

Operations Manual LM612 Series Inductive Loop Monitor™

THIS MANUAL CONTAINS TECHNICAL INFORMATION FOR THE 612 SERIES INDUCTIVE LOOP MONITOR™. INCLUDED ARE GENERAL DESCRIPTION, INSTALLATION, OPERATIONAL DESCRIPTION, ASSEMBLY AND SCHEMATICS.

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REVISION: JUNE 2000

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1. Description

The LM612 Series rack mounted dual channel inductive Loop Monitor™ is built on the international card format with double-sided 44 pin edge connectors for connection of power, loop and call outputs. Each channel has individual controls for setting up sensitivity, operational mode and frequency on the front panel. Two high intensity front panel LEDs indicate vehicle detection, timing operation and fault monitoring status for each channel. Call outputs are available in either relay or optically-isolated solid-state transistor form. Each LM612 channel will tune to any loop and lead-in inductance between 20 and 2500 microhenries and will provide satisfactory operation with lead-ins as long as 5000 feet. Loop diagnostic capabilities incorporated within the Loop Monitor™ enable the detection of short or open circuit loops and sudden changes of inductance exceeding 25 percent of the nominal inductance. Each type of fault is signified by the fault indicator emitting a different flash sequence. This information can greatly assist the user in the diagnosis of loop related problems.

2. Operation

Setting up the LM612 series Loop Monitor™.

- a) Make connections to power and loops. Power supply level should be between 16 and 30 VDC.
- b) Make sure that the unit is pushed fully home in its rack position.
- c) Check the front panel indicators. If both LEDs on either channel are flashing, there is a problem with the loop or the connections to the loop on that channel. A single flash followed by a pause indicates an open circuit. A double flash followed by a pause indicates a short circuit. Check the loop connections carefully.

Note: If power was applied before the loops were connected, the FAULT indicators alone may be flashing. Each channel may be reset by momentarily selecting a different sensitivity or mode and then returning to the original setting.

- d) Set operational mode, sensitivity and frequency for each channel as required, set delay and/or extend timing as required (LM612T and LM612TR).

Operational mode can be set to pulse, short presence or long presence as required. Use SHORT presence unless the loop is expected to be continuously occupied for a period in excess of fifteen minutes. This might occur with long loops in heavy traffic situations.

Sensitivity is set by selecting the desired level on the front panel Thumbwheel switch. Position 15 is the highest sensitivity, 1 is the lowest. It is suggested that a value of 4 be set initially, then increased or decreased as vehicles pass over the loop. If a channel is not to be used, it may be switched off by setting the sensitivity switch to 0.

Frequency only needs to be changed if interference occurs between adjacent loops connected to different Loop Monitors™. Interference or crosstalk may manifest itself as chattering of the call output or a detect call occurring at the same time as an adjacent unit when there is no vehicle present over the loop. If crosstalk is suspected, try to separate the frequencies of the channels causing the problem. For example, set one to LOW and the other to HIGH. Three frequency positions are available on each channel to assist in alleviating interference affecting more than two units.

Monitor operation and make adjustments to sensitivity and frequency as necessary. If the Loop Monitor™ channel detects a fault in the loop, the front panel indicators will display the fault type by emitting a sequence of flashes followed by a pause. The sequence will repeat until fault is rectified.

Faults from which the Loop Monitor™ has recovered are indicated by the FAULT indicator alone flashing. If the fault remains present both FAULT and DETECT indicators will be flashing.

The following are the fault types that can be detected and the flash sequences assigned to each:

- One flash indicates an open circuit loop or a loop inductance exceeding the upper limit of the tuning range.
- Two flashes indicates a shorted loop or loop inductance less than the lower limit of the tuning range.
- Three flashes indicates that a sudden change in inductance exceeding 25% $\Delta L/L$ has occurred.

3. Loop Installation

The following are suggested guidelines for loop installation.

To begin, make sure that the pavement surface in the area in which the loops are to be installed is dry and free of debris.

The outline of the loops should be marked on the pavement in such a way that the lines can be followed easily by the saw operator and not be erased by the water feed from the saw itself.

All 90 degree corners should be chamfered so that the course of the loop wire does not change direction sharply but rather at shallower angles of 45 degrees or less. Core drilling of the corners achieves the same effect but can still lead to failure due to sharp edges remaining in the corner area.

