INTELLIGENT CONTROLS

INSTALLATION AND PROGRAMMING MANUAL FOR MODELS

1511-LTC

PROGRAMMABLE POSITION MONITOR

000-2068 Rev. B

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This manual applies to all INCON model 1511-LTC monitors.

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INTRODUCTION

The Model 1511-LTC Programmable Position Monitor is a highly advanced solid-state instrument, which measures the position of a resistive position transmitter, commonly known as a "Slidewire". It provides both a user definable visual panel indication and optional analog and digital signal outputs.

The 1511-LTC is designed specifically for monitoring power transformer Load Tap Changer position, where the desired readout is in whole tap numbers, as the LTC moves from tap to tap.

Another powerful feature of the 1511-LTC is its ability to quickly average numerous samples of the position reading before updating the display. This provides a sure, stable reading of the LTC position, even when the signal may be affected by electrical noise. This feature makes the 1511-LTC perfectly suited for the noisy substation environment. All outputs are driven from the displayed value.

The 1511-LTC may be wired to existing resistive position transmitters. Additional 1511-LTCs may be wired to the same transmitter without compromising the accuracy or reliability of the system.

1.0 INSTALLATION

- The Model 1511-LTC is designed for use in any 50/60 Hz system compatible with electrical specifications given in Section 6.0 (Specifications, Pg. 32).
- The panel-mount case is designed to snap-fit into a **standard 1/8 DIN rectangular cut-out of 44mm (1.73 in.) by 92mm (3.62 in.)**
- Wiring is done to the rear of the case.
- #18 AWG (min.) type THHN, THWN, TFFN, or equivalent wire is recommended for power and relay wiring.
- #20 AWG (min.) shielded twisted 3-conductor wire is recommended for signal connection to the resistive position transmitter.
- #20 AWG (min.) shielded twisted pair wire is recommended for analog output wiring. Use appropriate spade lugs (provided) when connecting to the case terminals.
- Contact INCON Technical Service (1-800-872-3455) for application assistance if the resistive position transmitter and the 1511-LTC monitor are separated by a wire run of more than 300 feet.

