZH0964 will be superseded in April 1998

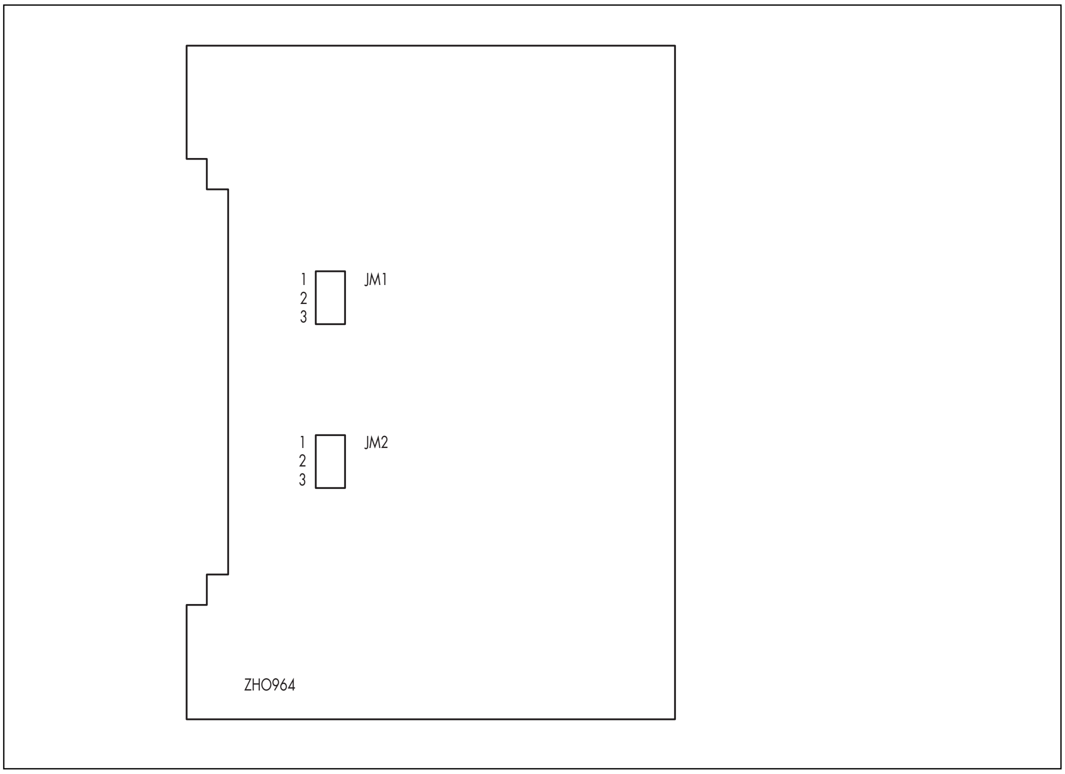


Figure 11: 1300nm optical device board

4.3 Microcomputer module link positions

(1) Memory Selection

JM1	Link	1–3 4–6 7–9
JM2	Link	1–3 4–6 7–9
JM3	Link	1–3 4–5 7–9
JM4	Link	1–2 4–6 7–8

(2) Watchdog Timer
JM5 Link 2–3

(3) Interrupt/DMA Select
JM6 Link 3–4
13–14

(4) RS232 Select *** User Selectable ***
JM7 Front panel socket Link 3–4 (default)

Rear panel socket Link 1–2

See Figure 12 for the microcomputer module link positions.

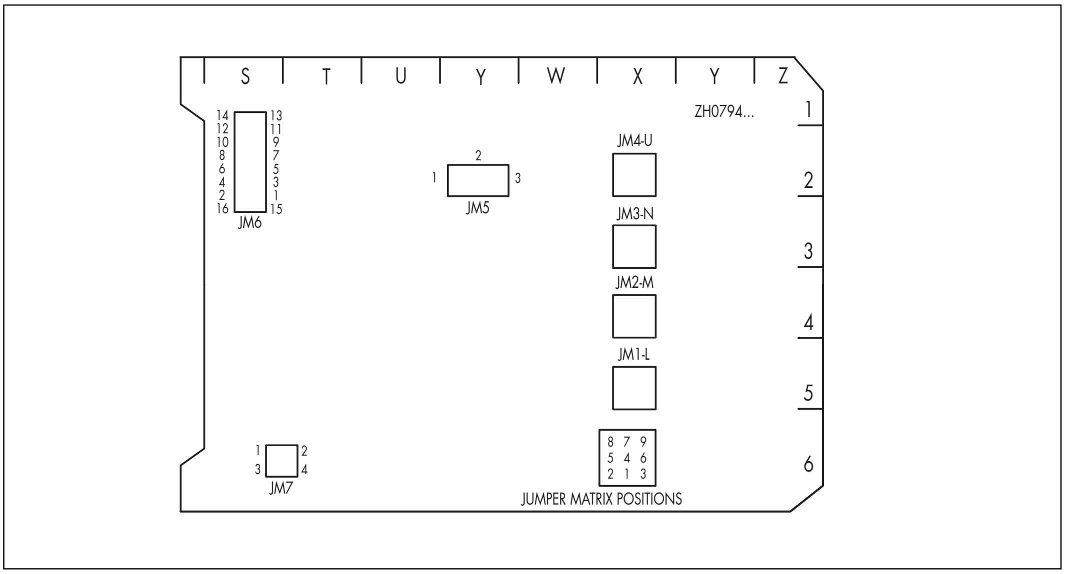


Figure 12: Microcomputer module link positions

4.4 Analogue and status input module link positions

(1) Address Decode

JM1	Link	1–2
		3–4

(2) Interrupt/DMA Select

JM2	Link	1–2

See Figure 13 for the analogue and status input module link positions.

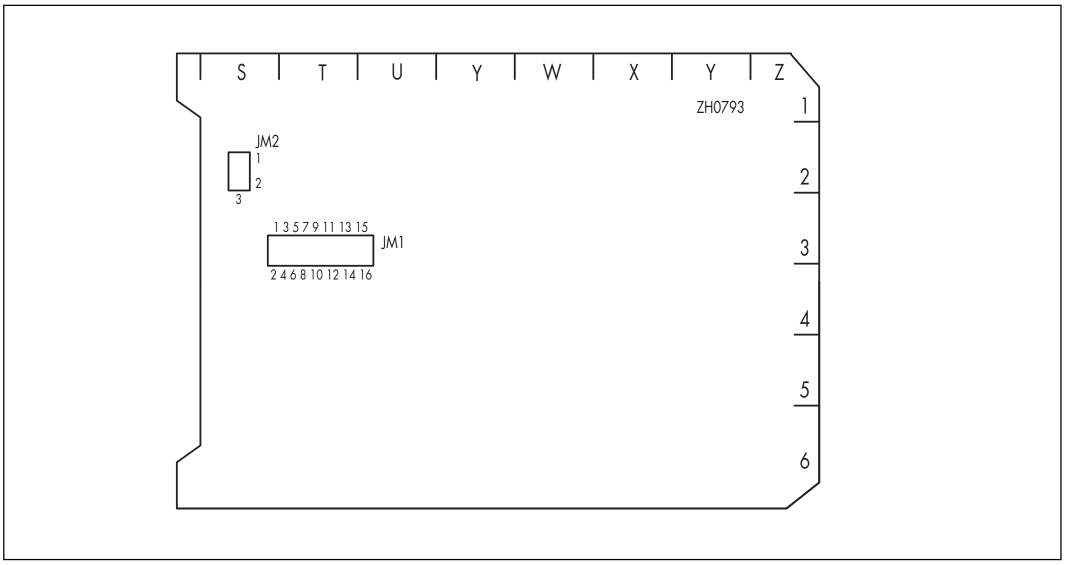


Figure 13: Analogue and status input module link positions

4.5 Front panel operator interface link positions

JM1	Link	1–2

See Figure 14 for the front panel operator Interface link positions.

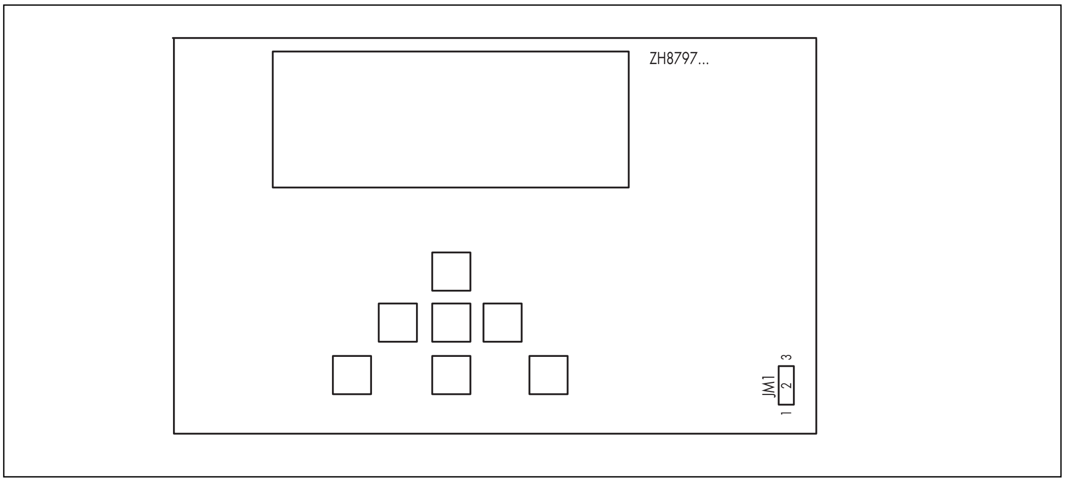


Figure 14: Front panel operator interface link positions

Section 5. TYPE MITZ OPTICAL TO ELECTRICAL SIGNAL INTERFACE UNIT

The MITZ is an interface unit which allows the LFCB relay to be connected to a remote PCM multiplexing equipment through optical cables (50/125µm multi-mode fibre cables are recommended). The interface unit is usually located close to the PCM multiplexer and provides optical to electrical and electrical to optical signal conversion between the LFCB relay and the multiplexer.

5.1 G.703 Co-directional interface unit

Model No : MITZ01

Outline diagram : GJ0025 sht 3

External connection

Diagram : 10MITZ01

Circuit diagram : 1MITZ01

PCB No : ZJ0113 Interface board
ZJ0114 Fibre optic device board
ZJ0115 Back-plane PCB
ZJ0116 Power supply board

Versions : Two versions are available covering the following dc supply voltages

Nominal rating	Operative range	Maximum withstand
24 – 54V	19.0 – 60V	65V
110 – 250V	87.5 – 275V	300V

DC burden : 2W max

Weight : 2.2 kg

The MITZ 01 supports the CCITT G.703 co-directional interface. The interface unit consists of a single withdrawable module housed in a size 4 MIDOS case. The unit has 4 boards:

5.1.1 An interface board which contains the necessary signal conversion circuitry.

5.1.2 A power supply board which provides a regulated voltage rail for the interface logic and the optical devices.

5.1.3 A fibre-optic device board which contains the optical transmitter and receiver devices. This board is fixed in the rear of the case.

5.1.4 A back-plane PCB which is situated at the rear of the module and interconnects the other three boards together.

Electrical connections to the MITZ 01 unit are made via a standard 28-way MIDOS connector (see Table 9). The power supply input has an isolation level of 2.5kV.

The G.703 signals are isolated by pulse transformers to 1kV.

Since the G.703 signals are only of ±1V magnitude, the cable connecting the MITZ 01 unit and the multiplexer must be properly screened against electromagnetic noise and interference. The interface cable should consist of pairs of 24AWG, twisted and shielded, and have a characteristic impedance of about 120 ohms. The choice of grounding depends strictly on local codes and practices. We recommend that the interface cable shield should be connected to the multiplexer frame ground. The cable may also be connected to the MITZ 01 case ground if no earth loop current is expected.

Fibre optic connections to the unit are made through SMA 9mm type connectors. The optical characteristics are similar to the LFCB 850nm short haul fibre optic interface.

Operative distance:	– 2km
Wavelength:	850nm
Transmitter type:	LED
Typical transmit output level:	–18dBm
Receiver type:	PIN
Maximum receive level:	–12dBm
Receive sensitivity:	–18dBm to 32dBm
Optical budget:	0 – 14dB

Note: The transmit output level given is power launched into 1m of 50/125µm fibre.

Terminal No.	Function	
3 4	Transmit Data/Clock (to PCM) Transmit Data/Clock (to PCM)	– A – B
7 8	Receive Data/Clock (from PCM) Receive Data/Clock (from PCM)	–A –B
25 26	Auxiliary Supply Input Auxiliary Supply Input	(+ve) (–ve)

Table 9: Terminal allocation of the MITZ 01 optical to G.703 interface unit

Digital Current Differential Relay Type LFCB 102

Chapter 5 Functional Description

Section 1. OPERATING PRINCIPLE

1.1 Data sampling

An LFCB current differential system consists of identical relay units at each end of the protected circuit. In contrast to conventional analogue relays, the three phase currents at each line end are measured by sampling at regular intervals. The signal samples are converted into digital data codes.

Current signals from line CT are first fed into relay input CT and scaled down to a signal level compatible with the electronic input circuits. This also provides galvanic isolation between the relay and substation plants. The scaled analogue signals are then filtered by single-pole, low pass filters for anti-aliasing purposes and for removing high frequency distortions. The signals are then multiplexed into a sample and hold amplifier (SHA) and converted into digital data by a 12-bit analogue-digital converter (ADC). See Chapter 4 for further description of the analogue input circuit.

The LFCB relay has an input range of 30In, ie. an input rms current of 30 times nominal current is converted to the full range value of the 12-bit ADC (±2048 peak to peak). An input signal in excess of 30In would be distorted by having its peaks clipped as illustrated in Figure 1. This ADC saturation effect causes the relay to measure the magnitude of the current signal smaller than the actual value.
This however seldom causes any discrimination problem since 30In is generally above the level of through fault currents.

Another source of conversion error is quantization error. As the signal after data conversion is represented by the nearest quantizing value, there can be a conversion error of up to $\pm 1/2$ lsb (least significant bit) level). This error is only significant when the input signal is small. For example, an input current of 0.1In would be converted as 7 lsb (peak) and the quantizing error can amount to an error of 7%.

The LFCB 102 relay has a sampling rate of 8 samples per cycle. An internal free running clock controls the sampling of the current signals. There is no direct synchronisation of sampling between relays, leading to a possible phase difference of up to $1/2$ sampling period between the clocks at different line ends. Effective synchronisation is achieved by an alignment procedure described later.

1.2 Filtering and pre-processing of data

The sampled data represent the instantaneous values of the current signals and may contain dc offset, harmonics and high frequency components. It is necessary to filter and pre-process the data to a form suitable for the calculation of the magnitudes of differential and bias currents. A digital filtering technique called the one-cycle Fourier method is used. The process extracts the power frequency components of the current signals out in vector form.

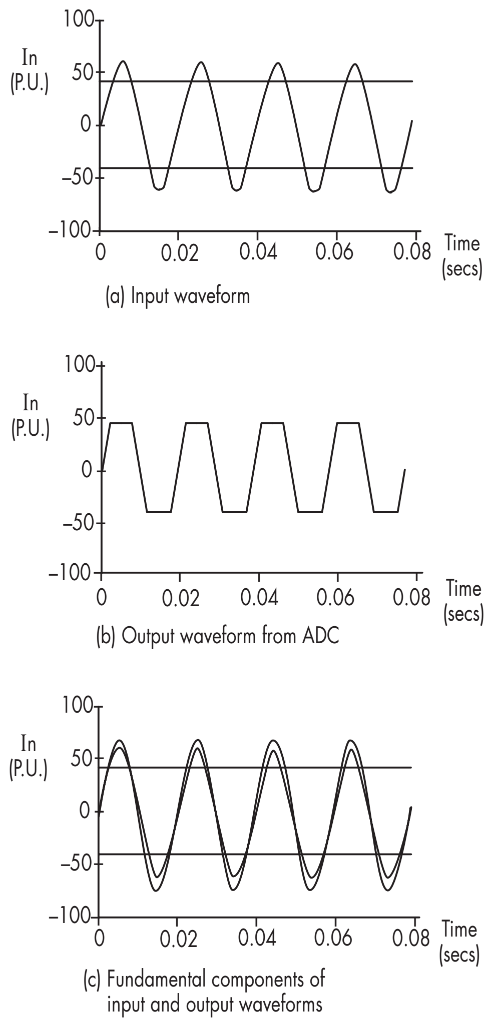


Figure 1: ADC saturation effects

The algorithm can be expressed as:

$$\text{Is} = \frac{2}{N}\left[\sum_{n=1}^{N-1} \sin \omega n \Delta t . i_n\right]$$

$$\text{Ic} = \frac{2}{N}\left[\frac{i_O}{2} + \frac{i_N}{2} + \sum_{n=1}^{N-1} \cos \omega n \Delta t . i_n\right] \qquad \text{——(1)}$$

where N – Number of samples per cycle.

ω – Fundamental angular frequency.

i_n – Instantaneous value of signal i sampled at time n_t.

Is – Fourier sine integral of signal i.

Ic – Fourier cosine integral of signal i.

i_0 – Instantaneous value of signal i sampled at time 0.

i_N – Instantaneous value of signal i sampled at time N_t.

If the fundamental component of the CT current signal observed at time t is Isin(wt + ϕ), the outputs of the Fourier filter will be a vector representation of the signal, ie:

$$I\angle\phi = (Is + jIc)$$
$$Is = I\cos\phi$$
$$Ic = I\sin\phi \qquad (2)$$

The vector $I\angle\phi$ is the fundamental current vector at the instant of a particular sample. The fundamental current vector I at any time other than the sampling instant can be determined by rotating the vector $I\angle\phi$ by an appropriate angle according to the power frequency and the required time shift. As the phase angle ϕ is related to the time reference of the data window, Is and Ic are not static but sinusoidal quantities.

The LFCB 102 relay has a sampling rate of 8 samples per second, ie. N=8. The corresponding Fourier equations are:

$$Is = \frac{1}{4}\left[\frac{1}{\sqrt{2}}\left(i_1 + i_3 - i_5 - i_7\right) + \left(i_2 - i_6\right)\right]$$
$$Is = \frac{1}{4}\left[\frac{1}{\sqrt{2}}\left(i_1 - i_3 - i_5 + i_7\right) + \frac{1}{2}\left(i_0 - 2i_4 + i_8\right)\right] \qquad (3)$$

1.3 Data message

Having measured and processed the currents at each end, the vector values need to be sent to the other end so that the differential and bias currents can be calculated. The current vector values (Is and Ic of a, b and c phases, each being 14 bits long) are packed together with other timing, status, command and error checking data into a 21 bytes long message. A standard digital communication protocol called HDLC (High Level Data Link Control) is used.

Please see Section 4.2 for an explanation of the HDLC protocol.

1.4 Data polling and measurement of channel delay time

Consider a three-ended system as shown in Figure 3. Three identical relays, A, B and C are placed at the different ends of the line and, as described in Sections 1.1 and 1.2, perform data sampling and pre-processing. Relay A samples its current signals at time tA1, tA2 etc., and relay B at time tB1, tB2 etc. Note that the sampling instants at the three ends will not in general be coincidental or of fixed relationship due to slight drifts in sampling frequencies.

To simplify the explanation, we shall first consider just the communication between relays A and B. Assume that at time tA1, relay A sends a data message to relay B. The message contains a time tag tA1 together with other timing and status information and the current vector values calculated at tA1. The message arrives at end B after a channel propagation delay time tp1. Relay B registers the arrival time of the message as tB*.

Since relays A and B are identical, relay B also sends out data messages to end A at selected sampling times. Assume relay B sends out a data message at tB3. The message contains therefore the time tag tB3. It also returns the last received time tag from relay A, ie. tA1, and the delay time td between the arrival time of the received message tB* and the sampling time tB3, ie. td = (tB3 – tB*).

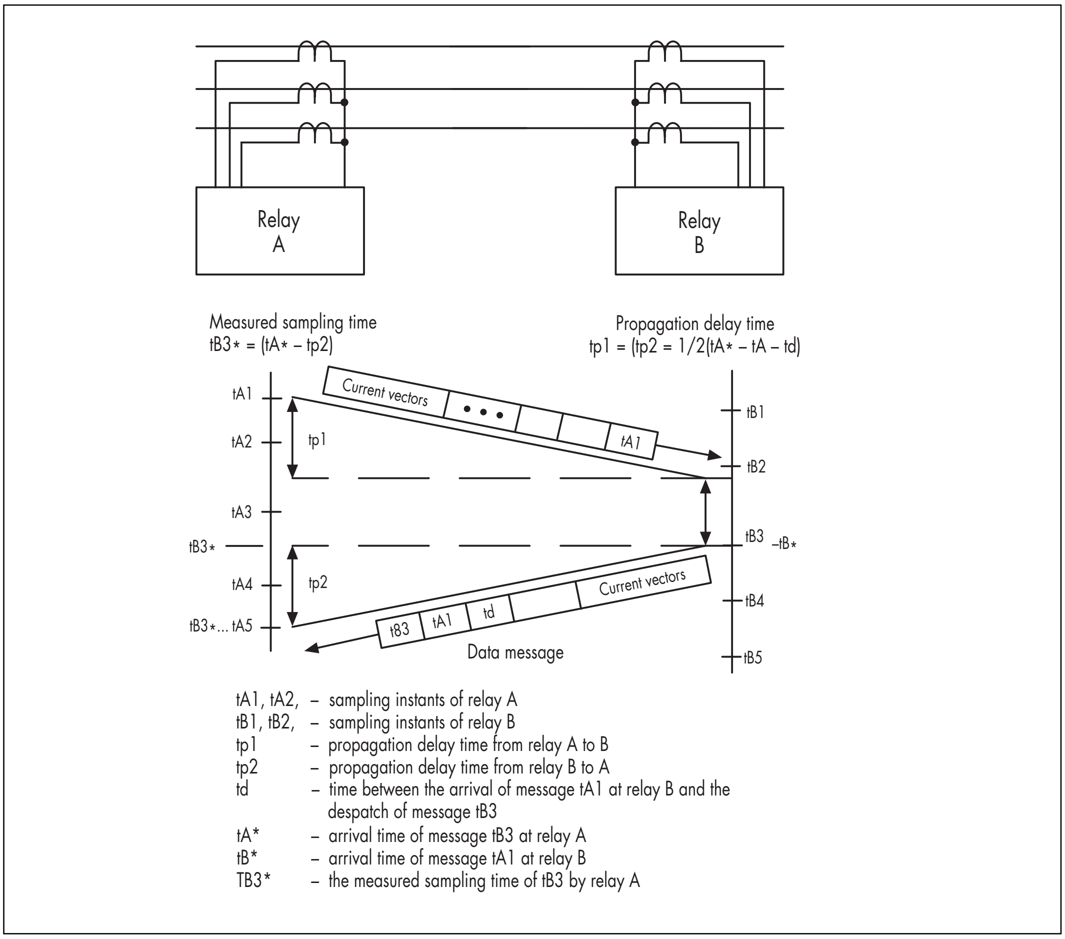


Figure 3: Data polling and propagation delay time measurement

The message arrives at end A after a channel propagation delay time tp2 and its arrival time is registered by relay A as tA*. From the returned time tag tA1, relay A can measure the total elapsed time as (tA* – tA1). This equals the sum of the propagation delay times tp1 and tp2 and the delay time td at end B.

$$(tA^* - tA1) = (td + tp1 + tp2) \qquad —(4)$$

The transmit and receive channels normally follow the same path and so have the same propagation delay time. The propagation delay time can therefore be measured as:

$$tp1 = tp2 = {}^1/_2(tA^* - tA1 - td) \qquad —(5)$$

Note that the propagation delay time is measured for each data poll and this can be used to monitor any change on the communication link. Also the time tag tA1, etc. can be used to spot missing messages and also as a message validity check in addition to the usual cyclic redundancy and message length checks. See Section 4.3 for more discussions on system security measures taken by the LFCB relay.

1.5 Time alignment of received current vectors

With the measurement of the propagation delay time, the sampling instant of the received data from relay B can be calculated. As shown in Figure 3, the sampling time tB3 is measured by relay A as

$$tB3^* = (tA^* - tp2) \qquad —(6)$$

In Figure 3, tB3* is between tA3 and tA4. To calculate the differential and bias currents, the vector samples of all three ends must correspond to the sampling instants. It is necessary therefore to time align the received tB3* data to tA3 and tA4. As (Is + jIc) represents a vector rotating in an anti-clockwise direction on the complex plane at an angular frequency w, it is possible to extrapolate the end B signals at time tA3 and tA4 by transforming the vector information at tB3*.

Using a look-up table, the parameters say (a + jb) to perform a phase shift corresponding to the time (tA4 – tB3*) can be obtained. The vector value of end B current at time tA4 can then be calculated as:

$$IB4 = (Is + jIc)(a + b)$$

$$= (a.Is - b.Ic) + j(b.Is + a.Ic) \qquad —(7)$$

The value of the end B current at time tA3 can be obtained likewise by rotating IB4 backward by a fixed angle corresponding to the sampling time period. Note that the current vectors of the three phases need to be time aligned separately. As two data samples can be obtained from each data message, the process needs to be done only once every two samples, thus reducing the communication bandwidth required. Note that the current vectors of the three phases need to be time aligned separately.

1.6 Calculation of differential and bias currents

If $I_{A\text{-}a}$, and $I_{B\text{-}a}$ are the time aligned a-phase current vector signals for ends A and B at a particular time, then the a-phase differential and bias current values can be calculated as:

$$|Idiff_a| = |(I_{A-a} + I_{B-a})|$$

$$|Ibias_a| = {}^1/_2(|I_{A-a}| + |I_{B-a}|) \qquad —(8)$$

Since the LFCB relay works on a per phase basis, a total of 12 current magnitudes need to be calculated from the phase current vectors, viz $Idiff_a$, $Idiff_b$, $Idiff_c$, I_{A-a}, I_{A-b}, I_{A-c}, I_{B-a}, I_{B-b} and I_{B-c}.

Given the vector components Is and Ic of a current signal *i*, the amplitude $|I|$ can be calculated as:

$$|I| = \sqrt{(Is^2 + Ic^2)} \qquad —(9)$$

The square root function cannot be easily implemented in a microprocessor. Instead, a 4-segment linear approximation technique is used which gives an overall accuracy of –0.5% to +0.25%. The algorithm can be expressed as:

Let $u = max(Is,Ic)$

$v = max(Is,Ic)$

then (i) for $u > 4v$, $|I| = 0.9950u + 0.1225v$

(ii) for $4v \geq u > 2v$, $|I| = 0.9398u + 0.3476v$

(iii) for $6v \geq 3u > 4v$, $|I| = 0.8518u + 0.5264v$

(iv) for $4v \geq 3u$, $|I| = 0.7559u + 0.6560v$ —(10)

1.7 Tripping criteria and settings

The LFCB 102 relay has a dual-slope percentage biased restraint characteristic as shown in Figure 4. The characteristic is determined by four protection settings:

I_{S1} – The basic differential current setting which determines the minimum pick-up level of the relay.

k_1 – The lower percentage bias setting used when the bias current is below I_{S2}. This ensures good sensitivity to resistive faults under heavy load conditions.

I_{S2} – A bias current threshold setting above which the higher percentage bias k_2 is used.

k_2 – The higher percentage bias setting used to improve relay stability against CT saturation and other distortion effects under heavy through fault current conditions.

The tripping criteria can be formulated as:

(i) for $|Ibias| \leq I_{S2}$, ——(11)

$$|Idiff| > k_1.|Ibias| + I_{S1}$$

(ii) for $|Ibias| \leq I_{S2}$, ——(12)

$$|Idiff| > k_2|Ibias| - (k_2 - k_1)I_{S2} + I_{S1}$$

All four settings are user adjustable. This flexibility in settings allows the relay characteristic to be tailored to suit particular sensitivity and CT requirements. Such flexibility however is not always needed but makes it more complicated to determine the settings. To simplify the protection engineer's task, we recommend three of the settings to be fixed to:

I_{S2} = 2.0 pu

k_1 = 30%

k_2 = 150%

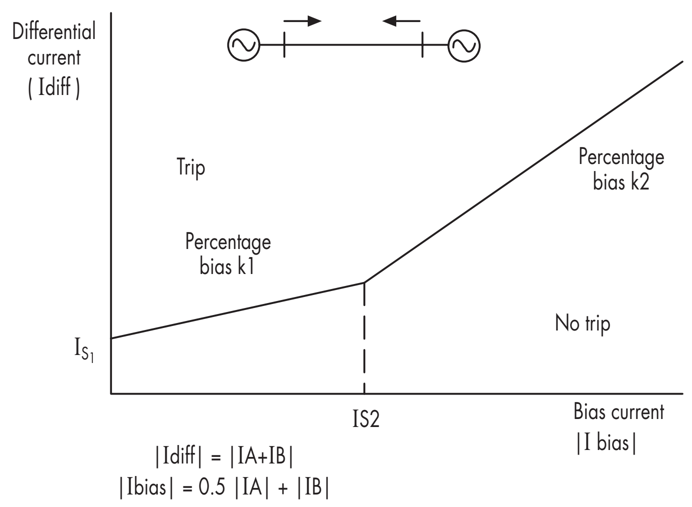


Figure 4: Dual slope percentage bias characteristic

These settings will give a relay characteristic suitable for most applications.
It leaves only the I_{S1} setting to be decided by the user. Please see Section 2.1 for guides of setting I_{S1}. Also see Section 2.6 for the CT requirements of the LFCB relay when set at these I_{S2}, k_1 and k_2 settings.

The relay trips when 4 consecutive data samples satisfy the above tripping criteria.

1.8 Using the maximum bias current of the three phases as bias current

The differential currents of each of the three phases are compared individually with the bias current according to the tripping criteria given by equations (11) and (12). A heavy internal fault, say an a-phase to ground fault, may leave a remnant flux in the CT core at one of the two ends and form a low impedance path. If an external fault occurs subsequently to another phase, say b-phase, a small spill current can pass through the low impedance path of the a-phase CT core. As this happens at one end only, it can lead a differential relay to see it as a single end fed fault and causes maloperation.

This is averted in the LFCB relay by deriving the bias quantity from the maximum of the bias currents of the three phases, ie.

$$|Ibias| = \max(|Ibias_a|, |Ibias_b|, |Ibias_c|) \quad \text{——(13)}$$

This effectively imposes a higher bias to the healthy phases and helps to stabilise the relay against the spill current caused by CT saturation effects. There may be concerns about the sensitivity of the relay when there is a simultaneous heavy external fault on one phase and a high resistive internal fault on another phase. This however is no worse than the situation of having both faults on the same phase under which neither an individually biased nor maximum biased scheme would operate correctly. The gain in stability through the maximum bias scheme would far out-weigh the slight loss in sensitivity.

Section 2. PROTECTION RELATED ISSUES

2.1 The minimum operating current

It should be noted that the minimum operating current is related but not equal to the IS1 setting.

Consider a single end fed fault with no load but fault current I. Then

$$|Idiff| = I$$

$$|Ibias| = \tfrac{1}{2}I$$

Assuming $|Ibias| < I_{S2}$, then from (11) the relay will operate if

$$|Idiff| > k_1.|Ibias| + I_{S1}$$

or $I > k_1.\tfrac{1}{2}I + I_{S1}$

or $$I > \frac{I_{S_1}}{(1 - 0.5k_1)} \quad \text{——(14)}$$

The minimum operating current is therefore a function of the $I_{S1}1$ and k_1 settings. Since k_1 is recommended to be set to 30% (See Section 1.7) the minimum operating current will be:

$$I_{min} = 1.176I_{S1} \quad \text{——(15)}$$

The minimum setting for I_{S1} is 0.2 pu. The minimum operating current is therefore 0.235 pu.

The selection of I_{S1} is based upon the magnitude of line capacitance current I_{cap} and switching transients expected on the protected line. For general applications, it is recommended that:

$$I_{S1} \geq 2.5 I_{cap} \qquad \text{——(16)}$$

This allows for transient in-rush current during line energization and increases in capacitive charging current caused by system overvoltages during normal load and external fault conditions.

2.2 Relay sensitivity under heavy load conditions

The sensitivity of the relay is governed by its settings and also the magnitude of load current in the system. For a three-ended system with relays A, B and C:

$$|Idiff| = |(I_A + I_B)|$$

$$|Ibias| = 0.5(|I_A| + |I_B|)$$

Assume a load current of I_L flowing from end A to B and C. Assume also a high resistive fault of current I_F being singly fed from end A. For worst case analysis, we can assume also I_F to be in phase with I_L. Then:

$$I_A - I_L + I_F$$

$$I_B = -I_L$$

$$|Idiff| = |I_F|$$

$$|Ibias| \leq |I_L| + 0.5|I_F|$$

2.2.1 Relay sensitivity when $|Ibias| < I_{S2}$

For $|Ibias| <$ IS2, the relay would operate if $|Idiff| >$ k1 $|Ibias|$ + IS1

or $|I_F| > k_1(|I_L| + 0.5|I_F|) + I_{S1}$

or $(1 - 0.5k_1)|I_F| > (k_1|I_L| + I_{S1})$

or $|I_F| > (k_1|I_L| + I_{s_1})/(1 - 0.5k_1)$ ——(17)

(1) for $|I_L| = 1.0$ pu, the relay would operate if $|I_F| > 0.59$ pu

(2) for $|I_L| = 1.5$ pu, the relay would operate if $|I_F| > 0.76$ pu

(3) for $|I_L| = 1.59$ pu, the relay would operate if $|I_F| > 0.80$ pu

If $|I_F| = 0.80$ pu and $|I_L| = 1.59$ pu, then $|Ibias| = 1.99$ pu which reaches the limit of the low percentage bias curve.

2.2.2 Relay sensitivity when $|Ibias| > I_{S2}$

For $|Ibias| > I_{S2}$, the relay would operate if

$$|Idiff| > k_2|Ibias| - (k_2 - k_1)I_{S2} + I_{S1}$$

or $|I_F| > k_2(|I_L| + 0.5|I_F|) - (k_2 - k_1)I_{S2} + I_{S1}$

or $(1 - 0.5k_2)|I_F| > (k_2|I_L| - (k_2 - k_1)I_{S2} + I_{S1})$

or $|I_F| > (k_2|I_L| - \dfrac{(k_2 - k_1)I_{s_2} + I_{s_1})}{(1 - 0.5k_2)}$ ——(18)

For $I_{S1} = 0.2$ pu, $k_1 = 30\%$, $I_{S2} = 2.0$ pu and $k_2 = 150\%$, then, (1)for $|I_L|$ = 2.0 pu, the relay would operate if $|I_F|$ > 3.2 pu

(2)for $|I_L|$ = 2.5 pu, the relay would operate if $|I_F|$ > 6.2 pu

2.2.3 Fault resistance coverage

Assuming the fault resistance R_F is much higher than the line impedance and source impedance, then for a 400kV system and 2000/1 CT,

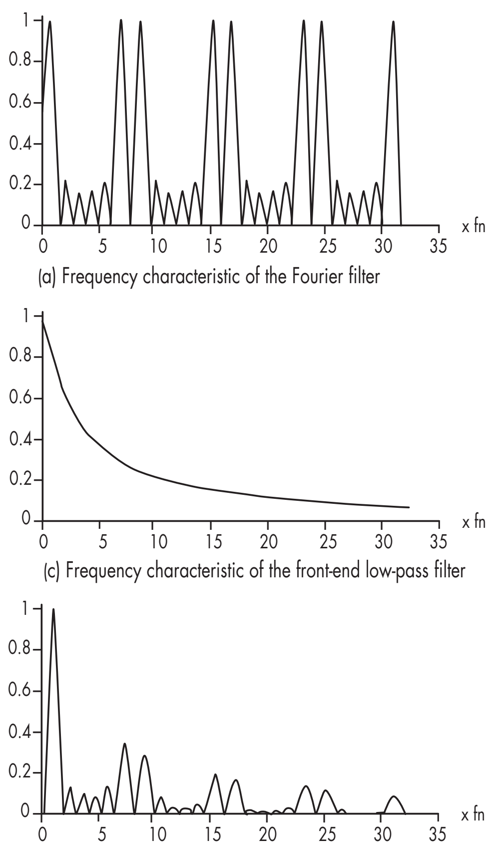
$$|I_F| = ((400/\sqrt{3})/R_F)/2 \text{ pu}$$
$$= 115.5/R_F \text{ pu}$$

Based on the analysis in Section 2.2.2, the relay will detect a 100 ohm fault if the load current is below 1.66 pu.