When the outline of the loop and lead-in has been marked, the pavement can be cut. Diamond blade cutting saws are recommended. The saw cut should be approximately 1.5 inches deep and 3/8" to 1/2" wide. The saw slot should then be cleaned and allowed to dry. Compressed air is useful both for ejecting debris and speeding up the drying process. All debris in the vicinity of the saw slot should also be removed so that it is not accidentally pushed back in.

Recommended loop wire is 14 gauge stranded copper wire with an insulating sheath of polypropylene type THHN or XHHW. IMSA specification 51-1 or 51-3 cable is suggested. Start laying the cable from the termination of the lead-in out towards the loop, continue around the loop for the number of turns required and finally return to the lead-in termination. When winding quadrupole loops ensure that the correct figure-of-eight configuration is maintained with the wires laid in the same direction in the center arm of the loop. Leave the lead-in cable out of the slot so that it may be twisted together before being laid in the slot.

As a general rule loops with circumference lengths less than 30 feet require 3 turns of wire, loops with greater circumference lengths should have 2 turns. Lead-ins should be twisted with a minimum of 3 to 4 twists per foot to prevent any separation of the lead-in wires.

If long lead-ins are required, it is suggested that the loop cable be spliced onto shielded, pre-twisted, lead-in wire (IMSA spec 50-2 is suggested) at a convenient pull box location close to the loop. The shield may be connected to earth at the cabinet end but should then be insulated and isolated from earth ground at the loop end.

Make sure that the loop wire is pushed fully to the bottom of the saw slot. Small pieces of foam rubber or similar material may be used at various points around the circumference to prevent the loop wire from rising up while the sealant is poured.

Many different types of loop sealant are now available. Single part types are the easiest to apply since no mixing is required, but they also tend to be more expensive in terms of linear feet of saw slot filled. When applying the sealant, make sure that it is able to sink to the bottom of the slot and completely encase the loop wire. The wire should not be able to move when the sealant has set. Ensure that there is enough sealant to completely fill the slot; if possible the sealant should protrude slightly above the surface of the pavement so that small rocks or other debris cannot collect in the slot.

The sealant manufacturer's instructions concerning setting time should be noted -- especially when determining the length of time to wait before allowing vehicles to cross the loop area.

4. Theory of Operation

The Loop Monitor™ works on the principle of measuring the period of a pre-determined number of cycles from an oscillator whose frequency is directly related to the inductance of the loop to which the unit is connected. The measurement is done by counting the number of cycles of a stable crystal reference that occur during the period to be measured. This scheme provides a high resolution measurement in a short period of time. Consecutive measurements can be compared with each other to determine whether or not the frequency of the loop oscillator has changed sufficiently to indicate the presence of a vehicle. Each channel is sequentially scanned so that only one loop oscillator is energized at any one time.

The Loop Monitor™ circuitry can be broken down into four major blocks. The loop oscillators, digital processing circuitry, switch controls and outputs/indicators. Each oscillator input incorporates a transformer to isolate the loop from the internal oscillator circuitry. Neon surge arrestors are used to protect the unit from transient damage. Loop oscillator frequency may be modified by switching capacitors in or out of the oscillator circuit in order to avoid crosstalk. The output signals from the oscillators are fed through squaring circuits before being supplied to the digital processing portion. Although the LM612 has two loop oscillators, a single digital processing section is used to measure the period of both oscillators one after the other.

The microcontroller first of all determines the status of the front panel switches: The Operational mode determines whether the detection calls are to be momentary pulse or continuous presence and the sensitivity setting determines the number of loop oscillator cycle 'blocks' to use in the period measurement process. The microcontroller then begins the measurement process by energizing the loop oscillator for the channel to be measured.

During period measurement the microcontroller counts the number of cycles of the crystal based reference frequency. When the period ends, the count is compared with a stored reference and detection decisions are made. Small changes which occur over a relatively long period of time are considered due to the changing environment, and the stored reference is modified accordingly by the microcontroller.

Detection calls are made via optically isolated transistors. These isolate the traffic controller input from the Loop Monitor™ circuitry. Output call and loop fault monitor status are indicated by means of high intensity LEDs which are visible from the front of the unit.

5. Description of Circuit Operation

The following description is valid for both channels of the LM612. Reference designators are shown for channel 1 with those relating to channel 2 in parentheses.