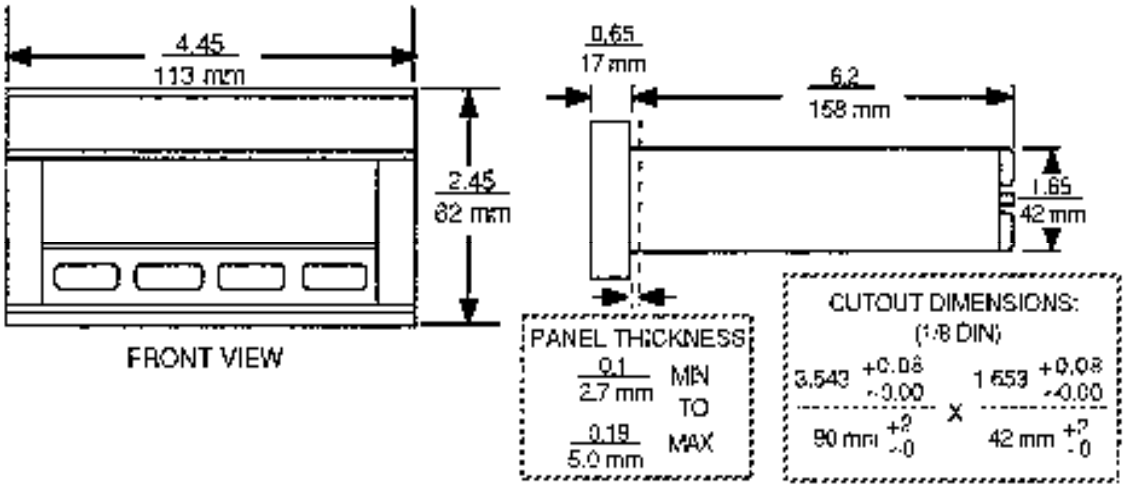

Figure 1.1 Mechanical Dimensions

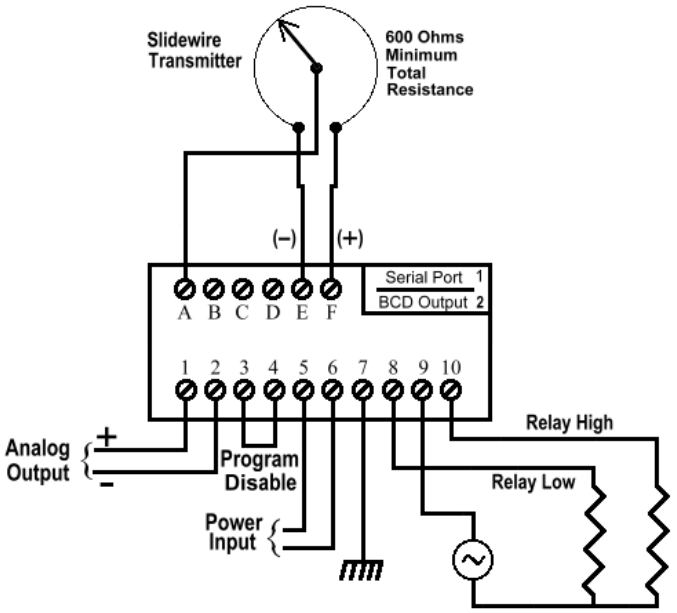

Figure 1.2 Field Wiring Diagram

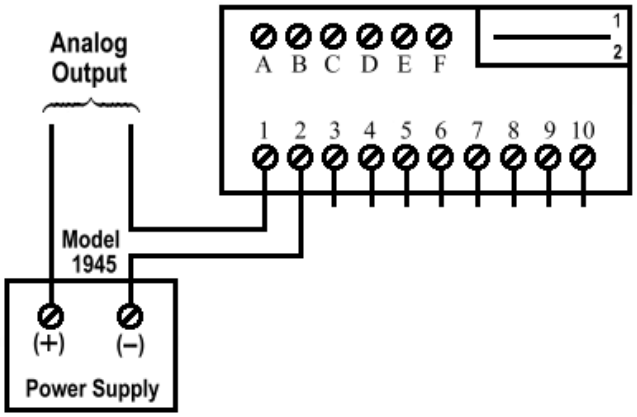

Figure 1.3 Field Wiring Diagram with 4-20mA Output

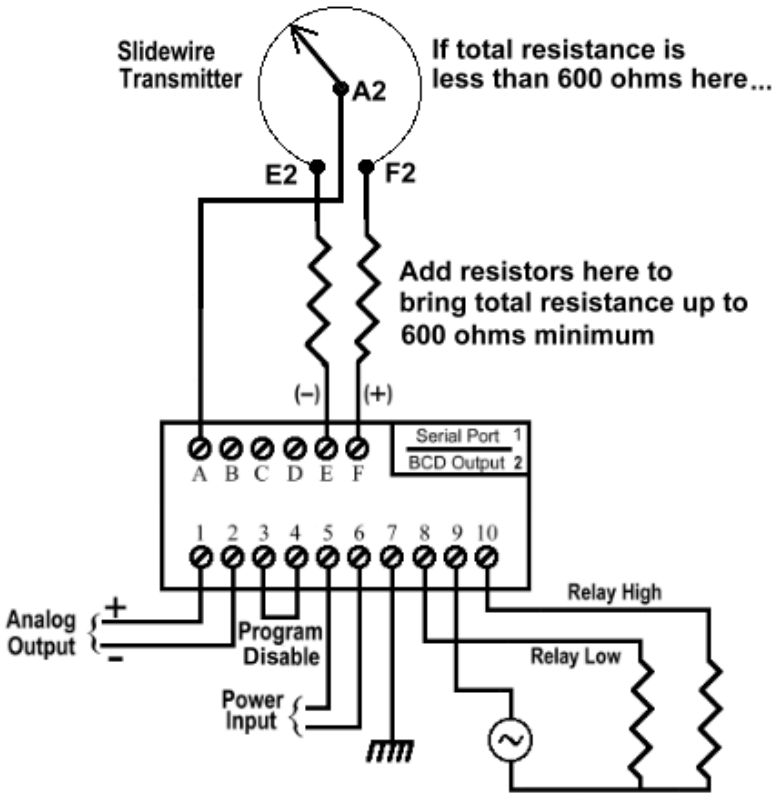

Figure 1.4 Field Wiring Diagram for Low Resistance Transmitters

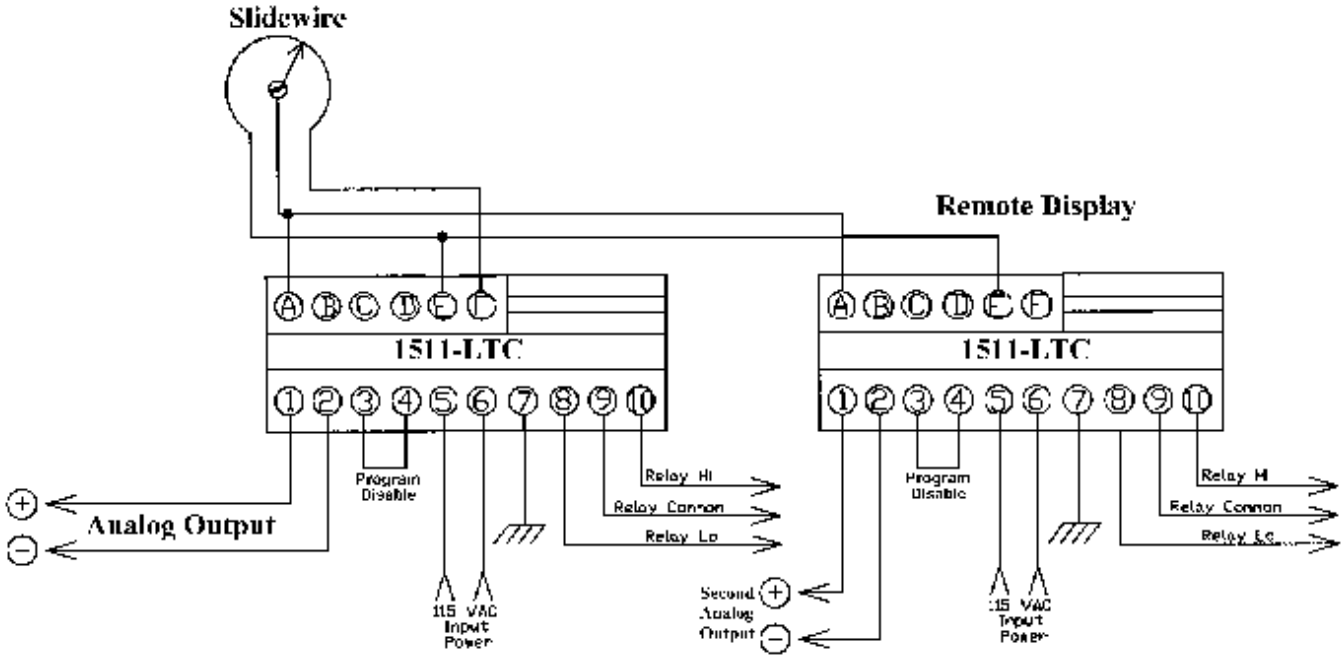

Figure 1.5 Field Wiring Diagram Multiple 1511-LTC's on One Transmitter

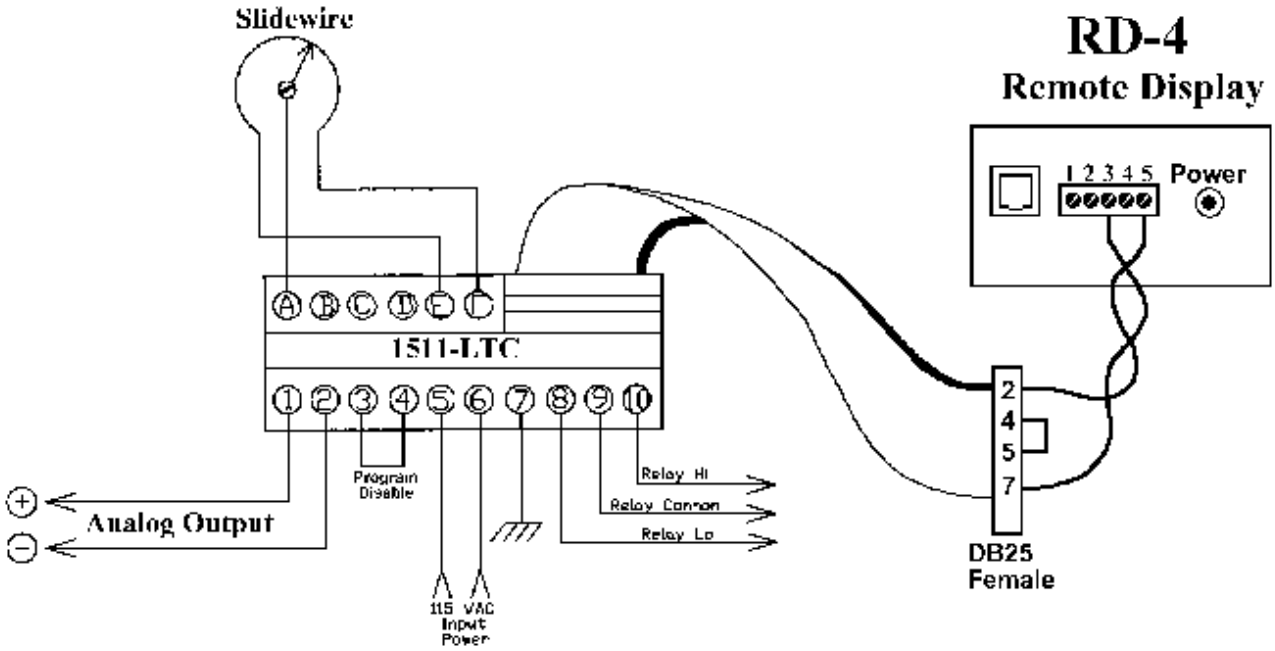

Figure 1.6 Field Wiring Diagram for 1511-LTC with RD-4

Terminal	Function	Terminal	Function
A	Signal Input	1	Analog Output +
B	(Spare)	2	Analog Output –
C	Signal Ground	3	Program Mode Inhibit
D	Signal Ground	4	Inhibit Return
E	Signal Ground	5	Line L1
F	+24 VDC Transmitter Power	6	Line L2
		7	Chassis Ground
		8	Relay Low Contact N.O.
		9	Relay Common
		10	Relay High Contact N.O.

Table 1.1 Terminal Functions

Switch #	Function
1	RS-232 Communications Option Enable
2	RS-485 Communications Option Enable
3	Spare
4	High / Low Relay Limit Option Enable
5	Analog Output Option Enable
6	Spare
7	Parallel BCD/BIN Option Enable
8	Spare

Table 1.2 DIP Switch Functions

Installation Notes:

1) **The resistive position transmitter must be at least 600 ohms total.** If the total resistance is lower than 600 ohms, resistors must be added to bring the total resistance up to 600 ohms or more. (See Figure 1.4)
2) A resistor may be wired remotely across the analog output terminals to convert analog output current to a voltage. Use Ohm's Law to calculate the proper resistance for the desired voltage based upon the 1511-LTC's rated output current.
3) Maximum analog output load resistance: 0-1mA = 10K ohms; +/-1mA = 10K ohms; 0-2mA = 5K ohms; 4-20mA = 500 ohms.
4) Models with 4-20 mA analog output options must have an EXTERNAL LOOP POWER SOURCE of 10.0 VDC minimum, 24.0 VDC maximum, in series with the current loop. The INCON Model 1945 Power Supply is recommended for these installations, (See Figure 1.3).
5) In cases where additional remote indication is needed, several 1511-LTCs may be wired in parallel to the same transmitter. (See Figure 1.5) or an RD-4 Remote Display can be used (figure 1.6).
6) A wire jumper or keyswitch may be installed between terminals 3 & 4 to prevent the program from being changed. When these terminals are jumpered the menu will read "**EP**-x" instead of "**OP**-x", which indicates that you can Examine each Parameter, but not change them.
7) For models with serial or BCD options, plug the cable onto the card edge with the red stripe towards the outside of the case.
8) After installation and programming, install the rear terminal guard with screws provided.

Application Bulletins:

1) Analog outputs of 0-1mA, +/-1mA, and 0-2mA can be changed in the field to any one of the other two. The configuration jumpers are located on the bottom PCB (see Figure 1.7).

   For 0-1mA, jumper: J8 only. For +/-1mA, jumper J10 only.
   For 0-2mA, neither J8 or J10 are jumpered.

To effect a change of the analog output in the field, the following steps must be taken.

A) Remove the monitor from its case.

B) Remove the 2 screws from the top PC board.

C) Separate the **bottom PCB** from the **middle PCB**.

D) Make the appropriate changes to the J8 & J10 Jumpers.

E) Carefully re-assemble the PCB's. Do not bend any of the interconnection pins.

F) Install the 2 screws into the top PCB and slide the unit back into its case.

G) Perform the Analog Output Calibration procedure, Section 4.0, Pg. 28 in this manual.

Figure 1.7 J8 & J10 Jumper Location

2.0 PROGRAMMING

The Model 1511-LTC has three methods of programming, numeric menu (traditional 1250-style), alphanumeric menu, and serial port programming commands. Depending upon the serial port option ordered, the serial programming commands will be either RS-232 ASCII commands or RS-485 packet commands. (See Table 2.1 for a full listing of all programming menu items. See Figure 2.1 for a simple programming flowchart. See Table 2.2 for a full listing of all serial port programming commands and syntax.)

To access the numeric or alphanumeric programming menu, press the MENU key for several seconds until the display goes blank, then press the SELECT/ENTER key. The display should read "OP 0". The default menu is the numeric menu. To choose the alphanumeric menu, press the DOWN key to select OP 99. Press the SELECT/ENTER key, the display should read "to OP". Press the SELECT/ENTER key. The display should read "run". You are now in the alphanumeric menu mode.

To change a parameter using the numeric or alphanumeric menus, select the parameter to be changed from the menu, press the SELECT/ENTER key. The parameter's present setting will now be displayed. You can change the setting by pressing the UP or DOWN key. To store the new setting, press the SELECT/ENTER key. The display will return to the menu.

