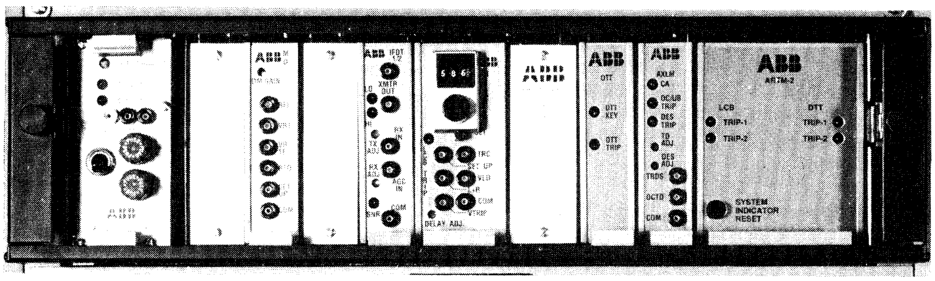
ABB Power T&D Company Inc.
Relay Division
Coral Springs, FL
Allentown, PA

Effective: September 1996
Supersedes D.B. dated December 1995
Mailed to: E, D, C/40-100B,41-900B

For Phase and Ground Fault
Protection of Transmission Lines
Device Number: 87L

Type LCB II High-Speed Current Differential Relay System



BASIC SYSTEM

Standard Functions

- Current only system- no potential required:
  - Extremely low CT burden (0.002 Ohm)
  - Accommodates 3 to 1 difference in CT ratios
  - Immune to system swings (out-of-step)
  - 1 Amp or 5 Amp cts
- High Speed Operation:
  - Trip time: 10-30 ms with time decreasing as multiples above pick up increases.
- Unique sequence network vastly reduces the phase and magnitude dependency and sequence purity problems found in traditional designs.
- Unique comparison circuit performs a true phasor evaluation of the local and remote quantities.
- True differential comparison up to 5 times pick-up-then a gradual change to phase comparison above 5 times pickup.
- Provides 2 terminal line protection, with option for 3 terminal line protection.

FEATURES

- Low battery burden (160 mA)
- Inherent Weak feed capability - will trip all terminals if pickup level is reached at any terminal for internal fault.
- High speed channel monitoring circuits provide channel condition indication, alarm contact, and input to trip decision logic.
- Advanced SNR detection circuit minimizes noise effect on audio tone interface application.
- Self-contained, adjustable channel delay equalization, with independent settings for 2 and 3 terminal applications.
- Selectable Relay Operation on Loss of Channel:
  - Block Trip
  - Overcurrent Trip (Instantaneous or Time Delayed)
  - Unblock Trip and Unblock w/Time Delayed Trip
  - An adjustable timer is included for time delayed overcurrent tripping.
- Self-Contained Communications Channel Equipment:
  - Audio Tone Output
  - Direct Fiber Optic Output (See Specifications for details)
- Installation adjustments and test points available from front panel.
- Meets ANSI C37.90 and IEC-255 specifications.
- Single Mother Board based chassis to accomodate all options.

Optional Functions

- Shared-Channel Direct Transfer Trip
- Third Terminal Line Logic
- Stub bus protection in a ring bus arrangement.
- Magneto-Optic Current Transducer Input (MOCT)
- Complete Video Training Course Available.
- Test Panel and Functional Test Box.

APPLICATION

The LCB II provides high speed protection for long and short lines. It is particularly suitable for lines too short to be protected by impedance measuring systems, such as the run from generator to switchyard. The channel flexibility built into the LCB allows application on lines up to 400 kilometers. The LCB is suitable for any system voltage from subtransmission through UHV. The LCB is available loose and unmounted or completely mounted and wired in a panel or cabinet.

The basic LCB is a self-contained, 19" wide rack-mounting chassis (3RU high), prewired for all available options. The relay can be supplied with an optional fiber optic interface for direct connection to the user's fiber optic cable or an integral audio tone output suitable for interface with the user's leased lines (3002 or equivalent), microwave or carrier channels with equivalent 3002 characteristics.

A graded index fiber optic patch cable is available for fiber optic applications, 10 meters long, 50/125 micrometers, dual window (850/1300nm) with SMA or ST connectors on each end. Estimates of allowable communication channel lengths for the LCB-II over direct fiber optics are as follows:

Wavelength and Mode	Total Atten. In System (dB)	Cable Atten. (dB/km)	Distance (km)
850nm, Multi-mode	40	3.0	12
1300nm, Multi-mode	30	1.5	18
1300nm, Single-mode	15	0.5	24
1300nm, Single-mode with "High Power"	28	0.5	48

The relay is set based on the same setting criteria as used in previous pilot wire systems with some minor differences. The power system information required is as follows:

I_{3p} = The minimum three phase fault current from the strongest terminal.