With a short time overload current of 2.0 pu, the relay will be able to detect a fault of 36 ohm or lower fault resistance.

2.3 Effects of harmonics

The front end analogue low pass filter and the digital Fourier filter both work to eliminate the effects of harmonics on the measurement of the fundamental component values. Their frequency characteristics are shown in Figure 5.
Due to aliasing effect, 7th and 9th harmonics are seen as fundamental components. They cannot be eliminated by the Fourier filter but can only be attenuated by the analogue low pass filter. Components with frequencies which are not exact multiples of the fundamental frequency also cannot be completely eliminated.



(a) Frequency characteristic of the Fourier filter

(c) Frequency characteristic of the front-end low-pass filter

(c) Combined frequency characteristic of the Fourier and low-pass filters (gain normalised at fundamental frequency fn)

Figure 5: Frequency characteristics

Presence of these components can cause measurement errors to the magnitudes of phase currents. Under load and external fault conditions the total inflow currents equal the total of outflow currents. The errors measured by the relays therefore tend to cancel out each others and no differential currents will result.

With an internal fault, measurement errors at the three ends will not be the same. The measured differential currents and bias currents can be either higher or lower than the true fundamental component values and so can affect the sensitivity of the relay.

From the frequency characteristic given in Figure 5 the gain at 7th harmonic is 0.35. If the input current contains a 7th harmonic component the magnitude of which is 10% of that of the fundamental component, it can cause a measurement error of up to 3.5% of the value of the fundamental component current.

The energization of a transmission line can generate a switching transient with rich harmonic content. The frequency components of the transient is related to the line impedance and capacitance, the line length, and the presence of VAR compensating reactors and capacitors. If there is a dominant 7th or 9th harmonic content, then the I_{S1} setting must be set higher to avoid relay maloperation during energization.

2.4 Transformer magnetising in-rush current.

The LFCB 102 relay should not be applied to circuits with in-zone power transformers. The relay does not incorporate harmonic restraint against magnetising in-rush. An in-zone magnetising in-rush current is seen as single-end fed fault current. As shown in Figure 6, the Fourier filter works to extract the fundamental frequency component of the magnetising current. Although the measured current is much smaller than the magnetising in-rush current magnitude, it can still exceed the normal setting of I_{S1} and cause maloperation.

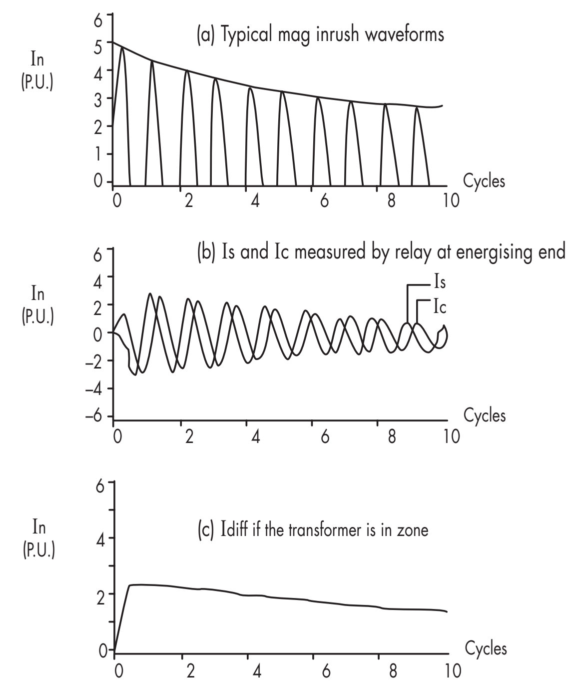


Figure 6: Effects of magnetising in-rush current

If the transformer is outside the protected zone, then the sum of in-rush currents measured at the three ends of the protected line will be zero. No differential current is measured and the relays remain stable.

2.5 Effects of power frequency variation

The sampling frequency of the LFCB is controlled by an internal crystal oscillator. Since only current input signals are available to the LFCB, it is not feasible to use the analogue input signals to synchronise the sampling frequency with the power frequency. The accuracy of the relay is therefore affected when the power frequency varies.

If the input current signal is:

$$i = I \sin[(\omega + \partial\omega)t + \phi]$$

where ω – the rated power frequency

$\partial\omega$ – the variation in frequency

∂t – the sampling time period

then the LFCB relay will measure the current magnitude as:

$$|\text{Icalculated}| = \frac{4(\omega + \partial\omega)}{\partial\omega(2\omega + \partial\omega)T} \cdot \frac{\sin \partial\omega T}{2} . I \left[0.5 + \frac{\sin(\omega\partial t + \partial\omega\partial t)}{2 \sin \omega\partial t}\right] \quad \text{——(19)}$$

As shown in Figure 7a |Icalculated| is larger than the true magnitude I when the frequency is above the rated frequency and smaller when the frequency is below the rated frequency. For an operative frequency range of –6% to + 2%, equation (19) shows a magnitude accuracy variation from –6% to +1.7%. The actual accuracy measured is from –6.8% to +1.3%.

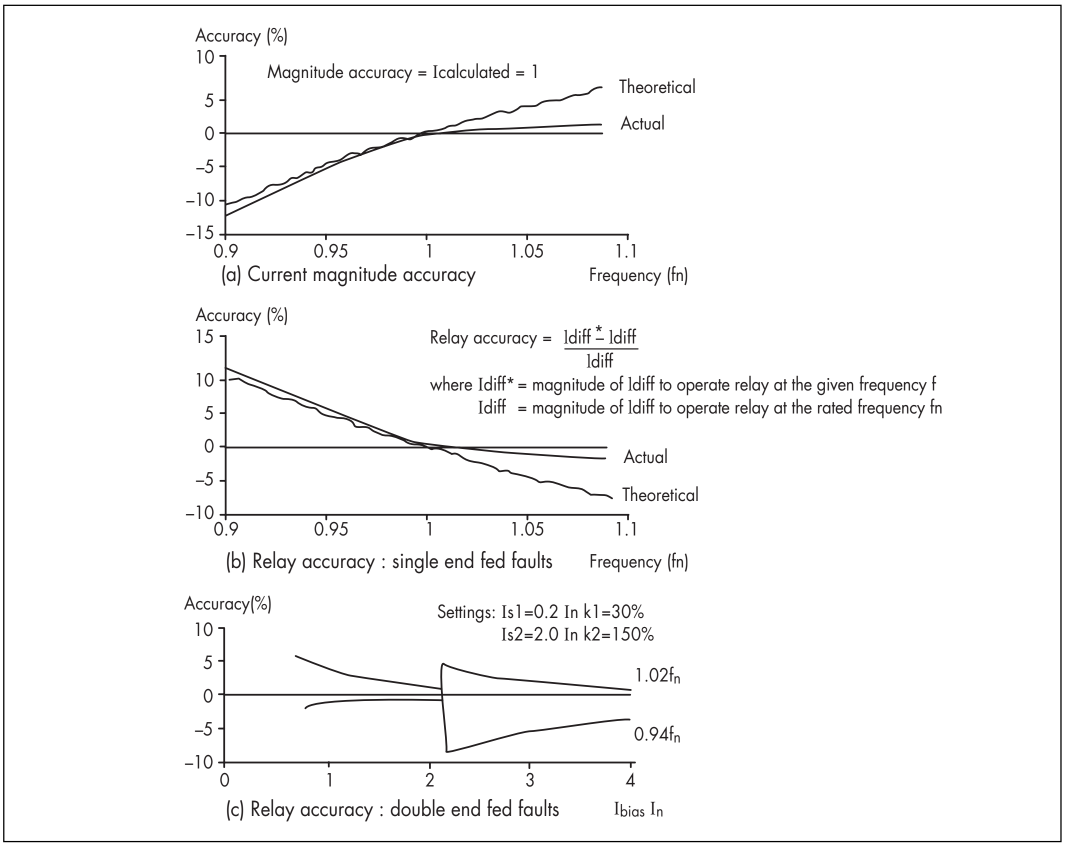


Figure 7: Measurement errors due to frequency variation

Under single-end fed fault conditions, the relay accuracy as depicted in Figure 7b is the inverse of the magnitude accuracy. If |I calculated| is larger than I because the frequency is above the rated frequency, then it will take a smaller fault current to operate the relay.

For double end fed internal faults, the relay accuracy will be affected by settings and the magnitudes of the bias and differential currents. The measured relay accuracy along the operating characterististic corresponding to settings of:

I_{S1} = 0.2In, I_{S2} = 2.0In, k_1 = 30% and k_2 = 150% is shown in Figure 7c. Note that the relay is least accurate when the bias current is close to I_{S2}.

Under load and external fault conditions the inflow currents and outflow currents are affected similarly by frequency variations. This gives a cancelling effect and helps to reduce the error effect to differential currents.

2.6 Current transformer requirements

Figure 8 shows a typical CT saturated current wave form. The fundamental frequency component measured by the Fourier filter is smaller than the original signal magnitude if it is not saturated. The phase information is generally preserved. If the CT at one end of the protected line saturates under an external fault condition, then a differential current will be measured. Depending on the extent of saturation and the bias settings used, the relays may remain stable or maloperate.

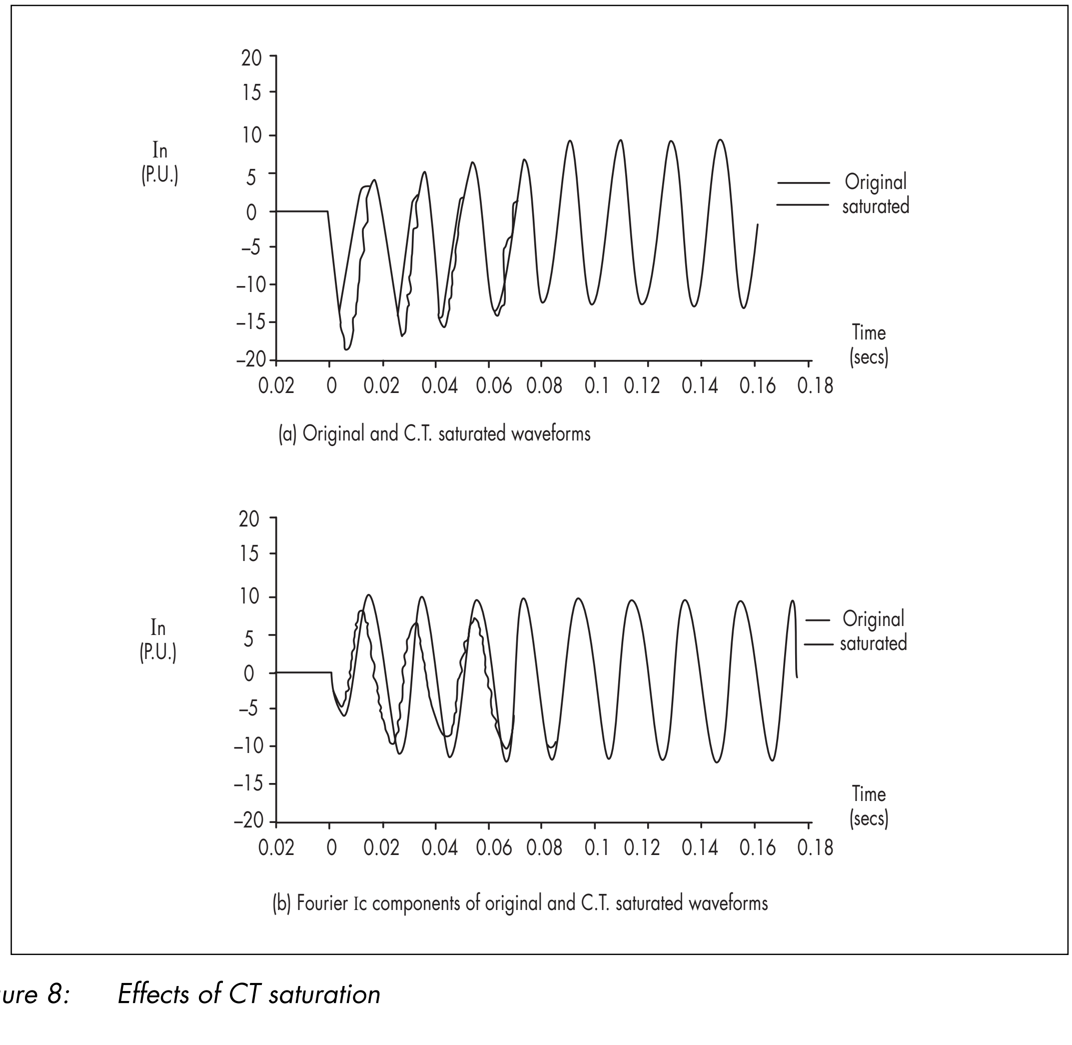


Figure 8: Effects of CT saturation

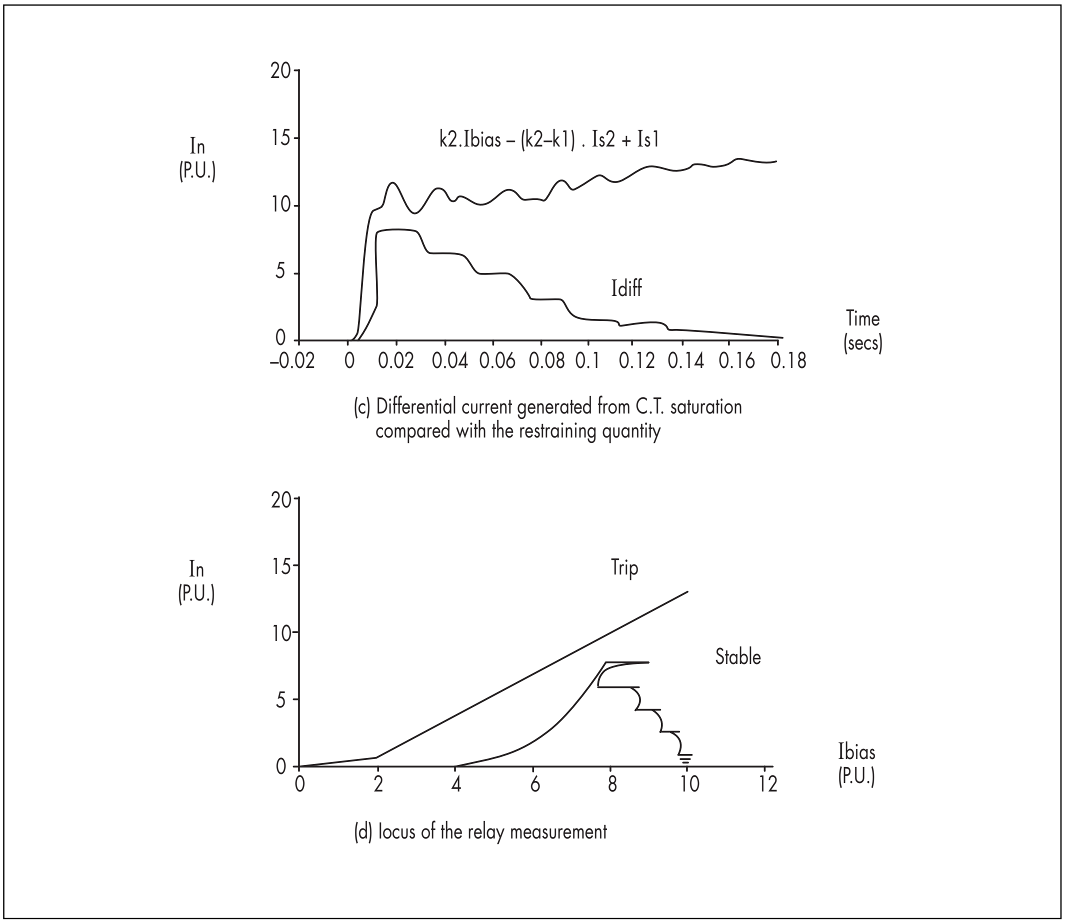


Figure 8: Effects of CT saturation (continued)

CT saturation is related to the fault level, the system X/R ratio, and lead burden. For general applications, we recommend (See Section 1.7) to fix three of the settings to:

I_{S2} = 2.0 pu

k_1 = 30% (or twice the CT mismatch if the mismatch is larger than 15%)

k_2 = 100%

Class X BS3938 CTs are required. With the above settings, the CT is required to meet the following specification:

$$V_k \geq 85In(R_{CT} + 2R_L) \qquad \text{——(20)}$$

where: V_k – Required CT kneepoint voltage

In – Rated CT secondary current

R_{CT} – CT secondary winding resistance

R_L – Resistance of one lead from CT to relay

A smaller CT can also be used if the maximum value of [through fault current. system X/R] is below 120In, ie.

if max $[I_F.(X/R)] < 120In$ for external faults

then $V_k \geq 75In(R_{CT} + 2R_L)$ ——(21)

In cases where the CT installed meet the following specification:

$$V_k \geq 180In(R_{CT} + 2R_L) \qquad \text{—(22)}$$

then the relay may be made more sensitive by setting k_2 to 100% instead of 150%

2.7 Differential protection intertrip

When the relay reaches a trip decision, it sends out a differential intertrip command to the remote ends. This is done by flagging the corresponding command bits in the out-going data messages. This built-in feature ensures all ends operate within a short time whenever one end reaches a trip decision. This is useful for marginal fault conditions close to the relay characteristic during which there may be a long delay between relay operations at three line ends or that the second and third relays may not operate at all if the fault current is single end fed from the operated end. Under normal fault conditions, each end should have reached trip decision independently before the differential protection intertrip command arrives. Consequently the feature normally has no effect to the operating time of the relays. It however slows down the time of the relay as the relay can only reset after the differential intertrip command in the received data message has reset.

The intertrip command is validated by checking the consistency of the command bits in two successive messages. The delay time for the acceptance of the differential intertrip command at the remote end after a local trip decision can be estimated as follows:

Differential intertrip delay time =

Delay time in sending out the message (0 – 2 samples)

+ Time to send out the whole message (2.7ms)
+ Channel propagation delay time (?)
+ Extra time to validate intertrip command bits (2 samples)
+ Software processing time (1 sample max)

Ignoring the channel propagation delay time, the typical delay time of the intertrip function is (4 samples + 2.7ms), ie. 12.7ms (50Hz) or 11ms (60Hz).

2.8 Operating time

The operating time of the LFCB relay may be estimated as follows:

Typical operating time =

Time between fault inception and data sampling at remote ends (0 – 1 sample)

+ delay time between data sampling at remote ends and sending out data message (0 – 2 samples)
+ time to send the data message (2.7ms for 21 bytes at 64kbits/s)
+ channel propagation delay time
+ processing time required for time alignment and differential protection (1 sample max)
+ time for the fault to be detected (2 – 8 samples)
+ extra time required to reach trip decision (2 samples)
+ pick-up time of trip output relays (2ms)

Note that the sum of the first 5 times represents the time taken from fault inception to the detection of the fault based on the vector information contained in the data

message. For a severe fault, it will only take 2 or 3 data samples after the fault inception for a significant magnitude of differential current to be measured. If we take this to be half a cycle, ie. 4 samples, then the typical operating time of the relay, not including the channel propagation delay time, will be (8.5 samples + 4.7ms). This gives 26ms for 50Hz operation or 22ms for 60Hz operation.
The operating time can vary by $\pm 1^1/_2$ samples, ie. about ±4ms for 50Hz operation and ±3ms for 60Hz operation.

Figure 9 shows the measured operating time of the LFCB relay.

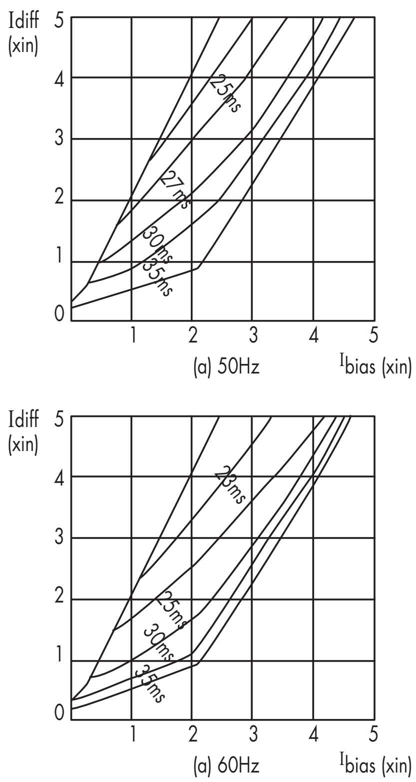


Figure 9: Measured operating time of the relay

2.9 Reset time

The differential protection reset time of the LFCB relay can be estimated as follows:

Differential protection reset time =

Time between fault clearance and data sampling at remote ends (0 – 1 sample)

+ delay time between data sampling at remote ends and sending out data message (0 –2 samples)
+ time to send the data message (2.7ms for 21 bytes at 64kbits/s)
+ channel propagation delay time
+ processing time required for time alignment and differential protection (1 sample max)
+ time to detect the fault has been cleared (2 – 8 samples)
+ time delay to send out the first data message with the differential intertrip command reset (0 – 2 samples)

+ time to send the data message (2.7ms for 21 bytes at 64kbits/s)
+ channel propagation delay time
+ processing time required by remote relays to process differential intertrip command (1 sample max)
+ time to validate the removal of differential intertrip command (2 samples)
+ drop off time of trip output relay (8ms)

Ignoring the channel propagation delay time, the maximum relay reset time would be (17 samples + 13ms), ie. 55ms for 50Hz systems or 48ms for 60Hz systems.

2.10 Accuracy

There are several sources of error which affect the accuracy of the relay under reference conditions:

1) The relay CT and analogue low pass filter has an accuracy of ±2%.
2) The analogue-digital converter has an internal voltage reference which has an accuracy of ±1%.
3) The analogue to digital conversion gives a quantizing error of $\pm^1/_2$ LSB.
4) The Fourier filtering process gives a numerical error of ±1 LSB.
5) Time delay for the HDLC controller to accept the first byte of data and send it out as a serial bit stream (0 – 125µs).
6) Time delay for a PCM multiplexer to assemble the first data byte from the bit stream (0 – 125µs).
7) Time latency for the relay to detect the received message and then register its arrival time (0 – 200µs).
8) Numerical error of the time alignment process (±1 LSB).
9) Accuracy of the magnitude calculation algorithm (–0.5%, +0.25%).
10) Numerical error for calculating the percentage bias and for comparing the differential and bias currents (±2 LSB).

We can divide these error sources into 3 groups. The first group, errors (1), (2) and (9), is related with the input circuitry and the magnitude calculation technique used. It can cause a maximum error of ±3.5% to the measured signal magnitudes.

The second group, errors (3), (4), (8) and (10), is related with quantizing error and numerical errors. They are therefore independent of the input signal magnitude. To reduce numerical errors, the analogue-digital data are multiplied by two to increase the data resolution to 13 bits before proceeding to the Fourier filter and subsequent processes. This means 1 pu current is represented as 136 LSB internally and the quantizing error becomes ±1 LSB. The maximum error caused would be +4 LSB or 0.03 pu current. The error is therefore not significant unless the input signals are very small.

The third group, ie. errors (5), (6), (7), is related with communication and the accuracy's in measuring the channel propagation delay time and in registering the message arrival time. They represent the incurred error in estimating the sampling time of data received from the remote end.

The total time uncertainty (0 – 450µs) can cause up to 8° or 10° phase error in time alignment in 50Hz and 60Hz applications respectively.

Since bias currents are calculated from the magnitudes of phase currents which are derived directly from the local and received current vectors, the above time alignment phase error has no effect on the bias current measurement. The differential currents however are derived from the time aligned vectors and the phase errors can theoretically produce an error component of up to 14% (50Hz) or 17% (60Hz) of the magnitude of the received phase current vector.

Since the relay has a percentage biased characteristic, the measurement error imposes no problem under normal loading or external fault conditions. As shown in Figure 10, the error component is in near quadrature with the received phase current vector. Differential current measured under internal fault conditions is, on the other hand, generally in phase with the phase current. As a result, the inaccuracy caused by the phase error is reduced.

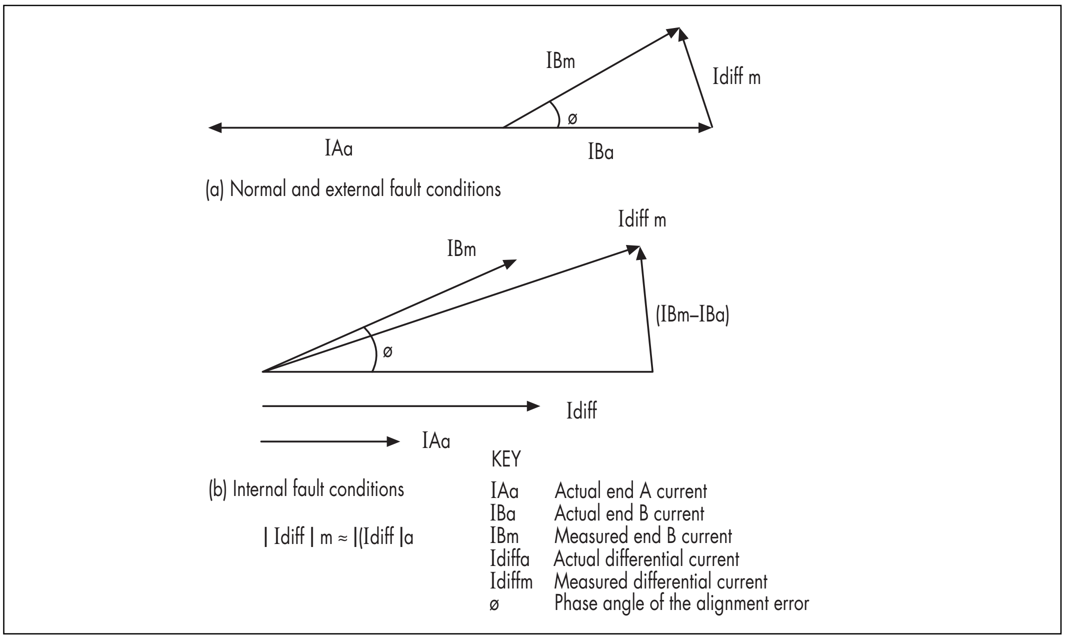


Figure 10: Effects of time error

Errors (3) – (10) are of random nature. They may help or counteract each others. As the relay makes the trip decision based on 4 consecutive data samples, the effect of these random errors is greatly reduced.

The overall accuracy of the LFCB relay is measured to be better than ±10% under reference conditions.

2.11 Returning ratio

The returning ratio is defined as the differential current value at which the relay just returns to a reset condition divided by the differential current value at which the relay just operates.

The threshold of operation of the LFCB relay occurs when the differential current and the bias current are along the percentage bias characteristic shown in Figure 4. For faults on the boundary of operation, noise in the input signal or random errors can cause the relay to operate intermittently. A hysteresis feature is incorporated in the relay to overcome this hunting effect. It reduces the bias quantity of the faulty phase by 25% once a trip decision is made, thereby extending the relay operating limits.

The returning ratio of the LFCB relay is therefore 75%.

Section 3. ADDITIONAL FUNCTIONS

In addition to current differential protection, the LFCB relay provides a number of additional functions which are unmatched by conventional analogue relays. These include self monitoring, test facilities, event recording, fault recording, current magnitude measurements, communication error statistics, channel propagation delay time measurement, intertrip, permissive intertrip, and remote access via an RS232 serial link.

3.1 Self-monitoring

The LFCB relay includes a number of self-monitoring features designed to guard against hardware or otherwise fatal errors from causing maloperation of the relay. The self monitoring software locks out the relay and reports the error when a fatal error is detected. The watchdog timer and self-monitoring software also detect temporary non-fatal errors and recover the relay operation by resetting the system.

Power-on diagnostic tests are carried out automatically by the relay when it is first switched on. Firstly there are system checks on the main relay components, ie. watchdog timer, microprocessor, interrupt controller, DMA controller and timers. Configuration checks are then carried out on memory components to ensure the correct type of memory is present and properly located. Random access memory (RAM) is then checked by read/write tests to each location. Erasable programmable read only memory (EPROM) is checked by check sum tests.

In addition to the power-on diagnostic tests, there is a number of system checks which monitor the operation of the relay on a continuous basis. These include RAM read/write tests, EPROM and EPROM (electrical erasable programmable read only memory) check sum tests, and tests which monitor the operation of the communication module.

Once an error has been detected, a message containing an error code is reported on the front panel LCD. The 'Relay Inoperative Alarm' output contact also closes to indicate the failure. The system must then either lock out or attempt a recovery depending on the type of error. In either case the self-monitoring software forces a system reset via the watchdog circuitry so that the system can be brought back to a defined starting state.

Please read Chapter 9 for details of the error codes for the various causes of failure and actions to be taken when failure occurs.

3.2 Test facilities

Test facilities are provided to enable the features of the relay to be thoroughly tested during commissioning, routine maintenance and fault finding operations. One test facility provided is the 25-way 'parallel' socket at the front panel which doubles as a parallel printer port and a test socket. The internal voltage rails of the relay are brought out to the test socket. Under normal conditions, ie. when the port is not used as a printer port, the states of the trip and block auto-reclose outputs of the relay are repeated on the output lines of the test socket. These allow checks to be made while the relay is on the relay panel and the line is energised. All these outputs are short circuit protected.

The test socket also has eight TTL inputs. Seven of these input lines are connected in parallel with the seven keys at the front panel. This can be used to emulate keystrokes at the front panel. This permits the use of a programmable secondary injection test set to issue operator commands for data dumps or setting changes in

an interactive manner. Most commissioning, routine testing and fault finding operations can then be performed automatically to save line outage time.
Please see Table 8 of Chapter 4 for detailed pin connections of the test socket

In addition to the test port, a number of manually operated test facilities are provided through the front panel operator interface.

A measurement function is provided (see Section 3.3) which can be called to display the phase currents and sequence component currents on the LCD This can be used as a check for the analogue input hardware and software and also CT polarity and connections.

Test options are provided to display the on/off states of the opto-isolated status inputs and to perform lamp tests on the four front panel indicating LED.

Further test options enable relay outputs to be tested by forcing the relevant output contacts and the test socket terminals to the active state. They can be used to check the proper functioning of the relay output modules. A trip test of the circuit breaker or test of the alarm circuits can be performed conveniently by this method.
A security interlock is built in for these relay output tests. They are performed only if the relay is out of service, ie. the 'Inhibit Trip/Alarm outputs' opto-input is energised.

Please see Chapter 7 for details of the measurement and test option functions.

3.3 Current magnitude measurements

The relay measures the rms magnitudes of the local line current, remote line current, differential current and bias current of the different phases. The local positive, negative and zero phase sequence currents are also measured. Upon request, these values can be displayed on the front panel LCD one at a time.

The function can be used as a confidence test for the analogue input module during commissioning, routine maintenance testing and fault finding. The sequence current measurement is particularly useful for checking CT polarity and connections.

3.4 Event recording

The ten most recent alarms/events are stored by the relay. The records are stored in non-volatile EPROM memory and are preserved even in case of a power loss.

Each event record gives the cause of the event and is stamped with the time and date of its occurrence. Events which occur under the 'Relay Out Of Service' condition, ie. when the 'Inhibit Trip/Alarm Outputs' input is energised, are tagged differently for easy identification.

Please see Chapter 7 for more details of the function.

3.5 Fault recording

The relay stores the three most recent fault records in non-volatile EPROM memory. Each fault record contains information of the fault type and the magnitudes of the local current, remote current, differential current and bias current of all three phases. Each record is stamped with the time and date of the operation of the relay. Faults recorded under the 'Relay Out of Service' condition are tagged differently to distinguish them from those of normal operations.

Please see Chapter 7 for more details of the fault recording function.

3.6 Communication error statistics

The relay performs rigorous tests to check the integrity of received data messages. An error statistics record is continuously updated which contains the number of valid and corrupted messages received by the two channels. The bit error rate of the communication channels can be calculated based on these statistical data. Please see Section 4.4 for more explanation.

The statistics record is kept in volatile memory and is lost if the power supply to the relay is switched off or fails.

Please see Chapter 7 for details of reading and clearing the communication error record.

3.7 Propagation delay time measurement

The relay measures the propagation delay times of the two communication channels as part of the protection process. The measured delay times can be displayed on the front panel LCD. The propagation delay time tp given in equation (5) of Section 2.4 represents the total elapsed time from sending out the first bit of a data message from one end to the arrival of the last bit of the message at the other end. The measured time tp therefore is the sum of the communication channel propagation delay time and the time taken for a whole message to be sent out by the relay, ie.

$$tp = tcp + tmsge \qquad \text{——(23)}$$

where tp – Measured propagation delay time.

tcp – Channel propagation delay time.

tmsge – Time to send out a 21bytes message.

For 64 kbits/s operation, it takes 2.7ms to send out the 21bytes message

($21 \times 8\text{bits} \div 64000 = 2.7\text{ms}$). As the LFCB relay can be used for different data rates, a different tmsge value needs to be subtracted from tp to find the actual channel propagation delay time. If this is to be done by the relay, then an extra parameter setting is required to inform the relay about the operating data rate. To keep it simple, the relay only displays the total propagation delay time tp. A user interested in the actual channel propagation delay time can still deduce it following the above equations.

3.8 Print facility

Information stored in the relay can be printed out via the parallel port or the serial port at the front panel by issuing a ‘Print’ command (See Chapter 7 for operating details and Chapter 4 for the pin-outs of the parallel and serial ports). Each print-out is stamped with the relay user identifier which is user-programmable, and the time and date when the print-out is made.

3.9 Calendar clock

The relay runs a calendar clock in software. The calendar clock provides the time and date for event recording, fault recording and other functions. The clock has no battery back-up and so must be set every time after the power is switched on.

When powered on, the relay defaults the date and time to 1 January 1980 00:00:00 and displays a ‘date and time not set’ message on the LCD. The message is removed once the calendar clock is set.

The time base of the clock is derived from an internal free running crystal oscillator. The clock may slip after a long period of operation. An opto-isolated input is provided in the relay for a time sync signal to be injected to the relay to synchronise the clock at regular intervals. Please see Chapter 7 for details of reading and setting the calendar clock, and how to set the time sync intervals.

3.10 Intertrip

The 'Intertrip' facility is better viewed as an auxiliary signalling channel provided by the LFCB relay. An opto-input is allocated for this facility. When the 'Initiate Intertrip' input is activated, the relay flags a corresponding status bit in its transmit messages. No trip output or indication is given by the relay as they are more suitably provided by the equipment activating the intertrip. The flagged 'Intertrip' bit in the messages commands the remote relays to activate their 'intertrip' output contacts. In contrast to the permissive intertrip (see Section 3.11), no interlock is imposed and separate output contacts are provided (85–1 to 85–4). The facility may therefore be assigned by the user for any trip or signalling purposes such as direct transfer trip, or to block auto-reclose. Figure 11 shows the logic diagram of the 'Intertrip' facility.

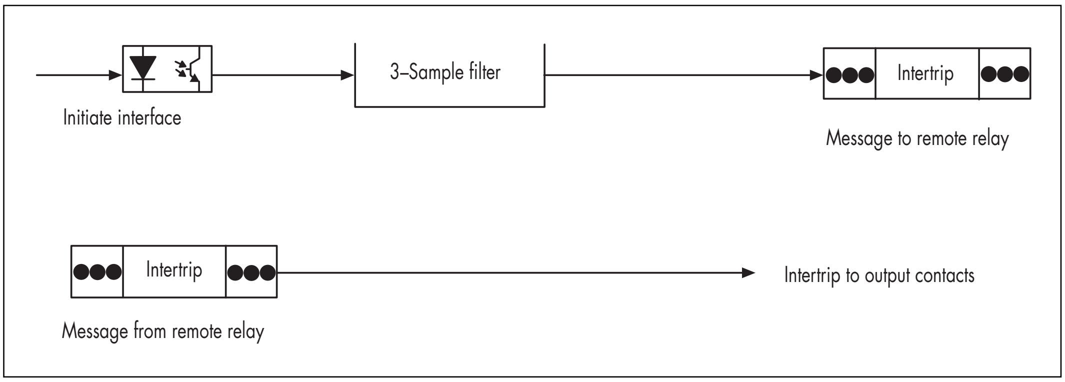


Figure 11: LFCB 102 intertrip logic

The opto-input has a 3-sample software filter for pick-up and 1 sample for drop-off.