Table 2.1 Numeric and Alphanumeric Menu Items:

Num-eric	Alpha-numeric Protocol	Default Value:	Programmable Range:	Function:
OP 0	Run			Press the SELECT/ENTER key to exit the Program mode
OP 1	rLY E	OFF	On or OFF	Enables the High/Low Relays
OP 20	LotAP	-16	-50 to +1	Lowest Tap Number
OP 21	HItAP	+16	+2 to +50	Highest Tap Number
OP 22	nEu	1	0 to 9	Segmented Mode: Number of neutral taps
OP 23	n St	0	Any valid tap number	Segmented Mode: Sets lowest neutral tap
OP 24	rY Lt	-16	Any valid tap number	Segmented Mode: Sets low relay limit tap
OP 25	rY Ht	+16	Any valid tap number	Segmented Mode: Sets high relay limit tap
OP 27	CALLo		<< Press UP & DOWN at the same time >>	Calibrate to measured input signal at Lowest Tap
OP 28	CALHI		<< Press UP & DOWN at the same time >>	Calibrate to measured input signal at Highest Tap
OP 29	dSPrL	OFF	On or OFF	Enables display of "r" or "L"
OP 30	CAL E	OFF	On or OFF	Enables analog output Calibration Mode
OP 31	L CAL		LO	Forces the analog output to its lowest signal output
OP 32	H CAL		HI	Forces the analog output to its high scale signal output
OP 33	d CAL		- -	Forces the analog output to its mid scale signal outputs
OP 34	t CAL		LO then HI	Forces the analog output to alternate between high and low scale signal outputs

Num-eric	Alpha-numeric Protocol	Default Value:	Programmable Range:	Function:
OP 39	dOG t		<< Press ENTER >>	Forces a Watchdog Reset (factory use only)
OP 40	LED t			Display LED Test: Turns on all LED's
OP 41	RS t			RS-232 Echo Test: Re-transmits characters received through the RS-232 serial port
OP 43	RLY t		LO Then HI	Relay Test: UP and DOWN keys toggle between LO and HI relays
OP 50	DSPbL	OFF	On or OFF	Causes the display to go blank after 60 sec.
OP 51	RS232	0	0 to 4, and 6	RS-232 Mode: 0=Serial Disabled, 1=Data Logger Mode, 2=Polled Mode, 3=Sampled Mode, 4=Serial Command Mode, 5=Reserved, 6=RS485 MODBUS Mode, 7=Remote Display Driver Mode
OP-52	bCd	0	0 to 6	BCD Mode: 0=BCD Disabled, 1=Multiplexed BCD 2=Parallel BCD High, 3=Parallel BCD Low 4=2's Compliment Binary, 5=Sign plus Magnitude Binary, 6=Offset Binary
OP 53	Aut25	OFF	On or OFF	Auto-Reset after "FA 25" error
OP80	POrt	9600 8 n 1 128	2400, 4800, 9600, 14400, 19200, 28800,38400, 57600, 76800 7 or 8 n, E, O 1 or 2 0 to 255	Sets serial port parameters: (press the UP or Down key to select a value, press the enter key to advance to the next parameter) Baud rate Word length Parity (n=none, E=even, O=odd) Stop bits Address (for RS-485 Multi-drop)
OP 99	to OP	to OP		Toggles between Numeric and Alphanumeric menus

To prevent accidental or unwanted changes to the program parameters, a jumper wire may be installed across terminals 3 & 4 (see Figure 1.4). With this jumper installed, the numeric menu will read "EP *nn*" instead of "OP *nn*". All parameters can be viewed but no changes can be made.

Important Programming Note:

Under certain conditions, changing the Lowest Tap Number (OP 20) or Highest Tap Number (OP 21) will invalidate other parameters.

Example: When High Tap = 16 and Low Tap =-16, Neutral Start Tap=0, Relay High Limit = 16 and Relay Low Limit = -16. Changing the Low Tap Number to "1" will invalidate the Relay Low Limit and the Neutral Start Tap.

Error code "Er23L" indicates an invalid Neutral Start Tap that is below the Lowest Tap Number. Error code "Er23H" indicates an invalid Neutral Start Tap that is Above the Highest Tap Number. A new value must be given for the Neutral Start Tap (OP 23). Error codes "Er24i" and "Er25i" indicate invalid Low Relay or High Relay limits respectively. Re-enter the appropriate relay limits (OP 24, OP25).

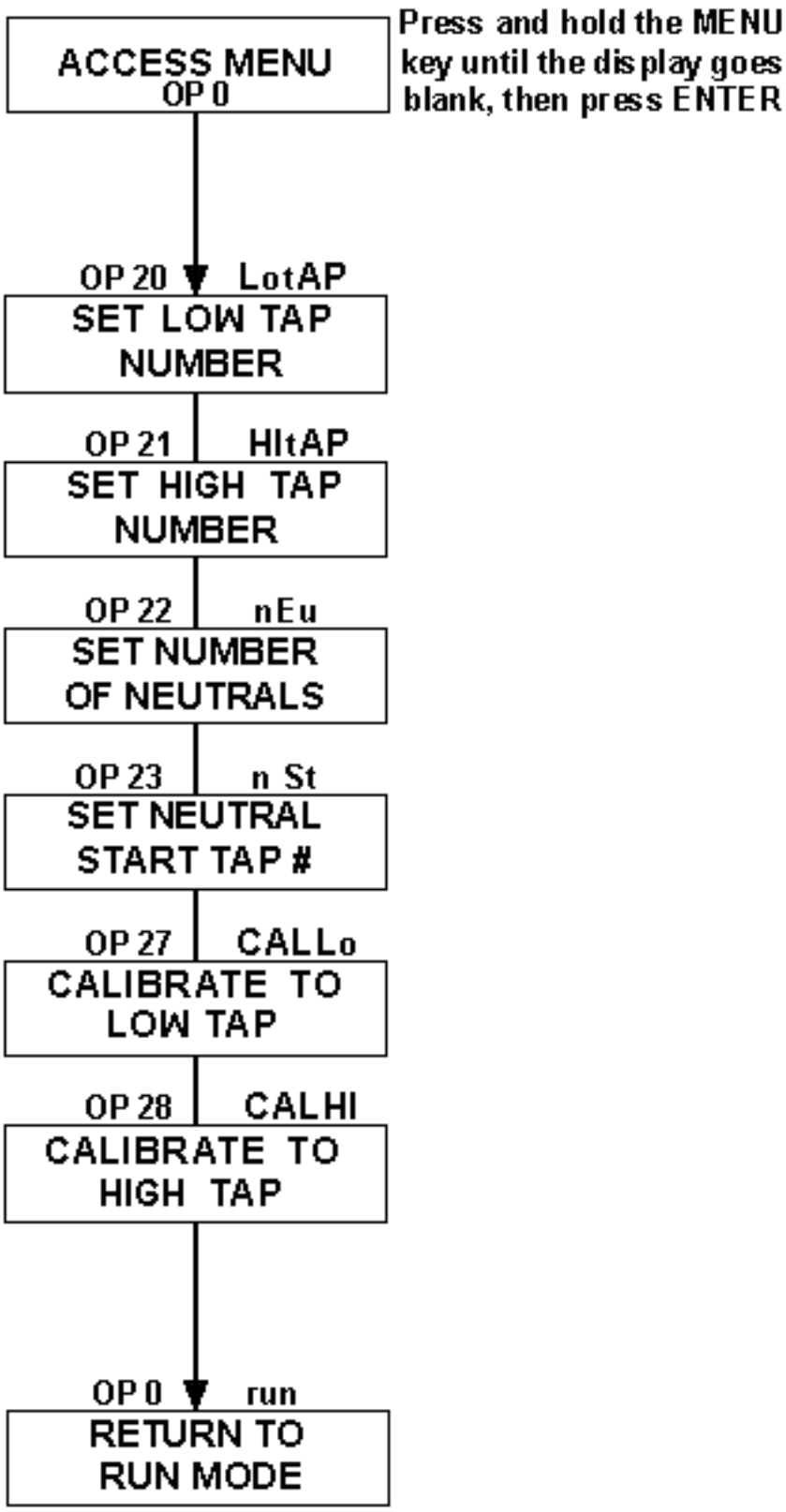

Figure 2.1 Simplified Programming Flowchart

2.1 Serial Port Programming

To change a parameter using the RS-232 serial port programming commands, connect a computer terminal to the serial port cable. The terminal must have the proper Comm. port settings to communicate to the 1511-LTC (see section 3.4, Pg. 21). See Table 2.2 for a listing of all programming commands and syntax. At the command prompt, type a command followed by the new parameter setting, using proper syntax as shown in Table 2.2. Typing the command only, without a new parameter setting, will cause the 1511-LTC to transmit the present setting for that parameter.