Each loop oscillator is based upon a transistor array Q5 (Q6), loop transformer T1 (T2) and primary capacitor C1 (C2). Frequency modification capacitors C5 and C7 (C6 & C8) are switched in via SW3 (SW6). Transient protection is provided by neon surge arrestor Z1 (Z2). When a loop is connected to the loop input terminals, and the unit is under power, the oscillator will attain its natural frequency according to the inductance of the loop and the capacitance which has been added via the front panel switches. The output signal is found on pin 7 of Q5 (Q6) and is a sine wave at the oscillator frequency while the oscillator is energized. Transzors Z9 (Z10) are used to limit any voltage surges which may appear on the circuit side of the loop transformer.

The output signals from both of the oscillators are fed into schmitt circuits (U6) to form square wave signals. The output of the schmitt triggers are fed into the digital processing IC, U4. A 64MHz crystal reference is used by the digital processing IC for its internal clock and is divided down to 4MHz for use by the microcontroller U5 as the main microprocessor clock.

The microcontroller reads the sample from the digital processing IC at end of each measurement cycle via its serial input port. This sample represents the period of the loop oscillator waveform to a very high precision.

Switch settings are read by first setting port bits PC2 (PC6) high to select each switch bank, then latching the switch bits into the digital processing IC and reading them serially into the microcontroller serial port. The controller output port PC3 (PC7) is used to drive the output opto-isolator via a driver transistor Q3 (Q4). The front panel LED indicators DS1 and DS2 (DS3 and DS4) are driven by processor ports PC0 to PC1 (PC4 and PC5) via transistor drivers Q7 and Q9 (Q8 & Q10).

A monolithic regulator VR1 provides stable 5 volt power supply to the circuitry. If the power supply to the Loop Monitor™ should drop below 15 VDC, a low voltage reset circuit based upon transistors Q1 and Q2 will cause the reset line to the microcontroller to drop to the reset state and remain until the supply returns to a level above the 15 volt cutoff point.

6. Trouble Analysis

The following chart should be used to troubleshoot the Loop Monitor™ and installation. If the LM612 series itself is suspect, see section 7 for a complete internal testing sequence.

a) No LEDs lit - unit does not operate.

Power supply fault.

The LM612 series requires a 24 VDC nominal supply. Each unit consumes between 40 and 70mA depending on detect status. The Loop Monitor™ will operate at voltages as low as 16 volts; however, supply voltages below this may result in the unit entering a reset state. In this case, the unit will appear to be non-functional.

Reset Line held low.

This fault is likely to affect all units in the rack since the external reset line is usually common to every rack position. Measure the voltage on the external reset line. If it is below 15 volts, remove each unit one by one until the reset line returns to the power supply level. The unit that was removed last should be checked carefully for other faults. See section 7.

b) Fault and Detect LEDs flashing.

Faulty connections in Loop or lead-in wiring.

Check the type of fault being indicated by the number of flashes. The type of fault may assist in locating the problem. A double flash followed by a pause, indicates a shorted loop or loop inductance too small. A single flash followed by a pause indicates an open circuit loop or loop inductance too large.

c) Channel does not detect all vehicles.

Sensitivity too low.

Increase sensitivity by one setting and observe detection.

d) Channel is noisy/chatters/gives false detect calls.

Two or more units are interfering with each other (crosstalk).

Check frequency settings on units which are connected to loops closest to the Loop Monitor™ exhibiting crosstalk; several may be showing signs of crosstalk themselves. Adjust the frequency switches on all units and all channels affected so that the largest possible margin exists between frequencies of loops positioned the closest.

Poor connections.

Loop connections are very important to the satisfactory operation of the Loop Monitor™. All connections whether they are in the cabinet or at the roadside must be secure, preferably soldered and, in the case of connections made at the roadside, waterproofed to prevent shorting to ground.

Poor loops.

Loops which have become degraded due to the passage of traffic may cause Loop Monitors™ to exhibit crosstalk-like symptoms. It may be possible to reduce the sensitivity while maintaining adequate detection of vehicles. However, the ideal solution is to replace the loop.

7. Trouble Shooting Sequence Chart.

Apply power (24 VDC) to the unit (Pin B on the edge connector) referenced to logic ground (Pin A). Connect a 100 microhenry inductor to the loop inputs Pins D and E (channel 1) and Pins J and K (channel 2) to simulate the connection of loops.

All of the following signal measurements are referenced to logic ground.

a) Unregulated Power Supply.

Voltage across capacitor C4 should be 19 Volts ± 1 Volt.

Possible component faults are: diode CR11, capacitor C4 or voltage regulator U3.

b) Regulated Power Supply.

Voltage across capacitor C12 should be 5 Volts ± 0.2 Volt.

Possible component faults are: voltage regulator U3.

c) Microcontroller Clock.

