

# Model 224 Series

Firmware 2.00

## Operations Manual

Four Channel DIP Switch Programmable Inductive Loop Detector

This manual contains technical information for the  
**Model 224 Series** Loop Detector

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# Model 224 Operations Manual

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## Section 1 General Description

This operation manual is for people installing, operating, and troubleshooting Reno A&E Model 224 inductive loop vehicle detectors. The Model 224 is a scanning, four channel, card rack type loop detector.

The Model 224 uses a microcontroller to monitor and process signals from four separate loop/lead-in circuits. The operation of each channel is independently programmed with a front panel six-position DIP switch module to provide the following selections:

- Seven sensitivity levels ( $-\Delta L/L$  %)
- Presence or Pulse mode
- Four frequency selections

The Model 224 is a Fail-Safe detector. Fail-Safe operation, which is the standard for intersection control, generates a continuous Call output state as long as a loop failure condition exists.

The Model 224 sequentially excites the four loop circuits. This eliminates the possibility of adjacent loop fields coupling together (crosstalk) when the loops are connected to the same detector. Each time the loop circuit is activated, loop data is obtained and recorded. The data is compared to previous samples for both the amount and rate of change. A slow rate of change is continuously tracked, as in the case with environmental drift. If a rapid change exceeds a threshold set by the sensitivity level, then the output is activated.

Each channel has a single, dual color (green / red) Detect / Fail LED indicator. The LED provides an indication of the channel's output state and loop failure condition. A vehicle presence is indicated when the Detect / Fail LED is illuminated in a green state. A loop failure condition is indicated when the Detect / Fail LED is illuminated in a red state.

If the total inductance of the loop input network goes out of the range specified for the detector, or rapidly changes by more than  $\pm 25\%$ , the channel will enter the Fail-Safe mode of operation. The Detect / Fail LED will illuminate (red) to indicate that an open loop failure or an inductance change condition of greater than  $+25\%$  exists. The Detect / Fail LED will flash (red) at a one Hz rate to indicate a shorted loop failure or an inductance change condition of greater than  $-25\%$  exists. Either indication will continue as long as the loop failure exists. If the loop self-heals, the channel will resume operation in a normal manner, except the Detect / Fail LED will flash (red) at a rate of three 50 millisecond flashes per second, thus providing an alert that a loop fail condition has occurred. Any prior loop failure indication will continue until the detector is manually reset or power is removed.

The Detect / Fail LED will illuminate (green) to indicate a vehicle presence in the loop area. If a prior Loop Failure condition has occurred and detection occurs, the Detect / Fail LED will flash red at a rate of three 50 millisecond flashes per second followed by a single 750 millisecond green flash. This prior loop failure indication will continue until the detector is manually reset or power is removed.

In addition, the Reno A&E Model 224 has a test mode that thoroughly tests the detector module without the need for external test equipment. The test mode uses the microcontroller to verify the proper operation of the entire detector's input and output circuitry including switches, LEDs and outputs. Each channel's loop oscillator circuit can also be tested to verify the correct frequency range in each of the four frequency selections.

The Model 224 Series is comprised of the following detectors:

- |              |   |
|--------------|---|
| Model 224-R  | For applications calling for a four channel, 2.00 wide (double width) rack mount detector with relay outputs and an audible detect signal (buzzer).       |
| Model 224-SS | For applications calling for a four channel, 2.00 wide (double width) rack mount detector with solid-state outputs and an audible detect signal (buzzer). |

## Section 2 General Characteristics

### 2.1 LOOP FREQUENCY

There are four (4) selectable loop frequency settings (normally in the range of 20 to 100 kilohertz) for each detector channel. The actual loop operating frequency is a function of the loop / lead-in network and the components of the loop oscillator circuit. Adjacent loops connected to different detectors may crosstalk and require changing of the operating frequency of one of the loop circuits. If crosstalk is a problem, select another loop frequency for stable operation. The four frequency selections are selected via DIP switches 1 and 2 on each of the four, front panel mounted, six-position DIP switch modules.

*NOTE: The detector channel must be reset after changing the frequency setting.*

### 2.2 PRESENCE / PULSE MODE

Two modes of operation for each channel of the detector are available. Presence or Pulse Mode is selected by setting the state of DIP switch 3 on each of the four front panel mounted six-position DIP switch modules.

**PRESENCE MODE:** Provides a Call hold time of at least four minutes (regardless of vehicle size) and typically one to three hours for an automobile or truck. This is the factory default setting and the most common setting.

**PULSE MODE:** An output Pulse of  $125 \pm 10$  milliseconds duration is generated for each vehicle entering the loop detection zone. Each detected vehicle is instantly tuned out if it remains in the loop detection zone longer than two seconds. This enables detection of subsequent vehicles entering the loop detection zone. After each vehicle leaves the loop detection zone, the channel resumes full sensitivity within one second.

*NOTE: Changing the Presence / Pulse Mode switch setting of an individual channel will reset that channel.*

### 2.3 SENSITIVITY

There are seven (7) selectable sensitivity levels plus OFF for each channel. The sensitivity levels are designed so that a one level increase actually doubles the sensitivity and a one level decrease halves the sensitivity. The seven sensitivity levels and OFF setting are selected via DIP switches 4, 5, and 6 on each of the four front panel mounted, six-position DIP switch modules. (See Section 3.4 for actual detection levels and response times for each sensitivity level.)

*NOTE: Changing the Sensitivity level of an individual channel will reset that channel.*

### 2.4 AUDIBLE DETECT SIGNAL

The pushbutton on the front panel labeled **BUZZER** is used to enable an Audible Detect Signal. When this feature is enabled (ON), an audible signal will be activated whenever the detection zone for the selected channel is occupied. The audible signal indicates actual occupancy of the loop detection zone. This feature allows a technician to watch the detection zone on the street and confirm correct detector operation without having to look at the detector front panel LEDs as well.

### 2.5 TEST MODE

Test Mode uses the microcontroller to verify the proper operation of the detector's controls and indicators (switches and LEDs). Each channel's loop oscillator circuit is also tested to verify the correct frequency range in each of the four frequency selections.



## Section 3 Specifications

### 3.1 PHYSICAL

WEIGHT: 6.0 oz (170 gm).

SIZE: 4.50 inches (11.43 cm) high x 2.00 inches (5.08 cm) wide x 6.88 inches (17.46 cm) long including connector (not including front handle). Handle adds 1.00 inch (2.54 cm) to depth measurement.

OPERATING TEMPERATURE: -40° F to +180° F (-40° C to +82° C).

CIRCUIT BOARD: Printed circuit boards are 0.062 inch thick FR4 material with 2 oz. copper on both sides and plated through holes. Circuit board and components are conformal coated with polyurethane.

CONNECTOR: 2 x 22 contact edge card connector with 0.156 inch (0.396 cm) contact centers. Key slots located between B/2 & C/3, M/11 & N/12, and E/5 & F/6. See Section 3.6 for contact assignments.

### 3.2 ELECTRICAL

POWER: 10.8 to 30 VDC. 100 milliamps maximum.

LOOP INDUCTANCE RANGE: 20 to 2000 microhenries with a Q factor of 5 or greater.

LOOP INPUTS: Transformer isolated. The minimum capacitance added by the detector is 0.068 microfarad.

LIGHTNING PROTECTION: The detector can tolerate, without damage, a 10 microfarad capacitor charged to 2,000 volts being discharged directly into the loop input terminals, or a 10 microfarad capacitor charged to 2,000 volts being discharged between either loop terminal and earth ground.

RESET: Each detector channel can be manually reset by momentarily changing any corresponding channel DIP switch position (except the Frequency DIP switches). Pressing and holding the front panel pushbutton labeled **BUZZER** until the buzzer sounds and all four channel Detect / Fail LEDs are illuminated (red) initiates a detector reset. When the pushbutton is released, the buzzer will continue to sound and the four channel Detect / Fail LEDs will remain illuminated for an additional second. When the buzzer and Detect / Fail LEDs turn off, the detector will be reset. The detector can also be reset by connecting a logic ground signal to Contact C of the edge card connector or the return of power after a power loss.

RELAY RATING: The relay contacts are rated for 6 Amps maximum, 150 VDC maximum, and 180 Watts maximum switched power.