Table 2.2 Serial Programming Commands:
◊=space ⬇=enter

Command Syntax:	Function:	Explanation:
SETUP⬇	Enter the Setup Mode	This command must be entered before any other commands can be made.
EXIT⬇	Re-starts the serial connection	Changes to comm. port settings will take effect
RUN⬇	Return to the Run Mode	Changes to settings will take effect
DISP⬇	Displays all setup parameters	Each setup command is displayed with the current parameter values following it
POS⬇	Displays current position data	Transmits the displayed tap position value
RLYENA◊*ON*⬇	Enables High/Low Relays	"*ON*" or "*OFF*" When enabled allows setting relay limits
LOTAP◊*nn*⬇	Set lowest tap number	*nn*= an integer from -50 to +1
HITAP◊*nn*⬇	Set highest tap number	*nn*= an integer from +2 to +50
NEUTRALS◊*n*⬇	Set number of neutral taps	*n*= an integer from 0 to 9
NSTART◊*nn*⬇	Set lowest neutral tap number	*nn*= an integer, any valid tap number
RLYLT◊*nn*⬇	Set low relay tap number	*nn*= an integer, any valid tap number
RLYHT◊*nn*⬇	Set high relay tap number	*nn*= an integer, any valid tap number
LOCAL⬇	Calibrate to low tap input signal	Must be on lowest tap when used
HICAL⬇	Calibrate to high tap input signal	Must be on highest tap when used
DISPRL◊*ON*⬇	Enables the display of "r" (raised) and "L" (lowered) tap numbers	"*ON*" or "*OFF*" When enabled, causes the display to show "r" and "L" in function modes 20 and 21 only
ANACAL⬇	Enter analog calibration mode, the 1511-LTC analog output will be forced to Low / Mid / High signal output	Press the space bar to toggle between Low / Mid / High analog output. Press the enter key to stop calibration
WDOGTEST⬇	Forces a Watchdog Reset	This command is for factory use only.
LEDTEST⬇	Turns on all display segments	Press the enter key to stop the LED test
RLYTEST⬇	Turns on one relay at a time for testing	Press the space bar to toggle between Low relay and High relay
DSPBL◊*ON*⬇	Enables the display blanking feature	"*ON*" or "*OFF*" When enabled causes the display to go blank after 60 sec.
SERIAL◊*n*⬇	Set serial RS-232 communication mode	0=Serial Disabled, 1=Data Logger Mode, 2=Polled Mode, 3=Sampled Mode, 4=Serial Command Mode, 5= Reserved, 6=RS485 Mode, 7=Remote Display Driver
AUTO25◊*ON*⬇	Enables the automatic reset after an "FA 25" error	"*ON*" or "*OFF*" When enabled, will automatically return to normal run mode after input signal returns to normal range

Command Syntax:	Function:	Explanation:
BCD◊ *n*⬇	Sets the BCD/Binary port mode	0=disabled, 1=Multiplexed BCD, 2=Parallel BCD High, 3=Parallel BCD Low, 4=2's Compliment Binary, 5=Sign Plus Magnitude Binary, 6=Offset Binary
ADDRESS◊ *n*⬇	Sets the MODBUS device address	*n* = 0 to 255
PORT◊*bbbb*◊*w*◊*p* ◊*s*◊*a*⬇	Sets the comm. port settings: baud rate, word length, parity and stop bits	*b*= 2400, 4800, 9600, 14400, 19200, 28800, 38400, 57600, 76800 baud *w*= 7 or 8 bit word *p*= n, E, O *s*= 1 or 2 stop bits
MENU◊*ALPHA*⬇	Sets the keyboard menu type	*"OP"* = Numeric menu or *"ALPHA"* = Alpha-numeric menu
HELP⬇	Provides a list of all available serial commands	All commands will be listed with proper syntax

To prevent accidental or unwanted changes to the program parameters, a jumper wire may be installed across terminals 3 & 4. With this jumper installed, the numeric menu will read "EP *nn*" instead of "OP *nn*". All parameters can be viewed but no changes can be made.

Important Programming Note:

Under certain conditions, changing the Lowest Tap Number or Highest Tap Number will invalidate other parameters.

Example: When High Tap = 16 and Low Tap =-16, Neutral Start Tap=0, Relay High Limit = 16 and Relay Low Limit = -16. Changing the Low Tap Number to "1" will invalidate the Relay Low Limit and the Neutral Start Tap.

Error code "Er23L" indicates an invalid Neutral Start Tap that is below the Lowest Tap Number. Error code "Er23H" indicates an invalid Neutral Start Tap that is Above the Highest Tap Number. A new value must be given for the Neutral Start Tap.

Error codes "Er24i" and "Er25i" indicate invalid Low Relay or High Relay limits respectively. Re-enter the appropriate relay limits.

Base 1 Uni-polar

This mode is used for LTC monitoring when the lowest tap number is **1**. There may be multiple neutral taps. They can be located anywhere between the lowest and highest taps as long as they are grouped together in one section. The analog output is stepped and jumps with each tap change.

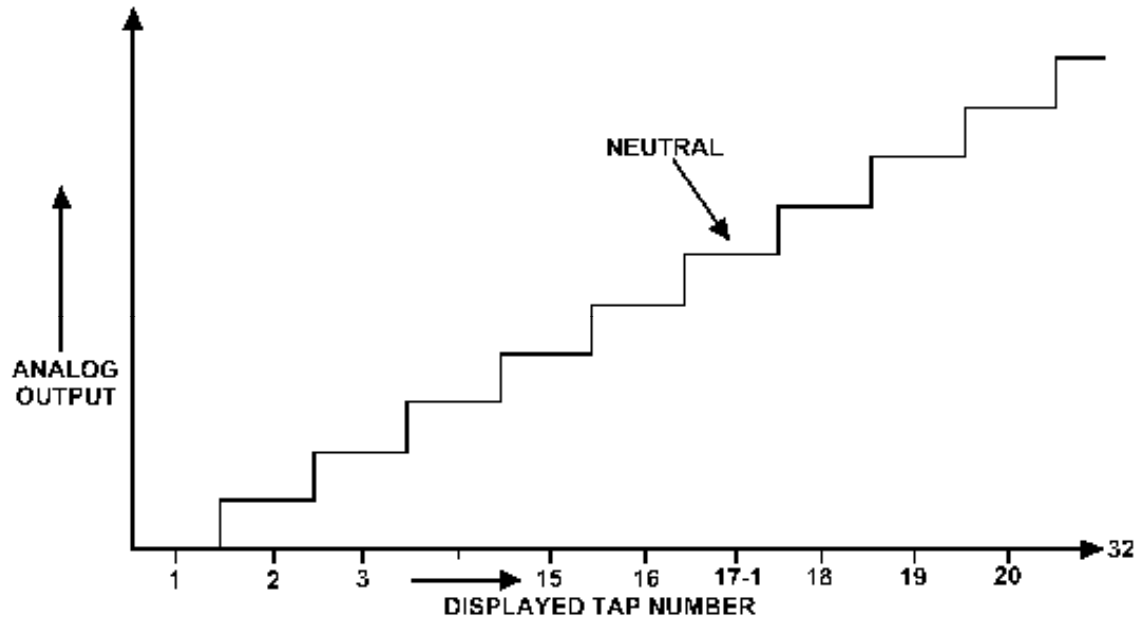

Figure 2.2 Base 1 Uni-polar Mode Analog Output

Programming Example:

A typical transformer Load Tap Changer application with taps numbered 1 to 32, 1 neutral tap (17-1), would be programmed as follows:

OP 20 Lowest Tap = 1	OP 22 Number of neutrals = 1
OP 21 Highest Tap = 32	OP 23 Lowest neutral tap = 17

Base 0 Uni-polar Segmented

This mode is used for LTC monitoring when the lowest tap number is **0**. There may be multiple neutral taps. They can be located anywhere between the lowest and highest taps as long as they are grouped together in one section. The analog output is stepped and jumps with each tap change.

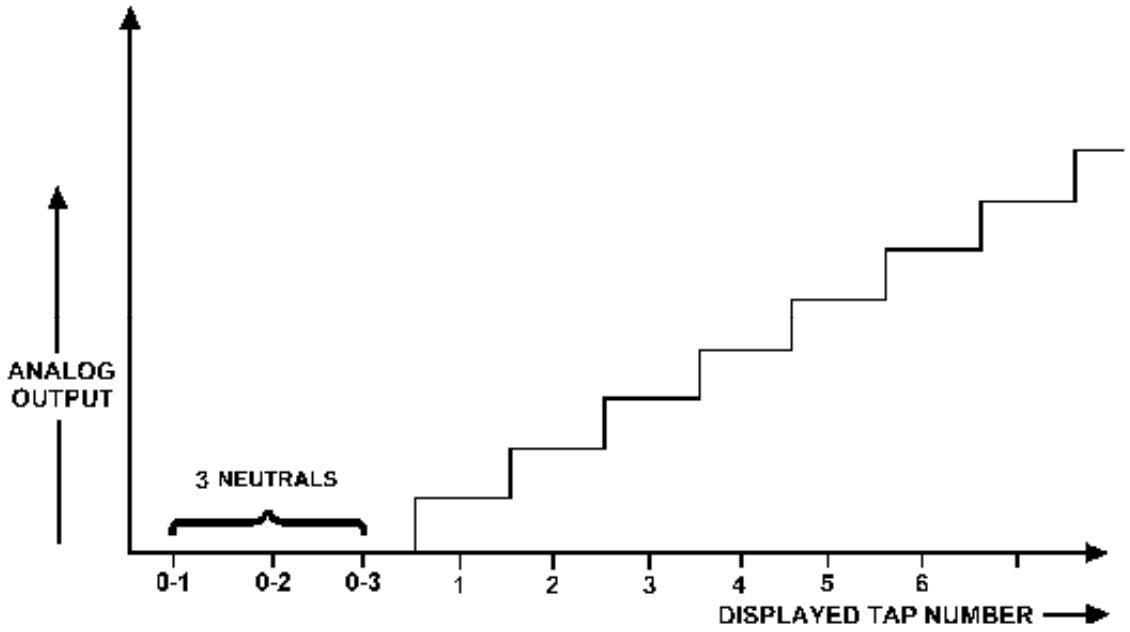

Figure 2.3 Base 0 Uni-polar Mode Analog Output

Programming Example:

A typical transformer Load Tap Changer application with taps numbered 0 to 32, 3 neutral tap0 (0-1, 0-2, 0-3), would be programmed as follows:

OP 20 Lowest Tap = 0	OP 22 Number of neutrals = 3
OP 21 Highest Tap = 32	OP 23 Lowest neutral tap = 0

Bi-polar
This mode is used for LTC monitoring when the there are raised and lowered taps. There may be multiple neutral taps. They can be located anywhere between the lowest and highest taps as long as they are grouped together in one section. The analog output is stepped and jumps with each tap change.