Waveform at pin 27 of U5 should be a rough square wave at 4MHz with a peak to peak voltage of 5 Volts ± 0.2 Volt.

Possible components at fault are: U4 or Crystal Y1.

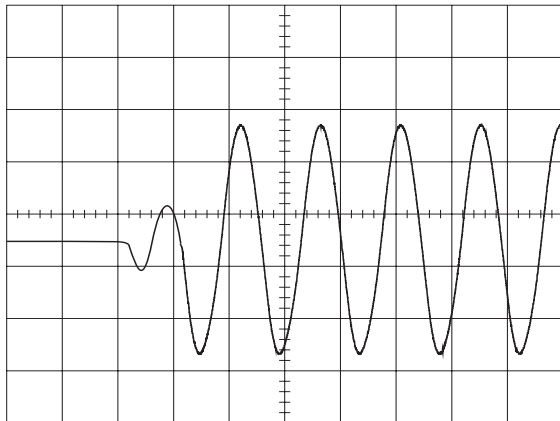
d) Reset Input to Microcontroller.

Voltage at pin 1 of U5 should be 5 volts ± 0.2 Volt.

Possible components at fault are: transistors Q1 and Q2, zener diode CR12, microcontroller U5.

e) Loop Oscillator Output.

Connect one channel of a dual channel oscilloscope to pin 9 (pin10) of U5. Select trigger on the rising edge of this signal. Using the other channel of the oscilloscope monitor pin 7 of Q5 (Q6); the signal should be as follows.



2V / div.

20 μ s / div.

If the above waveform is not found, possible fault areas are Q5 (Q6), Z9 (Z10) or T1 (T2).

f) Outputs and Indicators.

Monitor the outputs so that when the channel is in the detect state, the outputs can be seen to be conducting.

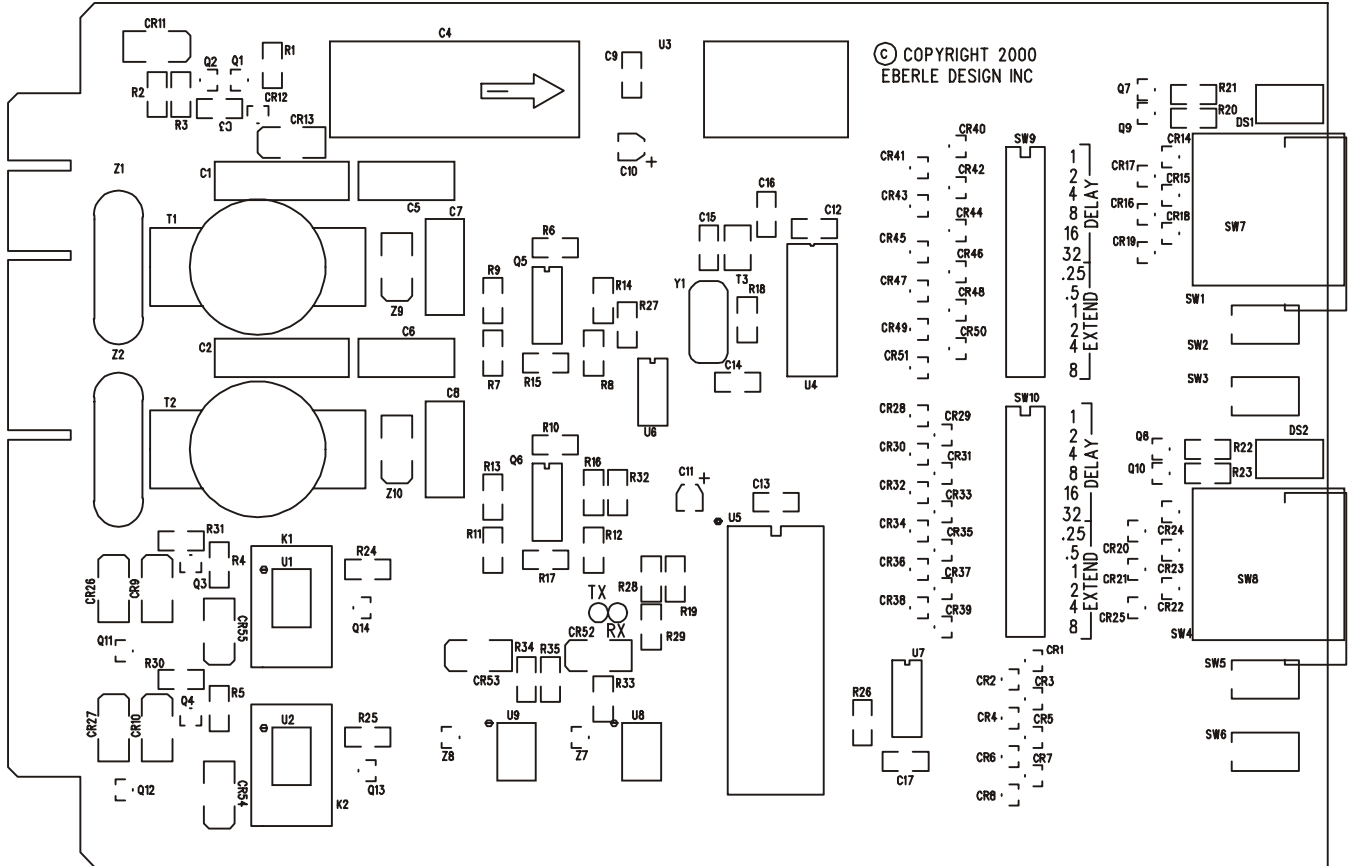
Enter a detect condition by bringing an aluminum or similar non-ferromagnetic object close to each simulated loop. The DETECT indicator should illuminate and the opto-isolated output should be conducting (relay de-energized).