SOLID STATE OUTPUT RATING: Optically isolated. 30 VDC max. collector (drain) to emitter (source). 50 mA max. saturation current. 2 VDC max. transistor saturation voltage. The output is protected with a 33-volt Zener diode connected between the collector (drain) and emitter (source).

### 3.3 OPERATIONAL

DETECT / FAIL INDICATORS: The detector has one super bright, high intensity, two color (green / red) light emitting diode (LED) per channel to indicate a Call output and/or the status of any current or prior loop failure conditions. A continuous ON (green) state indicates a Call output. A continuous ON (red) state indicates that a current open loop failure condition or an inductance change condition of greater than +25% exists. This condition also generates a Call output. A one Hz (red) flash rate indicates that a current shorted loop failure condition or an inductance change condition of greater than -25% exists. This condition also generates a Call output. A flash rate of three 50 millisecond (red) pulses indicates a prior loop failure condition. A flash rate of three 50 millisecond (red) pulses followed by a single 750 millisecond (green) pulse indicates a prior loop failure condition and a current Call output (detect state).

If any channel has the audible detect feature activated, that channel's Detect / Fail LED will be illuminated in an orange state for any Call output condition.

Detect / Fail LED	Meaning
OFF	No Detect / No Loop Failure Condition (No Call Output)
Solid ON (Green)	Detect (Call Output)
Solid ON (Orange)	Audible Detect Signal Activated, Detect (Call Output)
Solid ON (Red)	Open Loop Failure or Inductance change condition of greater than +25% exists
One Hz flash rate (Red) (50% Duty Cycle)	Shorted Loop Failure or Inductance change condition of greater than -25% exists
Three 50 ms (Red) flashes per second	Loop Failure condition occurred but no longer exists
Three 50 ms (Red) flashes per second followed by a single 750 ms (Green) flash	Loop Failure condition occurred but no longer exists and Detect (Call Output)
Three 50 ms (Red) flashes per second followed by a single 750 ms (Orange) flash	Loop Failure condition occurred but no longer exists, Audible Detect Signal Activated, and Detect (Call Output)

RESPONSE TIME: Response time is 120 ms  $\pm$ 40 ms for all sensitivity levels.

SELF-TUNING: The detector automatically tunes and is operational within two seconds after application of power or after being reset. Full sensitivity and hold time requires 30 seconds of operation.

ENVIRONMENTAL & TRACKING: The detector is fully self-compensating for environmental changes and loop drift over the full temperature range and the entire loop inductance range.

GROUNDING LOOP OPERATION: The loop isolation transformer allows operation with poor quality loops (which may include one short to ground at a single point).

LOOP FEEDER LENGTH: Up to 5000 feet (1500m.) maximum with proper feeder cable and appropriate loops.

LOOP (FAIL) MONITOR: If the total inductance of the channel's loop input network goes out of the range specified for the detector, or rapidly changes by more than  $\pm$ 25%, the channel will immediately enter the Fail-Safe mode of operation. The Fail-Safe mode of operation generates a continuous call during the loop failure. The Detect / Fail LED will provide an indication to identify the type of loop failure condition that exists. A continuous ON (red) state indicates that a current open loop failure condition or an inductance change condition of greater than +25% exists. A one Hz (red) flash rate indicates that a current shorted loop failure condition or an inductance change condition of greater than -25% exists. This will continue as long as the loop fault exists. **However, if the detector is reset, or power is momentarily lost, the detector will return if the loop inductance is within the acceptable range. If any type of loop failure occurs in one (or more) loop(s) in a group of two or more loops wired in parallel, the detector will not respond with a Fail-Safe output following any type of reset. It is essential that multiple loops wired to a common detector channel always be wired in series to ensure Fail-Safe operation under all circumstances.** If the loop self-heals, the detector will resume operation in a normal manner except that the Detect / Fail LED will begin to flash at a rate of three 50 millisecond (red) flashes per second, thus providing an alert that the detector has experienced a prior loop failure condition. During this state, the Detect / Fail LED will also illuminate for 750 milliseconds (green) for a Call output. The Detect / Fail LED will continue this display pattern indicating the prior loop failure condition and/or detect state until the detector is manually reset or power is removed.

### 3.4 TABLE: SENSITIVITY, -L/L, AND RESPONSE TIMES

Sensitivity Level	Industry Reference	DIP Switch 4	DIP Switch 5	DIP Switch 6	- $\Delta$ L/L Threshold	Response Time
0		OFF	OFF	OFF	OFF	-----
1		ON	OFF	OFF	0.64%	120 ms $\pm$ 40 ms
2	Low	OFF	ON	OFF	0.32%	120 ms $\pm$ 40 ms
3		ON	ON	OFF	0.16%	120 ms $\pm$ 40 ms
4	Normal	OFF	OFF	ON	0.08%	120 ms $\pm$ 40 ms
5		ON	OFF	ON	0.04%	120 ms $\pm$ 40 ms
6	High	OFF	ON	ON	0.02%	120 ms $\pm$ 40 ms
7		ON	ON	ON	0.01%	120 ms $\pm$ 40 ms

### 3.5 TABLE: DEFAULT SETTINGS, FRONT PANEL MOUNTED DIP SWITCHES

DIP Switch	Function	Setting	Position
1	Frequency	0	OFF
2			OFF
3	Presence / Pulse Mode	Presence	ON
4			OFF
5	Sensitivity	2	ON
6			OFF

### 3.6 TABLE: CONTACT ASSIGNMENTS

#### SOLID STATE OUTPUTS

Contact	Function
A	DC Common
B	DC +
C	Reset Input
D	Channel 1 Loop Input
E	Channel 1 Loop Input
F	Channel 1 Output, Collector (Drain)
H	Channel 1 Output, Emitter (Source)
J	Channel 2 Loop Input
K	Channel 2 Loop Input
L	Chassis Ground
M	No Connection
N	No Connection
P	Channel 3 Loop Input
R	Channel 3 Loop Input
S	Channel 3 Output, Collector (Drain)
T	Channel 3 Output, Emitter (Source)
U	Channel 4 Loop Input
V	Channel 4 Loop Input
W	Channel 2 Loop Input
X	Channel 2 Loop Input
Y	Channel 4 Output, Collector (Drain)
Z	Channel 4 Output, Emitter (Source)

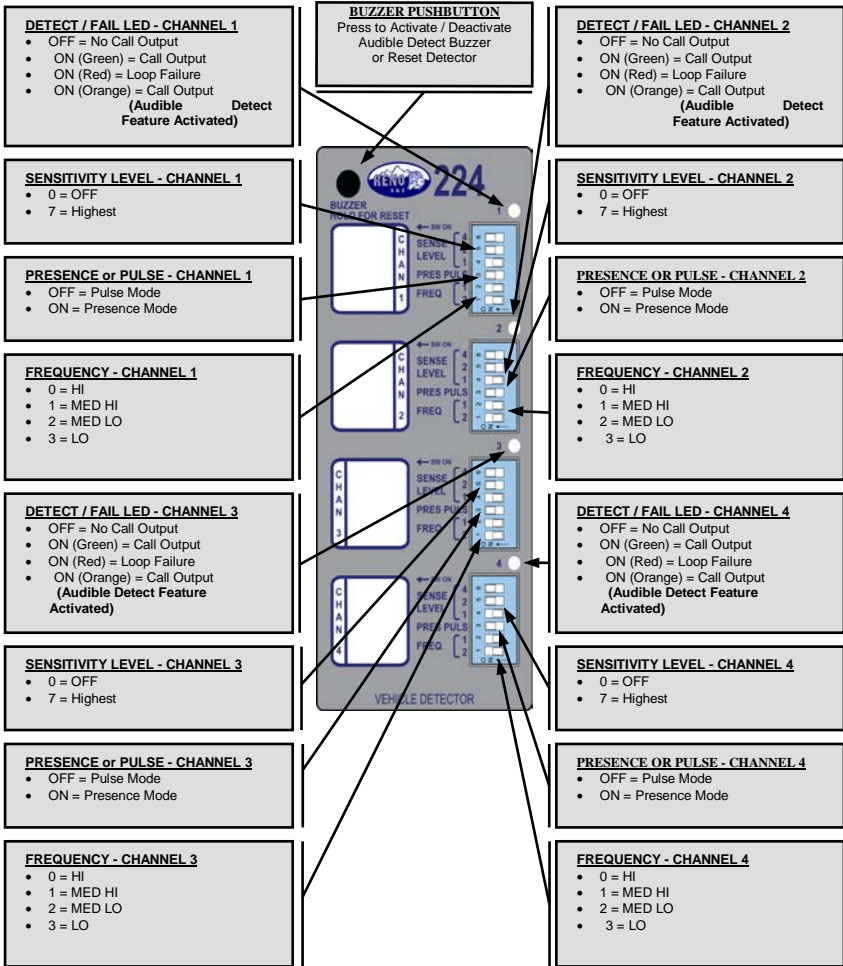
Contact	Function
1	No Connection
2	No Connection
3	No Connection
4	Channel 1 Loop Input
5	Channel 1 Loop Input
6	No Connection
7	No Connection
8	Channel 2 Loop Input
9	Channel 2 Loop Input
10	No Connection
11	No Connection
12	No Connection
13	Channel 3 Loop Input
14	Channel 3 Loop Input
15	No Connection
16	No Connection
17	Channel 4 Loop Input
18	Channel 4 Loop Input
19	No Connection
20	No Connection
21	No Connection
22	No Connection