I_g = The minimum phase to ground fault current as fed from the strongest terminal.

I_L = The maximum expected load current through the protected line.

The above quantities are secondary current magnitudes.

The relationship of the sequence network voltage output (VF) referenced to secondary sequence current quantities is:

$$VF = (14.14/T)\,(C_1 \times \bar{I}_{a1} + C_2 \times \bar{I}_{a2} + C0 \times \bar{I}_{aO})$$

Where VF = voltage output of network

T = current setting of the relay

C1 = positive sequence network setting constant

C2 = negative sequence network setting constant

C0 = zero sequence network setting constant

$\bar{I}_{a1}$, $\bar{I}_{a2}$, and $\bar{I}_{a0}$ = A phase positive, negative, and zero sequence current components respectively (phasor quantities)

The setting criteria are as follows:

I3p $\geq$ I0.1 x T/C1I

IL $\geq$ I1.25 x (0.1xT/C1)I (See note below)

Ig $\geq$ Io.3xT/(C1+C2+C0)I

NOTE: If the system is strapped to block on loss of channel then the IL criterion may be ignored.

Figure 1 represents the operating characteristic of the comparison circuit if the fault currents at the two ends of the line are either in-phase (internal fault) or out-of-phase (external fault). This curve indicates that tripping occurs for internal faults including internal faults with some outfeed current at one terminal.

The graph in Figure 2 shows the relay characteristic when the local (VL) is at three times pickup, and the remote varies in-phase and magnitude. A family of curves similar to this one could be drawn for different magnitudes of local voltage. It can be seen that the relay system will operate for small amount of outfeed at the remote terminal. This is the differential aspect of the LCB, and provides outfeed trip capability in weak terminal applications. As observed in the drawing the relay has about an 82 characteristic; that is, the two quantities can be up to 82° out-of-phase and the relay will trip for any set of magnitudes above pickup.

LCB-II System Operation

The basic operation of the LCB relay system performs a true differential comparison of line current flowing through each terminal of the protected line. A pilot channel, either fiber optic or audio tone, is used to bring in the remote terminal signal(s) for comparison to the local signal. The unique methods used to represent the three phase current and securely transmit the remote signal produce the application flexibility and fidelity of the LCB. The LCB II functional block diagram is shown in Figure 3.

Three phase currents are converted in the current transformation circuit to representative voltages which are fed to the sequence network. This active, solid state circuit produces a precise, repeatable single phase voltage representative of the three phase line current. The relative amounts of positive, negative and zero sequence signal may be adjusted to best match the power system conditions. The single phase voltage signal is simultaneously fed to the modulator and delay equalizer circuits.

In order to provide accurate and rapid comparison for fast tripping requirements, the voltage developed by the sequence network at each terminal must be reproduced at the remote terminals with minimum of delay and distortion. The encoding technique employed in the LCB relay system to perform this function is known as pulse period modulation (PPM), wherein the carrier period is varied linearly with the modulating signal amplitude.

The device which develops the pulse train is called the modulator. The circuit which translates the PPM signal from remote terminal(s) to a magnitude wave is the demodulator.

Since the signals to be compared are varying continuously with changes in line current, an accurate differential (comparison) measurement requires that the remote and