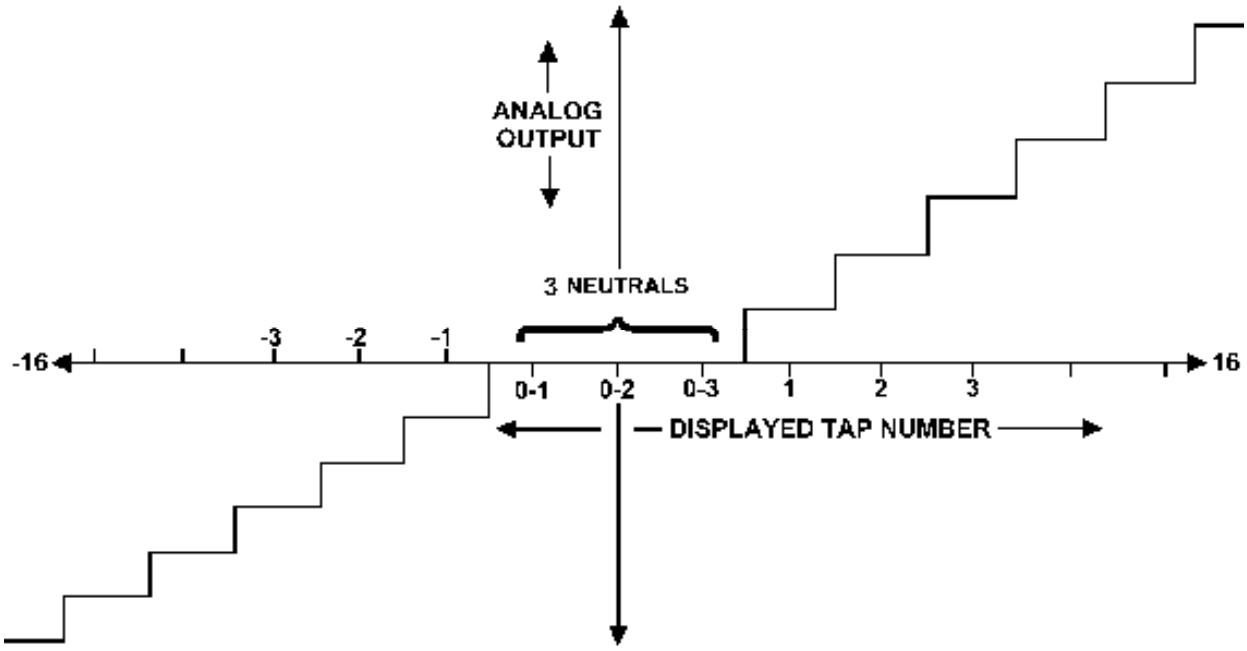

Figure 2.4 Bi-polar Mode Analog Output

Programming Example:
A typical transformer Load Tap Changer application with 16 raised and 16 lowered taps, 3 neutral taps, would be programmed as follows:

OP 20 Lowest Tap = -16	OP 22 Number of neutrals = 3
OP 21 Highest Tap = 16	OP 23 Lowest neutral tap = 0

Programming Notes:
Programming for the Analog Output option is covered in Section 3.1.
Programming for the High/Low Relays option is covered in Section 3.2.
Programming for the Serial RS-232 Communication option is covered in Section 3.3.
Programming for the Serial RS-485 Communication option is covered in Section 3.4.
Programming for the Parallel BCD option is covered in Section 3.5.

3.0 OPTIONS

The Model 1511-LTC may be configured with one or more options. This section describes general use of each option, including wiring and programming for each option.

3.1 Analog Output Option "-0", "-1", "-2", "-4", "-10", "-11"

The analog output on the 1511-LTC may be used to feed position information to a remote monitoring system such as SCADA or a remote indicator such as the INCON model 1511-Z. The analog output automatically spans between the highest and lowest taps and divides the output signal equally between all taps.

Wiring:

The 4-20mA analog output option must be wired with an external power supply of 10.0 to 24.0 volts DC in series with the analog output current loop. (See Figure 1.3) The INCON Model 1945 is available for this purpose. All other analog output options are self-powered. Refer to Table 3.1 below for analog output load limits.

Table 3.1 Analog Output Load Limits

Analog Output:	Load Minimum	Load Maximum
0 to 1 mA	Zero Ohms	10K Ohms
+/- 1 mA	Zero Ohms	10K Ohms
0 to 2 mA	Zero Ohms	5K Ohms
4-20 mA	Zero Ohms	400 Ohms with 10 volt power supply
4-20 mA	Zero Ohms	1100 Ohms with 24 volt power supply

3.2 High / Low Relay Limits Option "-R"

The High / Low Relay Limits may be used as feedback in a control system or as an alarm when the position has exceeded desired limits. The high and low relays are normally open, dry contacts that do not latch when they are turned on. When the position value falls below the low relay limit, the low relay turns on. When the position value rises above the low relay limit, the low relay will turn off. When the value rises above the high relay limit the high relay turns on. When the value falls below the high relay limit, the high relay turns off.

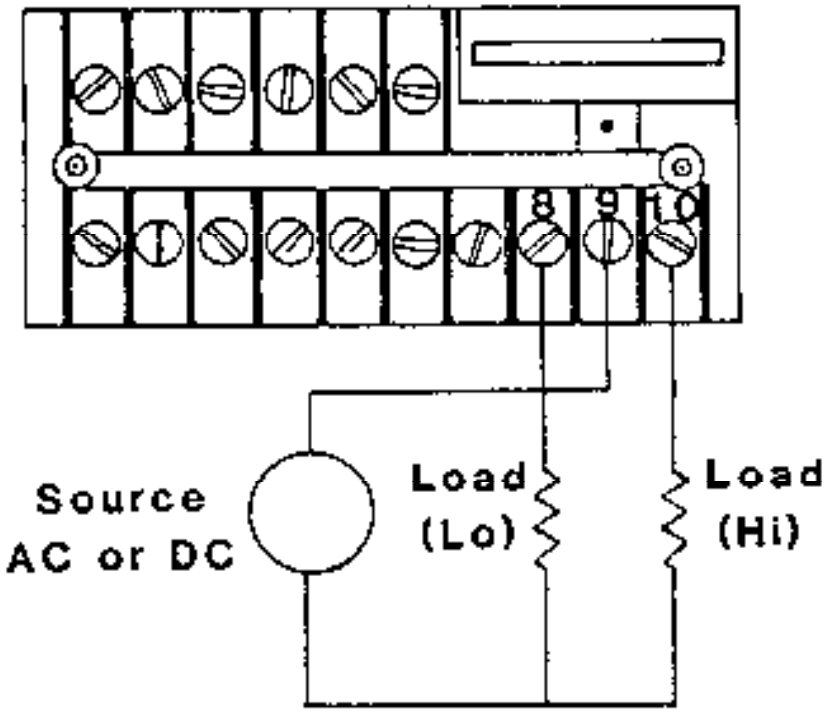

Figure 3.1 Relay Field Wiring Diagram

3.2.1 Programming the Relay Limits

Before relay limits can be set, the relay option must be enabled in the menu. To do this use the **OP 1, rLY E, RLYENA** command to toggle the condition to "**ON"**. If this condition is left in the OFF state an error message "ERR 1" will appear when attempting to set relay limits. Use the **OP 24, rL Lt, RLYLT** command to set the Low Relay Limit and the **OP 25, rL Ht, RLYHT** command to set the High Relay Limit.

Important Programming Note:

The relay limits should always be programmed AFTER the Lowest Tap Number, Highest Tap Number, Number of Neutrals, and Neutral Start Number are programmed. The programmed relay limit values may be invalidated by changes to these parameters. Error codes "Err24" and "Err25" indicate invalid Low Relay or High Relay limits respectively. When an error code appears, re-enter the appropriate relay limit.

3.3 Serial RS-232 Option "-S"

The Serial RS-232 (DCE) option on the Model 1511-LTC can be used to program the instrument or to retrieve position data from the instrument. There are seven operating modes for the serial RS-232 port:

Serial Disabled This mode stops all serial communication. To select this mode use the **OP 51, RS232, SERIAL** command to choose mode **"0"**. If you are programming the instrument through the serial port, using the serial command mode, this "disabled" mode will not take effect until the command "**EXIT**" is entered. The only way to de-select this "disabled" mode is to use the menu command **OP 51, RS232**, and select another mode.

Data Logger Mode This mode causes the 1511-LTC to transmit the present position value on the display (including sign) once a second. To select this mode use the **OP 51, RS232, SERIAL** command to choose mode **"1"**. **"**. If you are programming the instrument through the serial port, using the serial command mode, this mode will not take effect until the command "**RESTART**" is entered.

Polled Mode When this mode is selected, the 1511-LTC can be interrogated at any time via the RS-232 port for the current position. This is done by first instructing the 1511-LTC to latch the current position by transmitting an asterisk (*) to the unit. The position is then extracted, one character at a time, by transmitting the digits 0 through 6. Zero causes the sign character to be transmitted, 1 through 6 causes each position digit to be sent. The decimal point, wherever it may be positioned, is considered to be a digit. To select this mode use the menu command **OP 51, RS232, SERIAL** command to choose mode **"2"**.