#### RELAY OUTPUTS

Contact	Function
A	DC Common
B	DC +
C	Reset Input
D	Channel 1 Loop Input
E	Channel 1 Loop Input
F	Channel 1 Output, Relay Normally Open
H	Channel 1 Output, Relay Common
J	Channel 2 Loop Input
K	Channel 2 Loop Input
L	Chassis Ground
M	No Connection
N	No Connection
P	Channel 3 Loop Input
R	Channel 3 Loop Input
S	Channel 3 Output, Relay Normally Open
T	Channel 3 Output, Relay Common
U	Channel 4 Loop Input
V	Channel 4 Loop Input
W	Channel 2 Loop Input
X	Channel 2 Loop Input
Y	Channel 4 Output, Relay Normally Open
Z	Channel 4 Output, Relay Common

Contact	Function
1	No Connection
2	No Connection
3	No Connection
4	Channel 1 Loop Input
5	Channel 1 Loop Input
6	No Connection
7	No Connection
8	Channel 2 Loop Input
9	Channel 2 Loop Input
10	No Connection
11	No Connection
12	No Connection
13	Channel 3 Loop Input
14	Channel 3 Loop Input
15	No Connection
16	No Connection
17	Channel 4 Loop Input
18	Channel 4 Loop Input
19	No Connection
20	No Connection
21	No Connection
22	No Connection

## Section 4 User Interface



NOTE: There are no internal switches or jumpers to set.

## Section 5 Installation and Set-Up

Each channel has a front panel mounted six-position DIP switch module that is used to control the operation of the channel. The various DIP switches can be set before or after the detector card is inserted into a card rack wired with appropriate contact assignments. The PRESENCE / PULSE switches can be pre-selected for the desired mode operation. The SENSE LEVEL and FREQUENCY switches may require adjustment after the detector card has been inserted into the card rack. When the detector is inserted, each channel will automatically tune to the loop circuit and begin operation within two seconds.

Plug the detector into an appropriately wired card rack receptacle and apply power.

### 5.1 FRONT PANEL PROGRAMMING DIP SWITCHES

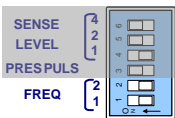


**Frequency:** The Model 224 detector sequentially activates each channel's loop circuit; so crosstalk between adjacent loops connected to different channels of the same detector is normally not a concern. Adjacent loops connected to different detectors may crosstalk. This may require changing the operating frequency of one of the loop circuits. If crosstalk is a problem, select another loop frequency for stable operation. Each channel of the Model 224 has four frequency selections that allow altering the resonant frequency of the loop circuit. The four frequency selections are selected with two DIP switches marked 1 and 2 on the DIP switch module. The value (1 or 2) to the left of the DIP switch is assigned to the switch when the switch is **ON**. If the switch is **OFF**, the switch has a value of zero (0). By adding the switch **ON** and **OFF** values, the two switches can combine for values from 0 to 3 that indicate one of the four frequency selections. Use the following table as a reference for the switch selections and frequency settings. The factory default setting of these switches is DIP switch 1 **OFF** and DIP switch 2 **OFF** (HI).

*NOTE: After changing either frequency DIP switch setting, it is necessary to reset the detector channel by momentarily changing the position of one of the other four DIP switches.*

Frequency	DIP Switch 1	DIP Switch 2	Switch Values
HI *	<b>OFF</b> *	<b>OFF</b> *	0 + 0 = 0 *
MED HI	<b>ON</b>	<b>OFF</b>	1 + 0 = 1
MED LO	<b>OFF</b>	<b>ON</b>	0 + 2 = 2
LO	<b>ON</b>	<b>ON</b>	1 + 2 = 3

\* Factory default setting.



**Presence / Pulse Output Mode:** One of two output modes can be selected for each channel via DIP switch 5.

**PRESENCE (PRES):** When the switch is in the **ON** position, Presence Mode is selected. Presence Mode provides a call hold time of at least four minutes (regardless of vehicle size) and typically one to three hours for an automobile or truck. This is the factory default setting and the most common setting.

**PULSE (PULS):** When the switch is in the **OFF** position, Pulse Mode is selected. Pulse Mode will generate a single 125 millisecond pulse output for each vehicle entering the loop detection zone. Any vehicle remaining in the loop detection zone longer than two seconds will be tuned out providing full sensitivity for the vacant portion of the loop detection zone. Full sensitivity for the entire loop detection zone is recovered within one second following the departure of any vehicle that has occupied the loop detection zone longer than two seconds.

*NOTE: Changing the setting of this switch will reset the channel.*



**Sensitivity:** Each detector channel has seven sensitivity levels plus OFF that are selected with three DIP switches marked 4, 5, and 6 on the DIP switch module. The value (1, 2, or 4) to the left of the DIP switch is assigned to the switch when the switch is **ON**. If the switch is **OFF**, the switch has a value of zero (0). By adding the switch **ON** and **OFF** values, the three switches can combine for values from 0 to 7 that indicate OFF or one of the seven sensitivity level selections. Choose the lowest sensitivity level that will consistently detect the smallest vehicle that must be detected. Do not use a sensitivity level any higher than necessary. The following table shows the actual sensitivity for each combination of switch settings. The factory default settings of these switches is DIP switch 4 **OFF**, DIP switch 5 **ON**, and DIP switch 6 **OFF** (Sensitivity Level 2,  $-\Delta/L = 0.32\%$ ).

*NOTE: Changing the sensitivity setting will reset the channel.*

Sensitivity Level	Industry Reference	DIP Switch 4	DIP Switch 5	DIP Switch 6	Switch Values	$-\Delta/L$ Threshold
0		OFF	OFF	OFF	0 + 0 + 0 = 0	OFF
1		ON	OFF	OFF	1 + 0 + 0 = 1	0.64%
2 *	Low *	OFF *	ON *	OFF *	0 + 2 + 0 = 2 *	0.32% *
3		ON	ON	OFF	1 + 2 + 0 = 3	0.16%
4	Normal	OFF	OFF	ON	0 + 0 + 4 = 4	0.08%
5		ON	OFF	ON	1 + 0 + 4 = 5	0.04%
6	High	OFF	ON	ON	0 + 2 + 4 = 6	0.02%
7		ON	ON	ON	1 + 2 + 4 = 7	0.01%

\* Factory default setting.

## 5.2 FRONT PANEL MOUNTED PUSHBUTTON – AUDIBLE DETECT SIGNAL (BUZZER) / RESET

The pushbutton on the front panel labeled **BUZZER** is used to enable an Audible Detect Signal. When this feature is enabled (on), an audible signal will be activated whenever the detection zone for the selected channel is occupied. The audible signal indicates actual occupancy of the loop detection zone. Only one channel can be turned on at a time. Turning this feature on for one channel automatically turns it off for the other channels. To activate this feature, press the pushbutton. The first time the pushbutton is pressed, a short (50 millisecond) audible signal confirms the activation of the feature for Channel 1. The second time the pushbutton is pressed, two short (50 ms) audible signals confirm the activation of the feature for Channel 2. The third time the pushbutton is pressed, three short (50 ms) audible signals confirm the activation of the feature for Channel 3. The fourth time the pushbutton is pressed, four short (50 ms) audible signals confirm the activation of the feature for Channel 4. To deactivate this feature, press the pushbutton once more. A long (250 millisecond) audible signal confirms the deactivation of the feature. This feature is automatically disabled 15 minutes after activation or on loss of power.