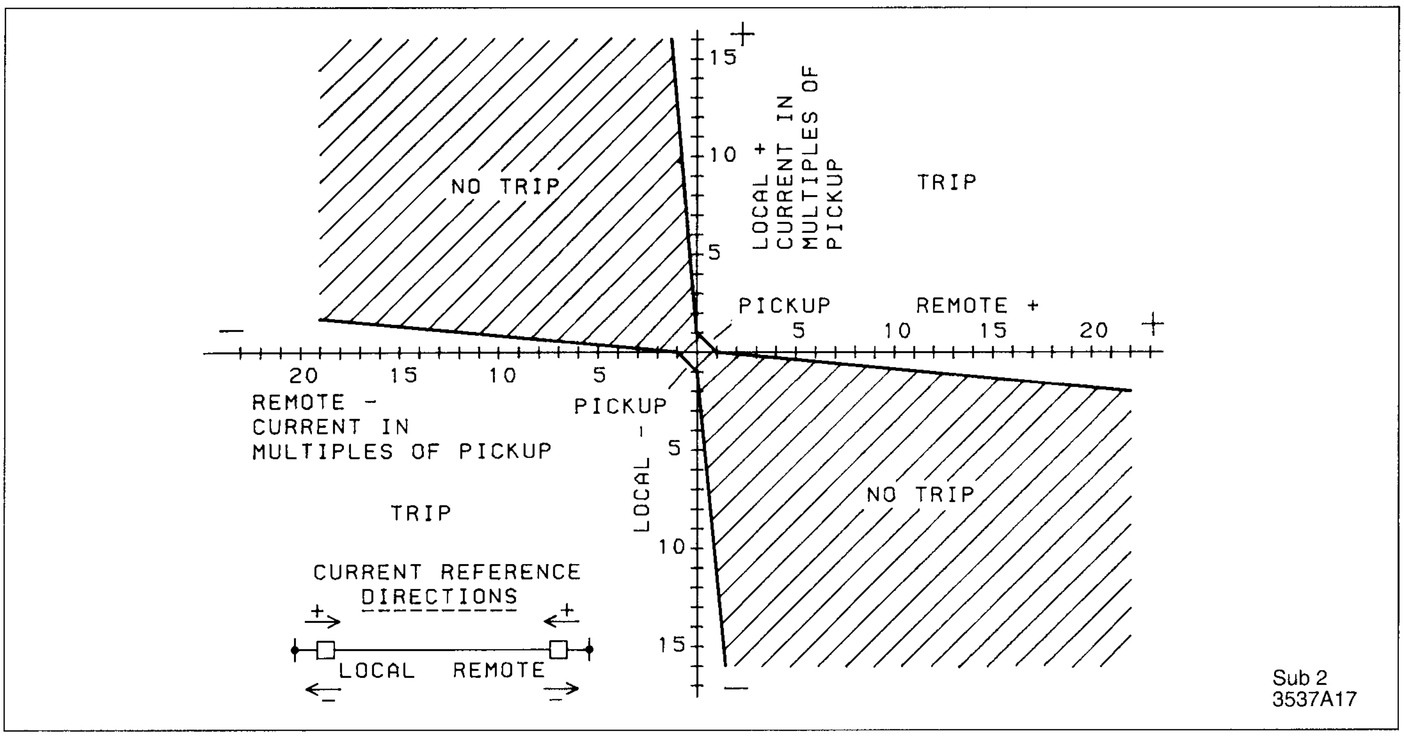


Figure 1. LCB Operating Characteristics (IN/OUT phase)

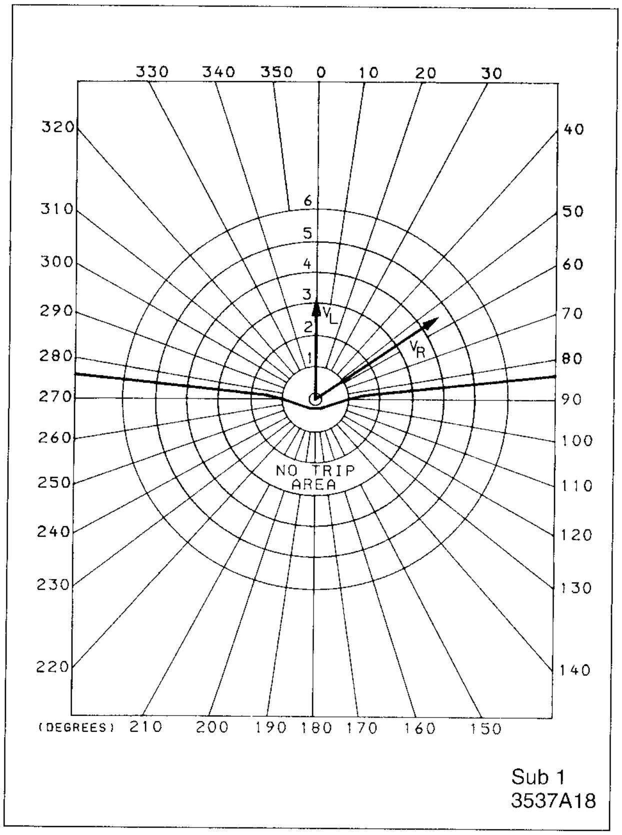


Figure 2. LCB General Operating Characteristics

The fiber optic transmitter is an amplifier-diode combination which turns a light emitting diode (LED) on and off with a period determined by the pulse period modulation output from the modulator-circuit.

The fiber optic receiver consists of a photo diode producing pulses which are amplified by a trans-impedance amplifier. Automatic gain control and conditioning circuits are provided for channel monitoring and loss of channel detection.