The intertrip status bit is validated by double checking two consecutive communication messages. The operating time of the intertrip function can be estimated as follows:

The Intertrip operating time =

Delay time in sampling the 'Initiate Intertrip' opto input (0 – 1 sample)

+ Software filter delay time (3 samples)
+ Delay time in sending out the message (0 – 2 samples)
+ Time to send out the whole message (2.7ms)
+ Channel propagation delay time (?)
+ Extra time to confirm intertrip status bit (2 samples)
+ Software processing time and delay time for transferring command to main processor (1 – 2 samples)
+ Intertrip output relay pick up time (2ms)

Ignoring the channel propagation delay time, the typical operating time of the intertrip function is then (8 samples + 4.7ms), ie. 25ms (50Hz) or 21ms (60Hz).

The intertrip reset time is 2 samples faster than its operating time because the software filter delay time is only 1 sample. The typical reset time is therefore 20ms (50Hz) or 17ms (60Hz).

Since the intertrip contacts may be used for direct tripping, the intertrip output stays closed for 60ms minimum from the time the intertrip command is accepted. As a result, the intertrip facility is not suitable for fast ON/OFF signalling applications.

3.11 Permissive intertrip

The 'Permissive Intertrip' is a facility provided to intertrip circuit breakers at the remote ends. The 'Initiate Permissive Intertrip' input may for example be connected to an output contact of a busbar relay to intertrip remote breakers upon a busbar fault. When the 'Initiate Permissive Intertrip' input is activated, the relay flags a corresponding status bit in the communication message. No local trip output or indication is given as they are more suitably provided by the equipment activating the permissive intertrip. On detection of the flagged permissive intertrip status bit in its received message, the remote LFCB 102 relay check if the current flowing into the initiating end exceeds the current threshold setting I_{S1} and if so the relay trips after the PIT time setting is exceeded. This allows time for the fault to be cleared by circuit breakers at the initiating end.

The scheme is therefore very similar to a conventional interlocked overcurrent one except the overcurrent check is now done at the remote ends and no additional overcurrent relay is needed. The permissive intertrip shares the same trip output contacts with the current differential protection function and all three phases are tripped.

Figure 12 shows the logic diagram for the 'Permissive Intertrip' facility.

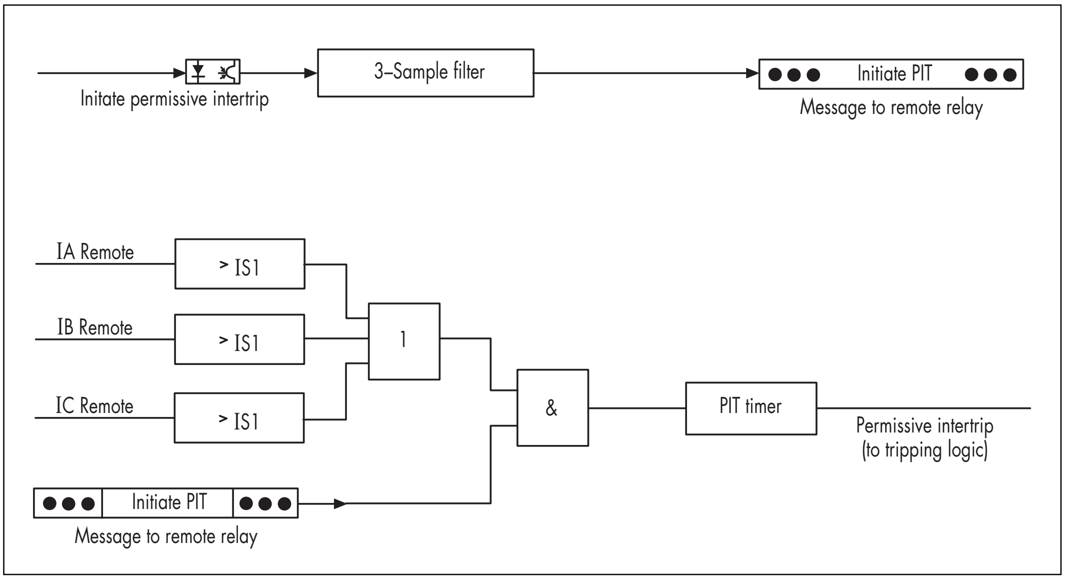


Figure 12: LFBC permissive intertrip logic

Similar to the 'Intertrip' facility, the 'Initiate Permissive Intertrip' opto-input also has a 3-sample software filter and the permissive intertrip status bit in the message is validated by double checking two consecutive messages. The typical delay time from initiating the opto-input to start timing the interlocked overcurrent is 25ms (50Hz) or 21ms (60Hz). Please see Chapter 7 for details of setting the permissive intertrip delay time.

The relay provides two output contacts for blocking auto-reclose on permissive intertrip. Please see Section 6.5 for details.

3.12 Remote access via an RS232 serial link

The LFCB relay has an RS232 serial port. Two 25-way D-type connectors are provided for the serial port, one on the front panel and the other at the back of the relay. The serial port is normally connected to the front panel connector and can be used to drive a serial printer. The relay glass cover needs to be removed to gain access to the front panel serial port.

For permanent connection to a peripheral equipment or a modem, the position of a jumper on the microcomputer module (see Chapter 4 for details) can be changed to divert the serial port to the connector at the back. A 'Remote Access' facility is provided which allows an operator to communicate with the relay using a visual display unit (VDU) or a personal computer. The facility emulates the front panel keypad and LCD and so allows access to the command menu. This means the user may interrogate the relay remotely for information and to change the settings.

Please see Chapter 4 for pin connections of the front and rear serial interface connectors and Chapter 7 for details of the remote access facility.

The RS232 serial port is not electrically isolated. For permanent connections, external transient suppressers or isolation barriers should be used. An RS232/fibre optic modem is ideal for this purpose.

Section 4. UNIQUE ADDRESSING FACILITY

A new feature is introduced into both LFCB 102 and LFCB 103 relays which allows the user to select an individual address for a relay. The relay will only accept a message if it carries the assigned address. This feature is used to prevent the relay from mal-operation due to in advertent loop-back and cross-connection of the communication channels. This is especially important when a communication system with multiplexers is used.

A new setting called RELAY ADDRESS is used for this purpose. Six groups of addresses are available, each group is to be used for a complete relay system. The user will need to assign an individual address from the same address group to each relay within a relay system. After the address has been assigned, the relay will only accept messages which carry its own address. It will also work out the address of its companion relays using its internal look-up table, and will send messages carrying their individual addresses, to the remote relays.

After the individual relay address has been set, the loop back test cannot be performed because the relay cannot accept its own message. A test option called LOOP BACK TEST ADDRESS is therefore available which allows a loop back test address to be selected. The relay will automatically revert back to its original address as soon as the loop back test address is de-selected.

4.1 Relay address

The RELAY ADDRESS setting is in the COMMUNICATIONS group of the operator interface menu. There are altogether six groups of addresses. Each group is applied to a set of relays which forms a protection system. Within a group, there are two addresses for LFCB 102 relays and three addresses for LFCB 103 relays. In addition to the six groups of addresses, there is also a universal address, represented as 0-0, which allows the new relay to be compatible with old relay versions. All the address patterns are carefully chosen so as to provide optimum noise immunity against bit corruption. There is no preference as to which address group is better than the other.

Addresses for LFCB 102 and LFCB 103 and the universal address are detailed separately in the following subsections.

4.1.1 LFBC102 Relays

The range of relay addresses available for LFCB 102 are as follows:

	Relay A	Relay B
Universal Addresses	0-0	0-0
Address Group 1	1-A	1-B
Address Group 2	2-A	2-B
Address Group 3	3-A	3-B
Address Group 4	4-A	4-B
Address Group 5	5-A	5-B
Address Group 6	6-A	6-B

For two relays to communicate with one another, their addresses have to be in the same address group. One relay should be assigned with address A and the other with address B. For example, if the group 1 address is used, the one relay should be given the address 1-A, and the other relay should be given the address 1-B. The relay with address 1-A will only accept messages with the 1-A address and will send out messages carrying address 1-B The relay assigned with address 1-B will only acccept messages with address 1-B and will send out messages carrying address 1-A.

4.1.2 LFCB 103 Relays

	Relay A	Relay B	Relay C
Universal Addresses	0-0	0-0	0-0
Address Group 1	1-A	1-B	1-C
Address Group 2	2-A	2-B	2-C
Address Group 3	3-A	3-B	3-C
Address Group 4	4-A	4-B	4-C
Address Group 5	5-A	5-B	5-C
Address Group 6	6-A	6-B	6-C

For three relays to work together as a protection system, their addresses must be in the same group and they should be assigned separately with addresses A, B and C.

They should also have a fixed connection configuration, as shown in Figure13a, in which channel 1 of one relay is connected to channel 2 of another relay.

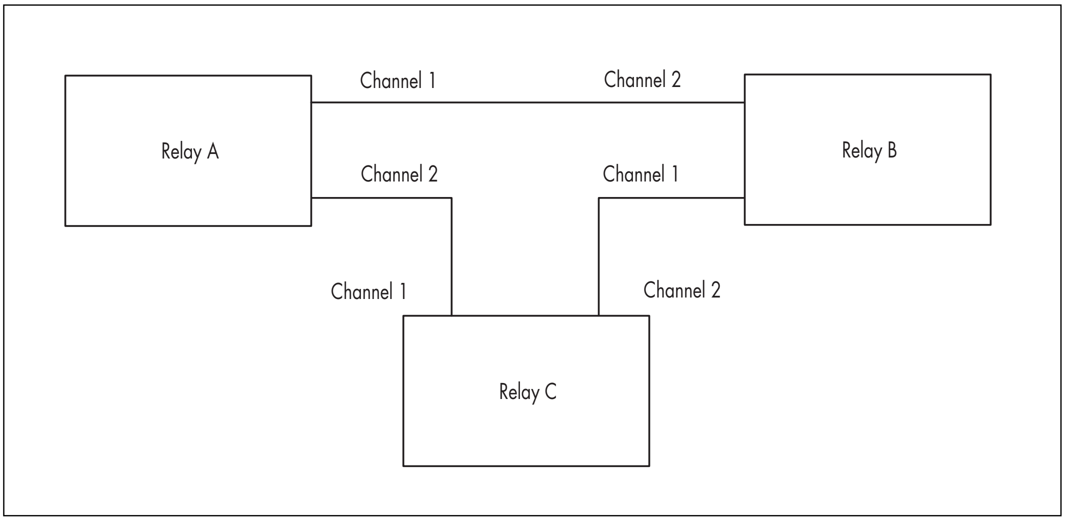


Figure 13a: LFCB 103 connection configuration

For example, if the group 1 address is used, addresses 1-A, 1-B and 1-C should be assigned to relays A, B and C respectively. Relay A will only accept messages with address 1-A and will send messages carrying addresses 1-B and 1-C to channel 1 and channel 2 respectively. Relay B will only accept messages with address 1-B and will send messages carrying addresses 1-C and 1-A to channel 1 and to channel 2 respectively. Similarly relay C will only accept messages with address 1-C and will send messages carrying addresses 1-A and 1-B to channel 1 and to channel 2 respectively.

Therefore, in order for the system to work, channel 1 of one relay must be connected to channel 2 of another relay.

If the user wants to use two LFCB 103 relays to protect a two terminal line, the relays will have to be reconfigured into two terminal operation. In this case they need to reconfigure one relay as L-R1 (local and remote 1) and the other relay as L-R2 (local and remote 2), so as to conform to the connection rule of channel 1 and channel 2. Within the same address group, there are three address combinations which the user can use. The addresses which he can assign to the relays configured as L-R1 and L-R2 can either be A and B, B and C or C and A respectively.

4.1.3 Universal address

Address 0-0 is the universal address which is available to both LFCB 102 and LFCB 103 relays. When address 0-0 is selected, the relay will accept messages with 0-0 and will also send out messages with address 0-0 to the remote relay. The universal address is used in previous relay versions which have no individual address select feature. This address is included in the settings so as to make the new relays compatible with the old relays.

Note that if address 0-0 is selected, the communication channel can be looped back without the message being rejected, therefore the security provided by the address select feature is lost.

Note also that 0-0 is the factory setting for the relay address.

4.2 Loop back test address

After the individual address has been set, the loop back test cannot be performed because the relay will not be able to accept its own message. An option is therefore required whereby a loop back test address can be selected before the loop back test is performed.

Under the CONTROL group of the operator interface menu and within the TEST OPTION function, a new option called LOOP BACK TEST ADDRESS is available which allows the user to set the loop back test address to be either ON or OFF. The procedure for setting this address is the same as the normal procedure for changing relay settings.

When the loop back test address is set to be ON, the green healthy LED will flash, indicating that the relay is now in the loop back test mode, and the user can now perform the loop back test. If there is no alarm condition, a warning message LOOP BACK TEST ADDRESS ON will also be displayed in the default level of the operator interface menu, overriding the message CURRENT DIFFERENTIAL.
All these indications are to remind the user that after he has finished the loop back test, he should set the loop back test address to OFF.

When the loop back test address is selected, the relay will send out messages to remote relays carrying the universal address and it will only accept messages with the universal address. The user can then loop back the communication channels and do the loop back test. While the relay is in this mode, the user is blocked from selecting a new relay address. If they attempt to go into the RELAY ADDRESS function of the menu and select a new setting, the message TEST ADDRESS MUST BE OFF will be displayed.

4.3 Operator interface

4.3.1 Relay address

The relay address setting is under the COMMUNICATIONS group of the operator interface menu, as shown in Figure 13b. The procedure for changing the relay address setting is the same as the normal procedure for changing relay settings. Note that if the relay is in the loop back test mode, the relay address setting cannot be changed.

The relay address setting can be examined with the front glass cover on by using the ACCEPT/READ key. This setting will also be printed out together with the other settings when the print settings function is executed.

COMMUNICATIONS ?? ??
– ERROR
– STATISTICS
– PROPAGATION DELAY TIME
– ALARM TIME
– RELAY ADDRESS – RELAY ADDRESS +[
0-0

?? check for setting changes when leaving the group

?? +[indicates this may be changed

Figure 13b: Position of the relay address setting within the menu

4.3.2 Loop back test address

The loop back test address is under the CONTROL group of the operator interface menu and is within the TEST OPTION function, as shown in Figure 13c.
The procedure for setting or resetting the loop back test address is the same as the procedure for changing other relay settings.

CONTROL ⁇
- CLEAR RECORDS
- SERIAL PORT DATA
- CLOCK SYNC DATA
- REMOTE PORT ACCESS
- SCHEME LOGIC
- TEST OPTION
  - OPTO INPUT STATE
  - PRESS –> FOR TEST LAMP
  - CONTACT TEST
  - LOOP BACK TEST ADDRESS OFF…+[…..

⁇ check for setting change when leaving the group

⁇ +[indicates this may be changed

Figure 13c: Position of the loop-back test address option within the menu

4.3.3 Actual address used

The address shown on the operator interface display is not the actual address used by the relay. The display serves to give easy identification and grouping to the range of addresses available. The actual 8-bit address pattern is shown in Table 1.

	Relay A	Relay B	Relay C
Universal Address	10000001 (81)	10000001 (81)	10000001 (81)
Address Group 1	10100101 (51)	10010011 (93)	10001000 (88)
Address Group 2	10010000 (90)	10001101 (8D)	10100011 A3)
Address Group 3	10001011 (8B)	10100000 (A0)	10010101 (95)
Address Group 4	00100001 (21)	1101000 (D1)	10000010 (82)
Address Group 5	11001001 (C1)	10000111 (87)	00010001 (11)
Address Group 6	10000100 (84)	00001001 (09)	11100001 (E1)

(note: numbers in brackets are hexadecimal numbers)

Table 1 Actual relay address 8-bit patterns

The universal address ‘81’ was used for previous relay versions without the individual address select feature. The pattern ‘81’ (10000001) was choosen so that all 8 bits of the HDLC flag byte ‘7F’ (01111110) will have to be corrupted before it can be interpreted as a correct message address, ‘81’ therefore has an 8-bit immunity against address corruption when compared to the HDLC flag.

All new addresses have a 6-bit immunity against address corruption when compared to the HDLC flag. All of them also have a 4-bit immunity against address corruption when the channel is accidentally looped back. This means under loop-back conditions, 4 address bits have to be corrupted before the relay can wrongly accept its own message. There is either a 4-bit or 2-bit immunity against address corruption under cross-connect situations.

Section 5. COMMUNICATION

The LFCB relay is specially designed for working with digital communication systems. To ensure compatibility with a wide range of communication equipment and media, the relay is designed to work within the signalling bandwidth of a standard CCITT PCM channel, ie. 64kbits/s. It can also operate at 56kbits/s for some North American PCM systems.

5.1 Data rate

The relay measures the local three phase currents at a constant sampling rate. The measured current values (in vector form) together with other timing and status information are sent as messages to the remote end. A message is sent every 2 samples. Each data message is 21bytes long.

A minimum gap equivalent to 4 bytes is required between messages. This gives allowance for automatic zero bit insertion (see Section 4.2 for explanation) and for the communication processor to process the received message and to prepare for new messages. The minimum data rate required on the communication channel is therefore to send 25 bytes within the available time of two data sampling periods.

Table 2 gives the number of bytes which can be sent through at different communication data rates and data sampling rates for 50Hz and 60Hz systems. Although it is possible to operate the 50Hz relay at the faster 12s/c sampling rate, it is not suitable for 60Hz systems with 56 or 64kbits/s channels. The sampling rate of the LFCB 102 relay is therefore chosen to be 8s/c. As shown in Table 2, the relay can operate faster if a higher speed communication channel is used.

Data rate (kbits/s)	Sampling rate (s/c)	Allowed message length (bytes)		Estimated operating time (ms)	
		50Hz	60Hz	50Hz	60Hz
58	8	35	29	26	22
64	8	40	33	26	22
200	8	125	104	24	21
500	8	312	206	24	20
56	12	23	19	–	–
64	12	26	22	22	–
200	12	83	69	20	17
500	12	208	173	20	17

Table 2: Relationship between communication data rate, sampling rate and relay operating time

5.2 The high-level data link control (HDLC) protocol

HDLC is a protocol for managing the flow of information on a data communication link. It can be thought of as an envelope in which information is transferred from one location to another on a data communication link. The protocol is widely used and support integrated circuit chips such as LSI protocol controllers are readily available. The LFCB relay adopts the HDLC protocol for its data messages.

The basic unit of information on an HDLC link is that of a frame. The frame format is shown in Figure 14. Each frame comprises five fields: flag, address, control, information, and frame check sequence. The flag fields (F) form the boundary of the frame and all other fields are positionally related to one of the two flags.
A frame starts with an opening flag and ends with an end flag. Flags are used for frame synchronisation. They also serve as time-fill characters between frames.
The opening flag serves as a reference point for the address (A) and control (C) fields. The frame check sequence (fcs) is referenced from the closing flag. All flags have the binary configuration 01111110.

Opening Flag	Address Field (A)	Control Field (C)	Information Field (1)	Frame Check Sequence (FCS)	Closing Flag
01111110	8 or more bits	8 or 16 bits	Any length 0 – N bits	16 bits	01111110

Figure 14 HDLC Frame Format

HDLC is a bit-oriented protocol, ie. the receiver must be able to recognise a flag at any time. The fact that the flag has a unique binary pattern would seem to limit the contents of a frame since the same pattern might inadvertently occur within the frame. This would cause the receiver to think the closing flag was received, invalidating the frame. HDLC handles this situation through a technique called 'zero bit insertion'. This technique specifies that within a frame a binary 0 be inserted by the transmitter after any succession of five continuous binary 1's.
Thus no pattern of 01111110 is ever transmitted by chance. On the receiving end, after the opening flag is detected, the receiver removes any 0 after 5 consecutive 1's. This means the frame transmitted can theoretically be up to 20% longer than the original one.

The address field is used to specify the destination of a frame on a multi-point data communication network. The control field embodies the link-level control of HDLC. However, the LFCB relay only works on point to point links and there is no message acknowledgement nor re-transmission. The address and control fields are not needed and their allocated space can be used for ordinary data instead. However, for security reasons a fixed address of 10000001 is used and a message will only be recognised if the address is correct. This prevents any bit corruption between frames being wrongly interpreted as a message. The information field is not interpreted by the HDLC device. Current vectors and the bulk of timing and status data are carried in this field in the LFCB relay message.

The frame check sequence field is the 16 bits immediately preceding the closing flag. This 16-bit field is used for error detection through a cyclic redundancy check word (crc). The 16-bit transmitted CRC is the complement of the remainder obtained when the A, C, I fields are 'divided' by a generating polynomial.
The receiver accumulates the A, C, and I fields and also the FCS field into its internal crc register.

At the closing flag, this register contains one particular number for an error-free reception. If this number is not obtained, the frame is received in error and should be discarded.

The closing flag terminates the frame. When the closing flag is received, the receiver knows that the preceding 16 bits constitute the FCS and that any bits between the control field and the FCS field constitute the information field.

5.3 Security checks on data messages

Correct operation of a current differential relay system relies heavily upon an error-free transmission of signals or data across its communication link. Failing this, the relay must be able to detect the errors and prevent them from causing maloperation.

To achieve this latter aim, the LFCB relay incorporates several levels of security checks on incoming messages to ensure their integrity before they are accepted for protection uses.

A message is rejected if it fails any of the following tests:

1) The address byte is not correct.

2) The cyclic redundancy check performed by the HDLC protocol controller can detect all single-bit errors and a high proportion of multiple-bit errors.

3) On passing the CRC check, the length of the received message is checked against the expected message length. Most multiple-bit error messages managing to pass through the CRC check will be blocked by this test. The test also prevents a transmit under-run message, which contains correct CRC check word, from being accepted.

4) The returned time tag in the message is checked against the last received time tag. The message is rejected if the two time tags are not in sequence. The new time tag is kept for checking the next message.

5) The new message is discarded if the communication processor is still working on the previous message. Under normal conditions, the communication processor will have finished processing the previous message before a new one arrives.

6) A 3-bit pattern contained in the message is checked against the time tag. This 3-bit pattern is used as the differential intertrip flag. Under non-tripping conditions, the pattern should be complementary to the last 3 bits of the message time tag.

7) The measured propagation delay time is checked against the last measured delay time. The message is discarded if the difference exceeds the delay time tolerance setting. The new propagation delay time however is kept for checking the next message. A genuine change in propagation delay time caused by a change-over of communication links will therefore block the relay operation by one to two messages.

All status and command information is double checked, ie. it is accepted only after it remains the same over two consecutive messages. Current vector data are effectively double checked as it takes 4 consecutive samples (ie. two messages) to reach a trip decision.

Figure 15 shows the flow chart of the message checking procedure.

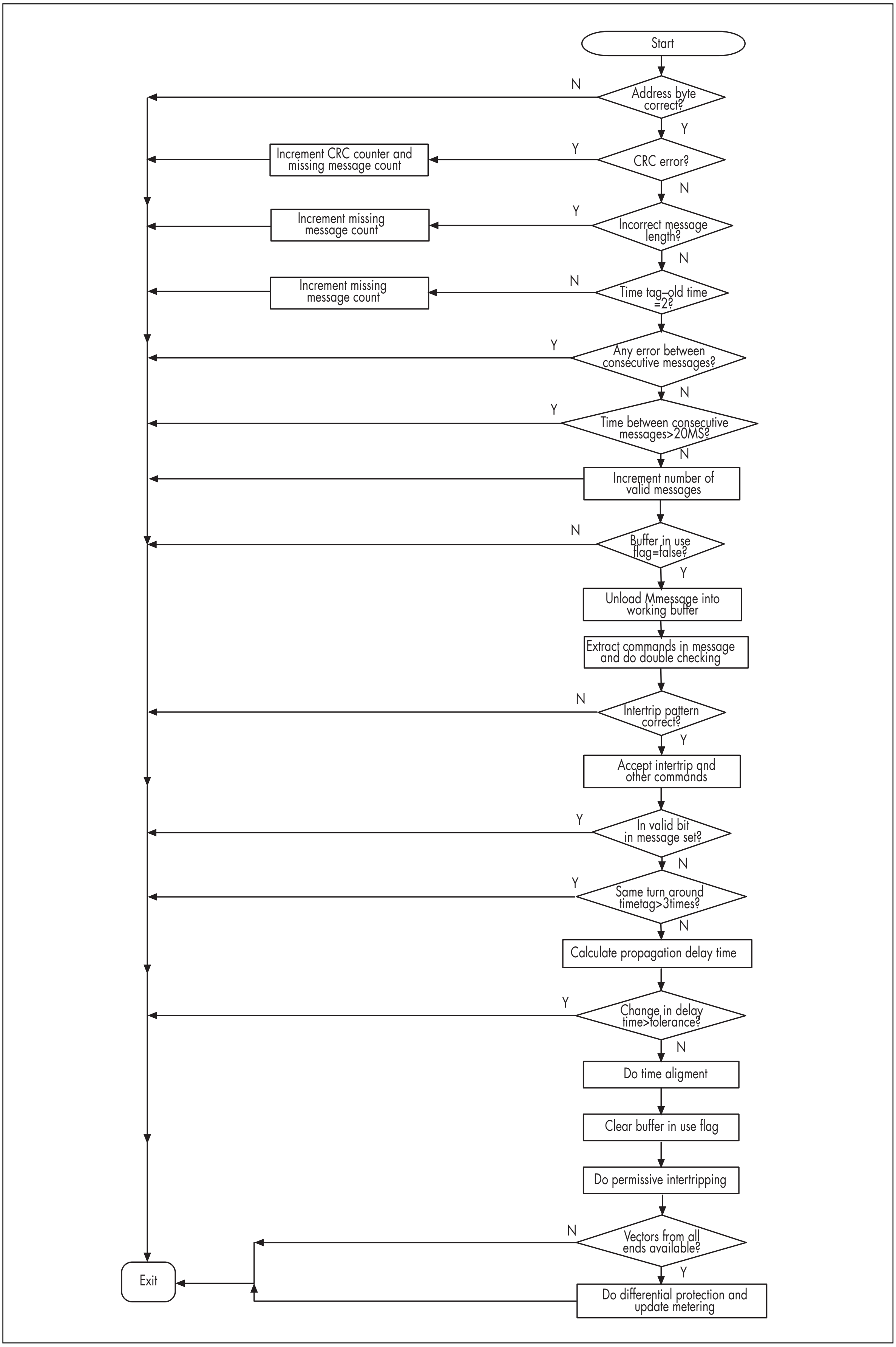


Figure 15: Message checking logic

5.4 Bit error effects

The noise characteristic of a digital communication channel can be expressed in terms of bit error rate (BER). This is the ratio of incorrect bits received to the total number of bits transmitted. The BER expected of a digital communication channel is normally better than 10^{-6}.

As discussed in Section 4.3, the LFCB relay performs many data error checks and so can maintain secure operation on a channel having a high bit error rate.

Since the relay only accepts a message if its time tag is in sequence with the previous one, the protection function is lost if one out of every two messages is corrupted. This corresponds to one error bit per two messages or a BER of about 3×10^{-3}. Communication noises however seldom occur in such an evenly distributed fashion but in bursts. Bursts can cause several bit errors in one message. Given the above BER, less messages will be affected and the protection may still function.

The relay has been tested to perform satisfactorily at a BER of 10^{-3}. The relay remains stable at higher error rates but the operating time is increased due to the loss of messages.

A ‘Communication Supervision’ alarm is raised by the relay if the message error rate rises above 25% and persists over a defined period of time. This is equivalent to a BER of 1.5×10^{-3}. See Chapter 7 for details of setting the alarm delay time.

To aid the bit error evaluation of the communication link, a communication error statistic is kept by the relay. This gives the number of crc errors detected, the number of lost messages, and the number of valid messages received for each of the two channels. The number of lost messages recorded is intended as an indicator for noises under normal communication conditions and not for recording long communication breaks. The lost message count is accumulated by incrementing a 16-bit counter when a message is rejected by the crc check, message length check and the sequential time tag check. The crc error count also has a separate16-bit counter. The valid message count has a 32-bit counter and so it overflows every 207 (60Hz) or 248 days (50Hz).

The error statistic record is automatically cleared on power-up. It can also be cleared by an operator command issued through the front panel interface. See Chapter 7 for details.

5.5 Communication interfacing

Several options are available for interfacing the relay to a communication link. The link can either be dedicated to current differential protection signalling or be multiplexed and shared with other protection or telecommunication equipment. It may employ optical fibres or conventional communication media. The modular design of the LFCB relay means that only the communication interface module is affected and needs to be varied to suit the different requirements.

5.5.1 Dedicated links

5.5.2 Optical fibres

Different types of fibres, optical transmitters and receivers are required for different ranges of communication distance. It can be summarised as follows:

Transmitter and receiver type	Single/Multi mode	Wavelength (nm)	Optical budget (dB)
LED/PIN	Multi	850 (short)	14
LED/PIN	Multi	850 (med)	19
LED/PIN	Multi	850 (long)	26
VCSEL/PIN	Multi	1300	30
VCSEL/PIN	Single	1300	30
VCSEL/PIN	Single	1550	30

LED – Light Emitting Diode.

PIN – Positive Intrinsic Negative Diode.

VCSEL – Vertical Cavity Surface Emitting Laser.

Table 3: Optical transmitters and receivers for different ranges of communication distance

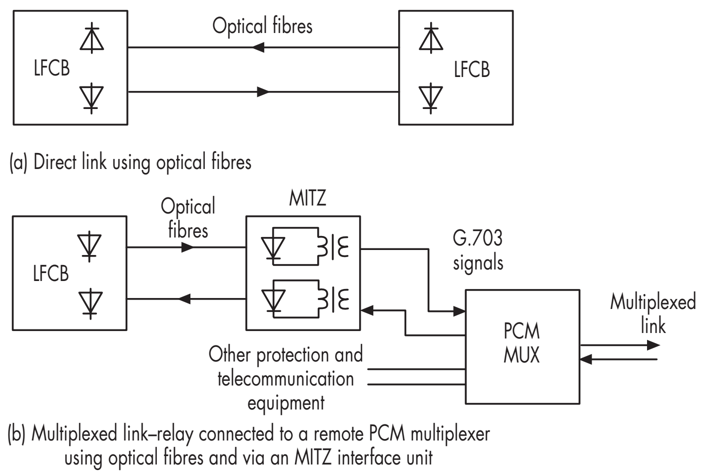


Figure 16: Recommended communication interface arrangements

Table 3 should be used as a rough guide only. Communication distance can vary subject to the type of optical fibres used (core diameter, single-mode/multi-mode, attenuation, dispersion etc.), installed cable loss (joints), connector loss, and required allowance for design tolerance, component degradation and maintenance. 850nm wavelength optical devices are cheaper and easier to work with.

They are used mainly in short distance applications with 50/125µm multi-mode fibres. Fibre attenuation at this wavelength is typically 3dB/km. 1300nm wavelength devices are used in longer distance applications.

Fibre attenuation is about 1.1dB/km for 50/125µm multi-mode fibres and 0.5dB/km for 8/125µm single-mode fibres. The longest transmitted distance without using regenerators is about 50km for present day commercial systems.

The LFCB relay has three versions of 850nm wavelength optical communication interfaces:

i) Short distance (<2km)

ii) Medium distance (<5km)

iii) Long distance (<8.5km)

SMA 9mm type optical connectors are used for these 850nm wavelength communication interfaces. Please see Chapter 4 for details of these three versions of optical interfaces.

Note : The 850nm medium and long haul design will be replaced with the new design when stocks of the obsolete components are used up.

Special considerations are required for longer distance applications. Please consult ALSTOM T&D Protection & Control for details.

5.5.3 Twisted pairs/coaxial cables

The LFCB relay with G.703 co-directional interface (see Section 5.5.2) can be connected directly to metallic links without the need for any special interface. For isolation and noise immunity reasons, this approach is not recommended except when an optical link is not available and the data transmission is only for a very short distance, using well screened cables.

5.5.4 Multiplexed links

Although it is feasible to operate the LFCB relay with dedicated optical links over long distances, the cost can be prohibitive beyond 10 – 20km. Except for short-haul applications, it is often preferred instead to share the optical links between protection and other telecommunication equipment using standard multiplexing techniques. For conventional communication media such as microwave systems, multiplexing is also necessary.

There are two common multiplexing techniques: frequency division multiplexing (FDM) and time division multiplexing (TDM). Modern digital communication systems use mainly TDM. A characteristic feature of digital communication systems is the multiplexing structure leading to standard fixed bandwidths from basic 64kbits/s channels. A pulse code modulated (PCM) system is used which enables data, voice and other forms of signals to be multiplexed together. The CCITT standards adopted by most European systems recommend multiplexing 64kbits/s channels into 2, 8, 34, 140Mbits/s and higher rate bit streams. A basic channel can be used to carry a 4kHz bandwidth voice signal or a digital signal of 64 kbits/s. The standards adopted by North American systems are slightly different. The primary multiplexer operates typically at 1.544Mbits/s. A basic channel, though also of 64kbits/s, normally only supports 56kbits/s data transmission.

To ensure compatibility with a wide range of communication equipment and media, the LFCB relay is designed to work within the signalling bandwidth of a basic 56/64kbits/s PCM channel. This is equivalent to the bandwidth requirement of a single analogue voice signal but as the LFCB relay sends all three phase currents and intertripping and status information through the same channel, it utilises the channel more efficiently.

Another advantage of digital communication is that extensive error checking can be built in to safeguard the integrity of relaying data (see Section 5.3). No extra guard channel is needed to monitor communication noises.

5.5.5 G.703 interface

The G.703 interface recommendation allows a few variants to co-exist. These result from different approaches taken towards data synchronisation.

For high speed data communication, data are generally transmitted synchronously, ie. a timing signal is generated to regulate when data can be transmitted and when received data should be read. The G.703 recommendation recommends three types of timing arrangements:

i) Co-directional interface, ie. timing and data signals are transmitted in the same direction. (Figure 17a).

ii) Contra-directional interface, ie. timing signals associated with both directions of transmission are originated from the multiplexer. (Figure 17b).

iii) Centralised clock interface, ie. all timing signals are supplied from a centralised clock. (Figure 17c).

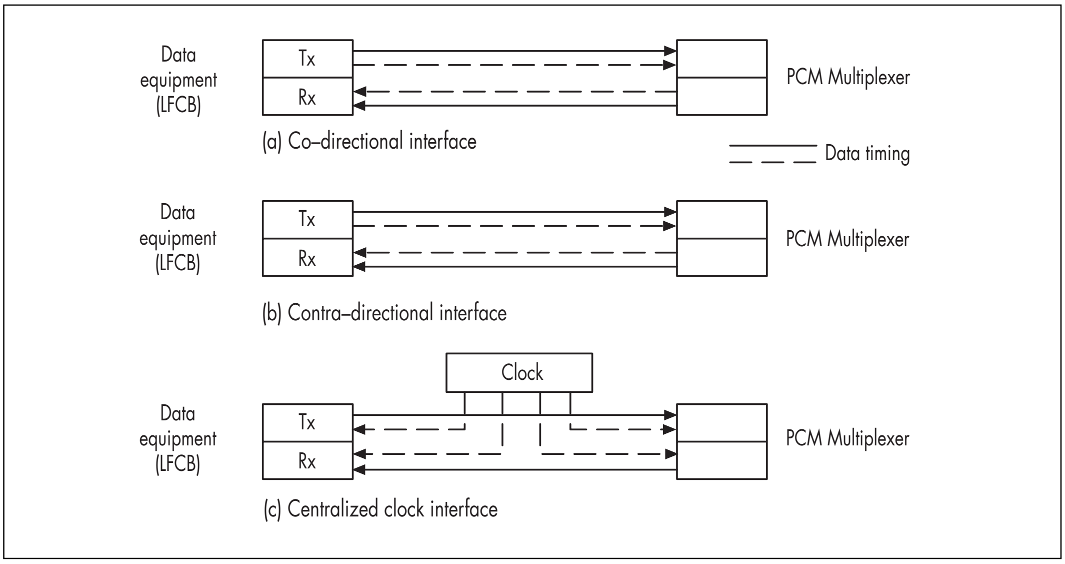


Figure 17: Three variants of G.703 timing arrangements

The co-directional interface is the most popular one and is supported by the LFCB relay. Since timing and data signals of the co-directional interface are in the same direction, they are encoded and transmitted together as a composite signal.