*NOTE: When operating in Pulse Mode, the audible detect signal will cease once a vehicle has occupied the detection zone for more than two seconds.*

To reset the detector, press and hold the front panel pushbutton labeled **BUZZER** until the buzzer sounds and all four channel Detect / Fail LEDs are illuminated (red). Release the pushbutton. The buzzer will continue to sound and the four channel Detect / Fail LEDs will remain illuminated for an additional second. When the buzzer and Detect / Fail LEDs turn off, the detector will be reset.

## 5.3 LOOP FAIL INDICATIONS

The Detect / Fail LED for each channel indicates loop failure problems according to the following table. The Detect / Fail LED is illuminated in a red state to provide an indication of either a current or prior out of tolerance (loop failure) condition. A continuous ON (red) state indicates that a current open loop failure condition or an inductance change condition of greater than +25% exists. A one Hz (red) flash rate indicates that a current shorted loop failure condition or an inductance change condition of greater than -25% exists. If the loop self heals, the channel will resume operation in a normal manner except that the Detect / Fail LED will begin to flash at a rate of three 50 millisecond (red) flashes per second, thus providing an alert that the channel has experienced a prior loop failure condition.

Detect / Fail LED	Meaning
OFF	No Loop Failure
Solid ON (Red)	Open Loop Failure or Inductance change condition of greater than +25% exists
One Hz flash rate (Red) (50% Duty Cycle)	Shorted Loop Failure or Inductance change condition of greater than -25% exists
Three 50 ms (Red) flashes per second	Loop Failure condition occurred but no longer exists

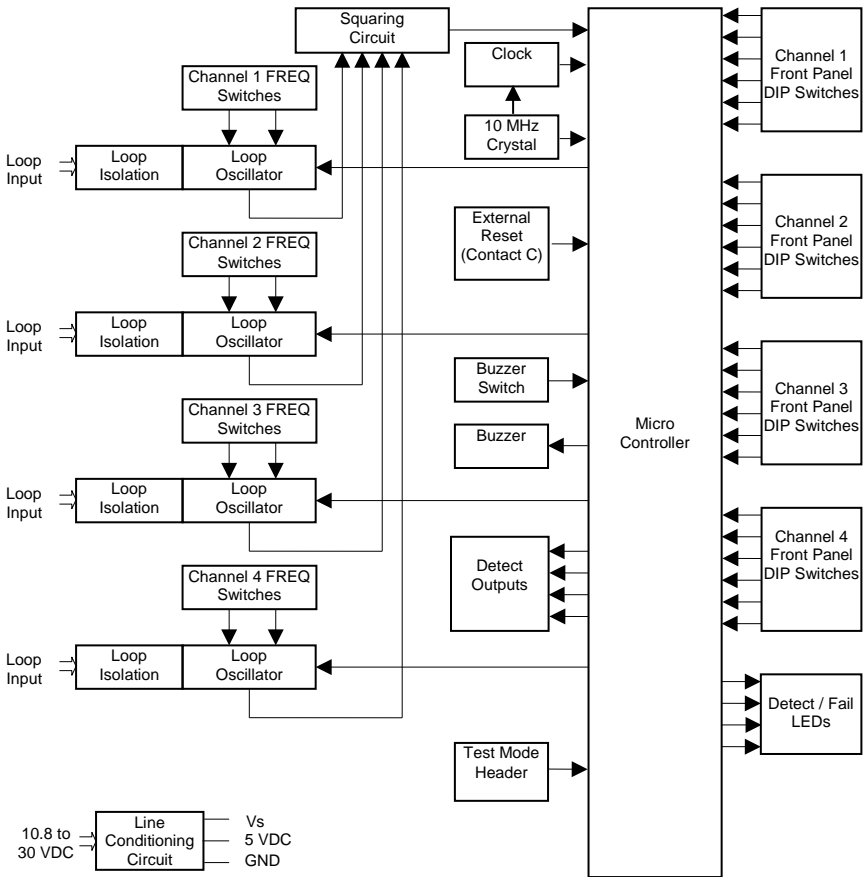
## 5.4 RESETTING THE DETECTOR

Changing the position of any of an individual channel's front panel mounted DIP switches (except the Frequency switches) will reset the channel. When the detector is installed and operating, the best method for resetting a channel is to momentarily change the position of the Presence / Pulse DIP switch and then return it to its original position.

Pressing and holding the front panel pushbutton labeled **BUZZER** until the buzzer sounds and all four channel Detect / Fail LEDs are illuminated (red) initiates a detector reset. When the pushbutton is released, the buzzer will continue to sound and the four channel Detect / Fail LEDs will remain illuminated for an additional second. When the buzzer and Detect / Fail LEDs turn off, the detector will be reset.

The detector can also be reset by connecting a logic ground signal to Contact C of the edge card connector or the return of power after a power loss.

**Section 6 Block Diagram**





## Section 7 Theory of Operation

The Reno A&E Model 224 Detector digitally measures changes in the resonant frequency of four independent parallel tuned resonant circuits (loop / lead-in) to determine if a vehicle has entered the detection zones. The detector applies an excitation voltage to each loop circuit resulting in the loops oscillating at its resonant frequency. The current flow in the loop wire creates magnetic fields around the loop wire. When a vehicle passes over the loop area, the conductive metal of the vehicle causes a loading of the loop's magnetic fields. The loading decreases the loop inductance, which causes the resonant frequency to increase. By continuously sampling the loop's resonant frequency, the magnitude and rate of change can be determined. If the frequency change exceeds a selectable threshold (set by the sensitivity settings), the detector will activate an output signal. If the rate of change is slow, typical of environmental drift, the detector will continuously track and compensate for the change. The detector also monitors the loop frequency for out of range conditions such as an opened or shorted loop circuit.

The detector scans the loop / lead-in circuit connected to each detector channel. The scanning method alternates the on and off cycle of each channel's loop circuit. Each channel's oscillator circuit supplies the excitation voltage that is coupled to the loop circuit by a loop isolation transformer. The transformer provides high common mode isolation between the loop and detector electronics, which allows the detector to operate on poor quality loops including a single short to ground. The transformer also limits the amount of static energy (lightning) that can transfer to the detector electronics. A spark gap transient suppression device is connected across the loop inputs to the isolation transformer. This device will dissipate static charges prior to their reaching the transformer. The loop input is also filtered for 60-cycle noise. A network of three capacitors is connected to the detector side of the isolation transformer. The capacitors can be switched in or out of the oscillator circuit to shift the frequency of the loop circuit, thus providing frequency separation between adjacent loops.

The sine wave from the loop circuit is squared for the microcontroller to digitally measure the period of several cycles. A high-speed clock sets a reference count for the period in a counter. If the frequency increases, the period is shorter and the period count decreases. By comparing the new count with the reference count, a percentage of change can be calculated that indirectly relates to the inductance change. If the magnitude of the change exceeds a selectable threshold (sensitivity setting), the detector activates the output device.

The rate of change is also monitored. Slow rates of change typical of environmental drift are tracked and automatically compensated for. If the total inductance of the loop input network goes out of the range specified for the detector, or rapidly changes by more than  $\pm 25\%$ , the channel will immediately enter the Fail-Safe mode of operation. Fail-Safe operation generates a continuous call output in the Presence Mode or Pulse Mode. The Detect / Fail LED will turn ON (red) or flash (red) at a one Hz rate and remain ON or continue flashing as long as the loop failure condition exists. If the loop self-heals, the channel will resume operation in a normal manner; except the Detect / Fail LED will begin to flash at a rate of three red flashes per second, thus providing an alert of a prior Loop Fail condition. The Detect / Fail LED will continue indicating the last loop failure condition until the detector is manually reset or power is removed.