In the tone interface module the transmitter converts the modulator pulse output in a sinusoidal signal suitable for a voice channel which may be applied to microwave, or a 3002 unconditioned telephone channel. The receiver conditions the incoming signal to produce a nearly constant amplitude signal to the demodulator circuit. The output of the automatic gain control circuit is also used to monitor the incoming signal level and the signal-to-noise ratio. The fixed 1.7 kHz pilot signal is transmitted together with the modulated signal to provide frequency translator protection.

For the comparison process two quantities are generated from the local and remote voltages. The operate quantity is derived by vector addition of the local and remote voltages.

The restraint quantity is obtained by adding the local and remote quantities on a magnitude basis. The resultant voltage is opposite in polarity to the "operate" voltage. The "operate" and "restraint" voltages are combined and the resultant fed to a level detector which produces a trip signal if the resultant is above the pick-up setting.

Tripping circuits and relay indication are blocked for a period of approximately 3.5 seconds during dc power up conditions in order to permit associated relay and communication circuits to become stable. This power control circuit also blocks the trip immediately during momentary loss or dip of the power supply.

Direct Transfer Trip

An optional feature available for LCB systems is Direct-Transfer-Trip (DDT) function. The breaker or breakers at the remote terminal(s) of a protected line an be tripped at high speed from the local terminal using elements of the LCB and the same communications channel. An additional module is required at each terminal. Transfer tripping is keyed by an external contact from other protective devices.

local signals being compared be coincident in time. The delay equalizer circuit causes the local signal to reach the phasor comparison circuit at the proper time relative to the remote signal.

The channel interface module, whether fiber optic or tone, contributes to the reliability and simplicity of the LCB System by producing a 1.7 kHz pilot signal within the system which may be directly connected to the communications channel. This signal is used for channel monitoring during times when no load current is flowing and hence, no comparison signal is present.

Both modules contain a transmitter, a receiver, and channel monitoring circuitry. Channel condition data are fed to the trip decision logic circuit. An interface module is required for each remote terminal. With separate transmit and receive channels are required for either the tone or fiber optic module.

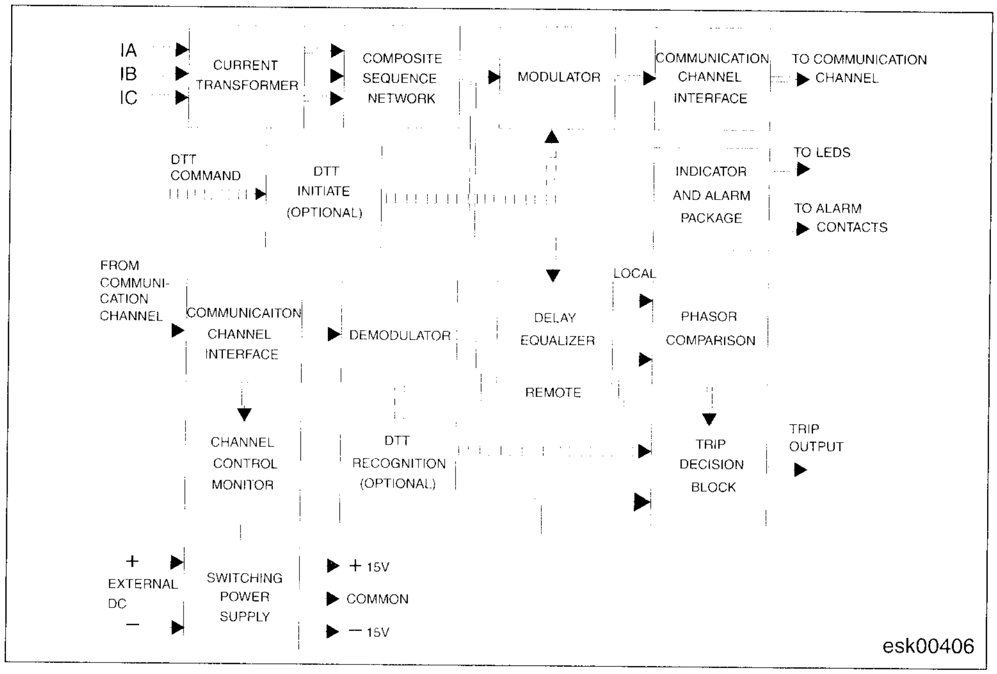


Figure 3. Function Block Diagram of LCB-II Relay

The transfer trip input is conditioned and then switches the operation of the PPM modulator to substitute a transfer trip signal. At the receiving terminals, the signal is processed by the channel interface and demodulator elements.

A valid direct transfer trip signal has a frequency of 400 Hz with an amplitude to produce a period deviation wider than the maximum allowed for the current comparison and must last at least 10 milliseconds time. If these criteria are met, the remote relay will automatically switch from the current comparison function to producing a direct transfer trip output. Direct transfer trip output is via a contact which is seperate from the comparison trip output.