The G.703 interface signals are ±1V three-level signals designed for pulse transformer coupling. Alternate Mark Inversion (AMI) is used to change polarity of each data bit so that there is no dc component from the signal to saturate the pulse transformer core.

Figure 18 shows an example of a G.703 co-directional signal. The pulse transformers used in the LFCB communication module give an isolation level of 500V.

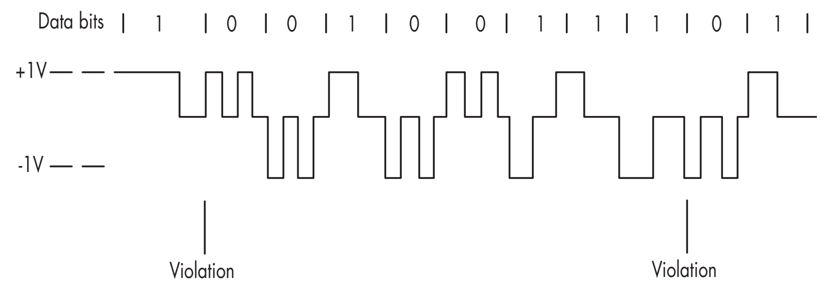


Figure 18: An example of a G.703 co-directional signal

Please see Chapter 4 for details of connections of the G.703 co-directional interface.

5.5.6 Optical link between relay and multiplexer with G.703

Since the G.703 interface signals are ±1V, they are susceptible to noise interference. If the relay is remote from the multiplexer(s) or if the connecting cable runs through a noisy area, then an optical link should be used for the interconnection. For that, we recommend the relay to have the short distance optical interface (see Section 5.5.1) and two ALSTOM T&D Protection & Control type MITZ interface units are required to be placed at the multiplexer end to provide optical/G.703 signal conversion (Figure 16b).

The MITZ 01 interface unit is of size 4 MIDOS construction and supports G.703 co-directional interfacing. The unit uses the same optical transmitter and receiver as the LFCB short distance optical interface. Please see Chapter 4 for more information on the MITZ interface.

Section 6. FUNCTIONS OF THE OPTO-ISOLATED STATUS INPUTS

The LFCB 102 relay has 6 opto-isolated status inputs. These opto-inputs together with 3 CT analogue inputs are provided in the analogue/status input module. The functions assigned for the opto-inputs are:

Inhibit trip/alarm outputs

Reserved

Initiate permissive intertrip

Initiate Intertrip

Reset indication and alarm

Time sync

All the opto-input functions are activated by applying the specified auxiliary voltage Vx(2) across the input terminals. This produces a nominal 10mA circulating current into the opto-isolated input circuit. If a particular function is not required, the corresponding opto-input may be left unconnected or shorted.

6.1 Inhibit trip/alarm outputs

This opto-input is normally activated by an external switch (the IN/OUT switch) and may be used to inhibit the operation of the relay trip and alarm outputs during test or other conditions. The input needs to be activated for at least 8 samples (20ms for 50Hz or 17ms for 60Hz) for the relay to accept the inhibit command. The trip and alarm outputs are held inhibited for 8 samples after the command is removed.

On accepting the inhibit command, the relay turns on the front panel 'Out of Service' LED and flags a status bit in the communication message. This instructs the relay at the remote end to also inhibit its trip and alarm outputs. The remote relay also flashes its 'Out of Service' LED to indicate that it has been remotely inhibited. Note that neither the local nor the remote relay raises an 'Out of Service' alarm. Such alarm, if desired, can be derived directly from an auxiliary contact of the IN/OUT switch. Figure 18 shows the logic of the 'Inhibit Trip/Alarm Outputs' feature.

It is possible to carry out injection tests directly after switching 'OUT' the system at one end. There exists the risk of a trip however if the wire connection of the opto-input circuit breaks and returns the system back to normal operation during the injection tests. If such a risk is to be avoided, then the relays at both ends must be switched 'OUT' before an injection test is started.

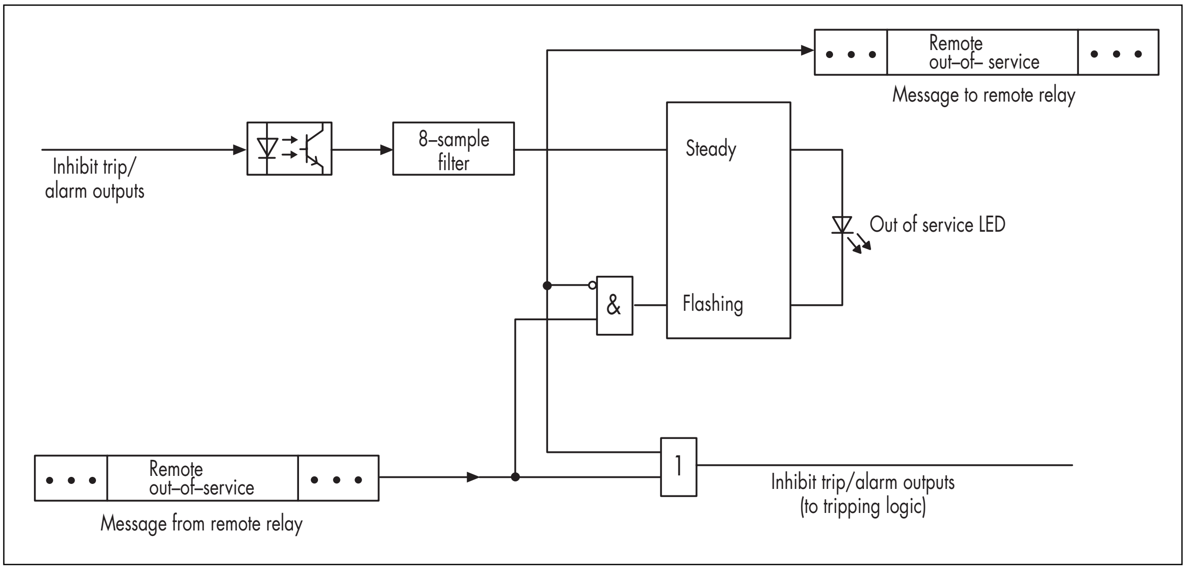


Figure 19: 'Inhibit trip/alarm outputs' logic

All the protection, alarm, recording and front panel indication functions of the relay perform normally under this 'OUT' condition. Faults and alarms recorded under the condition are however marked differently so as to allow an operator to distinguish the test records easily from normal operation ones.

6.2 Initiate permissive intertrip

The input is used to initiate the remote relay to perform a permissive intertrip. Please see Section 3.11 for details.

6.3 Initiate intertrip

The input is used to signal the remote relay to activate or deactivate its 'Intertrip' output contacts. Please see Section 3.10 for details.

6.4 Reset indication and alarm

When the 'Reset Indication and Alarm' is activated, the relay resets its alarm displayed on the LCD and on the 'Trip' and 'Alarm' LED. The facility may be used to remotely reset the alarm indication after a normal operation, an injection test or communication test. The fault and event records are not affected by this function.

The opto-input has an 8-sample software filter. The reset pulse must therefore last longer than 20ms (50Hz) or 17ms (60Hz).

6.5 Time sync

The 'Time Sync' is used to synchronise the internal calendar clock of the LFCB relay periodically. The relay can be set to accept 'Time Sync' signals of 5, 10, 15, 30 or 60 minutes intervals. If the 'Time Sync' is set to say, 30 minutes, then activation of the 'Time Sync' input will pull the internal calendar clock to the nearest hour or half-hour. The opto-input has an 8-sample software filter. The 'Time Sync' pulses must therefore last longer than 20ms (50Hz) or 17ms (60Hz).

Section 7. TRIP AND ALARM OUTPUTS

The LFCB relay has a total of 27 output contacts:

Trip A	4 NO
Trip B	4 NO
Trip C	4 NO
Any Trip	2 NO
Intertrip	4 NO
Protection Operated A	1 NO
Protection Operated B	1 NO
Protection Operated C	1 NO
Block Auto-Reclose	2 NO
Protection Scheme Inoperative Alarm	1 NO
Relay Inoperative Alarm	1 NC
Communication Supervision Alarm	1 NO
Power Supply Failure Alarm	1 NC

The trip, intertrip and block auto-reclose contacts have fast 2ms pick-up times. The 'Protection Operated' and alarm contacts have normal pick-up times of 8ms. The contact drop-off time is 8ms for all contacts except the intertrip contact which has a 2ms drop-off time.

All outputs are self-reset. The Trip A, Trip B, Trip C, Any Trip and the Protection Operated outputs have maximum reset times of 55ms (50Hz) or 48ms (60Hz). The Intertrip output has a maximum reset time of 23ms (50Hz) or 20ms (60Hz). Once energised, they remain closed for at least 60ms. The Block Auto-Reclose output is reset 100ms after all block auto-reclose conditions have been removed. The alarm outputs have reset times of one second.

Please see the external connection diagram of LFCB 102 relay (Drawing No. 10LFCB 102) for details of output connections.

7.1 Trip A (94A), Trip B (94B) and Trip C (94C)

These 3 groups of contacts are trip output contacts of the current differential protection function. The contacts operate when

1) A differential protection trip decision is reached locally, or
2) A differential protection transfer trip command is received in the messages sent by a remote relay.

The contacts are suitable for both single-pole and three-pole tripping. If the single-pole tripping mode is selected then, for a single phase to ground fault only, the corresponding phase group of contacts operate, ie. the 4 'Trip A' contacts (94A-1, 94A-2, 94A-3 and 94A-4) operate for phase A to ground faults. For two phase and three phase faults, all three groups of contacts operate.

These output contacts will respond as the Any Trip output and operate for any single phase, two phase and three phase faults if the three-pole tripping mode is selected.

These contacts also operate for 'Permissive Intertrip'. A permissive intertrip always operates all three contact groups to action three-pole tripping. Please see Section 3.11 for more explanation of the 'Permissive Intertrip' facility.

7.2 Any trip (94)

This contact group (94-1, and 94-2) operates for any types of differential protection trip and for permissive intertrip. See Figure 20 for the logic diagram of Trip A, Trip B, Trip C, and any Trip output contacts.

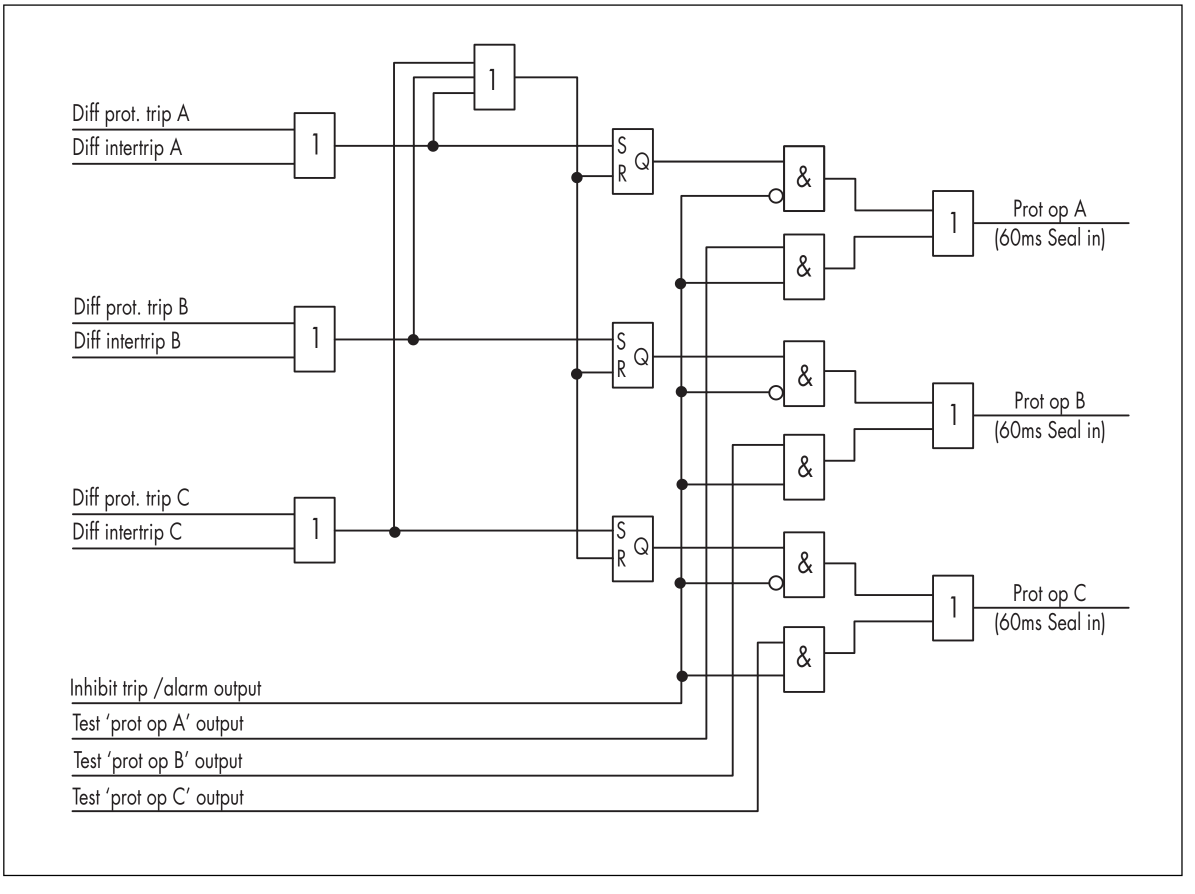


Figure 20: Trip output logic

7.3 Intertrip (85)

The contact group (85-1, 85-2, 85-3 and 85-4) operates when an 'Intertrip' command is received in the incoming messages. The facility can be used for direct transfer tripping or other signalling functions. Please see Section 3.10 for more explanation of the 'Intertrip' facility.

7.4 Protection operated A, B and C (94D)

These 3 outputs (94D(A)-1, 94D(B)-1 and 94D(C)-1) indicate which phase(s) of differential protection have operated. A two phase fault would cause only the two corresponding 'Protection Operated' contacts to close and not all three as in the case of the 'Trip A', 'Trip B' and 'Trip C' outputs. The outputs are suitable therefore for fault type annunciation or for fault locator uses.

Figure 21 shows the logic diagram of the Protection Operated A,B, and C output contacts. Note that this contact group does not operate for permissive intertrip.

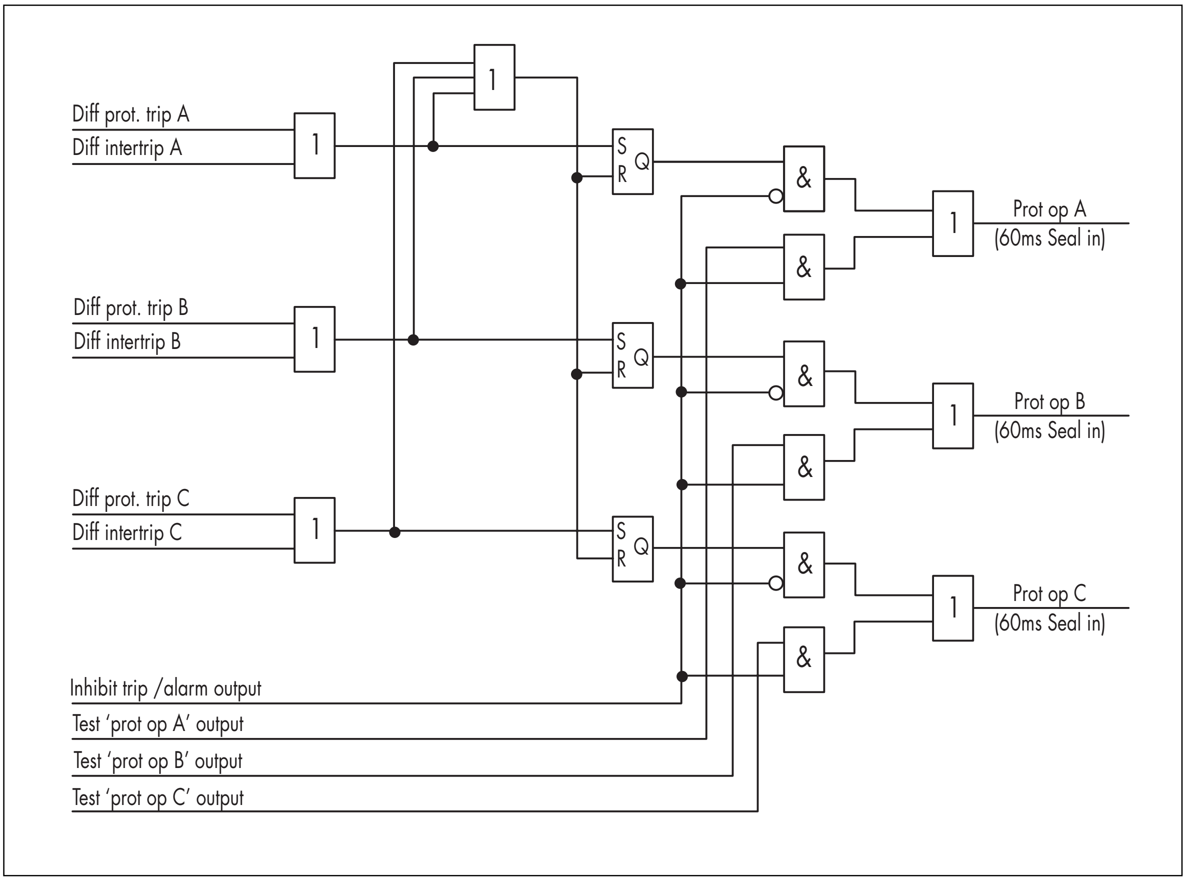


Figure 21: Protection operated output logic

7.5 Block auto-reclose (96)

The two contacts (96-1 and 96-2) are provided to block auto-reclose. It can be selected to block auto-reclose on permissive intertrip only, or on either permissive intertrip or three phase faults. The contacts are kept closed for a further 100ms (ie. a delay on drop-off) after all block auto-reclose conditions have been removed, Figure 22 shows the logic diagram of the Block Auto-Reclose output contacts.

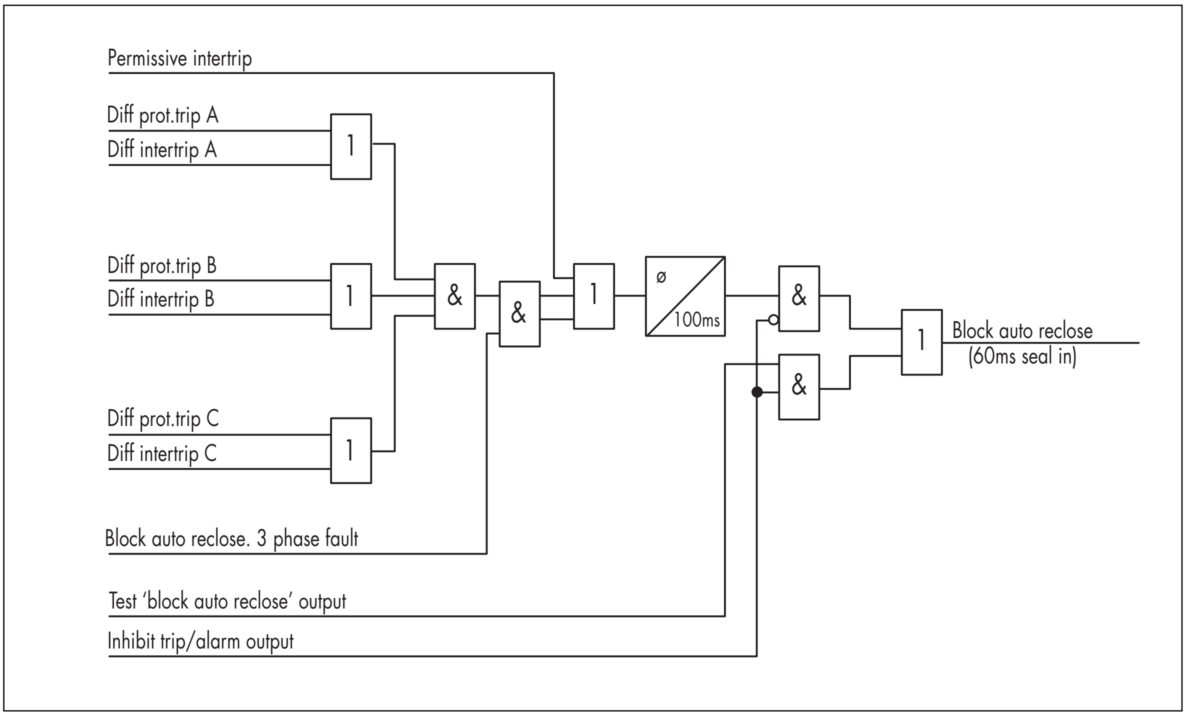


Figure 22: Block auto reclose logic

7.6 Communication supervision alarm (97Z)

The alarm contact (97Z-1) is activated if less than 75% of communication messages are received correctly within the specified time period (see Chapter 7 for details of setting the communication fail time setting). The relay would identify this alarm in the alarm display and alarm record as caused by receiver failure.

The communication supervision alarm may also be activated if a remote relay informs the relay (by flagging a corresponding status bit in the communication messages) that the remote relay has received less messages than expected. This will be identified as transmitter failure in the alarm display and record.

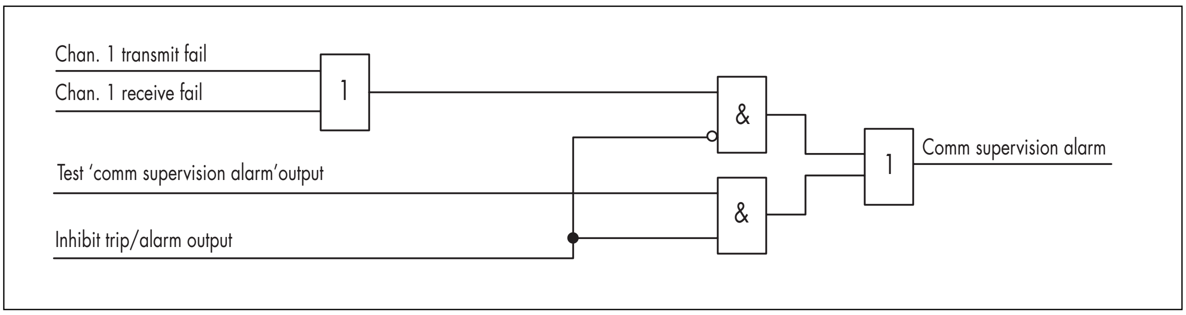


Figure 23: LFBC102 comm supervision alarm output logic

The failure of a communication channel whether caused by transmitter failure, receiver failure, or due to the communication link itself, will cause the communication supervision alarm to be raised at both ends. The cause of the failure can be then found by reading the alarm display of both relays, Figure 23, shows the logic diagram of the Communication Supervision Alarm output contact.

7.7 Relay inoperative alarm (97Y)

A normally closed contact (97Y-1) is used for this alarm. The contact is held open under healthy operating conditions. The following conditions would cause the contact to close:

1) Loss of dc auxiliary supply Vx(1).

2) Loss of any internal dc voltage rails.

3) Failure detected by the relay during power-on diagnostics.

4) Failure detected by the relay during routine run-time self-monitoring.

5) Loss of internal clock pulse signals.

6) Operation of internal watchdog circuit.

7.8 Protection scheme inoperative alarm (97X)

The alarm contact (97X-1) is closed when the differential protection scheme is no longer operative. For a three-ended system, this can be caused by the failure of two of the three communication links or if one of the relays is inoperative. If we call the three relays A, B and C, the failure of the communication link A-B would cause both A and B to raise the 'Communication Supervision Alarm'. Differential protection is maintained by relay C which will intertrip relays A and B through the two healthy communication links A-C and B-C if an internal fault occurs.

If, instead, relay A has gone inoperative, then relay A will have the 'Relay Inoperative Alarm' and relays B and C will have both the 'Communication Supervision Alarm' and the 'Protection Scheme Inoperative Alarm'. All three alarms would help therefore to quickly identify the causes of system failures.

Figure 24 shows the logic diagram of the Protective Scheme Inoperative Alarm output contact.

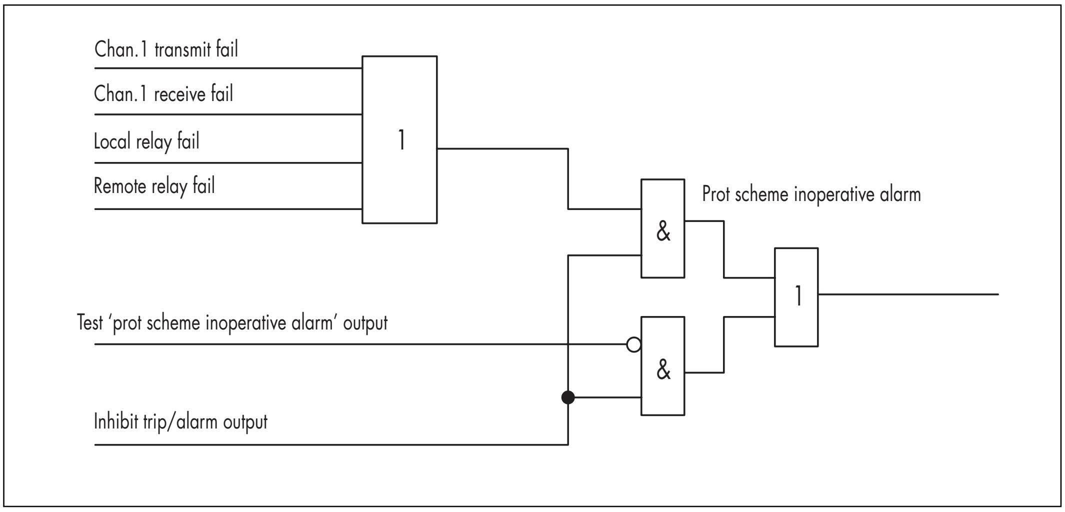


Figure 24: LFCB 102 protection scheme inoperative alarm logic

7.9 Power supply failure alarm (97W)

A normally closed contact (97W-1) is used for this alarm. The contact is held open under healthy operating conditions. The following conditions will cause the contact to close:

1) Loss of dc auxiliary supply Vx(1).

2) Loss of any internal dc voltage rails.

Digital Current Differential Relay Type LFCB 102

Chapter 6
Software Description

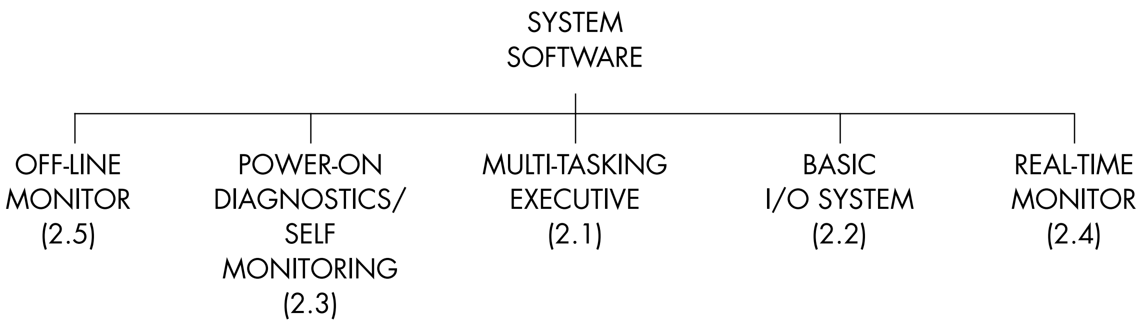
Section 1. INTRODUCTION

The LFCB current differential relay software is divided into three main groups: the system software, the main processor software and the communication processor software.

The system software is not application dependent and is used for all applications based on the multi-modular hardware. It consists of various diagnostic, debugging, input/output and multi-tasking handling facilities. It provides a common software environment within which different application programmes can be developed and operated efficiently. The system software is used in both the main processor and the communication processor.

The LFCB application software is split between the main processor and the communication processor. The main processor is the microprocessor in the microcomputer module. It is responsible for processing the analogue data, validating the status inputs, flagging alarms, updating the relay outputs and controlling the operator interface. The communication processor is the microprocessor in the communication module. It works as a slave input/output processor for the main processor and handles the exchanges of messages to and from the remote relay, time aligns remote current vectors, and performs the differential protection task.

Section 2. SYSTEM SOFTWARE



Software function block diagram for the system software

2.1 Multi-tasking executive (MTE)

The Multi-Tasking Executive (MTE) is a collection of features which allows a number of real-time application functions to be handled simultaneously. It operates by letting the application programmer to break down the application programme into separate tasks. Each task is assigned a relative priority. The executive allows only one task to be run at any instant. Other tasks which are activated are stored in queues if they cannot be executed immediately. The executive is also capable of letting a higher priority task to pre-empt a lower priority one.

The multi-tasking executive controls the real-time operation of the application software. Its major advantage is that once the different tasks of an application have been identified and their interactions defined, software development of individual task programmes can then be programmed as if it was a single task programme. The actual handling of task execution and priority scheduling is left to be handled by the multi-tasking executive.

2.2 Basic input/output system (BIOS)

The Basic I/O System provides a complete interface between the application software and the relay hardware. It is a set of hardware driver routines which allows the application programmer to control and transfer data to and from I/O devices easily. With the help of the BIOS software, the application programmer no longer needs to have a full understanding of how the I/O devices work, only what the devices should do. It also helps to make the application programme's hardware independent so that a modification in the hardware will only require an update on the BIOS software and not the application programmes. In doing so, it ensures portability and stability of application software.

The BIOS includes I/O device drivers for the following:

- Opto-isolated status input
- Relay output
- Serial port
- Parallel/test port
- Liquid crystal display
- Keypad input
- Analogue input

2.3 Power-on diagnostics/self-monitoring

After power up, the system software performs diagnostic checks on the following hardware components:

- Watchdog timer
- Microprocessor
- Interrupt controller
- Timer
- DMA controller
- EPROM
- RAM

The relay locks itself out if any of the power-on diagnostics fail. This disables all relay functions. An error message is displayed on the LCD and the 'Relay Inoperative' alarm contact is closed.

The system software consists of a number of self-monitoring routines which allow EPROM and RAM to be checked periodically. If a failure is detected, the power-on diagnostics are repeated to confirm the failure before the relay locks out.
An application programme can also incorporate special self-monitoring routines specific to the particular application. Depending on the types of failures, the application programme can have the options of resetting the relay to try to recover from the failure, repeating the power-on diagnostic tests for confirmation of failure conditions, or locking-out the relay completely.

In the LFCB relay, the RAM and the EPROM are checked continuously. In addition, if a processor out of sync failure (see Section 3.3.3) is detected, the relay is forced to reset. The relay locks itself out if the failure persists after three resets.

2.4 Real-time monitor

The Real-Time Monitor runs as a low-priority task. It is used mainly at the software development stage. It consists of a number of standard and application specific functions which allow the user to perform real-time debugging through a visual display terminal. The standard functions include examining and changing memory and I/O ports' contents while the application programme is running. The LFCB real-time monitor also contains some additional functions like examining the communication error statistics.

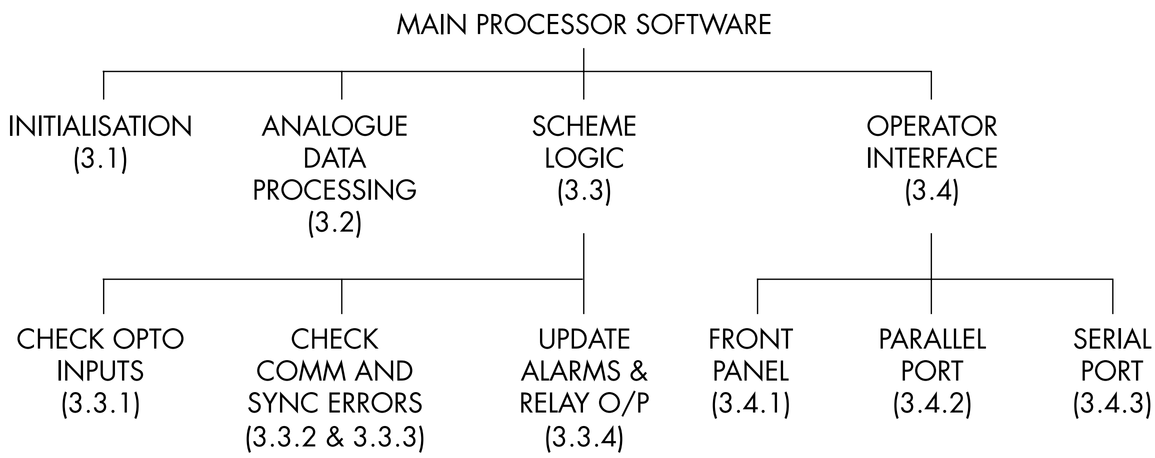
The real-time monitor is normally switched off in the final product software and not available to the user.

2.5 Off-line monitor

The off-line monitor provides a number of off-line debugging facilities. It allows the user to examine and to modify the contents of registers, memory and I/O ports, to set break-points, to single step and to execute a programme.

The off-line monitor is used mainly during the software development phase. Special instructions are required for gaining access to the off-line monitor functions. The off-line monitor is therefore transparent to the user.

Section 3. MAIN PROCESSOR SOFTWARE



Software function block diagram for the main processor

The main processor module controls the analogue and the status input module, the relay output modules, the operator interface module and the communication module. It processes the analogue and the status input data, updates the relay outputs and controls the operator interface. Information exchanges between the main processor and the communication processor are made through a 128-byte common memory area which is located in the communication processor module.

3.1 Initialisation

The main processor application software goes through the following initialisation procedures :

(1) Read the alarm status from the non-volatile EEPROM store. If any alarm was active and has not been cleared before the previous power down, then the alarm is restored and displayed (see Chapter 7, on how alarms are accepted and cleared). The software checks the validity of the alarm status before any action is taken. Any invalid alarm status is ignored and the corresponding EEPROM location is reset.

(2) If a relay has been remotely switched out of service before the power down, this particular status is stored in the EEPROM and is restored during initialisation.

(3) All the settings stored in the EEPROM are validated by checking whether they are within their defined ranges. If a setting is out of range, a default setting is applied and an "EEPROM setting alarm" is raised. The in-range settings are loaded from the EEPROM into the relay's working memory area.

(4) The main processor then initialises the timers, the interrupt controller, the analogue input module and all data variables. It then activates all the tasks before informing the communication processor that the initialisation is completed.

(5) The 'Relay Inoperative' alarm is deactivated.

3.2 Analogue data processing

The three phase currents and the status inputs are sampled at a sampling rate of 8 samples per cycle. All the data acquired are stored in 64-sample long cyclic buffers. Fourier filtering is applied to the analogue data to extract the Fourier sine (I_s) and cosine (I_c) integrals. The rms values of the phase currents are also calculated. All this information is then copied into the common memory area in the communication module for the communication processor to carry out the protection and metering functions.

3.3 Scheme logic

3.3.1 Opto-isolated status input checks

The status inputs are checked for consistency before the corresponding actions are taken. The 'Initiate Permissive Intertrip' and the 'Initiate Intertrip' status inputs require fast response and so are checked over three consecutive samples.
The other status inputs ('Inhibit Trip/Alarm Output', 'Reset Indication and Alarm' and 'Time Sync') are checked over 8 samples.

3.3.2 Communication error ehecks

The number of valid messages received is checked once every 100ms. If the number of valid messages received is less than 75% of the expected number, an internal error counter is incremented and a status flag is sent to the remote relay.
If the condition persists for longer than the communication alarm delay setting, then a 'Channel Receive Failure' alarm is raised which causes both the 'Communication Supervision Alarm' and the 'Protection Scheme Inoperative' alarm contacts to close.

The relay cannot check the integrity of its own transmit channel. It has to rely on status information sent by the remote relay to tell whether its transmit channel is performing satisfactorily. This status information is checked again once every 100ms. If the error condition persists longer than the alarm setting, a 'Channel Transmit Failure' alarm is raised which also causes both the 'Communication Supervision Alarm' and 'Protection Scheme Inoperative' alarm contacts to close.