The detector is designed to operate from D.C. power sources providing either 12 VDC or 24 VDC. On-board regulators provide regulated voltages so that the detector can safely operate over the full input voltage range of 10.8 VDC to 30 VDC. The unit is also provided with an external reset capability. When Contact C of the edge card connector receives a logic ground signal for a minimum of 30 microseconds, both channels of the detector are immediately reset. Changing any front panel switch (except the frequency switches) resets the associated channel.

The operating parameters of each detector channel are established by DIP switch settings on DIP switch modules located on the front panel. Operating parameters that can be selected on the front panel are Sensitivity, Presence / Pulse Mode, and Loop Frequency. A two pin header on the PC board can be used to enter Test Mode. A front panel mounted pushbutton is used for activation of an audible detect signal and detector reset. The loop frequency switches are directly connected to the tuning capacitors in the loop oscillator circuits. The settings of the remaining switches are strobed into the microprocessor. The microprocessor provides four output signals: a separate output line for each channel. Each output line drives a fail-safe optically isolated transistor. Solid state output devices provide faster turn on and turn off times, thus giving more accurate information when the detector is used in speed and/or occupancy applications. The output signals are connected to four, dual color (green / red), front panel mounted Detect / Fail LEDs. Each LED corresponds to an individual detector channel. The Detect / Fail LEDs are normally extinguished when there are no detect outputs, the loops are in tolerance, and there have been no previous failure conditions. A Detect / Fail LED will be steady ON (green) when a current detect output state exists. A Detect / Fail LED will be steady ON (red) when a current open loop failure or an inductance change condition of more than 25% exists. A Detect / Fail LED will flash at a one Hz rate (red) when a current shorted loop failure or an inductance change condition of less than 25% exists. When a Detect / Fail LED flashes at a rate of three 50 millisecond flashes per second (red), it is an indication that the loop is currently in tolerance, but the detector channel has previously experienced an out of tolerance condition. If a current detect output state exists and a detector channel has previously experienced an out of tolerance condition, the corresponding Detect / Fail LED will flash at a rate of three 50 millisecond flashes per second (red) followed by a single 750 millisecond flash (green). Either of these prior failure Detect / Fail LED flashing conditions will be reset whenever the detector is reset, the channel is reset, or power is interrupted.

The Reno A&E Model 224 detector is designed and manufactured using the latest available technology in electronic design and manufacturing, thus providing the highest possible performance and reliability. Once properly installed a Reno A&E loop detector will provide years of trouble free operation.

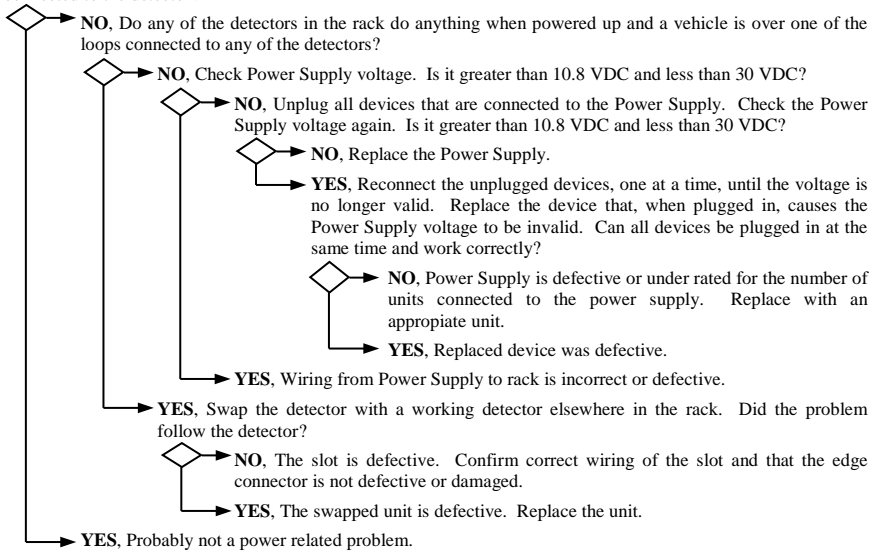
## Section 8 Maintenance and Troubleshooting

The Reno A&E Model 224 detector requires no maintenance. If you are having problems with your Model 224 detector, use the troubleshooting chart below to help determine the cause of the problem.

Symptom	Where To Start
No LEDs lit and detector does not respond to traffic.	See <b>Troubleshooting Power Problems</b> . Check for sensitivity set extremely low (0 to 2).
All Channel's LEDs are ON (Green) and cannot be turned OFF, even when the channel is disabled.	Check the Reset Input (Contact C), the detector is being continually reset.
LOOP FAIL indication (LED ON Red or flashing Red at a one Hz rate).	See <b>Troubleshooting Loop Fail Problems</b> .
Previous LOOP FAIL indication (LED flashing three times per second Red) and detector appears to be working correctly.	See <b>Troubleshooting Intermittent Loop Fail Problems</b> .
Detector intermittently stays in the Call state (LED ON Green).	See <b>Troubleshooting Intermittent Detector Lock Ups</b> .

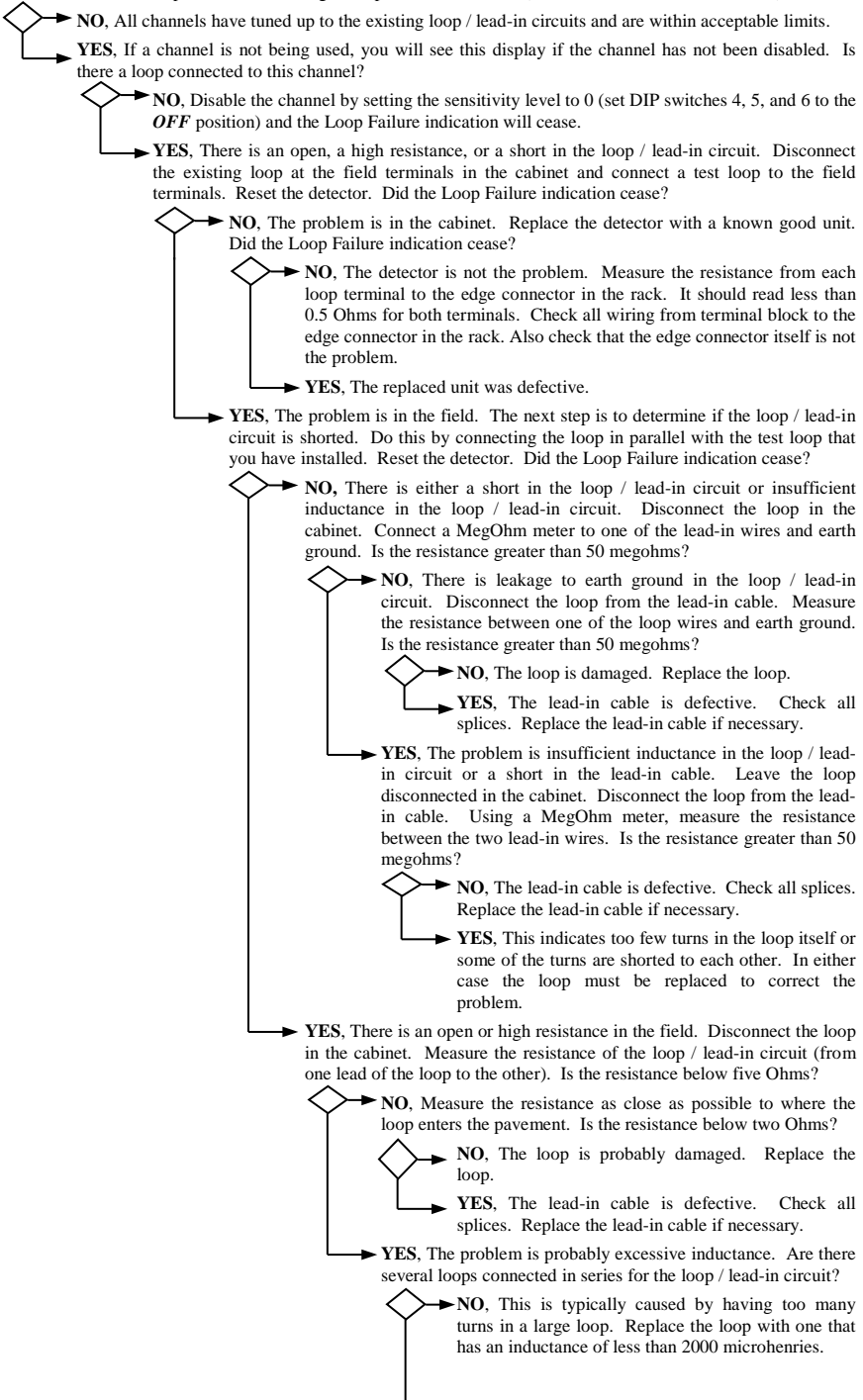
### 8.1 TROUBLESHOOTING POWER PROBLEMS

Do any of the LEDs turn ON (Green) when the detector is powered up and a vehicle is over one of the loops connected to the detector?