Comparator

A block diagram of the comparison circuit is shown in Figure 4. As previously mentioned, for the comparison process, two quantities are generated from the local and remote voltages. The first is called the operating quantity and is derived by the vector addition of the local and remote voltages with differential amplifiers. The operating quantity is given by the Equation below.

$$V_{OP} = |V_L + V_R|$$

Where: V_{OP} = the operating quantity

V_L = the local quantity (V_F phase-delayed)

V_R = the remote quantity

The restraint quantity is obtained by adding the local and remote voltages on a magnitude basis, (the phase angles do not enter into the result). The restraint quantity is given in the Equation that follows:

$$V_{RES} = |V_L| + |V_R|$$

Where: V_{RES} = the restraint quantity

The quantities V_{OP} and V_{RES} must now be compared to determine if the fault is internal or external to the protected line. The Equation below shows how this comparison is accomplished.

$$V_{OP} - 0.7V_{RES} \geq V_{PU}$$

Where: V_{PU} = a preset pickup threshold.

Three-terminal lines can be protected by the addition of another "remote" quantity. The operating quantity is the magnitude of the phasor sum of the local plus both remote voltages, and the restraint quantity is the sum of the magnitudes of the local quantity and both remote quantities.

$$V_{OP} = |V_L + V_{R1} + V_{R2}|$$

$$V_{RES} = |V_L| + |V_{R1}| + |V_{R2}|$$

Where: V_{R1} and V_{R2} are the two remote quantities.

For three-terminal lines, this comparison technique allows the relay to handle a significant amount of out-feed at one line terminal during an internal fault and still trip.

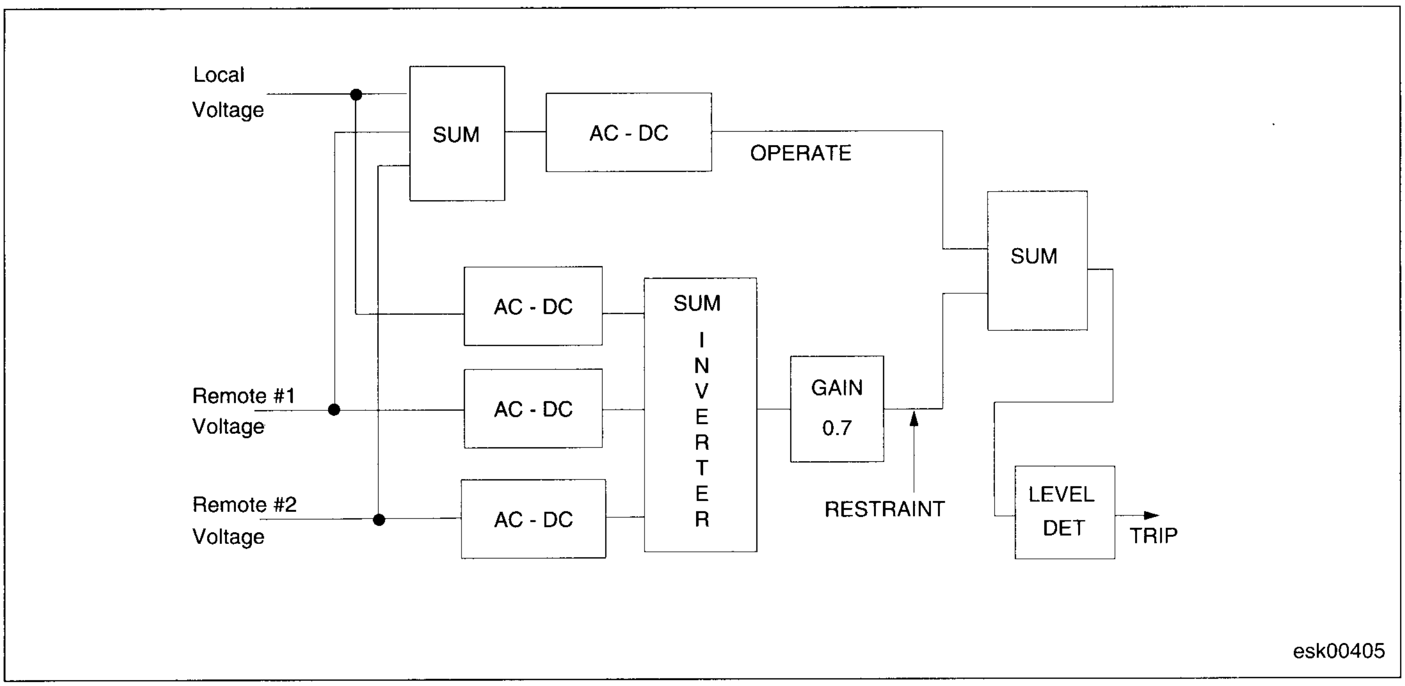


Figure 3. Comparison Circuit

LCB II Specifications

1. Ac Ratings:

CT Ratio Secondary-A	Continuous Rating-A	Ohm Burden	1 Second Rating-A
5	10.0	.002	250
1	2.0	.006	50