If a communication alarm persists for more than 30s, the main processor instructs the communication processor to re-initialise its dma controller and the HDLC controller. This is an attempt to recover from the failure condition caused by soft errors in the dma controller and the HDLC controller.

3.3.3 Synchronisation checks between the two processors

Analogue data are passed from the main processor to the communication processor once every sample. It is synchronised through a software handshaking protocol. Proper synchronisation in data passing is essential because errors in time alignment can occur if the current vectors are misinterpreted to the wrong sampling time.

If the communication processor detects a problem in synchronisation, an error counter is incremented and the communication processor attempts to re-establish synchronisation. It temporarily blocks the protection function and informs the remote relay to do the same.

The error condition is also monitored by the main processor. If the error condition persists longer than one second, then a 'Processors Out Of Sync' alarm is raised which causes the 'Protection Scheme Inoperative' and 'Relay Inoperative' alarm contacts to close.

The 'Processors Out Of Sync' failure can be caused by failures within the communication processor. In particular, if the self-monitoring function of the communication processor detects a failure condition, it locks itself out and causes an out of sync condition. The main processor tries to recover from this condition after 5 seconds by forcing a hardware reset. If the out of sync condition still persists after three resets, then the relay locks itself out.

3.3.4 Relay output update

The relay output contact status is updated once every sample. Both the communication supervision alarm and the protection scheme inoperative alarm will cause their corresponding contacts to close. The differential protection functions are performed by the communication processor. It informs the main processor through the common memory area if a fault condition is detected or if an intertrip command is received. The main processor then updates the trip output contact status and raises the appropriate alarms.

3.4 Operator interface

The operator interface software reads the front panel keypad and displays messages on the LCD It supports also the operation of the serial and parallel ports. The operator interface operates on a menu principle and this is controlled by a look-up table that describes the structure of the menu. As each key is pressed, the input is software debounced and is validity checked. The keypad input selects the menu commands and controls the movement around in the menu. The LCD is usually updated when a key is pressed. However it is updated every second when certain parts of the menu is displayed (e.g. the measurement function). A full description of the operator interface operation is given in Chapter 7.

3.4.1 Front panel, LCD and keypad

The front panel implementation covers the pressing of keys and the display of data on the LCD. The software waits for a key to be pressed and then calls the corresponding key checking software which will implement that key input by giving the relevant display and/or action.

3.4.2 Parallel port

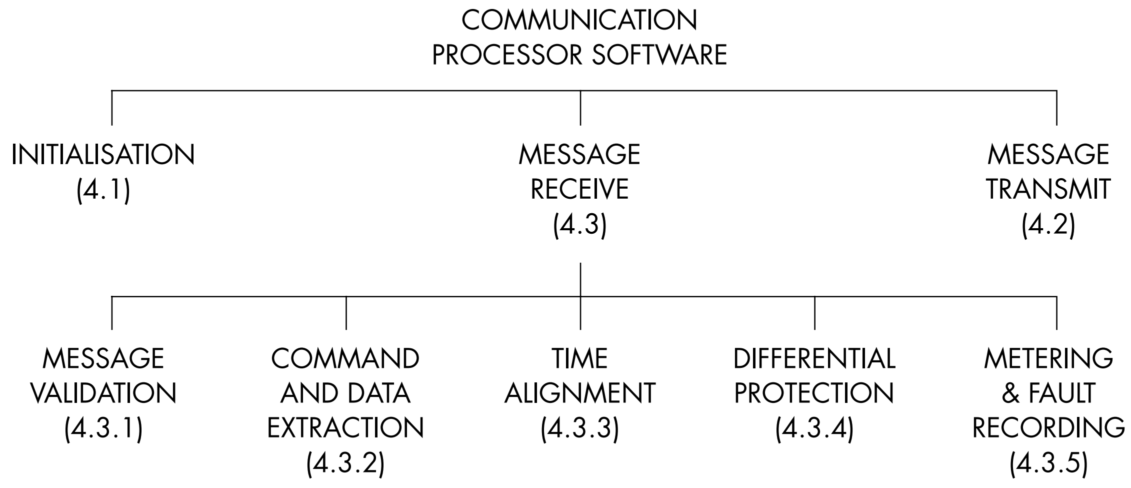
The parallel port allows relay data to be sent to a parallel printer. The software supports the 'Centronic' parallel printer protocol. The parallel port is first checked to determine if a printer is connected, otherwise the serial port is used.
The software also checks if the printer is connected and working during printing. If the printer is disconnected or fails, then printing is aborted to avoid causing delay and disruption.

When not in the 'Print' command mode, the parallel port works as a parallel input/output port for testing purposes. The test port is intended for working with computer based injection test equipment. Eight of the relay outputs are repeated as TTL output lines on the test port. Seven input lines are also provided to allow the 7 front panel keys to be emulated.

3.4.3 Serial port

The serial port can be used to drive a serial printer. It also allows a user to log on to the relay and to interrogate the relay using a personal computer or visual display terminal instead of using the front panel keypad and display. Once logged on, the port is implemented as if it was the front panel. The software redirects the output to the port and translates remote key presses into front panel keypad inputs. This can be viewed therefore as an emulation of the front panel operator interface.

Section 4. COMMUNICATION PROCESSOR SOFTWARE



Software function block diagram for the communication processor

4.1 Initialisation

On power-up or reset, the communication processor initialises its interrupt controller, dma controller and the HDLC controller. It then initialises all data variables, activates the application tasks, and waits for the main processor's initialisation procedures to complete before proceeding with its normal functions.

4.2 Message transmit

A 21-byte message is transmitted to the remote relay once every two samples. The communication processor formulates all the required information into a buffer before triggering the HDLC controller to transmit the message. The information contained in the message is as follows:

4.2.1 Local current vectors

They are the Fourier sine and cosine integrals of the current vectors acquired by the main processor. They are copied from the common memory area into the HDLC data buffer. However, if an out of sync condition is detected, a status flag is set in the message notifying the remote relay that the analogue data is invalid.
The remote relay then ignores the vector information, thus skipping the protection function until the next valid message arrives.

4.2.2 Timing information

Consists of the local time-tag, the received time-tag and the time elapsed since the last message received. They are required by the remote relay to calculate propagation delay time and to perform time alignment functions.

4.2.3 Command and status information

Consists of intertrip command, inhibit trip/alarm output command, permissive intertrip command, communication failure and data invalid status.

The Fourier sine and cosine integrals of the local phase currents, together with their rms magnitude values, are copied into a separate cyclic buffer called the VECTOR TABLE for later uses by the differential protection functions.

4.3 Message receive

A number of functions are initiated once a message is received from the remote relay:

4.3.1 Message validation

The message is validated by going through a number of tests as described in Chapter 5. The message is rejected if any of the tests criteria are not satisfied.

4.3.2 Command and data extraction

In order to restrict the length of the message to a minimum, the various commands, status, timing information and the current vectors are tightly packed together. It is necessary to unpack this information from the data message and store it in the appropriate locations or data buffers.

4.3.3 Time alignment

The propagation delay time is calculated from the timing data. It is used to determine the sampling instant of the received current vectors. They are then time-aligned with the local current vectors stored in the VECTOR TABLE by rotating the received vectors by an appropriate angle. The differential currents and bias currents can then be calculated. See Chapter 5 for a detailed explanation of the time alignment principle.

4.3.4 Differential protection

The differential and the bias current for individual phases are compared with each other according to the relay characteristic and the relay settings. If a fault condition is detected, the relay needs to confirm this for 4 consecutive samples before a trip decision is made. The trip decision and the fault type are conveyed to the main processor as two complementary trip flags for enhanced security.

4.3.5 Measurements and fault recording

The measurement functions provided by the relay display the rms magnitude of local and remote phase currents, the differential currents and the bias currents. Since the communication processor is responsible for gathering current vectors from local and remote ends to carry out the protection function, all this information is readily available. Normally the metering data are updated by the communication processor once every second by writing into the common memory area.

When a fault occurs, the fault currents' magnitudes need to be stored in the fault record. These are taken as the fault current magnitudes corresponding to 3/4 cycle after the trip decision (15ms for 50Hz system or 12.5ms for 60Hz system). This allows time for the fault currents to reach their full magnitudes before the data are captured for the fault records. The data will not be further updated for four seconds unless the fault develops into other phases or a new fault occurs.

Measurement data for the remote end are derived as part of the process in the protection task. When a communication failure condition occurs, these metering data are not available and the protection task is not executed. A low priority metering task takes over under this condition. It continuously updates the local metering, but flags the remote currents, the differential currents and the bias currents as unavailable.

Digital Current Differential Relay Type LFCB 102

Chapter 7
Operating Instructions

Section 1. INTRODUCTION

The operator interface of the LFCB Current Differential Relay consists of a two line by sixteen character liquid crystal display (LCD), a seven key keypad, a serial communications port, a parallel printer/test port and a set of four indication lamps. These are all used to enter settings and to obtain information from the relay.
The layout of the front panel is shown in Figure 1.

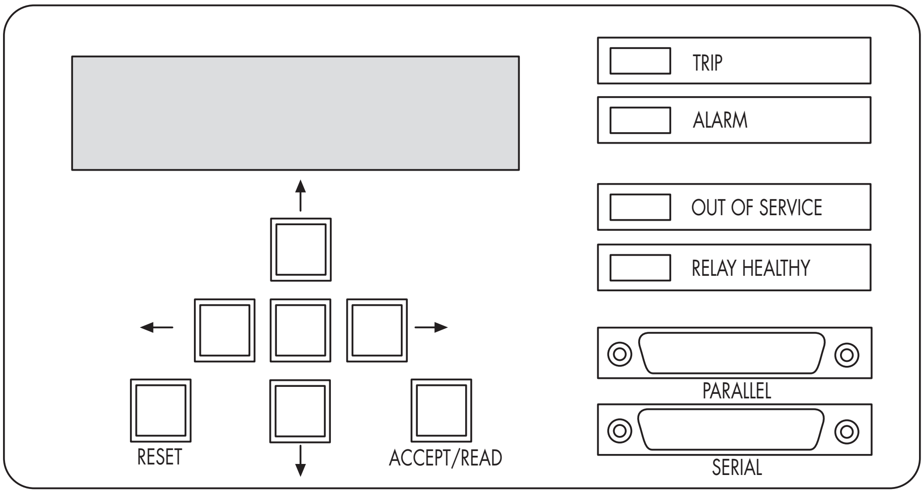


Figure 1: Layout of front panel

The LCD performs the majority of the displaying of information for the operator interface. It indicates alarms, settings and commands available.

The keypad is used to implement the operator interface commands. The seven keys consist of ↑, ↓, ←, and → keys, a SET key, a RESET key and an ACCEPT/READ key. With the front polycarbonate cover in position, only the ACCEPT/READ key and the RESET key are available. The depression of any key will generate one action of that key. However, if the key is held depressed, it will automatically repeat the action. The functions of each of these keys is as follows:

↑	move up in the menu or one step of a setting
↓	move down in the menu or one step of a setting
←	move left in the menu
→	move right in the menu or execute a command
SET	update setting changes or confirm a command
RESET	ignore setting changes or reset alarms
READ	list settings consecutively with each key press
ACCEPT	accept outstanding alarms and list non-reset alarms

The serial port is used either for a local serial printer/visual display unit to obtain print-outs of relay information or it is used as a remote connection to the operator interface giving the same displays as the LCD. The parallel port is used for driving a local printer or parallel I/O connections with a computer based injection test equipment.

The indicating lamps are used to indicate the status of the relay at any time.

They consist of a RELAY HEALTHY lamp, an OUT OF SERVICE lamp, an ALARM lamp and a TRIP lamp. The indication lamps operate together with the LCD. If an alarm is present and unaccepted then the ALARM lamp flashes.

If all the alarms are accepted but not reset the ALARM lamp is on but steady. If a trip condition is alarmed but not reset then the TRIP lamp will be on. The OUT OF SERVICE lamp, if constantly on, indicates that the relay trip and alarm outputs have been inhibited locally. If the relay has been inhibited by the remote relay then this lamp will flash. The RELAY HEALTHY lamp is triggered regularly by the microprocessor and should remain on. If there is a failure of an internal component or in the software which causes the microprocessor to operate incorrectly then this lamp will turn off.

Section 2. MENU SYSTEM

The operator interface operates on a menu type system which uses a horizontal tree-like structure with the various functions grouped under their relevant branch. This allows easy access to these functions without total knowledge of the capabilities of the relay. The default level is the top of the tree and displays the relay title - CURRENT DIFFERENTIAL. The menu will change to the default level after fifteen minutes of inactivity on the keypad. The movement to this default position at this time will abort any commands, changes or messages that were current at the time.

The menu tree consists of five levels these being default level, group level, function level, attribute level and change level. At each of these levels the menu may have several options or branches. The user may change option or branch by using the ↑ and ↓ keys and may change levels by using the ← and → keys. The group level divides the menu into groups of common functions. The function level gives the functions in a group, and each of these generally possesses several attributes. In some circumstances the functions are divided into sub-functions and in these cases the sub-functions occur at the attribute level and the attributes occur at the change level.

The LCD indicates the current position of the menu. This is in the form of a text message and indicates the present position in the menu.

If the user presses the → key at the default level then the menu will move to the first group. The user then has the option of changing groups (up or down) or entering the current group (right). When moving up and down in the menu, if there are no more options above or below respectively then the menu wraps around to the lowest or highest option in the given function or group. If the user enters the group then the menu will be at the first function of that group. Again one has the option of moving up or down a function or moving into the function. This procedure continues until the right edge of the menu is reached. Different functions have different right hand limits. If the user presses the ← key the menu will move to the previous level. Thus if the menu was at a given function, a depression of the ← key will move to the group of which that function is a member. Continued depressions of the ← key will move to the default level.

LFCB102 TREE STRUCTURED MENU

The Default Display is Current Differential. Moving one step to the right moves this into the First Level as shown in the diagram

First Level	Second Level	Third Level Set or Display	Fourth Level Display and/or Select {units}
PRINT	PUSH → TO PRINT ALL RECORDS	{printing in progress}	
	PUSH → TO PRINT SETTINGS	{printing in progress}	
	PUSH → TO PRINT ALARM RECORDS	{printing in progress}	
	PUSH → TO PRINT FAULT RECORDS	{printing in progress}	
	PUSH → TO PRINT COMMUNICATIONS	{printing in progress}	
PROTECTION SETTINGS	CURRENT DIFFERENTIAL	THRESHOLD LEVEL IS1	0.2 – 2.0 {xIn}
		PERCENTAGE BIAS k1	30 – 150 {percentage}
		THRESHOLD LEVEL IS2	2.0 – 20.0 {xIn}
		PERCENTAGE BIAS k2	30 – 150 {percentage}
MEASUREMENTS	PHASE A CURRENT	LOCAL	{display value} {pu}
		REMOTE	{display value} {pu}
		DIFF	{display value} {pu}
		BIAS	{display value} {pu}
	PHASE B CURRENT	LOCAL	{display value} {pu}
		REMOTE	{display value} {pu}
		DIFF	{display value} {pu}
		BIAS	{display value} {pu}
	PHASE C CURRENT	LOCAL	{display value} {pu}
		REMOTE	{display value} {pu}
		DIFF	{display value} {pu}
		BIAS	{display value} {pu}
	I_1	{display value}	{pu}
	I_2	{display value}	{pu}
	I_0	{display value}	{pu}
PROTECTION ALARM RECORDS	ALARMS	{scroll through <10 alarms}	
PROTECTION FAULT RECORDS	FAULTS	{scroll through <3 faults}	
COMMUNICA–TIONS	ERROR STATISTICS	CRC ERRORS	{display value} {Hex}
		LOST MESSAGES	{display value} {Hex}
		VALID MESSAGES	{display value} {Hex}
	PROPAGATION DELAY TIME	DELAY TIME	{display value} {ms.}
		DELAY TOLERANCE	250 – 1000 {us.}
	ALARM TIME	COMM FAIL TIMER	0.1 – 9.9. {secs.}
	RELAY ADDRESS	{display value}	see manual.
CALENDAR CLOCK	READ TIME AND DATE	TIME AND DATE	{display value}
	SET TIME AND DATE	YEAR	1980 – 2079
		MONTH	Jan – Dec
		DAY	1 – 31
		HOURS	1 – 24
		MINUTES	1 – 60
		SECONDS	1 – 60

Figure 2: LFCB 102 tree structured menu

First Level	Second Level	Third Level Set or Display	Fourth Level Display and/or Select {units}
CONTROL	CLEAR RECORDS	PUSH → TO CLEAR COMMS	{push SET to confirm}
		PUSH → TO CLEAR ALARMS	{push SET to confirm}
		PUSH → TO CLEAR FAULTS	{push SET to confirm}
	SERIAL PORT DATA	BAUD RATE	300, 600, 1200, 2400 or 4800
		BIT FRAMING	8N1/8O1/8E1/8N2/ 8O2/8E2 7N1/7O1/7E1/7N2/ 7O2/7E2
	CLOCK SYNC DATA	CLOCK SYNC TIME x mins	5, 10, 15, 30 or 60 {mins}
	REMOTE PORT ACCESS		LIMITED OR FULL
	SCHEME LOGIC	BLOCK A/R ON	PIT OR PIT AND THREE PHASE TRIP
		TRIPPING MODE	SINGLE OR THREE PHASE
	TEST OPTIONS	OPTO INPUT STATE	
		PUSH FOR LAMP TEST	
		CONTACT TEST	SEE BELOW
			PUSH > TO CLOSE
			RELAY INOP
			PUSH TO CLOSE
			RELAY OPA
			PUSH> TO CLOSE
			RELAY OPB
			PUSH > TO CLOSE
			RELAY OPC
			PUSH > TO CLOSE
			RELAY TRIP A
			PUSH > TO CLOSE
			RELAY TRIP B
			PUSH > TO CLOSE
			RELAY TRIP C
			PUSH > TO CLOSE
			RELAY ANY TRIP
			PUSH > TO CLOSE
			RELAY INTERTRIP
			PUSH > TO CLOSE
			RELAY BLOCK A/R
			PUSH > TO CLOSE
			RELAY COMM FAIL
			PUSH > TO CLOSE
			RELAY SCHEME INOP
		LOOPBACK TEST ADDRESS	ON OR OFF
IDENTIFIERS	USER IDENT	{display value}	{Character Set}
	MANUFACTURER SOFTWARE REF.	MAIN PROCESSOR	{display value}
		COMMS PROCESSOR	{display value}
		LFCB 102 50Hz 2 ENDS	

Figure 2b: LFCB 102 tree menu structure (continued)

The various positions of the menu have different purposes and these are as follows:

indications: these positions indicate the group or function position of the menu or the current state of a measurand or statistic. Where a value that is constantly changing is displayed, the display shall refresh with a new value once every second on the LCD and once every two seconds on the remote port.

settings: these positions indicate the current value of a relay setting and also allow the given setting to be changed. The indication of whether a change may be made is by means of an alternating up and down arrow after the setting value.

actions: these positions indicate that an action will be performed when the key is pressed. In most circumstances the action will be checked by the use of a confirmation press of the SET key. The menu will prompt the user to press the SET key if the action is to be carried out. If the ← key is pressed at this stage then the action will not be carried out. This prevents important commands from being executed inadvertently.

accepting: these positions are generally found after an update or ignoring of setting changes. The message displayed will remain on the LCD until the relevant accepting key is pressed (or the fifteen minute default time expires).

2.1 Actions

Where certain commands are to be actioned the menu will indicate that the → key should be pressed. In some commands there is a check to confirm that the command is to be actioned. This requires the user to press the SET key.
Once actioned, the menu will return to the display that indicates the command may be performed.

2.2 Settings

The relay settings are found at the right hand edge of the menu in the relevant function. On entering the attribute level of the function the setting title, value and units will be displayed. This indicates the value of the setting when the function was entered unless it has been changed since. When a setting is being displayed, a further depression of the → key will cause an alternating up and down arrow to be displayed after the units. This indicates that the setting may now be changed. This is carried out by use of the ↑ and ↓ keys. If the ↑ key is pressed then the setting displayed shall increase to the next available value.

These steps are fixed in the relay. In the event of there being no higher setting available then the lowest setting shall be indicated. On depression of the ← key, the setting displayed at that time will be stored in a temporary location to be transferred to the actual relay setting at a later stage. This allows multiple settings to be changed, but all updated together. When the user attempts to leave the current group, if any of the temporary values are different to their corresponding actual settings then the menu prompts the user to press the SET key to update the setting changes. If the SET key is pressed then the temporary values will become the actual settings. The alternative to pressing the SET key is to use the RESET key to ignore the changes or the → key to move back into the group. If the changes are updated or ignored then a message to this effect is displayed on the LCD.
A list of the setting ranges and steps is given in Section 8.

2.3 Alarms

In the event of an alarm, the ALARM lamp will flash to indicate there is an outstanding alarm. The LCD will flash 'ALARM' whenever the menu is at the default level. If the ACCEPT/READ key is pressed at this point, the first alarm will be displayed on the LCD. The alarms shown during this cycle will include those that have occurred previously but that have not been reset. When this alarm scan option is entered, the user must complete the scan before being allowed to return to default level.

Once all the new alarms have been accepted the ALARM lamp becomes steady. At this point a further depression of the ACCEPT key will bring up the message requesting a RESET key to clear the alarms. If the alarms are cleared then the ALARM lamp will extinguish and a message will indicate that the alarms have been cleared. If at the reset request message, the ACCEPT key is pressed then the menu returns to default level leaving the alarms accepted but not cleared. In this condition the ALARM lamp is steady and, at the default level in the menu the message 'ALARM' will be displayed. In the event of an alarm still being active when it is reset, the LCD will display a message indicating that some alarms are still active. Any alarms that were not active will be cleared.

When accepting alarms that contain phase information, these will only indicate the state of the trip condition at the time of the most recent alarm. In other words, if a differential trip occurs on the A phase and is cleared by the relay, an alarm "DIFFERENTIAL PHASE A" will be present in the relay. If some time later there is a B phase fault cleared by the relay, then accepting the alarms will indicate only the B phase fault. However, the A phase fault will still be recorded in the alarm and fault records. If the A phase fault is still present when the B phase fault occurs ie. a developing fault, then the alarm will indicate an AB fault.

In the event of the relay tripping, then the TRIP lamp will illuminate and will remain on until all outstanding trip alarms have been reset.

2.4 Setting scan

If the ACCEPT/READ key is depressed at the default level when no alarms are present then the LCD will display the internal settings of the relay. These settings are displayed one at a time with each depression of the READ key. The menu will return to the default level when either the last setting has been displayed or the RESET key is pressed. To alter settings, see appropriate section in this chapter.

2.5 EEPROM storage

The relay is equipped with EEPROM storage for the settings and alarm/fault records. These EEPROM storage areas are updated whenever there is a change in setting or record. The values are loaded from the EEPROM whenever the relay is powered on. In this event the settings are checked to ensure that they are within the specified range. If the setting is out of range then the default value will be loaded. The default settings, the ranges and the steps are listed in Section 8. There is no direct check on the alarm/fault records and it is possible that some incorrect data may be present. The relay should issue an EEPROM check sum/setting alarm for these errors.

2.6 Remote access

The menu system is also available via the serial port. The serial port continually scans to find a remote log on command. This then allows the remote user to gain access to the menu. The displays on the remote terminal or computer are exactly the same as those on the LCD. This means that the user may interrogate and change the relay from a remote point subject to the relevant link being installed. The implementation of the port assumes that the terminal connected is an ANSI or VT100 type. This allows certain control characters to be used to control the screen in a similar manner to the LCD.

Most modern terminals and computers can emulate one of these types of operation. There is a simple protocol for the use of the remote terminal link. It operates as follows:

Commands begin with a line feed character [Control J] and end with a carriage return character. On receipt of the first character, the screen clears and displays the first character. The command is only interpreted after the carriage return is entered.

The remote port may only gain access to the menu when it is at the default position. If a character is entered at any other position, the remote port receives a message that the menu is unavailable. If an invalid command is entered then the port receives an invalid command message.

To log on the user should enter the command LOGON which will then prompt for entry of a password. This password is fixed and is only for limited security from unauthorised users. The password is GECMLFCB. Having entered the password, which does not begin with a line feed but ends with a carriage return, the relay will enter the menu in one of two ways. If the remote access code is set to LIMITED then the menu will display a message indicating this fact. The menu will be at default mode and will operate normally except that no operations that require confirmation, such as changing settings, clearing errors etc. will be allowed. If the remote access level is set to FULL then the relay will display the default level message and will operate completely as normal.

When the remote port is logged on, a message to this effect is displayed on the LCD and the keys are disabled. However, the user at the relay may override the remote port by depressing the RESET key continuously for two seconds. This will log off the remote port giving the relevant message to that port. If the remote port remains inactive for fifteen minutes then the menu will automatically log off the remote port and return control to the local keys. In this event an auto-logoff message is displayed on the remote port.

The user at the remote port may also log off when finished. This is accomplished by entering the command LOGOFF with the relevant linefeed and carriage return characters. This then returns control to the local keys.

When the user is logged on to the remote port, the implementation of the keys are as follows:

↑ key	8
↓ key	2
→ key	6
← key	4
SET key	5
RESET key	1
READ/ACCEPT key	3

7	8	9
4	5	6
1	2	3

These represent a similar layout to those on the front panel when using a numeric keypad.

Section 3. THE LFCB102 MENU

The LFCB102 menu is divided into nine groups and these are as follows:

(1) PRINT

(2) PROTECTION SETTINGS

(3) MEASUREMENTS

(4) PROTECTION ALARM RECORDS

(5) PROTECTION FAULT RECORDS

(6) COMMUNICATIONS

(7) CALENDAR CLOCK

(8) CONTROL

(9) IDENTIFIERS

3.1 Print

This group contains options to send information contained in the relay to either the parallel port or the serial port. On execution of the commands the relay checks the parallel port to determine if a printer is connected. If a parallel printer is connected, then the information will be displayed on that device, otherwise the information shall be sent to the serial device. When the print command is executed the display will indicate that printing is in progress. Once completed the display will return to the print option executed. However, in the case where a parallel printer has been connected, if the printer fails, runs out of paper or is disconnected then after a short delay the display will indicate printing has failed. In this event the ACCEPT key will return the display to the print option.

The functions available in this group are:

Print All Records

Print Settings

Print Alarm Records

Print Fault Records

Print Communications

These commands are executed by pressing the → key and do not require any confirmation.

The commands display a proportion of the data contained in the relevant group. The information is preceded by the title

LFCB RELAY:

followed by the relays user identifier and on the following line, the date and time of the command is displayed.

3.1.1 Printing all the records

Enter the menu structure until the display read :

PUSH → TO PRINT

ALL RECORDS

To print all the records press the → key at which time the display will show PRINTING IN PROGRESS. If the parallel printer is present it will print immediately. Otherwise the data will be sent to the serial port whether any device is connected or not.

3.1.2 Printing the settings

Enter the menu structure until the display read :

PUSH → TO PRINT

SETTINGS

To print the settings press the → key at which time the display will show PRINTING IN PROGRESS. If the parallel printer is present it will print immediately. Otherwise the data will be sent to the serial port whether any device is connected or not.

3.1.3 Printing the alarm records

Enter the menu structure until the display read :

PUSH TO → PRINT

ALARM RECORDS

To print the alarm records press the → key at which time the display will show PRINTING IN PROGRESS. If the parallel printer is present it will print immediately. Otherwise the data will be sent to the serial port whether any device is connected or not.

3.1.4 Printing the fault records

Enter the menu structure until the display read :

PUSH → TO PRINT

FAULT RECORDS

To print the fault records press the → key at which time the display will show PRINTING IN PROGRESS. If the parallel printer is present it will print immediately. Otherwise the data will be sent to the serial port whether any device is connected or not.

3.1.5 Printing the communications records

Enter the menu structure until the display read :

PUSH → TO PRINT

COMMUNICATIONS

To print the communications records press the → key at which time the display will show PRINTING IN PROGRESS. If the parallel printer is present it will print immediately. Otherwise the data will be sent to the serial port whether any device is connected or not.

3.2 Protection settings

This group contains options to set up the operating parameters of the relay.
The group is divided into two functions, these being Current Differential, which contains the settings for the threshold and bias of the differential curves, and the Permissive Intertrip, which contains the delay timer setting for this feature.

3.2.1 Reading/setting the I_{S1} threshold

Enter the menu structure until the display read:

THRESHOLD LEVEL

I_{S1} : 0.20 pu

To change the I_{S1} threshold setting, press the → key. The display will now add an alternating ↑ ↓ following the value. By operating the ↑ or ↓ keys the value can be incremented or decremented between 0.20 pu and 2.0 pu in 0.05 pu steps.

Note: see also Chapter 7 section 2.4

On completing the changes, Exit the menu structure by pressing :

SET to accept the changes

or RESET to reject the changes.

3.2.2 Reading/setting the I_{S2} threshold

The operator may change these values in a similar fashion to that above but by using the following additional keystrokes:

THRESHOLD LEVEL

I_{S2} : 2.00pu

To change the I_{S2} threshold setting, press the → key. The display will now add an alternating ↑ ↓ following the value. By operating the ↑ or ↓ keys the value can be incremented or decremented between 0.20 pu and 2.0 pu in 0.05 pu steps.

3.2.3 Reading/setting the k_1 setting

The operator may change these values in a similar fashion to that above but by using the following additional keystrokes:

PERCENTAGE BIAS

k_1 : 30%

To change the k_1 setting, press the → key. The display will now add an alternating ↑ ↓ following the value. By operating the ↑ or ↓ keys the value can be incremented or decremented between 0.20 pu and 2.0 pu in 0.05 pu steps.

3.2.4 Reading/setting the k_2 threshold

The operator may change these values in a similar fashion to that above but by using the following additional keystrokes:

PERCENTAGE BIAS

k_2 : 150%

To change the k_2 setting, press the → key. The display will now add an alternating ↑ ↓ following the value. By operating the ↑ or ↓ keys the value can be incremented or decremented between 0.20 pu and 2.0 pu in 0.05 pu steps.

3.2.5 Reading/setting the PIT setting

Enter the menu structure until the display read :

TIME SETTINGS

PIT : 100ms

To change the PIT setting, press the → key. The display will now add an alternating ↑ ↓ following the value. By operating the ← or [keys the value can be incremented or decremented between 0ms and 200ms in 5ms steps.

Note : see also Chapter 7 section 2.4

On completing the changes, Exit the menu structure by pressing :

SET to accept the changes

or RESET to reject the changes.

3.3 Measurements

This group contains options to display the rms phase current magnitudes and the phase sequence components of the current. The group is divided into six functions, the first three being the A, B and C phase currents and the last three being the positive, negative and zero sequence currents. By entering the phase current functions the attribute level indicates the magnitudes of the relevant local, remote, differential and bias currents in per unit values. The local sequence component currents are displayed in per unit values at the function level.

All the preceding values are sampled once a second and averaged over four samples.

If the communication from the remote end has failed, then the remote current metering data will be replaced by the message: DATA UNAVAILABLE.

3.3.1 Displaying the A phase current magnitudes

Enter the menu structure until the display read :

LOCAL

0.00 pu

The value of the current will be updated once a second on the LCD or once every two seconds on the remote port.

The operator can return to the default display by pressing the ← key three times. To display the remaining A phase currents the operator can use the ↓ key as follows:

	Display =	LOCAL 0.00 pu
PRESS ↓	Display =	REMOTE 0.00 pu
PRESS ↓	Display =	DIFF 0.00 pu
PRESS ↓	Display =	BIAS 0.00 pu

The B phase and C phase current magnitudes can be displayed similarly to the A phase current magnitudes.

3.3.2 Displaying the phase sequence current magnitudes

Enter the menu structure until the display read :

I1

0.00 pu

The value of the current will be updated once a second on the LCD or once every two seconds on the remote port.

The operator can return to the default display by pressing the ← key twice.
To display the remaining sequence currents the operator can use the ↓ key as follows:

	Display =	I1
		0.00 pu
PRESS ↓	Display =	I2
		0.00 pu
PRESS ↓	Display =	I0
		0.00 pu

3.4 Alarm records

This group contains the information about the last ten alarms which occurred in the relay. When a new alarm occurs the oldest alarm is discarded and the remaining nine are shifted down one space. The information about an alarm consists of the following:

The time and date of the alarm.

Whether the relay was in or out of service at the time that the alarm occurred.

The type of the alarm.

The details of the alarm.

A list of the possible alarms and the details involved is given in Section 6.

On entering the alarm group the message 'NO ALARMS' will be displayed if there are no alarms recorded, otherwise the most recent alarm will be displayed.
The first information displayed is the time and date of the alarm. Also the alarm number is displayed. This number is from one to ten inclusive with one the most recent and ten the oldest alarm stored. The status of the relay at the time of the alarm is indicated by a symbol before the alarm number. If the relay was in service then the symbol is a #, otherwise it is **.

The next information displayed is the type and details of the alarm. The alarm type is shown on the top line of the display and the details on the bottom line. In the event that several alarms of the same type occur in the same second then they are recorded as one alarm but detailed in the alarm details. These may be displayed by using the ↑ and ↓ keys which leave the type on the top line and step through the details on the bottom line.

If the relay makes a trip decision for a differential fault, and the relay also receives a differential intertrip decision from the remote end then the latter alarm record will be blocked to prevent duplication of the same fault. In other circumstances the differential intertrip record will be logged as normal.

3.4.1 Displaying the alarm records

Enter the menu structure until the display read :

ALARM HH : MM : SS

#1 1988 Jan 01

This shows the operator the time and date of the most recent alarm.

To display the type and details the operator should proceed as follows:

PRESS →	Display =	DIFF PROT TRIP PHASES ABC

The above display indicates that this alarm was that of a 3 phase differential trip.

In certain alarms there may be more than one detail. These can be displayed using the above keystrokes and the following:

	Display	ALARM HH:MM:SS X1 1988 Jan 01
PRESS →	Display	COMM CHAN FAILED CHAN 1 RX FAIL
PRESS ↓	Display	COMM CHAN FAILED CHAN 1 TX FAIL

Up to ten alarms may be displayed and this is achieved as follows:

	Display =	ALARM #1	HH:MM:SS 1988 Jan 01
PRESS ↓	Display =	ALARM #2	HH: MM:SS 1988 Jan 01
PRESS ↓	Display =	ALARM #3	HH: MM:SS 1988 Jan 01
PRESS ↓	Display =	ALARM #4	HH: MM:SS 1988 Jan 01
PRESS ↓	Display =	ALARM #5	HH: MM:SS 1988 Jan 01
PRESS ↓	Display =	ALARM #6	HH: MM:SS 1988 Jan 01
PRESS ↓	Display =	ALARM **7	HH: MM:SS 1988 Jan 01
PRESS ↓	Display =	ALARM **8	HH: MM:SS 1988 Jan 01
PRESS ↓	Display =	ALARM #9	HH: MM:SS 1988 Jan 01
PRESS ↓	Display =	ALARM #10	HH: MM:SS 1988 Jan 01

Note that alarms 7 and 8 have ** where the others have #. This indicates that the relay was out of service when alarms 7 and 8 occurred.

3.5 Fault records

This group contains the information about the last three faults that occurred in the relay. When a new fault occurs the third fault is discarded and the remaining two are shifted down one space.

The information about a fault consists of the following:

The time and date of the fault.

Whether the relay was in or out of service at the time that the fault occurred.

The type of the fault.

The details of the fault.

The magnitudes of the phase currents at the time that the fault occurred.

A list of the possible faults and the details involved is given in Section 6.

On entering the fault group the message 'NO FAULTS' will be displayed if there are no faults recorded, otherwise the most recent fault will be displayed. The first information displayed is the time and date of the fault. Also the fault number is displayed. This number is from one to three inclusive with one the most recent and three the oldest fault stored. The status of the relay at the time of the fault is indicated by a symbol before the fault number. If the relay was in service then the symbol is a #, otherwise it is **.

The next information displayed is the type and details of the fault.

This information is followed by the phase current magnitudes at the time of the fault. The first value displayed is that of the A phase local current followed by the B and C phase local currents. These are followed by the A, B and C phase remote, differential and bias currents in the same sequence. The user may display the various currents by using the ↑ and ↓ keys.