Sampled Mode When this mode is selected, the 1511-LTC can be interrogated at any time via the RS-232 port for current position by transmitting a question mark (?) to the 1511-LTC. When the 1511-LTC receives a question mark, it responds by latching the current position and transmitting the value on the display in ASCII form. To select this mode use the menu command **OP 51, RS232, SERIAL** command to chose mode **"3"**.

Serial Command Mode This mode enables programming the instrument through the serial port. To select this mode use the menu command **OP 51, RS232** to choose mode **"4"**. When this mode is selected, no other serial communication can occur. In addition, if another Serial mode is chosen it will not be activated until the "**EXIT**" command is given through the serial port command line.

MODBUS Mode When this mode is selected, the 1511-LTC will respond to MODBUS commands via the RS-485 port. This option requires the RS-485 (-M) hardware option be installed. To select this mode use the menu command **OP 51, RS232** command to choose mode **"6"**. (See Section 3.4)

Remote Display Driver Mode This mode must be used when the 1511-LTC is connected to an INCON model RD4 Remote Display. It causes the 1511-LTC's RS-232 output to transmit the proper protocol and timing for the RD4 to mimic what is on the 1511-LTC's display. To select this mode use the menu command **OP 51, RS232** command to choose mode **"7"**.

The communication port settings: baud rate, word length, parity, stop bits, and address are programmable using the **OP 80, Port, PORT** command. (See Table 2.1 and 2.2 for command protocol and choices.)

Programming Note:
When the port is programmed for 2 Stop Bits, the Parity must be "NONE".

3.4 Serial RS-485 Multi-Drop Option "-M"

The Serial RS-485 option on the Model 1511-LTC can be used to program the instrument and to retrieve position data from the instrument. The MODBUS protocol is a master/slave packet based protocol with the 1511-LTCB operating as a RTU slave. The MODBUS function commands recognized by the 1511-LTCB are "**3**" (read multiple registers) and "**16**" (write multiple registers). By supporting these two commands the 1511-LTC is in level 0 compliance. Using these two commands it is possible to configure the 1511-LTC as well as monitor it for current position. MODBUS RTU command and response packets are formatted as follows:

3.4.1 RS-485 Packet Format - Read

Reading from Holding Registers:

GAP = A gap in transmission of 3.5 character frames indicates to the slaves that a new packet is to follow. No transmission gaps within a packet may exceed 1.5 character frames.

Byte 1 = Device Address: Address 0 is a broadcast address that all units respond to regardless of programmed address. All other addressed can be programmed and used in this mode.

Byte 2 = Function Code: When reading holding registers, this byte is "**03h**"

Data Block = Begins with the number of the first register (two bytes) in a command packet, or data from the first register (two bytes) in a response packet. Followed by the number of registers to be read (two bytes) in a command packet, or by data from subsequent registers.

Last 2 Bytes = Error Checking CRC – Lo Byte & Hi Byte

Table 3.2 Read Registers Command Format

GAP 3.5 Char	Device Address	Function Code	# of First Register Hi	# of First Register Lo	# of Registers to Read Hi	# of Registers to Read Lo	CRC Lo	CRC Hi
Min.	80h	03h	01h	03h	00h	04h	xx	xx

Table 3.3 Read Registers Response Format

GAP 3.5 Char	Device Address	Function Code	Byte Count	Data from First Register Hi	Data from First Register Lo	Data from Second Register Hi	Data from Second Register Lo
Min.	80h	03h	08h	01h	03h	00h	03h

……	……	Data from Last Register Hi	Data from Last Register Lo	CRC Lo	CRC Hi
……	……	00h	02h	xx	xx

3.4.2 RS-485 Packet Format - Write

Write to Holding Registers:

GAP = A gap in transmission of 3.5 character frames indicates to the slaves that a new packet is to follow. No transmission gaps within a packet may exceed 1.5 character frames.

Byte 1 = Device Address: Address 0 is a broadcast address that all units respond to regardless of programmed address. All other addresses can be programmed and used in this mode.

Byte 2 = Function Code: When writing to holding registers, this byte is "**10h**"

Data Block = Begins with the number of the first register to be written (two bytes), followed by the number of registers to be written (two bytes), in either command or response packets. In a command packet the programming data for the first register will be the next two bytes followed by programming data for subsequent registers.

Last 2 Bytes = Error Checking CRC – Lo Byte & Hi Byte

Table 3.4 Write Registers Command Format

GAP 3.5 Char	Device Address	Function Code	# of First Register to be written to Hi	# of First Register to be written to Lo	# of Registers to Write Hi	# of Registers to Write Lo
Min.	80h	10h	10h	00h	00h	04h

Byte Count	Program Data for First Register Hi	Program Data for First Register Lo	Program Data for Second Register Hi	Program Data for Second Register Lo
08h	00h	01h	03h	60h

……	……	Program Data for Last Register Hi	Program Data for Last Register Lo	CRC Lo	CRC Hi
……	……	00	01	xx	xx

Table 3.5 Write Registers Response Format

GAP 3.5 Char	Device Address	Function Code	# of First Register to be written to Hi	# of First Register to be written to Lo	# of Registers to Write Hi	# of Registers to Write Lo	CRC Lo	CRC Hi
Min.	80h	10h	01h	00h	00h	04h	xx	xx

3.4.2 RS-485 Packet Format – Error Exception Response

When the master sends a command, the MSB bit in the Function Code is always clear. When a slave responds to the command, the slave leaves the MSB bit in the Function Code clear if the response is a normal response and sets MSB bit on if the response is an error exception response.

GAP = A gap in transmission of 3.5 character frames indicates to the slaves that a new packet is to follow.

Byte 1 = Device Address: Address 0 is a broadcast address that all units respond to regardless of programmed address. All other addressed can be programmed and used in this mode.

Byte 2 = Function Code: This byte will be the last command sent plus the MSB set on.

Exception Code = Illegal Command = 01
Illegal Register = 02

Last 2 Bytes = Error Checking CRC – Lo Byte & Hi Byte

Table 3.6 Error Exception Response Format

GAP 3.5 Char	Device Address	Function Code	Exception Code	CRC Lo	CRC Hi
Min.	80h	90h	02	xx	xx

In the following Table 3.7 the meanings of the columns are as follows:

Register: MODBUS register address as seen in a MODBUS command beginning with register 40001 and ending with 45895. These addresses are in **decimal**.

Hex: The same register's address in **hexadecimal**, this value is calculated by subtracting 40001 from the register number. Thus register 40001 in decimal becomes 0000 in hex, and 40264 in decimal becomes 0107 in hex.

Function: Defines what each register contains or does when written. Some registers are read only and have no meaning when written. Others can be written or read. Others are write only special function and cause actions to be performed when they are written. Still others are "select registers", which select what other registers do when they are read or written. 45890 (1701h) is such a register, and selects which table position is affected by the other registers.

Format: This column defines what a register contains bit-by-bit in **binary**. A row of 16 symbols shows what each of the 16 bits of the register contain MSB first and LSB last. A BCD formatted floating point register is shown as follows (two 16 bit binary words):

Bcdabcdbbcdcbcdd bcde000000vspppp

bcda, bcdb, bcdc, bcdd, bcde are each four-bit BCD digits, as it would be seen on a display.
000000 are 6 unused bits that report as 0 when read and must be 0 when written.
v is an overflow bit that indicates that the number in the register is too big to display when it is a 1. 0 indicates a valid register value.
s is the sign bit and is 1 when the value in the register is negative. 0 indicates a positive number.
pppp is the position of the decimal point within the bcd digits.
Most registers are not as complex as a floating-point register.

An alternate floating-point format is supported and selected by writing a 1 to the 40256d (**00ff h**) register. This selects an IEEE floating-point format as follows (two 16 bit binary words):

seeeeeeeemmmmmmm mmmmmmmmmmmmmmmm

The format of the IEEE floating-point number is as follows:
s is the sign bit,
e is the exponent bits, and
m are the mantissa bits.

Table 3.7 RS-485 MODBUS Register Definitions

Register:	Hex:	Function:	Binary Format:
40001	0000	setup / run mode select	000000000000000**s** LSB (**s**) selects mode 0 – run mode 1 – setup mode (must be 1 before any program parameter can be changed)
40264	0107	tap, neutral	**tttttttt**0000**nnnn** "0000" are unused bits "**t**"= tap number "**n**"= neutral number
40513	0200	draghand reset control	00000000000000**HL** bit = 1 to reset "**H**"= high draghand "**L**"= low draghand
40516	0203	peak Tap draghand	**tttttttt**0000**nnnn** "0000" are unused bits "**t**"= tap number "**n**"= neutral number
40519	0206	valley Tap draghand	**tttttttt**0000**nnnn** "0000" are unused bits "**t**"= tap number "**n**"= neutral number
40769	0300	internal relay states	00000000000000**HL** relay on, bit = 1 "**H**"= high relay "**L**"= low relay
41025	0400	analog output	0000**aaaaaaaaaaaa** 12 LSBs
44353	1100	Low Tap #	**ssssssssssssssss** 16 bits, Low Tap #
44354	1101	High Tap #	**ssssssssssssssss** 16 bits, High Tap #
44356	1103	number of neutrals	000000000000**nnnn** 4 LSBs
44357	1104	neutral start segment	**ssssssssssssssss** 16 bits, first neutral tap
44358	1105	Display "r"&"L"	000000000000000**d** enabled, LSB(**d**)= 1
49217	1200	relays enable	000000000000000**r** enabled, LSB(**r**) = 1
49222	1205	relay low Tap	**ssssssssssssssss** 16 bits, low tap limit
49223	1206	relay high Tap	**ssssssssssssssss** 16 bits, high tap limit
45121	1400	display blank	000000000000000**b** enabled, LSB(**b**)=1
45122	1401	menu mode	000000000000000**m** LSB (**m**) select 0= numeric, 1=alphanumeric
45377	1500	bcd mode	0000000000000**bbb** 3 LSBs (**bbb**) select 000=disabled, 001=multiplexed BCD, 010=par bcd high, 011=par bcd low, 100=2's compliment bcd, 101=sign plus magn., 110=offset binary
45633	1600	RS-232 mode	0000000000000**rrr** 3 LSBs (**rrr**) select 000=datalogger mode, 001=polled mode, 010=sampled mode, 011=command, 100=reserved N/A, 101=RS485 Modbus, 110=remote display driver
45634	1601	baud	000000000000**bbbb** 4 LSBs (**bbbb**) 0000=300, 0001=1200, 0010=2400, 0011=4800, 0100=9600, 0101=14400, 0110=19200, 0111=28800, 1000=38400, 1001=57600, 1010=76800