2. Setting Range (amperes):

CT Ratio Secondary	3ø Fault Sensitivity	ø To Ground Fault Sensitivity
5	20. To 40.0	0.23 - 4.4
1	0.4 to 8.0	0.046 - 0.88

3. Frequency: 50 or 60 Hz

4. Carrier Frequency: 1.7 kHz, unmodulated

Maximum Deviation: ± 200 hertz without DTT option

Modulation Technique: Pulse period

5. Direction Transfer Trip (Option): 420 hertz modulating frequency.

6. Channel Delay Equalizer: Adjustable 0 to 8 ms

7. Input current Transformers: Linear response up to 100 per unit (1 p.u. = 5A or 1A symmetrical current) with an accuracy of 1%.

8. Power Supply Voltages:

Nominal	Range
48/60Vdc	38-70
110/125Vdc	88-140
220/250Vdc	176-280

9. Dc Burden (Watts):

2 Terminal LCB

Standby	Operate
20	35

Added Burden For:

DTT Option Standby	DTT Option Operate	3rd Terminal Standby	3rd Terminal Operate
5	15	5	5

10. Indicating Lights (LEDs)

Non Seal-in LEDs:

Module	Associated Functions
ALS(Switching power supply)	DC INPUT DC OUTPUT
IFT(Audio tone interface)	SNR (Signal-to-noise) HI (High level) LO (Low level)
IFO (Fiber optic interface)	LO (Low level)

Seal-in LEDs:

RELAY (Sensing logic)	LCB TRIP
DTT (Direct transfer trip)	DTT KEY DTT TRIP
AXLM (Auxiliary Logic)	CA (Channel Alarms) OC/UB TRIP DES TRIP
ARTM-1 (Trip)	LCB TRIP #1 LCB TRIP #2
ARTM-2 (Trip)	LCB TRIP #1 LCB TRIP #2 DTT TRIP #1 DTT TRIP #2

11. Indicator Reset:

A. Manual Reset on ARTM Modules.

B. AXLM Module has input to allow indicators to be reset remotely. Isolated input buffer, link selectable, for 15, 48, 125 or 250 Vdc.

12. Environmental Specifications:

Operating Temperature
-20^{o} to +60^{o}C

Storage Temperature
-40^{o} to +80^{o}C

Input/Output/Case (Earth Ground) 2800 Vdc, 1 minute per IEC 255-5 series C

Hostile Environment Protection

(a) SWC test per ANSI C37.90.1

(b) Impulse test per IEC 255-5 clause 8 (5000V, 1.2/50 microsecond. 0.5 Joule).

(c) Designed to meet proposed IEEE radiated EMI standards.

(d) Fast transient test per ANSI proposed standard C37.90.1

13. Contact Rating:

- Trip rated: Make and carry 30 amperes for a minimum of 100 ms.
- Non-Trip rated: 3 amperes continuous.
- Interrupting Rating (Amperes)

DC Supply	Resistive	Inductive
48 Vdc	3.75	1 75
125 Vdc	0.5	0.35
250Vdc	0.25	0.15

Form C Alarm - make, continuous, & interrupt 100VA, resistive.

14. Channel alarm (Contacts & Indication) output has adjustable time delay of 0.5 to 5.0 seconds.

15. Fiber Optic Cable Interface:

a) 850 nm, Multimode Fiber:

- Frequency response: 1.0-2.5 kHz
- Minimum optical power input to maintain 20 dB SNR is 0.5 nanowatts.
- Low signal level setting @ 850 nm: 0.5 nanowatts (-63 dBm).
- Optical channel capability is 40 dB when using a 50 micrometer core fiber cable, at 850 nm.
- LED optical power output - 1.0 milliwatt. (Not fiber-coupled output power.)

b) 1300 nm Single-Mode or Multimode:

- Frequency response: 1.0-2.5 kHz
- Minimum optical power input to maintain 20 dB SNR is 1.6 nanowatts.
- Low signal level setting @ 1300 nm: 1.6 nanowatts (-58 dBm).
- Optical channel capability is 15 dB when using a 9 micrometer core fiber cable, at 1300 nm.
- Optical channel capability is 30 dB when using a 50 micrometer core graded-index dual-window fiber cable, at 1300 nm.
- LED optical power output: 0.5 milliwatt. (Not fiber-coupled output power.)