The magnitudes of the currents displayed are those measured at a time of about $^{3}/_{4}$ cycle after the relay decided to trip. This is done to allow the measured fault currents to reach their steady state values so that the fault record can be more representative of the fault.

In the event of the relay making a trip decision for a differential fault, if the relay also receives a differential intertrip decision from the remote end then the latter fault record shall be blocked to prevent duplication of the same fault. In other circumstances the differential intertrip record will be logged as normal.

3.5.1 Displaying the fault records

Enter the menu structure until the display reads:

FAULT HH : MM : SS

#1 1988 Jan 01

This shows the operator the time and date of the most recent fault. To display the type and details the operator should proceed as follows:

PRESS →	Display =	DIFFERENTIAL PHASES ABC

The above display indicates that this fault is a three phase differential trip.

The operator may display the fault current magnitudes for this fault as follows:

	Display	=	DIFFERENTIAL	PHASES ABC
PRESS →	Display	=	LOCAL IA MAG	3.11.pu
PRESS ↓	Display	=	LOCAL IB MAG	3.13pu
PRESS ↓	Display	=	LOCAL IC MAG	3.10pu
PRESS ↓	Display	=	REMOTE IA MAG	1.45pu
PRESS ↓	Display	=	REMOTE IB MAG	1.45pu
PRESS ↓	Display	=	REMOTE IC MAG	1.44pu
PRESS ↓	Display	=	DIFF IA MAG	1.67pu
PRESS ↓	Display	=	DIFF IB MAG	1.68pu
PRESS ↓	Display	=	DIFF IC MAG	1.66pu
PRESS ↓	Display	=	BIAS IA MAG	2.28pu
PRESS ↓	Display	=	BIAS IB MAG	2.29pu
PRESS ↓	Display	=	BIAS IC MAG	2.26pu

Up to 3 fault records may be displayed in a similar manner to the alarms in the pervious section.

3.6 Communications

This group contains functions that indicate statistics of the communication channel and also settings relevant to the channel.

The functions available on entering the communications group are as follows:

Error Statistics

Propagation Delay

Comm Fail Timer

The error statistics function contains the crc error, lost message and valid message statistics. These are displayed by use of the ↑ and ↓ keys.

The propagation delay function allows the user to display the propagation delay from one relay to the other and to set a tolerance for the delay to allow rejection of inconsistent messages. The propagation delay value is sampled once a second and averaged over four samples.

If the communication link fails in either direction then the propagation delay time will be shown as **.

The comm fail timer is a setting that allows the user to set the time that a communication failure should exist before the alarm for comm supervision is raised.

3.6.1 Displaying the error statistics

Enter the menu structure until the display reads :

ERROR
STATISTICS
CRC ERRORS
CHAN 1 : 0

LOST MESSAGES
CHAN 1 : 0
VALID MESSAGES
CHAN 1 : –0

Note that the communication statistical values are displayed in hexadecimal format (base 16).

3.6.2 Displaying the propagation delay and displaying/setting the delay tolerance

Enter the menu structure until the display reads:

PROPAGATION
DELAY TIME
DELAY TIME
CHAN 1 : 2.8 ms

Enter the menu structure until the display reads:

DELAY TOLERANCE

250s

To change the delay tolerance setting, press the → key. The display will now add an alternating ↓ ↑ following the value. By operating the ↑ or ↓ keys the value can be incremented or decremented between 250µs and 1000µs in 50µs steps.

Note : see also Chapter 7 section 2.4

On completing the changes, Exit the menu structure by pressing :

SET 4 to accept the changes

or RESET to reject the changes.

3.6.3 Displaying/setting the communication fail timer

Enter the menu structure until the display reads:

COMM FAIL TIMER

9.9secs

To change the comm fail time setting, press the → key. The display will now add an alternating ↓ ↑ following the value. By operating the ↑ or ↓ keys the value can be incremented or decremented between 0.1s and 9.9s in 0.1s steps.

Note : see also Chapter 7 section 2.4

On completing the changes, Exit the menu structure by pressing :

SET to accept the changes

or RESET to reject the changes.

3.6.4 Displaying/setting the relay address

Enter the menu structure until the display reads:

RELAY ADDRESS

0.0

To change the comm fail time setting, press the → key. The display will now add an alternating ↓ ↑ following the value. By operating the ↑ or ↓ keys the value can be incremented or decremented between 1A, 1B.......6A, 6B.

Note : see also Chapter 5 section 4

On completing the changes, Exit the menu structure by pressing :

SET to accept the changes

or RESET to reject the changes.

3.7 Calendar clock

This group allows the user to set and display the real time calendar clock in the relay. The group is divided into two functions, one to display the date and time and the other to set up the various constituents. The time which is set up is implemented when the user leaves the set time portion of the group.

The date and time is defaulted to 1 January 1980 00:00:00 on power-up. The 'CURRENT DIFFERENTIAL' message will also be replaced by the 'date and time not set' message until the calendar clock is set.

3.7.1 Displaying the calendar clock

Enter the menu structure until the display reads:

READ TIME & DATE

1988 Jan 01

01 : 01 : 01

3.7.2 Setting the calendar clock

Enter the menu structure until the display read :

SET TIME & DATE

SET YEAR 1980

To change the year press the → key. The display will now add an alternating ↓ ↑ following the value. By operating the ↑ or ↓ keys the value can be incremented or decremented between 1980 and 2079.

By operating ← the key the user moves out of the change mode and may move to the other elements in the date and time as follows:

	Display	=	SET YEAR	1980
PRESS ↓	Display	=	SET MONTH	Jan
PRESS ↓	Display	=	SET DAY	1
PRESS ↓	Display	=	SET HOURS	1
PRESS ↓	Display	=	SET MINUTES	1
PRESS ↓	Display	=	SET SECONDS	1

These may each be changed by operating the → key at the relevant item and following the same procedure as changing the year.

The date and time set in this manner will be transferred to the relay clock as the user moves back to the SET TIME & DATE display by operating the ← key. This gives a means of synchronising the time.

Note that the date is checked for validity when exiting the command after the day is changed. If the day is greater than that allowed for the month, then the day will be set to the last day in the month.

3.8 Control

This group contains six functions which allow the user to carry out commands to clear recorded information, to set up operating control parameters, and to carry out test options on the relay. The group is divided as follows:

Clear Records
Serial Port Data
Clock Sync Data
Remote Access Level
Scheme Logic
Test Options

The clear record function allows the user to clear the communication statistics, the alarm records and the fault records. Each of these is carried out by depressing the → key but, as a security measure against inadvertent clearing, the user is prompted to press the SET button to confirm the command. These commands allow the user to put the relay into a cleared state.

The serial port data function allows the user to display and set the serial port data communication rate and the bit framing. This allows for various types of serial devices to be connected to the relay serial port.

The sync clock data function allows the user to display and set up the time interval for an external synchronising pulse to be applied to the relay. This then allows the relay to synchronise the internal clock to the time signal.

The remote access level function allows the user to set whether the remote port has the ability to carry out any of the commands that require confirmation. This can prevent persons from tampering with the relay settings etc.

The scheme logic function allows the user to select the modes of operation of the block auto-reclose and trip outputs. The block auto-reclose setting allows the user to select blocking auto-reclose on permissive intertrip only, or blocking auto-reclose on either permissive intertrip or three phase faults. The tripping mode setting allows the user to select single-pole tripping or three-pole tripping for the Trip A, Trip B and Trip C output contacts.

The test options allow the user to check the operation of the opto-isolated inputs of the relay, test the front panel lamps and to test the operation of the relay outputs.

On entering the test options function the current state of the opto-inputs is displayed. The user may then energise these inputs to confirm that they are working correctly. The testing of the remote reset input will indicate the operation of the input if no alarms are present but will give the remote alarms cleared message if any alarms are present when the input is energised. All the other inputs will carry out their normal functions.

The next test option available is the lamp test option which illuminates the TRIP, ALARM and OUT OF SERVICE lamps and extinguishes the RELAY HEALTHY lamp when the → key is depressed.

The other test option is the relay contact test option which allows the user to operate the relay output contacts. Since the operation of these contacts could have external implications the relay must be locally switched out of service before the user is allowed to select the commands.

If the relay is not locally switched out of service then the command will not be accepted and the message ‘relay must be out of service’ will be displayed.

The message may be cleared by pressing the key. Once in the option the user may select the contact function to be tested. The command is selected by depressing the → key and is confirmed by pressing the SET key. The contact shall remain in the test position until the user releases the SET key. The contacts take up the abnormal position of operation i.e. normally energised contacts drop-off and normally de-energised contacts pick-up.

3.8.1 Clearing the communication statistics

Where the user is interested in doing some statistical analysis of the communications channel, it may be required to clear the current error statistics.

Enter the menu structure until the display read :

PUSH → TO CLEAR

COMMS

PUSH SET UP

CONFIRM COMMAND

If the user operates the "SET" key then the error statistics will be set to zero. If the key is operated then the error statistics will be left as they were.

3.8.2 Clearing the alarm and fault records

Enter the menu structure until the display reads:

PUSH → TO CLEAR

COMMS

PUSH → TO CLEAR

ALARMS

PUSH → TO CLEAR

FAULTS

If the user operates the → key and then "SET" key at the latter two positions then the relevant records will be set to zero. If the ← key is operated when the confirm command message is displayed then the relevant records will be left as they were.

3.8.3 Displaying/setting the serial port format

It may be necessary for the speed and set-up of the serial port interface to be changed for differing interfacing equipment.

Enter the menu structure until the display reads:

SERIAL PORT DATA

BAUDRATE

2400

BIT FRAMING

8 NONE 1

The values of these serial port settings may be changed by operating the → key at the relevant display. The display will now add an alternating ↓ ↑ following the value. By operating the or keys the value can be incremented ↑ or ↓ decremented between the relevant limits as described in Section 8.3.

Note : see also Chapter 7 section 2.4

On completing the changes, Exit the menu structure by pressing :

SET 4 to accept the changes

or RESET to reject the changes.

3.8.4 Displaying/setting the clock synchronising period

If an external synchronising pulse is used to keep the relay clock synchronised, it may be required to set the period between these pulses.

Enter the menu structure until the display reads:

CLOCK SYNC

TIME 30mins

To change the clock sync setting, press the → key. The display will now add an alternating ↓ ↑ following the value. By operating the ↑ or ↓ keys the value can be incremented or decremented between the limits given in Section 8.3.

Note : see also Chapter 7 section 2.4

On completing the changes, Exit the menu structure by pressing :

SET 4 to accept the changes

or RESET to reject the changes.

3.8.5 Displaying/setting the remote port access level

When the remote access facilities of the relay are used, a selection must be made to the security level of the remote port. The relay thus provides facilities to set the security level of the remote port.

Enter the menu structure until the display reads:

REMOTE ACCESS

LIMITED

To change the remote access setting, press the → key. The display will now add an alternating ↓ ↑ following the value. By operating the ↑ or ↓ keys the value can be toggled between LIMITED and FULL.

Note : see also Chapter 7 section 2.4

On completing the changes, Exit the menu structure by pressing :

SET 4 to accept the changes

or RESET to reject the changes.

3.8.6 Displaying/setting the block auto-reclose mode

Enter the menu structure until the display reads:

BLOCK A/R ON :

PIT TRIP

To change the block auto-reclose operating mode, press the → key. The display will now add an alternating ↓ ↑ following the value. By operating the ↑ or ↓ keys the value can be toggled between PIT TRIP and PIT & 3PH FAULT.

Note : see also Chapter 7 section 2.4

On completing the changes, Exit the menu structure by pressing:

SET 4 to accept the changes

or RESET to reject the changes.

3.8.7 Displaying/setting the tripping mode

Enter the menu structure until the display reads:

TRIPPING MODE :

SINGLE - POLE

To change the relay tripping mode, press the → key. The display will now add an alternating ↓ ↑ following the value. By operating the ↑ or ↓ keys the value can be toggled between SINGLE-POLE and THREE-POLE.

Note : see also Chapter 7 section 2.4

On completing the changes, Exit the menu structure by pressing :

SET to accept the changes

or RESET to reject the changes.

3.8.8 Displaying the opto-isolated input status

This facility is provided in order to check the status of the opto-isolated inputs of the relay is provided and may be displayed using the user interface as follows:

Enter the menu structure until the display reads:

OPTO - INPUT STATES

0 0 1 0 1 0

If the opto-input is energised it will indicate a 1 otherwise it will indicate a 0.

The opto-isolated inputs as listed from left to right are as follows:

1) Inhibit Trip/Alarm Outputs
2) Reserved (not used in the LFCB102)
3) Initiate Permissive Intertrip
4) Initiate Intertrip
5) Reset Indication and Alarm
6) Time Sync

In the event of the 'Reset Indication and Alarm' input being operated whilst in the OPTO-INPUT STATE display then the menu will return to the default display and display a message if there are some current alarms, otherwise it will remain where it is.

3.8.9 Using the lamp test option

There is a facility to test the lamps on the front panel of the relay and this is available using the user interface as in Section 3.8.8 for the opto-isolated inputs and in addition the following:

	Display =	OPTO-INPUT STATES 0 0 1 0 1 0
PRESS	Display =	PUSH → FOR LAMP TEST

At this point if the user presses the ➔ key then the TRIP, ALARM and OUT OF SERVICE lamps will illuminate and the RELAY HEALTHY lamp will extinguish until such time as the user releases the ➔ key.

3.8.10 Using the contact test option

In several circumstances it is useful to be able to cause the output contacts to close without generating the relevant condition.

Enter the menu structure until the display reads:

CONTACT

TEST

The user may enter the CONTACT TEST option by operating the ➔ key.

The display will be as follows:

PUSH ➔ TO CLOSE

RELAY INOP

To test the relay inoperative contact the ➔ key should be operated. If the relay has not been inhibited locally, ie. out of service, then the message "relay must be out of service" will be displayed. In this event the ← key must be pressed. If the relay was inhibited then the command will be accepted. As a security measure against inadvertent operation, a message will be displayed requesting the user to push the "SET" key to confirm the command:

push SET to
confirm command

At this point if the user presses the "SET" key then the contact will close and remain closed until such time as the key is released.

The other relay contacts may be tested using the user interface as described above with the following additions.

	Display	=	PUSH ➔ TO CLOSE RELAY INOP	
PRESS ↓	Display	=	PUSH ➔ TO CLOSE PROT OP A	
PRESS ↓	Display	=	PUSH ➔ TO CLOSE PROT OP B	
PRESS ↓	Display	=	PUSH ➔ TO CLOSE	PROT OP C
PRESS ↓	Display	=	PUSH ➔ TO CLOSE	TRIP
PRESS ↓	Display	=	PUSH ➔ TO CLOSE	TRIP B
PRESS ↓	Display	=	PUSH ➔ TO CLOSE	TRIP C
PRESS ↓	Display	=	PUSH ➔ TO CLOSE	ANY TRIP
PRESS ↓	Display	=	PUSH ➔ TO CLOSE	INTERTRIP
PRESS ↓	Display	=	PUSH ➔ TO CLOSE	BLOCKA/R
PRESS ↓	Display	=	PUSH ➔ TO CLOSE SUPERVISION	COMM
PRESS ↓	Display	=	PUSH ➔ TO CLOSE INOP	SCHEME

3.9 Identifiers

This group contains functions to identify the particular relay. The group contains two functions, one the user identifier and the other the manufacturing identifiers. The user may set the user identifier to be any 32 character combination of alphanumeric and certain punctuation characters. This identifier will be output with any print option used. The manufacturer software references are factory set to identify the version of the relay software and are not setable by the user.

To set the user identifier, the user moves into the setting display as previously. However in this case the alternating arrow is replaced by a block character alternating with the first character of the identifier. This indicates that the ↑ and ↓ keys will change the first character. Use of the ← and → keys allows the user to move the block over the character to be changed. The ↑ and ↓ keys step the character through the ASCII table as given in Section 8.4. Once the user is happy with the identifier displayed, moving the cursor block past the leftmost character on the top line will move out of the setting mode. Again, the user will be given the choice of ignoring or updating the setting when leaving the group.

It should be noted that the → key will in fact move the block past the 32nd character and back to the beginning although obviously the reverse is not true for the ← key.

3.9.1 Displaying/setting the user identifier

Enter the menu structure until the display read :

USER IDENTIFIER

NO INDENTIFIER

DEFINED

The relay is dispatched with the above user identifier.

To edit the character string from the above position the following should be carried out. If the → key is operated then the first character of the display will begin to flash, alternating between the current character and a block. If the → key is operated again until the character to be edited is flashing, then that character may be changed by use of the ↑ and ↓ keys.

For example:

If the user identifier is currently set to

GEC S[U]BSTATION

400kV LINE 1

and the → key is pressed until the block is alternating with the U and then the ↓ key is operated, the display will now be

GEC S[V]BSTATION

400kV LINE 1

If the ↑ key is now operated the display will return to

GEC S[U]BSTATION

400kV LINE 1

Using this method any of the 32 characters may be set to any of the characters listed in the ASCII table in Section 8.4.

Once the user is satisfied with the display then the block should be positioned at the first character either by repeated use of the ← key or of the → key.

At this point an operation of ← the key will remove the block from the display.

On completing the changes, Exit the menu structure by pressing :

	SET	to accept the changes
or	RESET	to reject the changes.

Section 4. GENERAL POINTS ON THE USER INTERFACE OPERATION

The user should generally be able to return to the default level display by repeated operation of the ← key. If there is a current setting change and the message:

push SET to

update changes

is displayed then pressing the RESET key will abort the changes and further operations of the ← key will return to the default display.

As the user becomes familiar with the operation of the menu and the movement within the menu tree structure then it is not necessary to always return to the default level for each option. For example if the user is displaying the communication error statistics and wishes to change the comm fail timer then the following steps could be used.

	Display	=	VALID MESSAGES CHAN 1 : ED1234
PRESS ←	Display	=	ERROR STATISTICS
PRESS ↑	Display	=	ALARM TIME
PRESS →	Display	=	COMM FAIL TIMER 9.2 secs

Generally if the display contains a warning or information message it can be cleared by use of the ACCEPT/READ key. If this is not successful then the ← or → keys should clear it.

Section 5. MESSAGES

There are various messages which may occur during the use of the menu system. These messages are listed here with their respective meanings and alternative actions that must follow.

push SET to update changes	–	occurs when leaving the group in which a setting has been changed. Options are → to re-enter the group, SET to update and RESET to ignore.
all changes ignored	–	occurs after setting changes are aborted. Option available is ← which moves out of the group.
all changes updated	–	occurs after setting changes are updated. Option available is ← which moves out of the group.

push SET to confirm command	–	occurs when an action is to be performed and a validity check is implemented. Options are set to carry out the action or ← to abort the action.
push RESET to clear alarms	–	occurs when using ACCEPT key to accept alarms and there are no more alarms to accept. Options are RESET key to reset all alarms or ACCEPT key to leave alarms accepted but not reset.
some alarms are still active	–	occurs following an alarm reset when there are still alarms present Option is ACCEPT key, which returns menu to default.
all alarms cleared	–	occurs when all alarms are reset successfully. Option is ACCEPT key which returns to default.
remote alarm reset	–	occurs when the remote alarm reset opto-input is energised. Option is ACCEPT key which returns to default.
NO ALARMS	–	occurs when entering the alarm records group and there are no stored records. Option is ← key to leave the group.
NO FAULTS	–	occurs when entering the fault records group and there are no stored records. Option is ← key to leave the group.
relay must be out of service	–	occurs when attempting to execute the relay contact test command when the relay is not out of service. Option is ← key to return to the contact test command.
date and time not set	–	displayed at default level when there are no alarms and the date and time have not been set.
printing in progress	–	occurs when data is being sent to the parallel or serial port using the print command. Cleared when printing is completed.
printing has failed	–	occurs when parallel printer fails or runs out of paper. Option is ACCEPT key which returns to the print command.

The following are messages pertaining to the use of the remote port.
These messages occur on the remote port unless indicated otherwise.

invalid command	–	occurs when a carriage return is entered and the command does not conform to any recognised command. Option is to enter a correct command or if logged on, use one of the arrow keys.
relay being used locally	–	occurs when any character is entered while the relay is being accessed through the front panel interface and the menu is not at the default position. Option is to wait until the menu is at the default level and re-enter the command.
already logged on	–	occurs when entering a LOGON command when the relay is already logged on.
already logged off	–	occurs when entering a LOGOFF command when the relay is already logged off.

auto log off	–	occurs when either the port is inactive for fifteen minutes or the port is overridden by the RESET key. Option is to log on again.
remote port logged on	–	this message appears on the LCD when the remote port logs on. The message remains displayed until the port logs off. Options are wait until the message disappears or press RESET key for two seconds to gain access and log off the remote port.

Section 6. TYPES AND DETAILS OF ALARMS AND FAULTS

6.1 Alarms

The following alarm messages may occur when accepting alarms using the ACCEPT/READ key. In certain circumstances more detail on the alarm is contained in the alarm record.

DIFF PROT TRIP	–	differential trip originating in local relay.
DIFF INTERTRIP	–	differential trip originating in remote relay.
with details of:		
PHASES ABC	–	phase information for the above message.
LOCAL END FAIL	–	the local relay has failed.
with details of:		
PROC OUT OF SYNC	–	the main processor and comm processor in the relay have not been exchanging data correctly.
PROT SCHEME FAIL		the protection scheme has failed. This occurs if a comms link has failed or one of the relays has failed.
COMM CHAN FAILED	–	the communication channel has failed.
with details of:		
CHAN 1 FAILED		
PERMISSIVE TRIP	–	the local relay has tripped in response to the enable signal from the remote end and sufficient current at the remote end.
EEPROM ERROR	–	an error has occurred within the EEPROM storage of the relay.
with details of:		
SETTING	–	one or more of the relay settings is out of range and has been set to the default value.
CHECK SUM	–	the check sum of the EEPROM is incorrect. An incorrect piece of data is indicated.

For the alarm records the following additional details apply.

PROT SCHEME FAIL

with details of:

COMM FAILED – one of the comms channels has failed.

LOCAL END FAIL – the local relay has failed.

REMOTE END FAIL – the remote relay has failed.

COMM CHAN FAILED

with details of:

CHAN 1 RX FAIL – the local relay has failed to receive any messages. This alarm may indicate that the remote relay is not sending any messages and should appear at the same time as a TX FAIL at the remote end.

CHAN 1 TX FAIL – the remote relay is not receiving any messages. This alarm may indicate that the local relay may not be sending any messages and should appear at the same time as a RX FAIL at the remote end.

6.2 Faults

The following fault types apply in the fault records.

DIFFERENTIAL – a differential protection trip by the local relay.

DIFF INTERTRIP – a differential protection intertrip by the remote relay.

The fault records indicate the fault current magnitudes as follows.

LOCAL IA MAG

LOCAL IB MAG

LOCAL IC MAG

REMOTE IA MAG

REMOTE IB MAG

REMOTE IC MAG

IA DIFF

IB DIFF

IC DIFF

IA BIAS

IB BIAS

IC BIAS

Section 7. SAMPLE PRINT-OUTS

The following indicate sample printouts originating from the print options of the menu.

7.1 Print settings

LFCB RELAY : 400kV FAWLEY – NURSLING LINE 1

Printed on 1988 Jan 05 13:43:23

SETTING DATA

ITEM	VALUE		
THRESHOLD LEVEL	IS1	:	0.20 pu
PERCENTAGE BIAS	k1	:	30%
THRESHOLD LEVEL	IS2	:	2.00 pu
PERCENTAGE BIAS	k2	:	150%
TIME SETTING	PIT	:	100ms
DELAY TOLERANCE		:	250µs
COMM FAIL TIMER		:	9.9s
BAUDRATE		:	2400
BIT FRAMING		:	8 NONE 1
CLOCK SYNC PERIOD		:	30 mins
REMOTE ACCESS		:	LIMITED
BLOCK A/R ON		:	PIT TRIP
TRIPPING MODE		:	SINGLE-POLE

7.2 Print alarms

LFCB RELAY : 400kV FAWLEY – NURSLING LINE 1

Printed on 1988 Jan 05 13:43:23

ALARM RECORDS

DATE	TIME	ALARM TYPE	DETAILS
1988 Jan 05	12:15:59	DIFF INTERTRIP	PHASE B
1988 Jan 05	12:15:14	DIFF PROT TRIP	PHASE ABC
**1988 Jan 05	12:13:25	DIFF INTERTRIP	PHASE B
1988 Jan 05	11:43:42	PERMISSIVE TRIP	
**1988 Jan 05	11:41:12	DIFF PROT TRIP	PHASE C
**1988 Jan 05	11:41:03	DIFF PROT TRIP	PHASE BC
1988 Jan 05	10:12:22	COMM CHAN FAILED	CHAN 1 RX FAIL
1988 Jan 05	10:12:22	PROT SCHEME FAIL	COMM FAILED
1988 Jan 05	10:09:09	E2PROM ERROR	SETTING ERROR
1988 Jan 04	18:12:34	LOCAL END FAIL	PROC OUT OF SYNC

7.3 Print faults

LFCB RELAY : 400kV FAWLEY – NURSLING LINE 1

Printed on 1988 Jan 05 13:43:23

FAULT RECORDS

DATE	TIME	FAULT TYPE	DETAIL
1988 Jan 05	12:15:59	DIFF INTERTRIP	PHASE B
PHASE A	PHASE B	PHASE C	
LOCAL	0.00 pu	0.00 pu	0.00 pu
REMOTE	0.00 pu	0.45 pu	0.00 pu
DIFF	0.00 pu	0.45 pu	0.00 pu
BIAS	0.00 pu	0.22 pu	0.00 pu

DATE	TIME	FAULT TYPE	DETAIL
1988 Jan 05	12:15:14	DIFFERENTIAL	PHASE ABC
PHASE A	PHASE B	PHASE C	
LOCAL	3.11 pu	3.13 pu	3.10 pu
REMOTE	1.45 pu	1.45 pu	1.44 pu
DIFF	1.67 pu	1.68 pu	1.66 pu
BIAS	2.28 pu	2.29 pu	2.26 pu

DATE	TIME	FAULT TYPE	DETAIL
1988 Jan 05	12:13:25	DIFF INTERTRIP	PHASE B
RELAY WAS OUT OF SERVICE AT FAULT			
PHASE A	PHASE B	PHASE C	
LOCAL	3.11 pu	5.13 pu	3.10 pu
REMOTE	3.10 pu	1.45 pu	3.11 pu
DIFF	0.01 pu	3.68 pu	0.02 pu
BIAS	3.11 pu	3.29 pu	3.11 pu

7.4 Print communications

LFCB RELAY : 400kV FAWLEY – NURSLING LINE 1

Printed on 1988 Jan 05 13:43:23

COMMUNICATIONS RECORDS

ERROR STATISTICS

CRC ERRORS	CHAN 1 : 2C
LOST MESSAGES	CHAN 1 : 5E
VALID MESSAGES	CHAN 1 : EA3241

PROPAGATION DELAY TIME

DELAY TIME	CHAN 1 : 2.8ms

Section 8. SETTING RANGES AND DEFAULT VALUES

8.1 Protection settings

TYPE	MINIMUM	MAXIMUM	STEP	DEFAULT
Threshold IS1	0.20 pu	2.00 pu	0.05 pu	0.20 pu
Bias k1	30%	150%	5%	30%
Threshold IS2	1.00 pu	30.00 pu	0.05 pu	2.00 pu
Bias k2	30%	150%	5%	150%
Time Setting PIT	0ms	200ms	5ms	100ms

8.2 Communication settings

TYPE	MINIMUM	MAXIMUM	STEP	DEFAULT
Delay Tolerance	250µs	1000µs	50µs	250µs
Comm Fail Time	0.1s	9.9s	0.1s	9.9s

8.3 Control settings

TYPE	STEP						DEFAULT
Baudrate	300	600	1200	2400	4800		300
Bit Framing	8N1	8E1	8O1	8N2	8E2	8O2	8N1
	7N1	7E1	7O1	7N2	7E2	7O2	
Clock Sync	5mins	10mins	15mins	30mins	60mins		30mins
Remote Access	LIMITED		FULL				LIMITED
Block A/R	PIT TRIP		PIT & 3PH FAULT				PIT TRIP
Tripping mode	SINGLE-POLE		THREE-POLE				SINGLE-POLE

8.4 ASCII table

The following is a list of ascii characters in the order they occur when setting the user identifier.

space	@	‘
!	A	a
“	B	b
#	C	c
$	D	d
%	E	e
&	F	f
‘	G	g
(	H	h
)	I	i
*	J	j
+	K	k
,	L	l
–	M	m
.	N	n
/	O	o
0	P	p
1	Q	q
2	R	r
3	S	s
4	T	t
5	U	u
6	V	v
7	W	w
8	X	x
9	Y	y
:	Z	z
;	[	
<	\	
=	]	
>	^	
?	_	

Digital Current Differential Relay Type LFCB 102

Chapter 8
Commissioning Instructions

Section 1. GENERAL

The LFCB 102 relay is a digital current differential relay suitable for two-ended feeder applications. The relay communicates with the relay at the remote end, transmitting and receiving digital information regarding the phase current vectors, and other status and command information. The relay is connected to local main current transformers (CT), computing the mean bias and differential current from the local and remote information and deciding whether or not to trip, dependent upon the relay settings.

The relay has opto-isolated status inputs to provide intertrip, permissive intertrip, alarm/indication reset, time sync and trip/alarm output inhibit facilities. The relay can be connected to a local printer to print out settings, alarm and fault records and reconfiguration interlock facilities. The relay can be interrogated remotely using a serial terminal. The relay also includes test facilities so that it can be tested using a computer aided test equipment.

The commissioning instructions which follow assume that the communication link between the ends has been separately commissioned.

For the first part of the commissioning procedure, the facilities of the relay are checked by secondary injection testing with the communication links to the remote relays disconnected and the local relay's transmitters looped back to their own receivers. The second part of the procedure is concerned with end to end tests and on load tests to ensure that the complete protection system is working satisfactorily.

During commissioning it may be found necessary to refer to other sections of the Service Manual as detailed below:

Chapter 1 – General Description
2 – Applications
3 – Installation and Handling
4 – Hardware Description
5 – Functional Description
6 – Software Description
7 – Operating Instructions
9 – Fault Finding Instructions
10 – Diagrams

Section 2. COMMISSIONING PRELIMINARIES

2.1 Handling of electronic equipment

Reference should be made to Chapter 3 which describes simple precautions to be taken before handling electronic circuits which may be sensitive to electrostatic voltage discharge. With the front panel closed, the relay is completely safe from electrostatic discharge.

Prior to commissioning the relay, it is necessary to open the front panel and inspect the relay modules. Before this inspection, the operator should touch the earthed panel to discharge any electrostatic voltages.

If modules are removed from the case, they should be handled by the front plate, frame or edges of the printed circuit boards to avoid contact with electrical components or connections. Always store and transport modules in electrically conductive anti-static bags.

If it is necessary to change the position of a jumper link, for example to change the RS232 serial communication from the front panel socket to the rear panel socket, then the module should be placed on an anti-static surface and a conductive wrist strap should be worn.

2.2 Earthing

Ensure that the case earthing terminal above rear terminal block H is used to connect the relay to the local earth bar.

2.3 Inspection

With no dc auxiliary voltage connected, carefully examine the relay to ensure that no damage has occurred during transit. Check on the front nameplate label that the model number and rating information are correct.

Vx(1) – Rated voltage of auxiliary supply to the power supply module.

Vx(2) – Rated voltage of auxiliary supply to the opto-isolated status inputs of the analogue/status input module.

Remove the relay cover and open the front panel by undoing the large screw on the right hand side of the front plate. The equipment label on the back of the front panel contains information on model number, serial number, firmware reference, external connection diagram number, outline diagram number, arrangement diagram number, and details of the front panel and modules fitted in the relay. Check that the module references are correct and the modules are fitted into the correct positions. Complete the commissioning test record details as printed.

2.4 Wiring

Check that the external wiring is correct to the relevant external connection diagram and/or scheme diagram. If a test block type MMLG is provided, the connections should be checked to the scheme diagram, particularly that the supply connections are to the 'live' side of the test block (coloured orange and with allocated odd numbered terminals 1, 3, 5, 7 etc.). The auxiliary supply voltage Vx(1) for the scheme should be routed via test block terminals 13 and 15.

2.5 Insulation

The insulation of the relay and its associated wiring may be tested between

(1)all electrically isolated circuits,

(2)all circuits and earth.

An electronic or brushless insulation tester having a voltage not exceeding 1000V dc should be used. Accessible terminals of the same circuit should first be strapped together. Deliberate circuit earthing links removed for the tests must be subsequently replaced.

The outgoing terminal allocation for the relay is shown on the external connection diagram. Note also that terminals F5, F6, G1 and G6 are internally connected to contacts F1/F3, F2/F4, G3/G5 and G2/G4 respectively. A spare power supply failure alarm contact is connected to terminals H3/H4.

2.6 Isolate contacts

Isolate the output trip contacts of the relay from operating the tripping circuits.

2.7 Electrical testing

DANGER

DO NOT OPEN CIRCUIT THE SECONDARY CIRCUIT OF A CURRENT TRANSFORMER SINCE THE HIGH VOLTAGE PRODUCED MAY BE LETHAL AND COULD DAMAGE INSULATION.

When type MMLG test block facilities are installed, it is important that the sockets in the type MMLB 01 test plug, which correspond to the CT secondary windings, are LINKED BEFORE THE TEST PLUG IS INSERTED INTO THE TEST BLOCK. Similarly, an MMLB 02 single finger test plug must be terminated with an ammeter BEFORE IT IS INSERTED to monitor CT secondary currents.

2.8 CT shorting switches

Check the relay CT shorting switches by opening the relay front panel, and withdrawing the right hand Analogue Input Module (GM0036_ _ _) by about 1cm to disconnect the relay CT and operate the CT shorting switches inside the relay case.

It may be necessary to disconnect the front ribbon cable connector to allow the module to come forward 1cm. To do this, release the top and bottom connector catches and carefully release the connector and ribbon cable.

Check the CT shorting switches by measuring a short circuit on the relay case terminals A21–A22, A23–A24, A25–A26, or from the test block if fitted.

Replace the module and ribbon cable, close the front panel and tighten the front panel screw.

Section 3. COMMISSIONING TESTS

The following test instructions are based on injecting current directly into the relay terminals. However if an MMLG test block is incorporated in the scheme, then it is more convenient to inject current into the MMLG test block. Refer to the relevant scheme diagram for connections.

3.1 Test equipment

2 x Multimeters (0 – 250V ac, 0–10A ac)

1 x Electronic timer

1 x Variable auto-transformer 220/240V ac rated 5A for In = 1A relays.
For In = 5A, use auto-transformer either rated at 25A short time, or rated 5A and used with 240/50V step down transformer rated 25A.

2 x Variable resistors 100/200 ohm rated 3A for In = 1A relays.

For In = 5A, use 10/20 ohm rated 15A short time.

1 x Double-pole switch

1 x Single-pole switch

2 x Communication local loop-back link (see Section 3.2 below)

1 x If required Optical power meter to measure the optical signal level (sensitivity 0 to –50 dBm), with suitable connections for the type of termination used, ie. SMA, FC, or ST.

1 x Optical power meter to measure the optical signal level if required (sensitivity –10 to –50 dBm).

1 x MMLB01 test plug for use with MMLG test block if fitted.

1 x MMLB02 single finger test plug for use with MMLG test block if fitted.

1 x Local visual display terminal (VDU), a serial printer, or a parallel printer, complete with a suitable lead, if required to check the communication facility.

3.2 Local communication loop-back

Before carrying out the following tests please ensure that the internal module links are set as per the customers requirements, particular attention should be paid to the links within the communications module GM0051 OR GM0052. See Chapter 4 for details.

3.2.1 Direct link

Link the local channel 1 Tx output with the local channel 1 Rx input, and local channel 2 Tx outputs with local channel 2 Rx input with two suitable communication loop-back links as detailed in Table 1. The relay will then respond as if it were connected a remote relay, with the current at the remote end equal to and in phase with the current injected at the local end. The differential current seen by the relay is therefore equal to twice the injected current and the relay will operate if the differential current exceeds the relay setting.