Register:	Hex:	Function:	Binary Format:
45635	1602	word length	000000000000000**w** LSB (**w**) select 0 = 7 bits, 1 = 8 bits
45636	1603	parity	00000000000000**pp** 2 LSBs (**pp**) 00 = none, 01 = even, 10 = odd
45637	1604	stop bits	000000000000000**s** LSB (**s**) select 0 = 7 bits, 1 = 8 bits
45638	1605	address	00000000**aaaaaaaa** 8 LSBs (**aaaaaaaa**)

3.5 Parallel BCD/BIN Option "-PB"

The Parallel BCD/BIN option on the Model 1511-LTC can be used to communicate position values to a parallel digital input device. All parallel lines are TTL and CMOS compatible. Outputs are open collector type with 10K-ohm internal pull-up resistors to +5VDC, capable of pulling a 1K- ohm resistor to a TTL low state. All outputs are high-true and referenced to signal ground. The maximum switching capability is 5VDC, 100mA.

Table 3.8 Wiring: Digital Connector Pin-Out

DB-25 Pin#	1511-LTC Pin#	Parallel BCD Function I/O	Parallel BIN Function I/O	RS-232 Function	RS-485 Function
1	1	Chassis Ground	Chassis Gnd.	Chassis Gnd.	Chassis Gnd.
14	2	Digit 0, Bit 0 (O)	Data Bit 0 (O)		
2	3	Digit 0, Bit 1 (O)	Data Bit 1 (O)	Transmit (O)	Data A(I/O)
15	4	Digit 0, Bit 2 (O)	Data Bit 2 (O)		
3	5	Digit 0, Bit 3 (O)	Data Bit 3 (O)	Receive (I)	Data B(I/O)
16	6	Digit 1, Bit 0 (O)	Data Bit 4 (O)		
4	7	Digit 1, Bit 1 (O)	Data Bit 5 (O)	RTS (O)	Not Used
17	8	Digit 1, Bit 2 (O)	Data Bit 6 (O)		
5	9	Digit 1, Bit 3 (O)	Data Bit 7 (O)	CTS (I)	Not Used
18	10	Digit 2, Bit 0 (O)	Data Bit 8 (O)		
6	11	Digit 2, Bit 1 (O)	Data Bit 9 (O)		
19	12	Digit 2, Bit 2 (O)	Data Bit 10 (O)		
7	13	Signal Ground	Signal Ground	Signal Gnd.	Signal Gnd.
20	14	Digit 2, Bit 3 (O)	Data Bit 11 (O)		
8	15	Digit 3, Bit 0 (O)	Data Bit 12 (O)		
21	16	Digit 3, Bit 1 (O)	Data Bit 13 (O)		
9	17	Data Valid (O)	Data Valid (O)	/ Strobe	
22	18	Digit 3, Bit 2 (O)	Data Bit 14 (O)		
10	19	Digit 3, Bit 3 (O)	Data Bit 15 (O)		
23	20	Sign (O)	/Sign Data Bit 16 (O)		

3.5.1 Programming the Parallel BCD/Binary Output

The 1511-LTC can be programmed for two modes of Parallel Binary Coded Decimal and three modes of Parallel Binary. Refer to Figure 3.1 for Parallel BCD timing. Use the **OP 52, BCd, BCD** command to select a parallel BCD/Binary mode.

Parallel BCD Mode: In this mode the 1511-LTC will provide a 4 digit BCD (16 bits, 4 bits per digit, plus a sign bit) representation of the displayed value. (Multiple neutrals will be represented as the same BCD value.) To select this mode use the menu command **OP 52, BCd** to choose mode **"2"** or "**3**". Either will select this mode.

Parallel Binary 2's Complement Mode: In this mode the 1511-LTC will provide a 17 bit (16 bit magnitude plus sign bit) **binary** 2's complement representation of the displayed value. (Multiple neutrals will be represented as the same Binary value.) (See Table 3.6 for an example.) To select this mode use the menu command **OP 52, BCd** to choose mode **"4"**.

Parallel Binary Sign Plus Magnitude Mode: In this mode the 1511-LTC will provide a 17 bit (16 bit magnitude plus sign bit) **binary** sign plus magnitude representation of the displayed value. (Multiple neutrals will be represented as the same Binary value.) (See Table 3.6 for an example.) To select this mode use the menu command **OP 52, BCd** to choose mode **"5"**.

Parallel Offset Binary Mode: In this mode the 1511-LTC will provide a 17 bit (16 bit magnitude plus sign bit) offset **binary** representation of the displayed value. (Multiple neutrals will be represented as the same Binary value.) (See Table 3.6 for an example.) To select this mode use the menu command **OP 52, BCd** to choose mode **"6"**.

Notes:

The 1511-LTC will update the Parallel BCD/Binary output at least every 100 milliseconds but not more often than every 60 milliseconds. The DATA VALID line will be high when data is stable and may be safely read. The DATA VALID line will go low to indicate that the data is being updated. The DATA VALID line will return high after data has been updated and is stable.

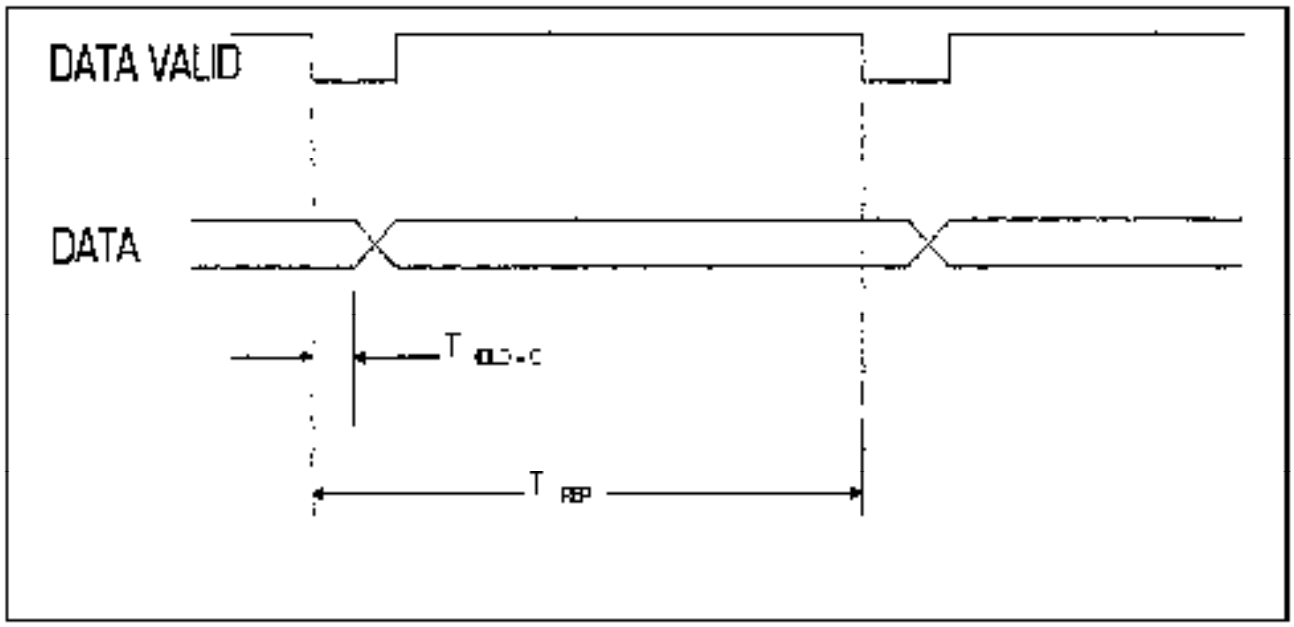

Figure 3.2 Parallel BCD Timing

Table 3.9 Parallel Binary Examples

Example of Binary 2's Compliment	
	17 Binary Bits:
+2	00000000000000010
+1	00000000000000001
0-1 Neut	00000000000000000
-1	11111111111111111
-2	11111111111111110
Example of Binary Magnitude Plus Sign	
+2	00000000000000010
+1	00000000000000001
0-2 Neut	00000000000000000
-1	10000000000000001
-2	10000000000000010
Example of Offset Binary	
+2	10000000000000010
+1	10000000000000001
0-3 Neut	10000000000000000
-1	01111111111111111
-2	01111111111111110