c) 1300 nm High Power

- Frequency response: 1.0-2.5 kHz
- Minimum Receiver Optical power input to maintain 20 dB SNR is 1.6 nanowatts.
- Low signal level setting @ 1300 nm 1.6 nanowatts (-58 dBm)
- Optical channel capability is 28 dB when using a 9 micrometer core fiber cable, at 1300 nm.
- LED optical power output 1μW (-30 dBm) (fiber-coupled output power.)

16. Audio Tone Interface:

Transmitter:

- Output level-Adjustable within the following ranges
  +15 to -5 dBm
  -4 to -25 dBm
  -23 to -40 dBm
- Amplitude Stability ± 1 dB
- Output Impedance 600 ohms, balanced
- Frequency stability 1%
- Frequency bandwidth 1.0 to 2.5 kHz

Receiver:

- Input sensitivity + 10 to -40 dBm, selectable with a 20 dB (± 10 dB) window
- Input impedance 600 ohms, balanced
- signal-to-noise ratio 20 dB over 1.5 kHz bandwidth

Audio tone interface can be applied over a 3002 unconditioned circuit or equivalent.

17. Meets ANSI-C37.90 and IEC-255, 256 standards.

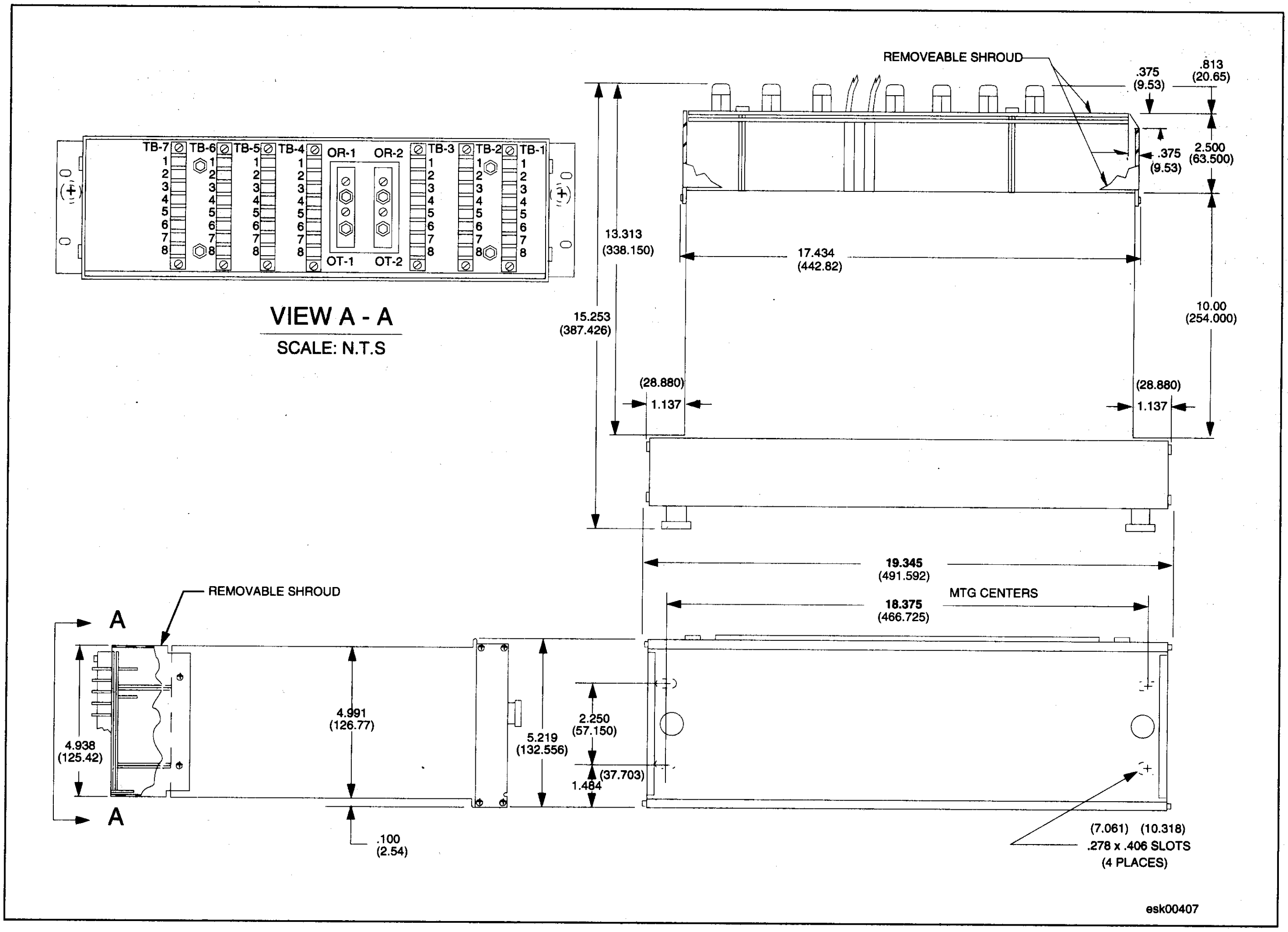


Figure 5. LCB Outline and Drilling

REFERENCE

LCB-II CURRENT DIFFERENTIAL RELAY BOOKLET	B-796-A
LCB-II BUYERS GUIDE	1MDB06014-EN
LCB-II ORDERING INFORMATION	PDL 40-215-C
LCB-II VIDEO TRAINING COURSE	
TYPE LCB-II CURRENT DIFFERENTIAL LINE PROTECTION RELAY SYSTEM (WITH DIN CONNECTORS)	I.L. 40-219
TYPE LCB-II RELAY MODULES (WITH DIN CONNECTORS)	I.L. 40-220
TYPE UCTB FUNCTIONAL TEST BOX	I.L. 40-250
A NEW CURRENT DIFFERENTIAL RELAY SYSTEM – TYPE LCB	RPL-83-2
POWER SYSTEM CONSIDERATIONS IN LCB-II CURRENT DIRRERENTIAL RELAY APPLICATIONS	RPL-85-2

LCB-II RELAY SYSTEM

CATALOG NUMBERING

8 T I T 5 A P

APPLICATION

Two terminal line	8
Three terminal line	9

DIRECT TRANSFER TRIP

Direct transfer trip - two terminal line	T
Direct transfer trip - three terminal line	U
No direct transfer trip	N

BATTERY SUPPLY VOLTAGE

48/60 Vdc	4
110/125 Vdc	1
220/250 Vdc	2

CHANNEL INTERFACE

Two terminal line (8 in APPLICATIONS above)	