Note: For 1300nm fibres whether single mode or multi mode a suitably terminated single mode optical test lead may be used to provide the loop-back connection.

Communication interface	Loop-back link between Tx and Rx
Short distance 850nm optical (GM0052.nnn)	50/125μm optical test lead terminated with 9mm SMA connectors.
Medium distance 850nm optical (GM0052.nnn)	50/125μm optical test lead terminated with 9mm SMA connectors and with 3 – 12dB attenuation.
Long distance 850nm optical (GM0052.nnn)	50/125μm optical test lead terminated with 9mm SMA connections and with 9 – 25dB attenuation.
1300nm optical interface, single-mode (GM0028.nnn)	Optical test leads terminated with FC or ST connectors.
1300nm optical interface, multi-mode (GM0114.nnn)	Optical test leads terminated with FC or ST connectors.
1550nm optical interface, single-mode (GM0114.nnn)	Optical test leads terminated with FC or ST connectors.
G.703 electrical interface (GM0051.nnn)	Suitably wired DIN plug or wire links.

Table 1: Local communication loop-back Link

3.2.2 Loop-back via Interface unit type MITZ

The MITZ interface unit is housed in a size 4 MIDOS case. It is used when an LFCB relay is remote from the PCM multiplexer and a cross-site optical cable is used to link the LFCB relay with the multiplexer. The LFCB relay normally has the short distance optical interface. The MITZ unit is located near to the PCM multiplexer and provides bi-directional optical to electrical signal conversion.

3.2.3 MITZ 01

If the MITZ 01 interface unit is incorporated, it may be commissioned with the LFCB relay by following the next set of instructions.

Examine the MITZ case and module carefully to see that no damage has occurred during transit. Check that the interface unit serial number on the module front plate and inside the module case are identical and that the model number and rating information is correct.

For an MITZ 01 optical to G.703 co-directional interface unit, remove any external wiring and loop back the G.703 signals by connecting a wire link between terminals 3 and 7, and a second wire link between terminals 4 and 8. Connect the Tx and Rx optical cables from the LFCB relay to the interface unit. Both the LFCB and the MITZ use 9mm SMA type optical connectors.

Check the dc auxiliary voltage Vx of the interface unit and connect a suitably rated, smoothed dc supply or station battery supply to terminals 25 (positive) and 26 (negative). Switch ON the supply and check that the green LED mounted on the front plate turns ON. Return to the LFCB relay to continue the commissioning of both the relay and the interface unit.

3.2.4 MITZ 02

The MITZ 02 must be commissioned in conjunction with the LFCB protection equipment with which it is specified. The LFCB trip circuits should be isolated and cross-site optical cables connecting the LFCB to the MITZ should be connected to the optical devices of the LFCB.

3.2.4.1 Power supply

With the incoming dc supply OFF, disconnect the V.35 connection to the MITZ 02 and remove the polycarbonate front cover before removing the relay module from the case. The incoming supply should be checked at the relay case terminals. The upper terminal should be positive with respect to the lower terminal and the voltage must be within the operative range 19-300V dc, record the voltage.

CAUTION

The relay is designed to withstand an ac ripple component of up to ±12% of normal dc supply auxiliary voltage. However, in all cases the peak value of the dc supply must not exceed the maximum specified operating limit.

Operation of the supply battery charger with the batteries disconnected could cause damage due to overvoltage.

3.2.4.2 Energise relay.

Insert the module. Set the data rate switch according to the communication channel bandwidth available. Set all other switches to 0. Connect the dc supply. The green RELAY HEALTHY LED should illuminate together with the two red LED's labelled DSR OFF and CTS OFF, switch the DSR, the CTS and both OPTO and V.35 LOOP BACK switches to 1. The DSR and CTS LED's should be extinguished and the two LOOP BACK LED's should be illuminated. Switch the DSR, the CTS and the V.35 LOOP BACK switches back to 0.

3.2.4.3 Optical loop back

Measure the receive level of the optical signal from the LFCB. The mean level should be in the range –12 to –27dBm. Record the value and connect the optical fibre to the optical receiver of the MITZ. Measure the optical output power from the MITZ transmitter using the optical power meter and length of 50/125μm optical cable. The mean value should be in the range –20 to –21.5dBm. Record the value and connect the optical fibre to the optical transmitter of the MITZ. The LFCB LOOP BACK commissioning tests should now be carried out.

3.2.4.4 Connection to multiplexer

Connect the V.35 signal connector. Switch the OPTO LOOP BACK switch to 0. At this point all LED's except the green SUPPLY HEALTHY should be extinguished. If the DSR OFF and/or CTS OFF LED's are ON then follow the setting up instructions given in Section 3.6.1. (Publication R8102)

3.2.4.5 Remote relays

Repeat for all LFCB/MITZ 02 in the protection scheme. When all ends are connected to the multiplexing equipment , the CLOCK SWITCH setting may be changed if necessary. The CLOCK SWITCH setting should only be checked if the multiplexing equipment is to source the transmitter send timing, refer to Section 3.6.2 (R8102) for details.

3.2.4.6 Records

Replace the front cover and record the positions of all the switches on the front panel of the MITZ 02

3.3 DC auxiliary supply

Check the rated auxiliary supply voltage Vx(1) on the relay front nameplate label and connect a suitably rated, smoothed dc supply or station battery supply to relay terminals H13 (positive) and H14 (negative). Before switching ON the supply, check that the 'Power Supply Failure' alarm contact H5–H6 and the 'Relay Inoperative' alarm contact G3–G5 are closed.

Switch ON the supply and check the following:

(1)'Power Supply Failure' alarm contact H5–H6 is open.

(2)'Relay Inoperative' alarm contact G3–G5 is open after about 12s.

(3)The relay performs power-ON diagnostic checks as indicated by rapid report messages displayed on the front panel LCD.

(4)The power-ON diagnostic tests are completed after about 12 seconds.
The relay then switches ON the green RELAY HEALTHY lamp and displays one of the following messages on the LCD:

"date and time not set" or "***ALARMS***" after the default message "CURRENT DIFFERENTIAL"

If the message "*** **ALARMS** ***" is displayed and the ALARM (top amber) LED flashes or remains lit or the TRIP (red) LED remains lit, they may be related to alarm or trip conditions which were present when the relay was previously energised. These alarm and trip indications maybe reset by pressing the ACCEPT/READ key several times until the message "push RESET to clear alarms" appears on the LCD. Pushthe RESET key to clear the alarms and the LCD will then display "all alarms cleared". Push ACCEPT/READ once to bring the display back to "date and time not set".

If the alarms do not reset, this could be due to one of the following reasons: either the relay address setting has been changed from the factory setting "0–0" (check this by reference to 3.5.below), or the loop-back connection is unsatisfactory.

Push →↑↑→↑→←←← to simulate the push key sequence of setting the date and time and the LCD will display the default message "CURRENT DIFFERENTIAL".

Note: that the relay will revert to the default display message if no key is pressed for 15 minutes.

3.4 Software

Press	→	↑	→	↑	to display "MANUFACTURER SOFTWARE REF"
	→				record display "MAIN PROCESSOR ???????"
	↓				record display "COMM PROCESSOR ???????"
	←	←	←		to return to default display.

3.5 Relay settings

Table 2 summarises the ranges of relay settings and the default settings the relay was set to when leaving the factory.

Push ACCEPT/READ to read and check the settings one by one. At the end of the settings, push ACCEPT/READ once more to bring back the default message "CURRENT DIFFERENTIAL".

It may be required to change a particular setting, for example from single to three-pole tripping; if so refer to Chapter 7.

Setting type	Range	Factory setting
Threshold level I_{S1}	0.20 – 2.00In	0.20In
Percentage bias k_1	30 – 150%	30%
Threshold level I_{S2}	1.00 – 30.00In	2.00In
Percentage bias k_2	30 – 150%	150%
Permissive intertrip time PIT	0 – 200ms	100ms
Communication channel delay tolerance	250 – 1000µ	250µ
Communication channel failure alarm time	0.1 – 9.9s	9.9s
Relay address	0 – 0 to 6 – B	0–0
Serial port baud rate	300 – 4800 baud	300 baud
Serial port bit framing format	7/8 data bits Even/odd/no parity 1/2 stop bits	8 bits none 1 bit
Time synchronisation period	5/10/15/30/60 minutes	30 min
Remote access level for serial port	Full/Limited	Limited
Block auto-reclose mode	PIT trip/ PIT & 3PH fault	PIT trip
Tripping mode	Single-pole/ Three-pole	Single-pole
Loop-back test address	ON or OFF	OFF

Table 2: Setting ranges and factory settings

Change the relay address to that specified by the customer and set the loop-back test address "ON". Refer to the Chapter 7 for details.

Check that the green RELAY HEALTHY LED flashes with a cycle time of approximately 4 seconds, reset any alarms as described in 3.2 above. Note that the default message is "Loop-back test address on".

3.6 Test options

Press → ↑ ↑ → ↑ to display "TEST OPTIONS"

3.6.1 Lamp test

Push → ↓ to display " PUSH → FOR LAMP TEST". Push → constantly and check all 4 LED's turn ON and after one second the green

RELAY HEALTHY lamp goes OFF. Release the → key and check that the RELAY HEALTHY lamp turns ON and the other 3 lamps go OFF after a short while.

3.6.2 Status input test

Check the rated auxiliary voltage Vx(2) on the relay front nameplate label and have available a suitably rated smoothed dc supply or station battery supply.

Push ↑ and check the LCD as detailed in Table 3 below when injecting voltage into the corresponding status input terminals.

At the end of the test, leave the Vx(2) supply connected to terminals

A1 and A2 to proceed to check the operation of relay output contacts.

Vx(2) APPLIED ACROSS positive	negative	DISPLAYED MESSAGE	
No voltage connected		OPTO-INPUT STATE 0 0 0 0 0 0	
A1	A2	OPTO-INPUT STATE 1 0 0 0 0 0 *	note(1)
A3	A4	OPTO-INPUT STATE 0 1 0 0 0 0	
A5	A6	OPTO-INPUT STATE 0 0 1 0 0 0	
A7	A8	OPTO-INPUT STATE 0 0 0 1 0 0	* note(2)
A9	A10	OPTO-INPUT STATE 0 0 0 0 1 0	
A11	A12	OPTO-INPUT STATE 0 0 0 0 0 1	

Table 3: Status input test display messages

Notes: (1) Check also that the OUT OF SERVICE lamp turns ON.

(2) Check also that the 'Intertrip' contacts F9–F11, F10–F12, G9–G11, G10–G12 close.

3.6.3 Contact test

Ensure that the relay contacts are isolated from all tripping and alarm circuits and that the relay is 'Out Of Service' by energising Vx(2) into status input terminals A1–A2 as described in Section 3.6.2.

Push ↑ ↑ to display "CONTACT TEST". Follow the test procedure detailed in Table 4 to test the output contacts.

Disconnect Vx(2) from terminals A1–A2 after completion of the contact test, and press ←←←← to return to the default display.

Output to be tested	Push key	Check contacts closed at terminals
RELAY INOP	→ → SET	G3 – G5
PROT OP A	↓ → SET	F1 – F3
PROT OP B	↓ → SET	F2 – F4
PROT OP C	↓ → SET	F7 – F8
TRIP A	↓ → SET	F17 – F19, F18 – F20, G17 – G19, G18 – G20.
TRIP B	↓ → SET	F21 – F23, F22 – F24, G21 – G23, G22 – G24.
TRIP C	↓ → SET	F25 – F27, F26 – F28, G25 – G27, G26 – G28.
ANY TRIP	↓ → SET	F13 – F15, F14 – F16
INTERTRIP	↓ → SET	F9 – F11, F10 – F12, G9 – G11, G10 – G12.
BLOCK A/R	↓ → SET	G13 – G15, G14 – G16
COMM SUPERVISION	↓ → SET	G7 – G8
SCHEME INOP	↓ → SET	G2 – G4

Table 4: Contact test procedures

The outgoing terminal allocation for the relay is shown on the external connection diagram. Note also that terminals F5, F6, G1 and G6 are internally connected to contacts F1/F3, F2/F4, G3/G5 and G2/G4 respectively. A spare power supply failure alarm contact is connected to terminals H3/H4.

3.7 Current input accuracy and polarity checks

Inject 0.5 pu current (ie. 0.5A for a 1A relay or 2.5A for a 5A relay) into the relay as shown in Figure 1. The relay will trip and give a steady TRIP and a flashing ALARM indication. All trip and protection operated output contacts will close.

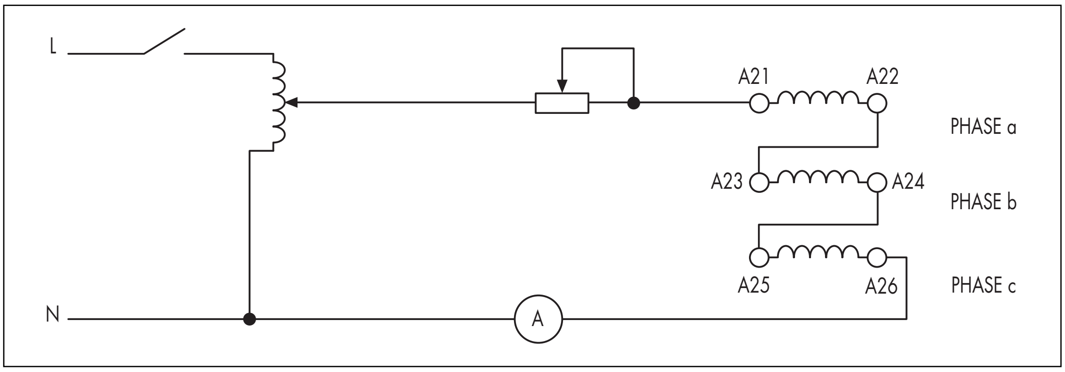


Figure 1: Connections for current input accuracy and polarity checks

Accept the alarm by pressing ACCEPT/READ twice. Check that the ALARM lamp changes from flashing to steady. Push ACCEPT/READ twice to display "*** **ALARM** ***". Check the following current measurements.

Press	→ ↓ ↓	to display "MEASUREMENTS"
Press	→ ↓ ↓ ↓	and check that I1 is 0.00 – 0.02 pu.
Press	↓	and check that I2 is 0.00 – 0.02 pu.
Press	↓	and check that I0 is 0.48 – 0.52 pu.
Press	↓ →	and check that A-phase LOCAL is 0.48 – 0.52 pu.
Press	↓	and check that A-phase REMOTE 1 is 0.48 – 0.52 pu.
Press	↓	and check that A-phase DIFF is 0.96 – 1.04 pu.
Press	↓	and check that A-phase BIAS is Press - 0.48 – 0.52 pu.
Press	← ↓ →	and check B-phase as above.
Press	← ↓ →	and check C-phase as above.
Press	← ← ←	to return to the default display.

Note: If the relay is wired to test terminals such that the connection as shown in Figure 1 is not easily obtained, then an alternative test may be carried out by injecting 0.5A into one phase only (for example into terminals A21/22 for A-phase CTs), and subsequently repeating the test for the other phases. With the relay in the measurement part of the menu, the readings should be as follows :

I_1	0.15 – 0.18 pu	
I_2	0.15 – 0.18 pu	
I_0	0.15 – 0.18 pu	
	Injected phase	Other phases
LOCAL	0.48 – 0.52 pu	0.00 – 0.02 pu
REMOTE 1	0.48 – 0.52 pu	0.00 – 0.02 pu
DIFF	0.96 – 1.04 pu	0.00 – 0.02 pu
BIAS	0.48 – 0.52 pu	0.00 – 0.02 pu

3.8 Relay operation, out of service and reset facilities

3.8.1 Relay setting accuracy

Connect a variable transformer, resistor and ammeter to inject current into the A-phase CT . Slowly increase the current until the relay operates. Record the injected current magnitude and check that it is within the range

0.11 to 0.13 pu. assuming I_{S1} = 0.2 pu. and k_1 = 30% .

If I_{S1} = 0.20 pu or k_1 = 30%, then the operate current should be equal to

$[0.5 \times I_{S1}/(1 - 0.5\ k_1)]$ pu.

Check that the TRIP lamp turns ON steadily and the ALARM lamp flashes. Check also that the output contacts operate as given in Table 5. Slowly decrease the current until the relay contacts reset. Check that the reset/operate current ratio is approximately 0.75/1.

Push ACCEPT/READ and check display "DIFF PROT TRIP PHASE A".

Push ACCEPT/READ and check display "DIFF INTERTRIP PHASE A".

Push ACCEPT/READ, RESET to clear alarms.

Push ACCEPT/READ to return to the default display.

Press → ↓ ↓ ↓ to display "PROTECTION ALARM RECORDS".

Press → → and check alarm record #1 is "DIFF PROT TRIP PHASE A".

Press ← ← ↓ to display "PROTECTION FAULT RECORDS".

Press → → and check fault record #1 is "DIFFERENTIAL PHASE A".

Press ← ← ← to return to the default display.

Phase to be tested	Current injection terminals	Trip contacts (sample)	Any trip contacts (sample)	Protection OP contacts (sample)
a	A21–A22	F17–F19	F1–F15	F1–F3
b	A23–A24	F21–F23	F1–F15	F2–F4
c	A25–A26	F25–F27	F1–F15	F7–F8

Note: If the relay setting is three-pole tripping, all the phase trip contacts will operate together, as each phase CT is injected with current above the operating level.

Table 5: Contact operations for relay setting accuracy test

3.8.2 Inhibit trip/alarm outputs (out of service)

Connect the correct dc auxiliary voltage Vx(2) to relay input terminals

A1 (positive) and A2 (negative) via a switch. Energise this 'Inhibit Trip/Alarm Outputs' status input and check that the amber OUT OF SERVICE lamp turns ON.

Inject an above setting ac current into the A-phase terminals so that the TRIP lamp turns ON and the ALARM lamp flashes. Check that the trip and protection operated contacts which previously operated during test in Section 3.8.1 are now inhibited. Switch OFF the ac current and accept and reset the alarms as described in Section 3.8.1. Repeat tests specified in Sections 3.8.1 and 3.8.2 above for phases B and C. Disconnect voltage Vx(2) from terminals A1 and A2.

3.8.3 Reset indication and alarm facility

Connect the correct dc auxiliary voltage Vx(2) to relay terminals A9 (positive) and A10 (negative) via a switch SW1. Inject ac current above the relay setting into one phase of the relay and check that the TRIP lamp turns ON and the ALARM lamp flashes. Switch OFF the ac current. Energise the 'Reset Indication and Alarm' status input by closing the switch SW1. Check that the TRIP and ALARM lamps reset and the display "REMOTE ALARM RESET" appears.

Push ACCEPT/READ to return to the default display. Disconnect voltage Vx(2) from terminals A9 and A10.

3.9 Bias characteristic

The following tests require a variable transformer and two resistors connected as shown in Figure 2.

A current is injected into A-phase which is used as the bias current and another current is injected into B-phase which is used as differential current. Ia is always greater than Ib.

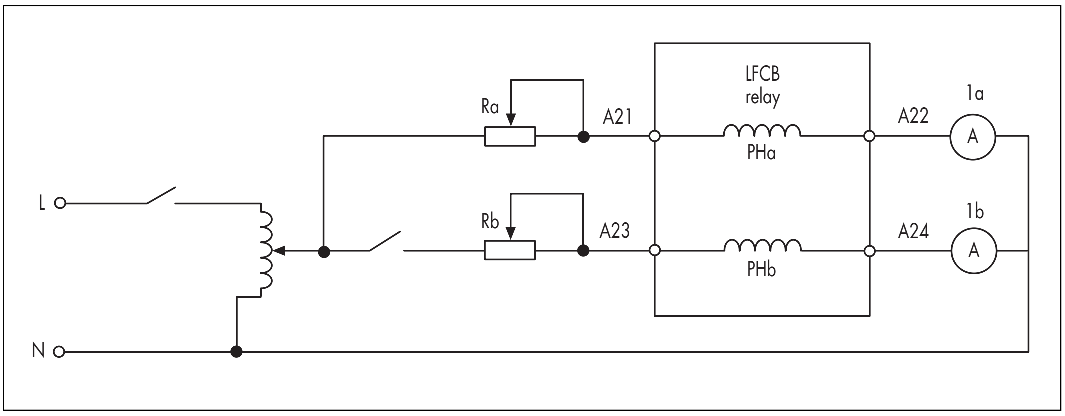


Figure 2: Connections for bias characteristics tests

3.9.1 Lower slope

Adjust the variac and resistor Ra to give a current of 1 pu in the A-phase. The relay will trip and the contacts associated with A-phase will operate. Push ACCEPT/READ twice to accept the alarms which indicate differential protection and intertrip phase A have operated. Push ACCEPT/READ twice more and check that the LCD displays a steady "*** **ALARMS** ***" message and the ALARM lamp is steadily ON.

Slowly increase the current in the B-phase until the phase B contacts operate and the ALARM lamp flashes again. Accept the alarms and check that the LCD shows phase A and B have operated. Record the phase B current magnitude and check that it is 0.25 pu ±10% assuming I_{S1} = 0.2 pu, k_1 = 30%, I_{S2} = 2.0 pu and k_2 = 150%. Generally the operate current is 0.5 x (Is_1 + 1.5 k_1) pu. Switch OFF the ac supply and reset the alarms.

3.9.2 Upper slope

Repeat test 3.9.1 with the bias current set in the A-phase to be 3 pu.

Slowly increase the current in b-phase until the relay operates for both A and B phases. Record the current magnitude and check that it is 1.15 pu ±20% assuming I_{S1} = 0.2 pu, k_1 = 30%, I_{S2} = 2.0 pu and k_2 = 150%.

Generally the operate current is:

$0.5 \times [(3 \times k_2) - \{(k_2 - k_1) \times I_{S2}\} + I_{S1}]$ pu

Note that for a 5A relay the A-phase bias current of 3 pu is 15A and this may exceed the rating of the variable transformer. The current should either be switched ON for short duration's only or an interposing transformer used to step up the current.

3.10 Differential protection operating time

Connect a variable transformer, resistor, ammeter and timer as shown in

Figure 3. Adjust the current to be 1 pu. Close switch SW1 and check that the average operating time is less than 30ms (50Hz) or 25ms (60Hz).

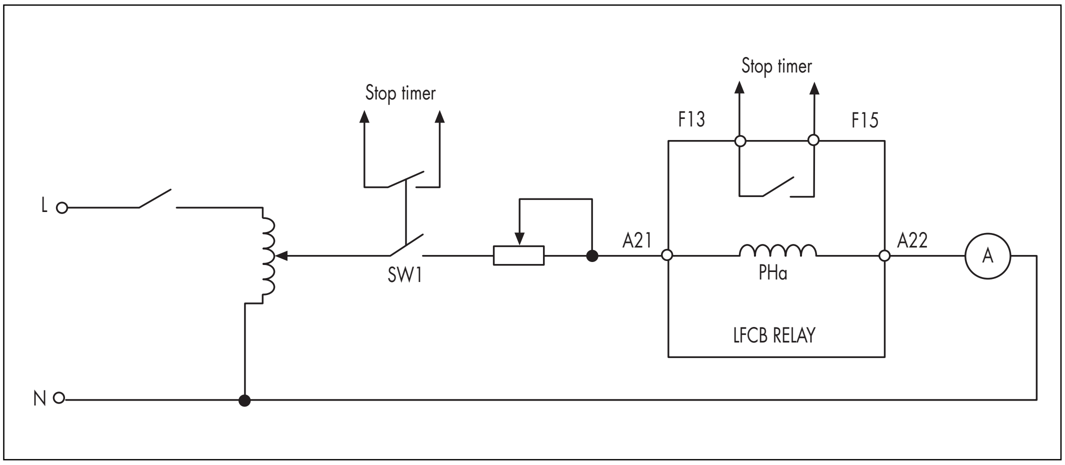


Figure 3: Connections for operating time test

3.11 Communication supervision alarm

Disconnect the communication loop-back link on channel 1 and check that the ALARM lamp flashes after the expiry of the communication alarm time (factory setting 9.9s). Check also that the alarm contact G7–G8 closes.

Reconnect the communication loop-back link and check that the alarm contact resets.

Push ACCEPT/READ and check display "PROT SCHEME FAIL".

Push ACCEPT/READ and check display "COMM CHAN FAILED CHAN 1 FAIL".

Clear these alarms and return to the default display.

Press → ↓ ↓ ↓ to display "PROTECTION ALARM RECORDS".

Press → → and check alarm record #1 displays "COMM CHAN FAILED CHAN 1 RX FAIL".

Press ← ← ← to return to the default display.

Repeat test for channel 2.

3.12 Intertrip facility

Connect a suitable auxiliary supply, switch and timer as shown in Figure 4. Close switch SW1 and check that the average intertrip operating time is less than 30ms (50Hz) or 26ms (60Hz).

Check that the 'Intertrip' contacts (sample F9–F11) operate. Open switch SW1 and check that the contacts reset.

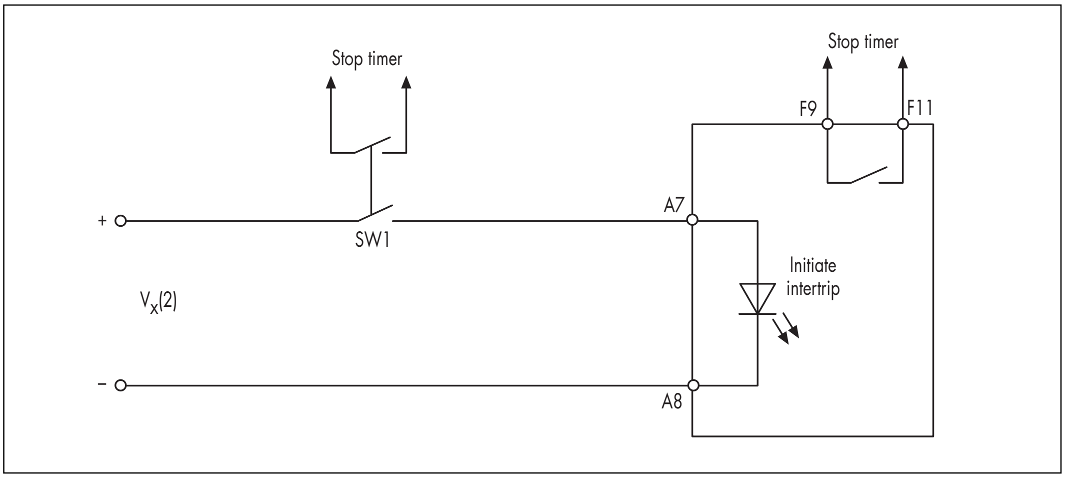


Figure 4: Connections for intertrip test

3.13 Permissive Intertrip facility

If this facility is not required, ensure that there are no connections to the 'Initiate Permissive Intertrip' opto-input. The terminals may be shorted to prevent inadvertent energization. To test the permissive intertrip facility, connect a variable transformer, resistor, ammeter, switch and timer as shown in Figure 5.

The test method assumes that the relay is set for single-pole tripping, and will not work if the relay is set for three-pole tripping mode, since all phases trip contacts will operate with the A phase contacts.

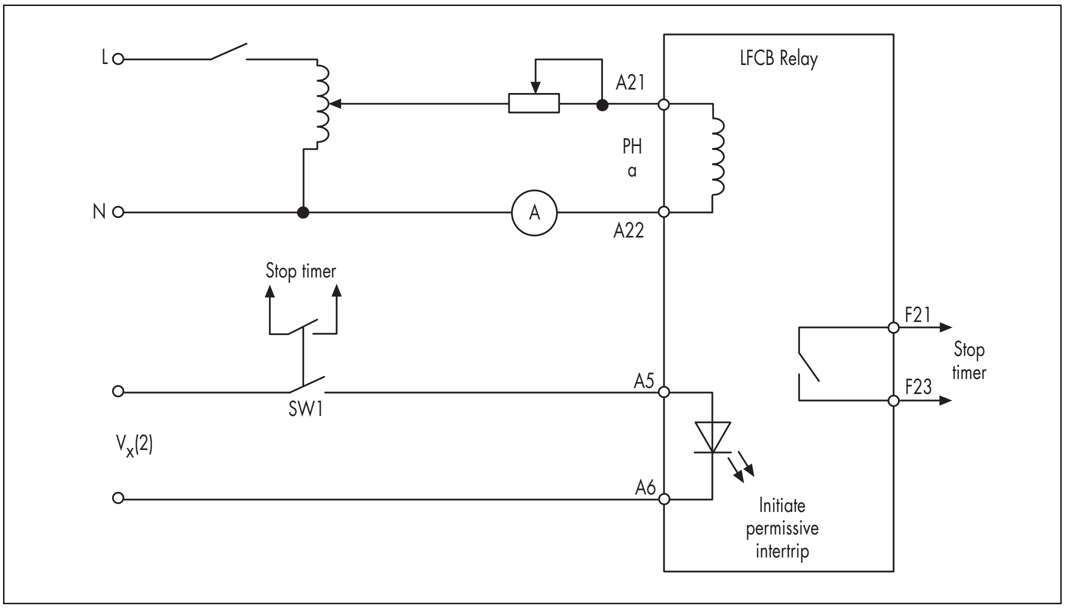


Figure 5: Connections for permissive intertrip test

Close switch SW1. Slowly increase the injected current Ia until the relay operates. Accept the alarms which should be "DIFF PROT TRIP PHASE A" and "DIFF INTERTRIP PHASE A".

Further slowly increase the current until the B and C-phase trip contacts operate and the ALARM lamp flashes again. Accept the alarm which should be "PERMISSIVE TRIP". The permissive intertrip operates when the current exceeds the Is_1 setting, and resets on removal of the current. For a relay set to the factory setting Is_1 = 0.2 pu, check that the injected current is 0.2 pu ±10%. Check that the 'Block Auto-Reclose' contacts (G13–G15, G14–G16) operate and reset with the permissive intertrip.

Set the current above the Is_1 setting, eg. 0.5 pu, open SW1 and check the operating time of the permissive intertrip from SW1 closure to 'Trip B' contact closure. The operating time should be the sum of the channel operating time (<30ms for 50Hz and <26ms for 60Hz) and the permissive intertrip time PIT setting (factory setting 100ms). The test may be repeated by switching both the current and switch SW1 OFF before measuring the operating time.

Disconnect the test equipment from the relay and reset the alarms to return to the default display.

Press → ↓ ↓ ↓ to display "PROTECTION ALARM RECORDS".

Press → → and check alarm record #1 shows "PERMISSIVE TRIP".

Press ← ← ← to return to the default display.

3.14 Time synchronisation

The 'Time Sync' period tsync is set in the factory to be 30 min. Energization of the 'Time Sync' opto-input will pull the internal calendar clock to the nearest hour or half-hour. Refer to Chapter 7 for setting the time sync period other than 30 min. For added noise immunity, the relay will not accept another 'Time Sync' pulse until $^1/_2$ tsync min. have expired. The following test cannot be carried out therefore within $^1/_2$ tsync min. of operation of the 'Time Sync' input during the status input test in Section 3.6.2, or from the time the relay was energised.

To test the facility, connect a suitable auxiliary dc voltage Vx(2) via a switch to the 'Time Sync' opto-input (terminal A11 (positive) and A12 (negative).

Push →↑↑↑→→ to display the calendar clock date and time. Close the switch and check that the clock time alters as indicated in Table 6.

Disconnect voltage Vx(2) from terminals A11 and A12.

Push ←←← to return to the default display.

Time Sync setting	Clock set to nearest	Minimum period between synch pulses to alter clock
5 min.	:00, :05, :10, :15, :20, :25, ... :55.	2.5 min.
10 min.	:00, :10, :20, :30, :40, :50.	5 min.
15 min.	:00, :15, :30, :45.	7.5 min.
30 min.	:00, :30	15 min.
60 min.	:00	30 min.

Table 6: Time synchronisation settings

3.15 Set calendar clock

Press	→ ↑ ↑ ↑	to display “CALENDAR CLOCK”.
Press	→ ↑	to display “SET TIME AND DATE”.
Press	→ →	and set the year ↑ using ↓and .
Press	← ↓ →	and set the month.
Press	← ↓ →	and set the day.
Press	← ↓ →	and set the hours (24 hour clock).
Press	← ↓ →	and set the minutes.
Press	← ↓ →	and set the seconds.
Press	←	
Press	←	to action the settings.
Press	↑ →	to read time and date.
Press	← ← ←	to return to the default display.

3.16 User identifier

Push →↑→ to display “USER IDENTIFIER”.

Push → to show the set user identifier. The relay is set to show “No Identifier Defined” in the factory.

Refer to Chapter 7 for entering your specific identifier for the relay. Return to the default display.

3.17 Serial port communication facility

Only if the serial or parallel port communication facility is required by the user, should the following sections be completed.

3.17.1 Front panel connector

The relay is set in the factory to direct the serial port RS232 communication facility to the front panel SERIAL connector. The front panel connector is suitable for direct connection with a local visual display terminal or a serial printer. The connecting cable should have no transpositions and have pins 2, 3 and 7 connected. See Chapter 4 for details.

Alternatively, a parallel printer may be connected to the front panel PARALLEL connector. The pin details are shown in Chapter 4. Note that the relay will only output to the serial port if there is no printer connected to the parallel port.

Check that the BAUD RATE and the BIT FRAMING FORMAT settings are compatible with the local terminal. If necessary, refer to Chapter 7 to change these settings.

To test the communication facility and to check the relay recording facility, connect a VDU or a serial printer to the front panel SERIAL port, or a parallel printer to the front panel PARALLEL port.

Press	→ → →	to print all records.
Press	↓ →	to print settings.
Press	↓ →	to print alarm records.
Press	↓ →	to print fault records.
Press	↓ →	to print communication records.
Press	← ←	to return to the default display.

3.17.2 Rear panel connector

The rear panel serial connector is designed for permanent connection of the relay serial communication facility to a remote terminal. The connector is configured as a Data Terminal Equipment (dte) for direct connection with a Data Circuit terminating Equipment (dce) such as a modem. To use this facility, it is necessary to direct the communication connection from the front panel connector to the rear connector. This is done by moving the jumper link JM7 in the microcomputer module from link 3–4 to link 1–2. See Chapter 4 for details.

After checking the BAUD RATE and BIT FRAMING FORMAT settings are compatible, connect the terminal equipment with the relay using a suitable lead as specified in Chapter 4.

To check the facility, proceed as described in Section 3.17.1 above.

3.18 Preparation for end to end and on load tests

The local loop-back secondary injection tests are now complete, and it is necessary to set the loop-back test address OFF. Refer to the Individual Address Select Feature Supplementary Information for details. After setting the test address OFF, check that the RELAY HEALTHY LED changes from flashing to a steady display. After expiry of the communication alarm time, the message "***ALARMS***" is displayed and the ALARM LED flashes. Depending upon the timing of the end to end and on-line tests, the relay may be de-energised or energised with the dc auxiliary supply. If the relay is de-energised the calendar clock will need to set again when the relay is next energised.

If the relay is left energised, ensure that the 'Inhibit Trip/Alarm Outputs' input is also energised. Disconnect the local loop-back link and connect the relay to the remote end.

Ensure the relay output contacts are disconnected from the tripping circuit. Note that the communication alarm and the protection scheme inoperative alarm will be active and cannot be reset if the communication channel or the remote relay is not yet fully operative.

3.19 End to end tests

Ensure that the dc auxiliary supplies are connected to the relays at both ends of the feeder, and to the MITZ interface units if used. Ensure that the relays are both 'Out of Service', that the tripping circuits are isolated, and that the main CTs are shorted.

If optical communication is used, record the optical signal levels of the relays and the MITZ interface units. Check that the signal levels are within the ranges given below, and that the end to end attenuation is satisfactory.

Tx level (LFCB relay and MITZ interface) : assumed for power launched into 1 metre of 50/125µm fibre.

Wavelength 850nm.

Nominal	–21 dBm
Range	–20 to –21.5 dBm.

Receive level MITZ 01 interface :

Short distance	–21 to –27 dBm

Received level LFCB relay :

Short distance	–21 to –27 dBm
Medium distance	–21 to –40 dBm
Long distance	–34 to –47 dBm

No damage will be caused if the received optical signal level exceeds the maximum level quoted. The communication bit error rate however may be affected.