## 8.2 TROUBLESHOOTING LOOP FAIL PROBLEMS

Is one of the four front panel LEDs showing a Loop Failure indication (ON Red or one Hz flash rate Red)?



- **YES**. If possible, connecting each loop to its own detector is preferred. Or try a parallel wiring arrangement for the loops if separate detection channels are not possible.

### 8.3 TROUBLESHOOTING INTERMITTENT LOOP FAIL PROBLEMS

Intermittent Loop Fail problems tend to be associated with bad splices in the loop / lead-in circuit, shorts in the loop / lead-in circuit, shorts to earth ground in the loop / lead-in circuit, or loose connections or bad solder joints in the signal cabinet. If you have any splices that are not soldered and sealed with an adhesive heat shrink or epoxy resin, replace the splice with one that is. Using a MegOhm meter, measure the resistance from one of the loop wires to earth ground. It should be greater than 50 megaohms. Inspect the loop. Look for exposed wires or debris pressed into the saw cut. Tighten all screw terminals in the signal cabinet that the loop circuit uses. Check solder joints in the loop circuit, especially on the rack itself. Disconnect and reconnect any connector used in the loop circuit and check for loose pins and sockets in these connectors. If your cabinet has lightning or surge suppression devices on the loop inputs in the cabinet, remove or replace them. Check for places in the field where the loop wire or lead-in cable may be pinched or chaffed. Look for wires pinched under junction box covers and where the wire enters conduit, especially where the loop wire leaves the saw cut and enters a conduit. After checking all of the above items, you could swap out the detector but this type of failure is rarely ever related to the detector.

### 8.4 TROUBLESHOOTING INTERMITTENT DETECTOR LOCK UPS

Problems of this type tend to be difficult to isolate due to the many possible causes and the short duration of the symptom (usually less than 30 minutes). If the problem occurs more frequently in the morning or when raining, suspect a short to earth ground in the loop / lead-in circuit. This can usually be verified by testing with a MegOhm meter but not always. Vibration can also be a possible cause. Loop wires may be moving slightly in a conduit due to vibrations from truck traffic. Utility lids in the street near the loop may also be a source of problems. Ensure that lids near a loop are bolted down so that they cannot move. Check that each set of loop wires is twisted together in any pull boxes and that lengths are not excessive. Inspect the loop. Look for exposed wires or debris pressed into the saw cut. Check for places in the field where the loop wire or lead-in cable may be pinched or chaffed. Look for wires pinched under junction box covers and where the wire enters a conduit, especially where the loop wire leaves the saw cut and enters a conduit. **If your cabinet has lightning or surge suppression devices on the loop inputs in the cabinet, remove or replace them.** If you have any splices that are not soldered and sealed with an adhesive heat shrink or epoxy resin, replace the splice with one that is. Solder all crimp connections in the loop circuit. Tighten all screw terminals in the signal cabinet that the loop circuit uses. Check solder joints in the loop circuit, especially on the harness itself. Disconnect and reconnect any connector used in the loop circuit and check for loose pins and sockets in these connectors.

### 8.5 TEST MODE OPERATION

Test Mode uses the microcontroller to verify the proper operation of the detector's controls and indicators (switches and LEDs). Each channel's loop oscillator circuit is also checked to verify the correct frequency in each of the four frequency selections. The frequency portion of the test requires the detector to be connected to a 100 microhenry loop. If an inductance value other than 100 microhenries is used, the frequency test results will be invalid.

**NOTE:** *The test procedures outlined below should not be performed in an operational traffic signal cabinet.*

#### Test Procedure - Programming DIP switches

- STEP 1.** Remove power from the detector.
- STEP 2.** Set all front panel Channel 1 Programming DIP switches (**S1**) to the **OFF** position.
- STEP 3.** Set all front panel Channel 2 Programming DIP switches (**S2**) to the **OFF** position.
- STEP 4.** Set all front panel Channel 3 Programming DIP switches (**S3**) to the **OFF** position.
- STEP 5.** Set all front panel Channel 4 Programming DIP switches (**S4**) to the **OFF** position.
- STEP 6.** Place a two pin shorting jumper into the PC board mounted two pin female header labeled **TEST**. Insert the detector into a suitable test fixture and apply power. All of the detector's LED indicators should be OFF and all of the test box's detect outputs should be OFF. Remove the two pin shorting jumper. All the LED indicators should remain OFF and all detect outputs should remain OFF.

**NOTE:** *To test the frequency range the channel must be connected to a 100 microhenry loop.* The other tests may be performed with loops within the range of 20 to 2000 microhenries.

**STEP 7.** Individually, turn **ON** DIP switches 6, 5, 4, and 3 of the Channel 1 Programming DIP switch module (**S1**). Turn **OFF** each switch after verifying the results listed in the table below.

DIP Switch Label	DIP Switch	LED Indications and Outputs
SENSE LEVEL 4	6	Channel 1 Detect / Fail LED Illuminated - GREEN
SENSE LEVEL 2	5	Channel 1 Detect / Fail LED Illuminated - RED
SENSE LEVEL 1	4	Channel 1 Detect / Fail LED Illuminated - GREEN
PRES PULS	3	Channel 1 Detect / Fail LED Illuminated - RED

**STEP 8.** Individually, turn **ON** DIP switches 6, 5, 4, and 3 of the Channel 2 Programming DIP switch module (**S2**). Turn **OFF** each switch after verifying the results listed in the table below.

DIP Switch Label	DIP Switch	LED Indications and Outputs
SENSE LEVEL 4	6	Channel 2 Detect / Fail LED Illuminated - GREEN
SENSE LEVEL 2	5	Channel 2 Detect / Fail LED Illuminated - RED
SENSE LEVEL 1	4	Channel 2 Detect / Fail LED Illuminated - GREEN
PRES PULS	3	Channel 2 Detect / Fail LED Illuminated - RED

**STEP 9.** Individually, turn **ON** DIP switches 6, 5, 4, and 3 of the Channel 3 DIP Programming DIP switch module (**S3**). Turn **OFF** each switch after verifying the results listed in the table below.

DIP Switch Label	DIP Switch	LED Indications and Outputs
SENSE LEVEL 4	6	Channel 3 Detect / Fail LED Illuminated - GREEN
SENSE LEVEL 2	5	Channel 3 Detect / Fail LED Illuminated - RED
SENSE LEVEL 1	4	Channel 3 Detect / Fail LED Illuminated - GREEN
PRES PULS	3	Channel 3 Detect / Fail LED Illuminated - RED

**STEP 10.** Individually, turn **ON** DIP switches 6, 5, 4, and 3 of the Channel 4 Programming DIP switch module (**S4**). Turn **OFF** each switch after verifying the results listed in the table below.

DIP Switch Label	DIP Switch	LED Indications and Outputs
SENSE LEVEL 4	6	Channel 4 Detect / Fail LED Illuminated - GREEN
SENSE LEVEL 2	5	Channel 4 Detect / Fail LED Illuminated - RED
SENSE LEVEL 1	4	Channel 4 Detect / Fail LED Illuminated - GREEN
PRES PULS	3	Channel 4 Detect / Fail LED Illuminated - RED

**STEP 11.** Remove power from the detector.

**Test Procedure - Frequency DIP switches**

**STEP 1.** Remove power from the detector.

**STEP 2.** Set all front panel Channel 1 Programming DIP switches (**S1**) to the **OFF** position.

**STEP 3.** Set all front panel Channel 2 Programming DIP switches (**S2**) to the **OFF** position.

**STEP 4.** Set all front panel Channel 3 Programming DIP switches (**S3**) to the **OFF** position.

**STEP 5.** Set all front panel Channel 4 Programming DIP switches (**S4**) to the **OFF** position.

**STEP 6.** Place a two pin shorting jumper into the PC board mounted two pin female header labeled **TEST**. Insert the detector into a suitable test fixture and apply power. All of the detector's LED indicators should be OFF and all of the test box's detect outputs should be OFF. Remove the two pin shorting jumper. All the LED indicators should remain OFF and all detect outputs should remain OFF.