4.0 Field Calibration and Test

Input Signal Calibration: The Model 1511-LTC must be calibrated after it is wired to the Slidewire (See Figure 1.2). **If the total Slidewire resistance is less than 600 ohms, additional resistance must be added in series with the Slidewire (see Figure 1.4).** Terminal "E" should be connected to the LOWEST TAP side of the Slidewire. Terminal "F" should be connected to the HIGHEST TAP side of the Slidewire

Calibration procedure:

- Enter the Program Mode.
- Scroll to "OP 27" and enter. The display should be flashing "CALLo".
- Move the LTC to the LOWEST TAP POSITION. (If the LTC is energized and cannot be moved, disconnect the wire from terminal "A" at the Slidewire and connect it to the wire from Terminal "E" at the Slidewire. Note: If a resistor has been added as in Figure 1.4, this wire must be connected at the point labeled "E2" in Figure 1.4, Pg. 6.)
- Press the UP and DOWN buttons at the same time. The display should go blank for a few seconds, then show a number for about 2 seconds, and then return to "OP 27".
- Scroll to "OP 28" and enter. The display should be flashing "CALHI".
- Move the LTC to the HIGHEST TAP POSITION. (If the LTC is energized and cannot be moved, disconnect the wire from terminal "A" at the Slidewire and connect it to the wire from Terminal "F" at the Slidewire. Note: If a resistor has been added as in Figure 1.4, this wire must be connected at the point labeled "F2" in Figure 1.4.)
- Press the UP and DOWN buttons at the same time. The display should go blank for a few seconds, then show a number for about 2 seconds, and then return to "OP 28".
- Note: If the display shows "ERR 2", there was a wiring error during this calibration. The low and high calibrations points were at the SAME signal voltage. Carefully review the wiring and repeat this procedure.
- Scroll to "OP 0" and enter twice to return to the Run Mode.

Analog Output Calibration: **The Model 1511-LTC should not require field calibration.** However, there are provisions in the menu to facilitate Analog Output Calibration. The analog output may be adjusted in the field. A calibrated multi-meter should be used to measure the output signal during calibration.

To enable analog calibration, select the **OP 30, CAL** menu command and choose the "On" mode. If you are using the RS-232 serial port, use the **ANACAL** command. The analog output may be forced to LOW, MID, and HIGH output signal states.

If menu commands are being used, select the **OP 31, L CAL** command to force the analog output to LOW scale output. If you are using the RS-232 serial port, press the space bar on the computer terminal. This toggles the output between LOW, MID, and HIGH outputs. The display on the 1511-LTC should read "LO". The analog output low scale may now be adjusted by turning the "ZERO" pot, accessible through the slot in the left side of the case (see Figure 4.1), until the output signal is reading properly on the multi-meter.

If menu commands are being used, select the **OP 32, H CAL** command to force the analog output to HIGH scale output. If you are using the RS-232 serial port, press the space bar on the computer terminal. The display on the 1511-LTC should read "HI". The analog output high scale may now be adjusted by turning the "SPAN" pot (see Figure 4.1) until the output signal is reading properly on the multi-meter. Repeat analog LOW and HIGH calibration steps several times to assure proper output signal calibration of both. Some interaction may occur between the ZERO and SPAN adjustments.

If menu commands are being used, select the **OP 33, D CAL** command to force the analog output to MID scale output. If you are using the RS-232 serial port, press the space bar on the computer terminal. The display on the 1511-LTC should read "**--**". The analog output should read a mid-scale signal on the multi-meter. There is no adjustment for this mid-scale output.

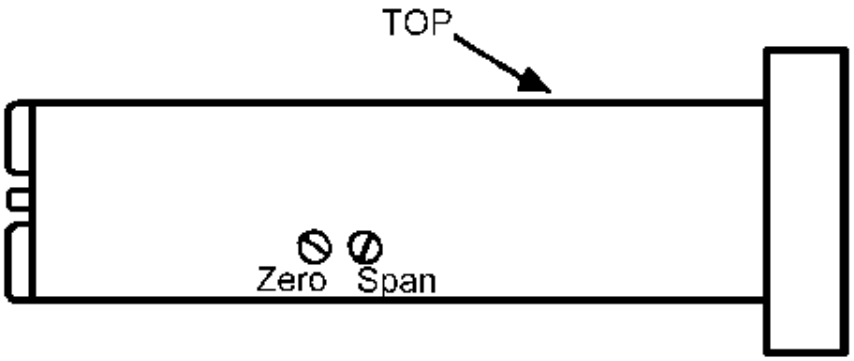

Figure 4.1 Analog Output Adjustment Pots

Self-Diagnostic Tests: The Model 1511-LTC regularly performs a number of self-check diagnostic tests and generates error codes in the form "FA *n*" and "ERR *n*" if it detects an internal fault. The "*n*" number indicates the type of failure detected. See Section 5.0 for a full list of error codes and their explanation.

Power Fail: The 1511-LTC is designed to shut its microprocessor off when it detects the line voltage falling below a fixed threshold, typically 85 to 105 / 170 to 210 VAC. This feature enables the microprocessor to properly store its data before the power is lost completely. The 1511-LTC will automatically re-start itself when the line voltage rises above the Power Fail Threshold voltage.

The software revision number can be displayed by pressing the "SELECT/ENTER" key while turning on the power to the 1511-LTC.

The 1511-LTC has the capability to delete all user-programmed values and restore all factory default program values. This "cold boot" is accomplished by pressing the "MENU" key while turning on the power to the 1511-LTC. There is no way to undo the effects of a cold boot.

The LED display can be tested. Use the **OP 40, LED t, LEDTEST** command to turn on all display LED's. Press the ENTER key to stop the test.

The RS-232 port can be tested. Use the **OP 41, RS t** menu command to enter the RS-232 Echo Test mode. With a computer terminal connected to the serial port, type in some characters. The 1511-LTC should receive these characters and re-transmit them back to the terminal. The characters typed should appear on the terminal display. Press the ENTER key to stop the test.

The High / Low relays can be tested. Use the **OP 43, RLY t, RLYTEST** command to turn on one of the relays. The UP and DOWN keys will cause the 1511-LTC to toggle between the High and Low relay. If you are using the RS-232 serial port, press the space bar on the computer terminal to toggle between the High and Low relay.

5.0 Error Codes

Table 5.1 Error Codes

DISPLAY	DESCRIPTION
FA 2	Watchdog Re-start (Processor Crash)
FA 3	Memory Error at start-up (User programming is erased, factory program defaults are re-loaded)
FA 5	Keypad Defective (Multiple keys depressed at the same time)
FA 27	Input Signal Error (Signal is out of range, or PCB failure has occurred)
Err 1	Relays not enabled (Change OP 1 to "On")
Err 2	Input Signal Calibration Error (Low Tap and High Tap calibration points measured the same voltage. Check signal input wiring during the input calibration procedure.)
Er23L	Neutral Start Tap value is too low. Re-enter this value (OP 23).
Er23H	Neutral Start Tap value is too high. Re-enter this value (OP 23).
Er24i	Low Relay Limit is invalid. Re-enter this value (OP 24).
Er25i	High Relay Limit is invalid. Re-enter this value (OP 25).
Er301	Analog output Calibration Mode not enabled (Change OP 30 to "On")
Er80c	Serial Port Parameter Conflict (Change Stop Bits or Parity setting)

6.0 Specifications

(All values are typical, unless otherwise specified)

ENCLOSURE:	RECTANGULAR PANEL MOUNTED METER
MATERIAL	PLASTIC
SIZE	89mm W X 41.3mm H X 178mm D
BEZEL	112mm W X 62mm h X 17.5mm D
MOUNTING	INTEGRAL SNAP-IN TABS
POWER INPUT:	
CONNECTOR	SCREW TERMINALS L1, L2, GND
VOLTAGE	115 VAC +/- 10%
OPTIONAL	230 VAC +/- 10%
FREQUENCY	47 TO 63 Hz
POWER CONSUMPTION	8 VA MAX
FUSE	INTERNAL (3/8 AMP)
ISOLATION	TRANSFORMER (1000 VAC)
TEMPERATURE RANGE	
OPERATING	0 TO 55 DEG. C
DISPLAY	5 DIGIT, 7 SEGMENT LED WITH SIGN 0.56 INCH HEIGHT FOUR STATUS INDICATOR LED'S
VIEWING DISTANCE	23 FEET
UPDATE RATE	10 TIMES PER SECOND
DISPLAY RANGE	TAP POSITIONS -50 TO 50
ACCURACY (25 DEG. C)	+/- 1.0% FULL SCALE MAX. (+/- 0.5% TYP.)
RESOLUTION	+/- 0.003% of FULL SCALE (+/- 0.0008 VDC)
TEMPERATURE DRIFT	+/- 0.01% PER DEGREE C
ELECTRICAL INPUTS	
SIGNAL INPUT	0 TO 24 VDC
TRANSMITTER POWER	24VDC @42mA
PROGRAM DISABLE	CONNECT TERMINAL #3 TO #4
ELECTRICAL OUTOUTS	
OPTIONAL HI/LO RELAYS	2 ea. FORM 1A N.O. 3A @ 250 VAC (RESISTIVE) 1/10 HP @250VAC 3A @30 VDC (RESISTIVE)
TOTAL ISOLATION	1000 VAC
ANALOG OUTPUT	
RESOLUTION	12 BITS (+/- 0.025%)
NON-LINEARITY	+/-0.1% OF FULL SCALE

Model 1511-LTC
Installation & Programming Manual

000-2068 Rev. B