Fiber optic, 850 nm, multi-mode fiber, SMA connector	A
Fiber optic, 850 nm, multi-mode fiber, ST connector	E
Fiber optic, 1300 nm, single mode or multimode fiber, SMA connector	B
Fiber optic, 1300 nm, single mode or multimode fiber, ST connector	F
Fiber optic, 1300 nm, high power/single mode fiber, ST connector	C
Audio tone	T
Three Terminal Line (9 in APPLICATIONS above)	
Fiber optic, 850 nm, multi-mode fiber, SMA connector	A
Fiber optic, 850 nm, multi-mode fiber, ST connector	E
Fiber optic, 1300 nm, single mode or multi-mode fiber, SMA connector	B
Fiber optic, 1300 nm, single mode or multi-mode fiber, ST connector	F
Fiber optic, 1300 nm, high power/ single mode fiber, ST connector	C
Audio tone	T

CURRENT INPUT AND FREQUENCY

1A, 50 Hz	1
1A, 60 Hz	2
5A, 60 Hz	5
5A, 50 Hz	6
MOCT	C

AUDIO TONE PROTECTION

Two terminal tone protection	A
Three terminal tone protection	B
No Tone Protection	N

TEST PANEL

Standard Test Panel	P
No Test Panel	N

ACCESSORIES

Card Extenders
- I-Style 1355D52G01 type UME-3D
- I-Style 1355D52G02 type UME-3D (Stiffened ext. for use w/vertical mount)

Portable Functional Test Box
- Style 1337D24G02 type UCTB Portable Functional Test Box 60/5t0 Hz, 5 Amp
- Style 1337D24G03 type UCTB Portable functional Test Box 60/50 Hz, 1 Amp

Fiber Optic Connector Cable
- Style 1604C71G04 10-meter long, 50/125 micrometer, dual window (850/1300 nm), graded index fiber optic cable with SMA-906 connectors on each end
- Style 1604C71G015 10-meter long, 50/125 micrometer, dual window (850/1300 nm), graded index fiber optic cable with ST connectors on each end
- Style 1604C71G08 10-meter long, 9/125 micrometer, single mode fiber optic cable with SMA-906 connectors on each end
- Style 1604C71G16 10-meter long, 9/125 micrometer, single mode fiber optic cable with ST connectors on each end (high power interface)

Consult factory for additional connector cable options.