**NOTE:** To test the frequency range the channel must be connected to a 100 microhenry loop. The other tests may be performed with loops within the range of 20 to 2000 microhenries.

**STEP 7.** Set the DIP switches 1 and 2 of the Channel 1 Programming DIP switch module (**S1**) and verify the results as listed in the table below.

DIP Switch 1 (FREQ 2)	DIP Switch 2 (FREQ 1)	LED Indications
OFF	OFF	Channel 1 Detect / Fail LED OFF
ON	OFF	Channel 1 Detect / Fail LED Flash - RED
ON	ON	Channel 1 Detect / Fail LED Flash - GREEN / RED
OFF	ON	Channel 1 Detect / Fail LED Flash - GREEN
OFF	OFF	Channel 1 Detect / Fail LED OFF

**STEP 8.** Set the DIP switches 1 and 2 of the Channel 2 Programming DIP switch module (**S2**) and verify the results as listed in the table below.

DIP Switch 1 (FREQ 2)	DIP Switch 2 (FREQ 1)	LED Indications
<i>OFF</i>	<i>OFF</i>	Channel 2 Detect / Fail LED OFF
<i>ON</i>	<i>OFF</i>	Channel 2 Detect / Fail LED Flash - RED
<i>ON</i>	<i>ON</i>	Channel 2 Detect / Fail LED Flash - GREEN / RED
<i>OFF</i>	<i>ON</i>	Channel 2 Detect / Fail LED Flash - GREEN
<i>OFF</i>	<i>OFF</i>	Channel 2 Detect / Fail LED OFF

**STEP 9.** Set the DIP switches 1 and 2 of the Channel 3 Programming DIP switch module (**S3**) and verify the results as listed in the table below.

DIP Switch 1 (FREQ 2)	DIP Switch 2 (FREQ 1)	LED Indications
<i>OFF</i>	<i>OFF</i>	Channel 3 Detect / Fail LED OFF
<i>ON</i>	<i>OFF</i>	Channel 3 Detect / Fail LED Flash - RED
<i>ON</i>	<i>ON</i>	Channel 3 Detect / Fail LED Flash - GREEN / RED
<i>OFF</i>	<i>ON</i>	Channel 3 Detect / Fail LED Flash - GREEN
<i>OFF</i>	<i>OFF</i>	Channel 3 Detect / Fail LED OFF

**STEP 10.** Set the DIP switches 1 and 2 of the Channel 4 Programming DIP switch module (**S4**) and verify the results as listed in the table below.

DIP Switch 1 (FREQ 2)	DIP Switch 2 (FREQ 1)	LED Indications
<i>OFF</i>	<i>OFF</i>	Channel 4 Detect / Fail LED OFF
<i>ON</i>	<i>OFF</i>	Channel 4 Detect / Fail LED Flash - RED
<i>ON</i>	<i>ON</i>	Channel 4 Detect / Fail LED Flash - GREEN / RED
<i>OFF</i>	<i>ON</i>	Channel 4 Detect / Fail LED Flash - GREEN
<i>OFF</i>	<i>OFF</i>	Channel 4 Detect / Fail LED OFF

**STEP 11.** Remove power from the detector.

An LED indication different than the ones described for each switch setting indicates the loop frequency is out of tolerance. Verify that the test loop has an inductance of 100 microhenries. If the test loop measures 100 microhenries the detector module should be serviced.

**Test Procedure - Front Panel Buzzer switch**

**STEP 1.** Remove power from the detector.

**STEP 2.** Refer to the table in Section 3.5 and set all front panel programming DIP switches (**S1**, **S2**, **S3**, and **S4**) to their default positions.

**STEP 3.** Insert the detector into a suitable test fixture and apply power. All the LED indicators should be OFF. **NOTE: To test the frequency range, the channel must be connected to a 100 microhenry loop.** The other tests may be performed with any loops within the range of 20 to 2000 microhenries.

**STEP 4.** Press the front panel mounted switch labeled **BUZZER**. The buzzer should sound once (50 ms).

**STEP 5.** Perform the actions and verify the results listed in the table below.

Action	LED Indications and Outputs
Input Call Channel 1	<ul style="list-style-type: none"> <li>● Channel 1 Detect / Fail LED Illuminated - ORANGE</li> <li>● Buzzer Sounds</li> </ul>
Remove Call Channel 1	<ul style="list-style-type: none"> <li>● Channel 1 Detect / Fail LED OFF</li> <li>● Buzzer Off</li> </ul>

**STEP 6.** Press the front panel mounted switch labeled **BUZZER**. The buzzer should sound twice (50 ms).

**STEP 7.** Perform the actions and verify the results listed in the table below.

Action	LED Indications and Outputs
Input Call Channel 2	<ul style="list-style-type: none"> <li>● Channel 2 Detect / Fail LED Illuminated - ORANGE</li> <li>● Buzzer Sounds</li> </ul>
Remove Call Channel 2	<ul style="list-style-type: none"> <li>● Channel 2 Detect / Fail LED OFF</li> <li>● Buzzer Off</li> </ul>

**STEP 8.** Press the front panel mounted switch labeled **BUZZER**. The buzzer should sound three times (50 ms).

**STEP 9.** Perform the actions and verify the results listed in the table below.

Action	LED Indications and Outputs
Input Call Channel 3	<ul style="list-style-type: none"> <li>● Channel 3 Detect / Fail LED Illuminated - ORANGE</li> <li>● Buzzer Sounds</li> </ul>
Remove Call Channel 3	<ul style="list-style-type: none"> <li>● Channel 3 Detect / Fail LED OFF</li> <li>● Buzzer Off</li> </ul>

**STEP 10.** Press the front panel mounted switch labeled **BUZZER**. The buzzer should sound four times (50 ms).

**STEP 11.** Perform the actions and verify the results listed in the table below.

Action	LED Indications and Outputs
Input Call Channel 4	<ul style="list-style-type: none"> <li>● Channel 4 Detect / Fail LED Illuminated - ORANGE</li> <li>● Buzzer Sounds</li> </ul>
Remove Call Channel 4	<ul style="list-style-type: none"> <li>● Channel 4 Detect / Fail LED OFF</li> <li>● Buzzer Off</li> </ul>

**STEP 12.** Press the front panel mounted switch labeled **BUZZER**. The buzzer should sound once (250 ms).

**STEP 13.** Remove power from the detector.

**Test Procedure - Reset**

**STEP 1.** Remove power from the detector.

**STEP 2.** Refer to the table in Section 3.5 and set all front panel programming DIP switches (**S1**, **S2**, **S3**, and **S4**) to their default positions.

**STEP 3.** Insert the detector into a suitable test fixture and apply power. All the LED indicators should be OFF. **NOTE: To test the frequency range, the channel must be connected to a 100 microhenry loop.** The other tests may be performed with any loops within the range of 20 to 2000 microhenries.