Check that the individual addresses of the relays as selected by the customer are correct, eg., if Group 1 addresses are selected, that one relay has address 1–A, and the other relay 1–B. Check that the loop–back test address is OFF.

Connect the communication end to end and reset any alarms.

3.20 On load tests

The objectives of the on load tests are:

(1) To check that each relay is correctly connected to the main CTs

(2) To check that the polarity of the main CTs is consistent at both ends.

(3) To ensure that the on-load differential current is well below the relay setting.

(4) To measure the magnitude of capacitive current and if necessary adjust the relay I_{S1} setting to ensure stability of the relay.

Ensure that the dc auxiliary supplies are connected to the relays at both ends of the feeder, and to the MITZ interface units if used. Ensure that the relays are both 'Out of Service' and that the tripping circuits are isolated.

If necessary, set the calendar clock as described in Section 3.15. Connect the relay through to the main CTs With the feeder dead, use the front panel 'Measurements' commands to read the measured current magnitudes and check that they are near to 0.00 pu.

Press	→ ↓ ↓	to display "MEASUREMENTS"
Press	→ →	to display IA LOCAL
Press	↓	to display IA REMOTE
Press	↓	to display IA DIFF
Press	↓	to display IA BIAS
Press	← ↓ →	to display IB LOCAL
Press	↓	to display IB REMOTE
Press	↓	to display IB DIFF
Press	↓	to display IB BIAS
Press	← ↓ →	to display IC LOCAL
Press	↓	to display IC REMOTE
Press	↓	to display IC DIFF
Press	↓	to display IC BIAS
Press	← ↓	to display I1
Press	↓	to display I2
Press	↓	to display IO
Press	← ←	to return to the default display "CURRENT DIFFERENTIAL"

With the feeder charged from one end only, repeat the above measurements and check that the circuit capacitive current I_{cap} is similar to that expected on all three phases.

Check that the relay I_{S1} setting is higher than 2.5 x I_{cap}. If necessary, change the I_{S1} setting to meet the above requirement.

With the feeder supplying load current, check that all the relay measurements are as expected and that the differential current is similar to the value of capacitive current I_{cap} previously measured for all three phases.

The load current should be high enough to be certain beyond all doubt that the main CTs are connected correctly to the relays. There is a possibility on cable circuits with high line capacitance that the load current could be masked by the capacitive current.

If necessary, reverse the connections to the main CTs and measure that the differential current is significantly higher than that for the normal connection. If the differential current falls as the connection is reversed, then the main CTs connections may not be correct and should be thoroughly checked. Repeat the test for all phases.

3.21 Clear records

Press	→ ↑ ↑ →	to display "CLEAR RECORDS"
Press	→ → SET	to clear the communication record
Press	↓ → SET	to clear the alarm record
Press	↓ → SET	to clear the fault record
Press	← ← ←	to return display to "CURRENT DIFFERENTIAL"

Wait for at least an hour after clearing the communication record before proceeding to record the communication error statistic data.

3.22 Relay settings and communication records

Use the key control or the 'Print' facility to record all the relay settings. Record also the communication error statistic data after a minimum period of an hour after the record was cleared. Check that the ratio of lost/valid messages is better than 10^{-4}.

Note that the communication error statistic data may only be taken with both send and receive communication channels in service.

Finally replace the trip links to connect the relay alarm and trip contacts to the system. Switch the local relay to be 'In Service' by de-energising the 'Inhibit Trip/ Alarm Outputs' opto-inputs. Check that the local 'Out of Service' lamp changes from a steady indication to a flashing indication. This shows that the relay is still 'Out of Service' as the inhibit input of the remote relay is still energised.

Switch the remote relay to 'In Service' and check that the 'Out of Service' lamps at both ends reset.

Ensure that all alarms are reset.

Section 4. COMMISSIONING TEST RECORD

Customer ______________________ Date ______________

Digital current differential relay type LFCB 102

Station ____________________ Feeder ________________

Model number LFCB 102 __________

Serial number ________________ Firmware reference __________

Auxiliary voltage Vx(1) ________ Vx(2) __________

Rated Current In ______________

2.8 CT shorting switches __________

3.2.2 MITZ Interface Unit (if fitted)

Model Number MITZ ________________

Serial Number ____________________

Auxiliary Voltage Vx ____________________

3.3 DC auxiliary supply

Power Supply Failure Contact ____________________

Relay Inoperative Contact ____________________

3.4 Software

Main Processor Ref ____________________

Comm Processor Ref ____________________

3.6 Test options

3.6.1 Lamp test ☐

3.6.2 Status input test ☐

3.6.3 Contact test ☐

3.7 Current input accuracy and polarity ________________

3.8 Relay setting

	Phase A	Phase B	Phase C
Pick-up	______ pu	______ pu	______ pu
Drop-off	______ pu	______ pu	______ pu

3.8.1 Out of service ________________

3.8.2 Reset indication and alarm ________________

3.9 Bias characteristic

3.9.1 Lower slope: I_{bias} = 1 pu, I_{diff} = __________ pu

3.9.2 Upper slope: I_{bias} = 3 pu, I_{diff} = __________ pu

3.10 Diff protection average operating time __________ ms

3.11 Communication supervision alarm time __________ s

3.12 Intertrip average operating time __________ ms

3.13 Permissive intertrip:

Operate current __________ pu

Operating time __________ ms

Block A/R check __________

3.14 Time sync facility ______________

3.15 Set calendar clock ______________

3.16 Enter user identifier ____________________________

3.17 Serial port operation: Front connector ____________

Rear connector ____________

3.18 End to end tests

Optical signal levels		Transmit		Receive	
LFCB relay	(ch 1)	___________	dBm	___________	dBm
LFCB relay	(ch 2)	___________	dBm	___________	dBm
MITZ interface	(ch 1)	___________	dBm	___________	dBm
MITZ interface	(ch 2)	___________	dBm	___________	dBm

End to end intertrip test _________________

End to end secondary injection tests

	Phase A		Phase B		Phase C	
Pick-up	____________	pu	___________	pu	___________	pu
Drop-off	____________	pu	___________	pu	___________	pu

3.19 On-load test measurements

Date _________________ Time _________________

	Feeder charged	Feeder loaded
Phase A Local Remote Diff Bias		
Phase B Local Remote Diff Bias		
Phase C Local Remote Diff Bias		
I_1 I_2 I_0		

3.20 Relay settings

Is_1 ____________________ pu k_1 ____________________ %

Is_2 ____________________ pu k_2 ____________________ %

PIT ____________________ ms

Comm delay tolerance ____________________ µs

Comm fail alarm time ____________________ s

Baud rate ____________________ baud

BIT framing ____________________

Time synch period ____________________ min

Remote access level ____________________

Block A/R on ____________________

Tripping mode ____________________

Configuration ____________________

Communication record taken _________ Hr after clearing previous record

Error statistics: CRC errors ______________

Lost messages ______________

Valid messages ______________

Propagation delay time (ch 1) ________________ ms

(ch 2) ________________ ms

____
Commissioning Engineer

____
Customer Witness

____
Date

____
Date

Digital Current Differential Relay Type LFCB 102

Chapter 9
Fault Finding Instructions

Section 1. PROBLEM ANALYSIS

1.1 Introduction

The following fault finding documentation is to enable the user to identify faulty components of the relay down to module level. With the exception of the power supply fuse there are no user serviceable parts within any module.

The procedure for repair is to identify the faulty module and replace it with the appropriate spare. The faulty module should be returned for repair and re calibration with as much information regarding the fault as possible.

This documentation assumes the user is conversant with the operating instructions and the hardware arrangement of the relay.

**** WARNINGS ****

(1) The relay must be de-energised before the hinged front panel is opened and any bus connections removed. Failure to comply with this instruction may result in damage to the electronic circuits of the modules or corruption of non-volatile memory.

(2) Modules must be removed from the case with the appropriate extraction tool to prevent damage to the modules.

(3) With the hinged front panel open, electrostatic discharge precautions must be observed.

1.2 Fault finding procedure

Problems which arise in the LFCB relay as a result of a faulty module will usually result in one of the following occurring:

(1) The relay will fail to power-up or initialise correctly.

(2) The diagnostic routines will lock the relay out.

(3) The relay will not function correctly.

The following fault finding instructions are therefore divided into these 3 main areas:

(1) Power-up failures.

(2) Self checking failures.

(3) General operational failures.

Depending on the type of failure found, refer to the relevant section below. Some sections consist of flow diagram type instructions to locate the faulty module.

**** IMPORTANT ****

(1) Before beginning any fault finding procedures, visually check all connections and link positions on all of the modules (see Chapter 4).

(2) Ensure all modules are in their correct position in the relay case. This isindicated by the module identification numbers corresponding with the module numbers on the relay case and with the module identification list fixed to the inside of the hinged front panel.

(3) When replacing modules, ensure the replacement has the same module number as that which it replaces.

(4) Ensure no modules show signs of obvious damage through improper handling.

(5) Check that the ribbon cable bus is connected correctly to each module and that no socket pins are bent or otherwise damaged.

1.3 Initialisation process

When the relay powers up normally, the following sequence of events should occur:

(1) The LCD displays faint black squares.

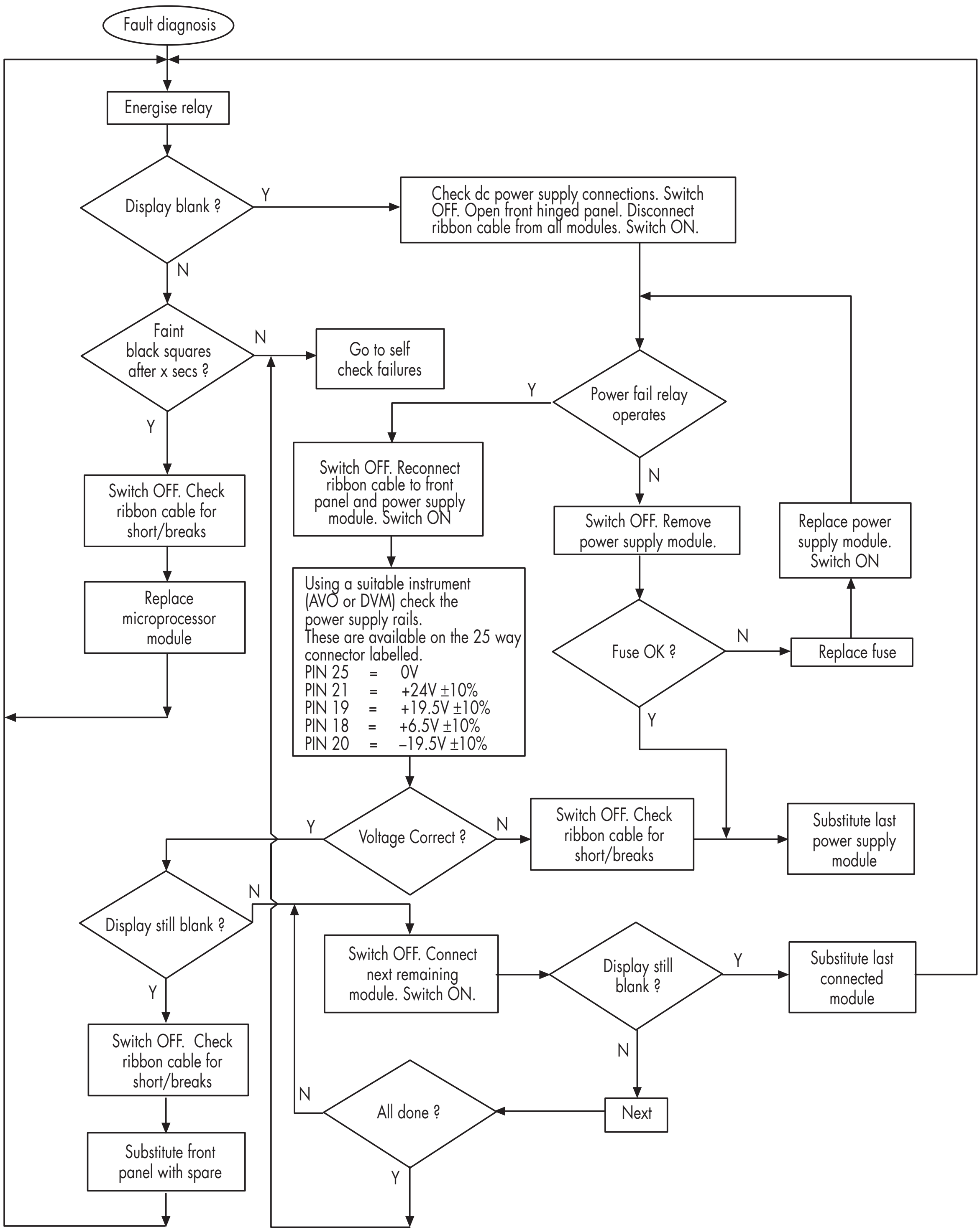
(2) After approximately 3 seconds the message "COLDSTART CHECK" together with the diagnostic programme version number will be displayed on the top line of the LCD, followed by a watchdog timer test message.

(3) The top line will then display "DIAGNOSTIC CHECK" and the bottom line of the LCD will change to show various diagnostic messages. This takes about 10 seconds.

(4) The protection software is then executed which is indicated by the message "CURRENT DIFFERENTIAL" being displayed on the LCD and the 4 indication lamps briefly flashing on.

Section 2. POWER-UP FAILURES

Failure of the relay to power-up usually indicates a power supply, microprocessor or front panel module problem.



Section 3. SELF-CHECKING FAILURES

The LFCB relay contains self-monitoring and diagnostic routines which are executed when the relay is energised. These check the main components of the relay to ensure that there is nothing drastically wrong with the system. This, coupled with the watchdog feature, ensures that the protection software should never execute if the relay is faulty. Obviously, every possible fault cannot be guarded against and certain faults will still enable the relay to function. These faults are covered in Chapter 7.3.1 Power On Diagnostics

When the relay is switched on it performs a number of system diagnostic checks to ensure the relay is fully operational. These especially concern the main microprocessor and memory. During the checks the LCD displays messages to indicate the current test.

3.2 Diagnostic system errors

A diagnostic system error will cause the relay to reset and display a message on the top line of the LCD of the form ' RESET CODE:XYZZ' where 'XY' is a 2 digit hexadecimal number representing various error flags, and 'ZZ' is a 2 digit hexadecimal error code which is used to determine the cause of the error. Under normal reset conditions this message only remains on the display for approximately 3s as it is cleared by the application programme when that restarts. In the case of a lockout situation, this message will be visible constantly.

3.2.1 Error flags

There are 8 error flags available, each of which is represented by a bit in the error flag byte which is displayed as a 2 digit hexadecimal number on the LCD. Only 5 flags are currently used: bits 0, 1, 2, 3 and 7. It is possible for more than one flag to be set which means the error flag number can have the values: 00–0F and 80–8F. This can be summarised in the following tables:

ERROR FLAGS	BIT	X= 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
LOCKOUT	7	–	–	–	–	–	–	–	–	x	x	x	x	x	x	x	x
ERROR FLAG	BIT	Y= 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
DIAGNOSTIC FLAG	0	–	x	–	x	–	–	–	x	–	x	–	x	–	x	–	x
WATCHDOG FLAG	1	–	–	x	x	–	–	x	x	–	–	x	x	–	–	x	x
BACKGROUND FLAG	2	–	–	–	–	x	x	x	x	–	–	–	–	x	x	x	x
EXCESSIVE RESETS	3	–	–	–	–	–	–	–	–	x	x	x	x	x	x	x	x

x Flag SET – Flag Reset

In the descriptions which follow, the possible values for the X and Y error flag numbers quoted indicate the error flag numbers which could be generated by the relevant bits being set.

Bit 7 – Lockout (error flags: X = 8).

If bit 7 is set, the first error flag digit will be '8' which indicates that the error is fatal. If this occurs the relay will be locked out, i.e. disabled from functioning, and can only be re-enabled by removing the auxiliary dc supply to the relay. This will also be indicated by the LCD alternating between "RESET CODE:8YZZ" and "LOCKOUTCODE:8YZZ" approximately every 3 seconds.

Bit 0 – Diagnostic test (error flags: Y = 1, 3, 5, 7, 9, B, D, F).

If bit 0 is set, the power on diagnostic routines will be executed before the relay function continues. This would normally only occur if the application programme discovers a system error but requires verification before the relay locks out altogether. This bit will be cleared on successful completion of the diagnostic tests.

Bit 1 – Watchdog inoperative (error flags: Y = 2, 3, 6, 7, A, B, E, F).

If bit 1 is set, it indicates that the watchdog is out of tolerance. This should not prevent the relay from operating unless it is grossly under tolerance, in which case it may cause the relay to reset continuously and eventually lock out due to the high number of resets that have occurred. This bit is usually only changed during the coldstart diagnostic check.

Bit 2 – Background error (error flags: Y = 4–7, C–F).

If bit 2 is set, the error condition was caused by the background self-monitoring routine which regularly checks the system memory. The error code will disclose which type of memory is faulty.

Bit 3 – Excessive number of soft errors (error flags: Y = 8–F).

Bit 3 is set after 100 resets have occurred since the last power-on. This also locks the relay out to prevent any further operations, so bit 7 will also be set. The error code will indicate the cause of the last reset which should be investigated. An error code of 08 will also be generated if no other error code is pending. The relay can be restarted after switching off its auxiliary dc supply for a few seconds.

3.2.2 System error codes

The error code number ranges from 00–FFh. Error code numbers in the range 01–2Fh indicate a system error. Higher error code numbers indicate an application programme generated error.

Error code 00 – Hardware or no error.

If the error code is 00, the processor reset was caused by the relay hardware. Probable causes of this error code would be the watchdog timing out, which may indicate that the software has crashed; or a non maskable interrupt (NMI) occurring which most probably indicates that the communication module is at fault.

This should not normally cause lockout on its own but normally be associated with an excessive number of resets.

If this is the case, try replacing the microprocessor module and/or the communication module.

Error code 01 – Processor error.

During the power-on diagnostic routine, the processor is checked for functionality. This includes testing all of its registers and flags and conditional jump instructions. The relay is locked out with an error code of 01 if any of these tests fails.
The microprocessor module should be replaced by a spare and the faulty module returned for repair.

Error code 02 – RAM error.

A read/write test is done on the entire RAM during the power-on diagnostic RAM TEST, and the relay is locked out with an error code of 02 if this test fails. The RAM is also tested regularly whilst the application programme is executing and if this produces an error, the relay is reset and the power-on diagnostics performed. Only if these also produce an error will the relay be locked out.
The microprocessor module should be replaced by a spare and the faulty module returned for repair.

Error code 03 – EPROM error.

The EPROM'S used have a check sum of zero. This check sum is checked during the power-on diagnostic EPROM TEST and also regularly whilst the application programme is executing. The relay is locked out if the check sum test fails during the power-on diagnostic routine. Two check sum failures are required during the background EPROM test for added security as it is unlikely that this test will fail. It is more probable that the check sum maintained in a RAM variable will fail due to interference. If two consecutive check sum tests fail, the relay is reset and the power-on diagnostics performed. Only if these diagnostics fail will the relay lock out. When a check sum error occurs a message will be displayed on the bottom line of the LCD of the form: 'AAAA CHKSUM:CCCC' where AAAA indicates the starting segment of the failed EPROM and CCCC is the check sum value which the diagnostics detected. The microprocessor module should be replaced by a spare and the faulty module returned for repair.

Error code 08 – Excessive number of soft errors.

When an excessive number of soft errors occurs, bit 3 of the error flags is set and the relay is locked out. If no other error code is pending at this time, an error code of 08 will be generated. Otherwise the error code will indicate the last reset error which caused the excessive number of resets.

Error code 09 – LCD RAM error.

The power-on diagnostic routine writes 4 bytes of test data into a RAM location of the front panel LCD RAM area and reads them back for comparison. The test determines if the LCD can be addressed and that the bus connections have no shorts or open circuits.

The relay will lock out with an error code 09 if the test fails. Check the bus connections to all modules and replace the ribbon bus if necessary.

Error code 11–1A – Control register read/write error.

Each control register in the interrupt controller, DMA controller and timer is tested. If any of them fail this read/write test, the relay is locked out. The microprocessor module should be replaced by a spare and the faulty module returned for repair.

The error code indicates which register failed as follows:

11	–int mask register	16	–DMA1 control register
12	–int priority mask register	17	–int 0 control register
13	–int status register	18	–int 1 control register
14	–timer control register	19	–int 2 control register
15	–DMA0 control register	1A	–int 3 control register

Error code 1B – Hot interrupt occurred.

During the interrupt controller test, all the microprocessor integrated peripherals are turned off, but their interrupts enabled. If any of them interrupt spuriously, the relay is locked out. This may be caused by spurious noises on the auxiliary power supply during power-up. The relay can be restarted after switching off the auxiliary dc supply for a few seconds. If the lockout condition persists, then the microprocessor module should be replaced by a spare and the faulty module returned for repair.

Error code 1C – Timer 2 inoperative.

In the timer test, timer 2 is set to interrupt after 1ms. If this does not interrupt after 2ms, the relay is locked out with this error code. The microprocessor module should be replaced by a spare and the faulty module returned for repair.

Error code 1D – Timer 2 out of tolerance.

If timer 2 interrupts during the timer test, it is tested for tolerance levels of +3%. If it is outside the tolerance levels, this is indicated on the bottom line of the LCD as either:

TIMER 2 FAST XXXX

or: TIMER 2 SLOW XXXX

where XXXX is the count value reached before the interrupt occurred.

Error code 1E – No DMA interrupt after transfer.

The DMA test uses DMA0 to transfer 16 known bytes from the EPROM to RAM, after which DMA0 should interrupt. This error code occurs if the interrupt does not occur after a reasonable time out period. The microprocessor module should be replaced by a spare and the faulty module returned for repair.

Error code 1F – DMA transfer error.

After the DMA transfer has taken place, the 16 bytes now in the RAM are compared with the original values and the relay is locked out if there are any discrepancies. The microprocessor module should be replaced by a spare and the faulty module returned for repair.

3.2.3 Application error codes

Error codes produced as a result of an application programme detecting an error are in the range 30h–FFh. Error codes 31h–35h all concern the communication module which contains its own self-checking software. When an error is detected, the communication module passes the error code to the main processor in the microprocessor module and locks out. The main processor detects this lockout condition as a ‘Processor Out Of Sync’ alarm which causes it to display the error code and reset the relay. If the error persists after three resets the relay is locked out. In this event the communication module should be replaced by a spare and the faulty module returned for repair.

Error code 31 – Communication initialisation error.

Failure of the communication module to initialise correctly after three attempts will result in this lockout condition.

Error code 32 – Communication RAM error.

The communication processor checks its RAM continuously in the background task. Any read/write error will cause the communication module to lockout with this error code. The communication module should be replaced with a spare and the faulty module returned for repair.

Error code 33 – Communication EPROM error.

The communication processor performs a check sum test on its EPROM continuously in the background task. An incorrect check sum will cause the communication module to lockout with this error code. The communication module should be replaced with a spare and the faulty module returned for repair.

Error code 34 – Communication setting checksum error.

A check sum is maintained for the local settings within the communication processor which is checked regularly. If this is found to be incorrect, the communication processor locks out and sends error code 34 to the main processor. The communication module should be replaced with a spare and the faulty module returned for repair.

Error code 35 – Communication processor out of sync error.

The analogue data passing between the main and the communication processor is through a software handshaking protocol. Both the main and the communication processor can detect the error if the handshaking is not working correctly. In this event the communication processor will skip doing protection, inform the remote relay that the analogue data is invalid and pass the error code to the main processor. The main processor will raise the processor out of sync alarm and if the error persists for 5 seconds it will reset the relay. After three resets the relay will lock out. If replacing the communication module has no effect, the microprocessor module should be replaced as either module could be at fault.

Section 4. OPERATIONAL FAILURES

Should the relay be suspected of being faulty, each module can be tested to verify that they are working correctly. Faulty modules can therefore be identified and replaced. This procedure is outlined in Section 4.1.

Section 4.2 describes common serial port errors.

4.1 Module verification

Several of the modules can be tested using the TEST OPTION sub-function available from the front panel menu structure. This can be selected from the root of the menu structure by using the following key sequences:

Press key	Display shows
	CURRENT DIFFERENTIAL
→	PRINT
↑	IDENTIFIERS
↑	CONTROL
→	CLEAR RECORDS
↑	TEST OPTIONS

4.1.1 Power supply module verification

The power supply has already been covered in Section 2. Check the voltage rails brought out on the Parallel Test Port as described in that section and that the power fail relay operates correctly when the supply is switched on and off. A faulty power supply can also be the cause of spurious resets, which can lock the relay out when they reach the limit of 100 resets.

4.1.2 Microprocessor module verification

The microprocessor module is tested extensively during the power-on diagnostics. To verify that it is working correctly therefore, switch off the auxiliary dc supply to the relay. Then switch it back on and observe the diagnostic check messages on the front panel LCD. A lockout error code of 01 or 11–20h indicates a faulty microprocessor module which should be replaced. In catastrophic cases of failure, the alarm messages on the LCD may not make immediate sense due to conflicts between alarms stored in the EEPROM.

The EEPROM in the microprocessor module is constantly checked for integrity. If an error is found, an EEPROM error alarm message is logged with details of CHECK SUM error or SETTING error. All settings which are corrupted are set to their default value. Persistent "EEPROM ERROR" alarm messages indicate the EEPROM in the microprocessor module is faulty and the module should be replaced.

4.1.3 Front panel module verification

A faulty front panel can be identified quite easily by visible inspection and use of the key pad. Failure of the LCD driver may result in stopping the operator interface from executing. This can be diagnosed by removing the front panel and driving the relay by an external terminal connected to the rear serial port. The appropriate jumper link on the microprocessor board must be set accordingly beforehand and it should be noted that the rear serial port has a slightly different pin configuration from the front serial port. A facility exists to test the LED indications from the front panel menu structure.

To select the lamp test, select the test option sub-function as outlined in Section 4.1, then select the LAMP TEST option by pressing → ↓. By pressing the → arrow key, the front panel led lamps, with the exception of the RELAY HEALTHY lamp, will light and remain lit until the key is released. During this test the RELAY HEALTHY lamp will turn off after a short while.

4.1.4 Relay output modules verification

Individual contacts on each relay output module can be energised from the front panel to verify that these modules function correctly. Because this function allows any of the relay contacts to be energised it could cause circuit breakers to trip if they are connected. Before using this option, therefore, be aware of the consequences of energising the contacts and disconnect the output contacts from external equipment if required. This option can only be used if the relay is made 'Out Of Service' by energising the 'Inhibit Trip/Alarm Output' opto status input.

To select the contact test, select the test option sub function as outlined in Section 4.1, then select the CONTACT TEST option by pressing → ↑ →. Use the ↑ and → arrow keys to select the output contacts to be tested. Then press the → arrow key to energise the relay contacts. This must be confirmed by pressing the SET key as an added security measure. The relay contact will remain in its energised state for as long as the SET key is pressed, returning to its de-energised state when the SET key is released. The contacts can be monitored from the corresponding external connections at the rear of the relay, or from the test ports on the front panel.

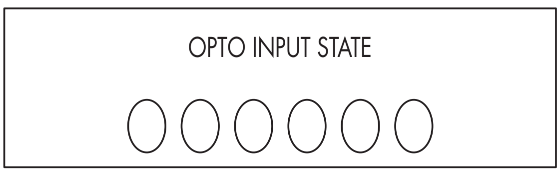
4.1.5 Analogue input module verification

The analogue input module contains both the opto-status inputs and the analogue current inputs. Both of these input sets can be tested using options from the front panel.

(1)Opto status inputs

Select the test option sub function as outlined in Section 4.1, then select the OPTO INPUT STATE test by pressing →.

This option displays the current status of the 6 opto-isolated status inputs on the front panel LCD which is updated once every second. The display is arranged as follows with the status indicated by either a '0' (inactive) or a '1' (active):



The opto-inputs are named from left to right as they occur in the following list:

1) Inhibit Trip/Alarm Output

2) Reserved

3) Initiate Permissive Intertrip

4) Initiate Intertrip

5) Reset Indication and Alarm

6) Time Sync

The opto-inputs can be tested by applying the appropriate auxiliary voltage Vx(2) across the relevant status input connections at the rear of the relay and monitoring the LCD. It should be noted that the status inputs still carry out their normal functions during this test.

(2) Analogue current inputs

The phase currents are measured using a multiplexed analogue-digital converter. The rms values of each of the phase currents used by the protection software can be read using the MEASUREMENTS front panel command, along with the calculated differential, calculated bias and the phase currents detected by the remote relay.

Select the MEASUREMENTS option by pressing the → ↓ ↓ → keys from the root of the menu structure. The ↑ and ↓ keys can be used to select the phase currents to be measured. Once the correct phase current is displayed on the LCD, press the → arrow key to display the local phase current. A test current can be injected into the corresponding input CT terminals, and its magnitude compared with the value displayed on the LCD.

Also available under this option are the positive (I1), negative (I2) and zero (I0) phase sequence currents. These can be used to help verify that the input CT'S are connected in the correct sequence and polarity. For equal balanced phase currents, there should be no negative or zero phase sequence currents; all the current should be positive phase sequence. If all of the current is negative phase sequence, this indicates a transposition of two of the phases, whereas a mixture of all three phase sequence currents indicates that at least one CT is of incorrect polarity.

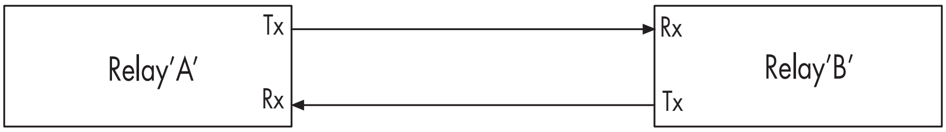
4.1.6 Communication module verification

The communication module contains its own self-checking features (see Section 3.2.3) which report error codes to the main processor. These check the communication RAM, EPROM, handshaking and initialisation process. As there is no direct access to the communication module no other verification tests can be performed.

Failure of the communication module is usually indicated by an alarm record and the flashing alarm indication. Complete failure of the communication module may result in the relay being constantly reset with an error code of 00. This can be confirmed by connecting a VDU terminal to the front panel serial port set to the last serial port setting. If the message NMI is displayed on every reset, the communication module requires replacement.

A communication failure will be indicated by an alarm message on the relays at both ends of the link. Consider the following set up:

If the communication channel fails only in one direction, say from A to B, relay 'B' will have a CHAN RX FAIL alarm message and relay 'A' will have a CHAN TX FAIL alarm message. The reverse would be true if the channel fails in the other direction.



If the channel fails in both directions, both relays would have a CHAN RX FAIL alarm message.

In the above cases it is likely that the communication hardware has failed in one or both of the relays. It is not possible to determine whether the fault lies in the communication module or in the receiving or transmitting devices mounted on the relay case. It is therefore necessary to substitute these in turn with spares until the communication link is restored.

If the communication processor and the main processor do not exchange data correctly, a LOCAL TERM FAIL alarm message will be generated with details of PROC OUT OF SYNC. Under this condition the relay will be reset three times to attempt a recovery. If this fails the relay will be locked out.

Application lockout error codes of 31–35 indicate a communication module failure. In the event of these error codes occurring the communication module should be replaced. If the error code is 35 and substituting the communication module has no effect, replace the microprocessor module as this could be at fault.

4.2 Serial port errors

The serial port can be selected to be connected to the front panel 'SERIAL' connector or to the connector at the rear of the relay. Check that the position of the select jumper link (see Chapter 4) in the microcomputer module is correct if there is no response from the serial port. The front serial connector pin out is designed for direct connection with a visual display unit or a serial printer. The rear connector pin out is different from that of the front connector and is designed for connection with a data set equipment (e.g. a modem). Check that all connections are correct. Check also that the serial port set up, i.e. baud rate, bit framing etc. is correctly set up as required.

Remote access to the relay is gained via the serial port. This uses standard ANSI codes to drive a VDU terminal. If codes such as '2J' or '1;1H' appear then you are not using a standard ANSI terminal. For proper display, an ANSI display terminal emulator must be used, e.g. DEC VT100 or an IBM PC with an appropriate communication package.

Section 5. COMMON PROBLEMS WITH MULTIPLEXED COMMUNICATIONS LINKS

5.1 Initial considerations

When ordering the LFCB the following points should have been considered:

a) The required data transmission rate – either 64kb/s or 56kb/s

b) The electrical interface required – either G.703 (MITZ 01) or V.35(MITZ 02) or X.21(MITZ03)

5.2 Commissioning the link

5.2.1 G.703

Use of G.703 requires a co-directional interfaced communications channel.

5.2.2 Clock signals

As the multiplexer usually carries more than just the LFCB signals, it will normally also supply the master clock signal, either directly or indirectly, however should it be required to supply the clock, the LFCB can operate in terminal timing mode rather than clock recovery.

The link settings on the ZH1011 PCB in the GM0052021/024 module for the modes are as follows :

	Terminal timing	Clock recovery
JM1 and JM2	2–3	1–4
JM4 and JM5	1–4	1–4

For operation at 64kb/s the PCB should be ZH1011001 with link JM3 set to 5–6

For operation at 56kb/s the PCB should be ZH1011004 with link JM3 set to 11–12

5.2.3 Operational checks

Check the Loopback operation where possible on :

a) The LFCB directly

b) The local MITZ and/or the local multiplexer

c) The remote MITZ and/or the remote multiplexer

Check also connecting two LFCBs/MITZs directly over the communications link or to another LFCB locally :

d) LFCB/MITZ – communications link(s) – MITZ/LFCB.

Note: The universal Address (0–0) or the Loopback test Address should be used where applicable during these tests.

5.2.4 Hardware integrity

Check the integrity and security of the connections to all the communications equipment.

5.2.5 Unique address facility

Use can be made of the unique address facility to prevent inadvertent loopback or cross talk.

5.3 Information required

When contacting ALSTOM T&D Protection & Control Ltd please ensure that the following information is given :

a) Contract reference number

b) Relay model, serial and software numbers

c) Brief description of problem

d) Details of tests carried out and any results/conclusions, include a list of relay settings

e) Line drawings of the communications link including :

   i) Types of equipment and approximate distance involved

   ii) Details of fibre or electrical connections

   iii) Brief outline of multiplexer requirements, e.g. G.703, X.21, V.35, at 64kb/s or 56kb/s

   iv) Clock source details.

   v) The current position of the link on JM1 to JM5 on the ZH1011 PCB for each LFCB

f) Actual optical budget of the communications link(s).

g) Details of any alarms read from the LCD

h) Details of the communications link performance as gathered in the communications records over a given time interval

I) If the relay performed a trip, please also supply printouts from all ends of all records along with details (if available) of the relevant line conditions pertaining at the time.

REPAIR FORM

Please complete this form and return it to ALSTOM T&D Protection & Control Limited with the equipment to be repaired. This form may also be used in the case of application queries.

ALSTOM T&D Protection & Control Limited
St. Leonards Works
Stafford
ST17 4LX,
England

For: After Sales Service Department

Customer Ref: ____________________ Model No: ________________

ALSTOM Contract Ref: ____________________ Serial No: ________________

Date: ____________________

1. What parameters were in use at the time the fault occurred?

   AC volts ____________ Main VT/Test set

   DC volts ____________ Battery/Power supply

   AC current ____________ Main CT/Test set

   Frequency ____________

2. Which type of test was being used? ____

3. Were all the external components fitted where required? Yes/No
   (Delete as appropriate.)

4. List the relay settings being used

   ____

   ____

   ____

5. What did you expect to happen?

   ____

   ____

   ____

   ____

continued overleaf

6. What did happen?

___

___

___

___

7. When did the fault occur?

Instant	Yes/No	Intermittent	Yes/No
Time delayed	Yes/No	(Delete as appropriate).	

By how long? ___________

8. What indications if any did the relay show?

___

___

___

9. Was there any visual damage?

___

___

___

10. Any other remarks which may be useful:

___

___

___

___ Signature

___ Title

___ Name (in capitals)

___ Company name

ALSTOM T&D Protection & Control Ltd St Leonards Works, Stafford, ST17 4LX England
Tel: 44 (0) 1785 223251 Fax: 44 (0) 1785 212232 Email: enquiries@pcs.alstom.co.uk Internet: www.alstomgpc.co.uk

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