**STEP 4.** Perform the actions and verify the results indicated in the table below. **NOTE: Unless otherwise noted, references to switches, pushbuttons, or inputs in the table correspond to labels on test equipment supplied by Reno A&E.**



Switch / Button / Input	Action	LED Indications and Outputs
Channel 1 <b>OPEN LOOP</b> Pushbutton	Press and Hold	<ul style="list-style-type: none"> <li>● Detector Channel 1 Detect / Fail LED Illuminated - RED</li> <li>● Detector Channel 1 Output ON</li> <li>● Test Fixture Channel 1 Detect LED ON</li> </ul>
Channel 1 <b>OPEN LOOP</b> Pushbutton	Release	<ul style="list-style-type: none"> <li>● Detector Channel 1 Detect / Fail LED Flash - RED (Three 50 ms Flashes Per Second)</li> <li>● Detector Channel 1 Output OFF</li> <li>● Test Fixture Channel 1 Detect LED OFF</li> </ul>
<b>RESET</b> Pushbutton	Press and Release	<ul style="list-style-type: none"> <li>● Detector Channel 1 Detect / Fail LED OFF</li> </ul>
Channel 2 <b>OPEN LOOP</b> Pushbutton	Press and Hold	<ul style="list-style-type: none"> <li>● Detector Channel 2 Detect / Fail LED Illuminated - RED</li> <li>● Detector Channel 2 Output ON</li> <li>● Test Fixture Channel 2 Detect LED ON</li> </ul>
Channel 2 <b>OPEN LOOP</b> Pushbutton	Release	<ul style="list-style-type: none"> <li>● Detector Channel 2 Detect / Fail LED Flash - RED (Three 50 ms Flashes Per Second)</li> <li>● Detector Channel 2 Output OFF</li> <li>● Test Fixture Channel 2 Detect LED OFF</li> </ul>
<b>RESET</b> Pushbutton	Press and Release	<ul style="list-style-type: none"> <li>● Detector Channel 2 Detect / Fail LED OFF</li> </ul>
Channel 3 <b>OPEN LOOP</b> Pushbutton	Press and Hold	<ul style="list-style-type: none"> <li>● Detector Channel 3 Detect / Fail LED Illuminated - RED</li> <li>● Detector Channel 3 Output ON</li> <li>● Test Fixture Channel 3 Detect LED ON</li> </ul>
Channel 3 <b>OPEN LOOP</b> Pushbutton	Release	<ul style="list-style-type: none"> <li>● Detector Channel 3 Detect / Fail LED Flash - RED (Three 50 ms Flashes Per Second)</li> <li>● Detector Channel 3 Output OFF</li> <li>● Test Fixture Channel 3 Detect LED OFF</li> </ul>
<b>RESET</b> Pushbutton	Press and Release	<ul style="list-style-type: none"> <li>● Detector Channel 3 Detect / Fail LED OFF</li> </ul>
Channel 4 <b>OPEN LOOP</b> Pushbutton	Press and Hold	<ul style="list-style-type: none"> <li>● Detector Channel 4 Detect / Fail LED Illuminated - RED</li> <li>● Detector Channel 4 Output ON</li> <li>● Test Fixture Channel 4 Detect LED ON</li> </ul>
Channel 4 <b>OPEN LOOP</b> Pushbutton	Release	<ul style="list-style-type: none"> <li>● Detector Channel 4 Detect / Fail LED Flash - RED (Three 50 ms Flashes Per Second)</li> <li>● Detector Channel 4 Output OFF</li> <li>● Test Fixture Channel 4 Detect LED OFF</li> </ul>
<b>RESET</b> Pushbutton	Press and Release	<ul style="list-style-type: none"> <li>● Detector Channel 4 Detect / Fail LED OFF</li> </ul>

**STEP 5.** Remove power from the detector.

## 8.6 VOLTAGE AND WAVEFORM MEASUREMENTS

The following voltage and waveform measurements are referenced to logic ground on Contact A of the edge card connector.

### VOLTAGES:

1. Verify 10.8 to 30 VDC on Contact B of the edge card connector.
2. Verify 5 VDC on the following:  
Pin 3 of U11 (regulator)  
Pin 3 of U3 (regulator)  
Pin 18 (Reset) and Pins 27 and 28 (VCC) of U6 (microcontroller).
3. Verify the operation of the crystal on Pin 30 of U6 (Figure 1, below) using a low capacitance x10 probe.
4. Verify channel 1, 2, 3, and 4 oscillator scan signals (Figure 2, below) on Pins 22, 21, 20, and 19 (respectively) of U6.
5. Verify channel 1, 2, 3, and 4 oscillator sine wave (shown in Figure 3, below) forms across surge protectors LA1, LA2, LA3, and LA4. The sine wave should be 8 to 12 Vp-p and between 20 and 100 kHz.
6. Verify the comparator square wave on Pin 7 of U9 (Figure 4, below). Turn OFF three of the channels (set the three Sensitivity Level DIP switches to the **OFF** position) to verify the operation of the remaining channel.

### WAVE FORMS:

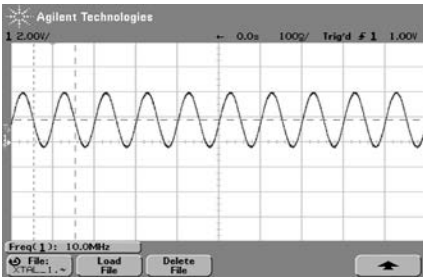


Figure 1.

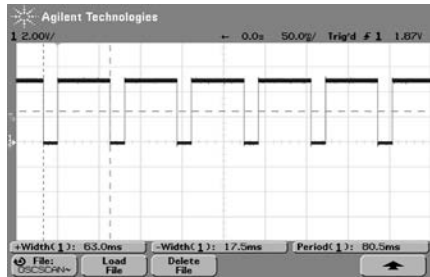


Figure 2.

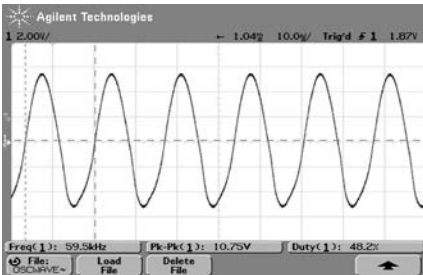


Figure 3.

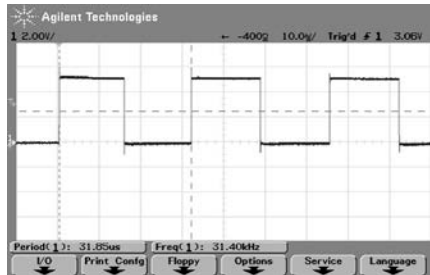


Figure 4.

## 8.7 THINGS TO KNOW ABOUT LOOPS

Always use a wire with cross-linked Polyethylene insulation (insulation type XLPE) for loop wire.

Typical sensing height is  $\frac{2}{3}$  of the shortest leg of a loop. Therefore, a 6' x 6' loop will have a detection height of 4'.

The inductance of a conventional four-sided loop can be estimated using the formula:

$$L = P \times (T^2 + T) / 4$$

Where: L = Loop Inductance in microhenries  
P = Loop Perimeter in feet  
T = Number of Turns of Wire.

Using the formula above, a 6' by 6' loop with 3 turns would have an inductance of:

$$\begin{aligned} L &= (6 + 6 + 6 + 6) \times (3^2 + 3) / 4 \\ L &= 24 \times (9 + 3) / 4 \\ L &= 24 \times 12 / 4 \\ L &= 24 \times 3 \\ L &= 72 \text{ microhenries.} \end{aligned}$$

The inductance of a Quadropole™ loop can be estimated using the formula:

$$L = [P \times (T_{OL}^2 + T_{OL}) / 4] + [CL \times (T_{CL}^2 + T_{CL}) / 4]$$

Where: L = Loop Inductance in microhenries  
P = Loop Perimeter in feet  
T<sub>OL</sub> = Number of Turns of Wire (Outer Legs)  
CL = Length of Center Leg in feet.  
T<sub>CL</sub> = Number of Turns of Wire (Center Leg)

Using the formula above, a 6' by 50' loop with a 2-4-2 configuration would have an inductance of:

$$\begin{aligned} L &= [(6 + 50 + 6 + 50) \times (2^2 + 2) / 4] + [50 \times (4^2 + 4) / 4] \\ L &= [112 \times (4 + 2) / 4] + [50 \times (16 + 4) / 4] \\ L &= (112 \times 6 / 4) + (50 \times 20 / 4) \\ L &= (112 \times 1.5) + (50 \times 5) \\ L &= 168 + 250 \\ L &= 418 \text{ microhenries.} \end{aligned}$$

Loop Feeder cable typically adds 0.22 microhenries of inductance per foot of cable.

Total inductance of loops connected in series:

$$L_{TOTAL} = L_1 + L_2 + L_3 + \dots + L_N.$$

Total inductance of loops connected in parallel:

$$L_{TOTAL} = 1 / [ (1 / L_1) + (1 / L_2) + (1 / L_3) + \dots + (1 / L_N) ].$$