Possible fault areas are: transistors Q3 (Q4) or Q7 (Q8), opto-isolator U1 (U2), LED DS1 (DS2).

8. LM612 Series Parts List

	Qty.	Description	Ref. Des.	Mfr.
1	2	Diode, S1K, 800V PIV	CR11 CR13	Motorola
2	2	Tanzorb, SMBJ5.0CA, 5.0V, 1500W	Z9-Z10	Taitron
3	2	Zener Diode, SML4756A, 1W, 47V	CR9-CR10	Motorola
4	1	Zener Diode, MMBZ5237, 400mW, 8.2V	CR12	Motorola
5	15	Diode, MMBD914	CR14-25 CR1-3	Motorola
6	2	Transistor, MMBT3906 PNP	Q1 Q2	PHILIPS
7	4	Transistor, MMBT3904 NPN	Q7-10	PHILIPS
8	2	Transistor, MMTF170 MOSFET	Q3 Q4	Motorola
9	2	Transistor Array CA3083M	Q5 Q6	Motorola
10	1	IC MC14093 Quad 2 I/P NAND Schmitt	U6	Motorola
11	1	IC LME124S Digital Timing Processor	U4	EDI
12	1	IC MC68HC05P6A Microcontroller	U5	Motorola
13	2	IC MOC8021 Opto-Isolator	U1 U2	Isocom
14	1	IC MC7805 Voltage Regulator	U3	Motorola
15	1	Capacitor, Electrolytic, 1000uF 35V	C4	IC
16	2	Capacitor, Electrolytic, 1uF 50V	C10 C11	IC
17	2	Capacitor, Polypropylene, 0.1uF 160V	C1 C2	IC
18	2	Capacitor, Polypropylene, 0.047uF 250V	C7 C8	IC
19	2	Capacitor, Polypropylene, 0.022uF 250V	C5 C6	IC
20	4	Capacitor, Ceramic, 0.1uF 50V	C3 C9 C12 C13	AVX
21	1	Capacitor, Ceramic, 47pF 50V	C15	AVX
22	1	Capacitor, Ceramic, 27pF 50V	C14	AVX
23	1	Capacitor, Ceramic, 0.01uF 50V	C16	AVX
24	2	LED Module Red and Yellow High Intensity	DS1 DS2	Taitron
25	2	Switch 16 position rotary	SW1 SW2	EECO
26	4	Switch ON-OFF-ON Toggle	SW3-SW6	Alco
27	2	Neon Surge Arrestor	Z1 Z2	CML
28	3	Resistor CF 1/4W 0 Ohm	R24-R26	SEI
29	10	Resistor CF 1/4W 10k Ohm		SEI
30	3	Resistor CF 1/4W 4.7k Ohm	R1 R4 R5	SEI
31	2	Resistor CF 1/4W 47k Ohm	R30 R31	SEI
32	2	Resistor CF 1/4W 4.3k Ohm	R9 R13	SEI
33	2	Resistor CF 1/4W 3.6k Ohm	R6 R10	SEI
34	2	Resistor CF 1/4W 47 Ohm	R14 R16	SEI
35	2	Resistor CF 1/4W 27k Ohm	R15 R17	SEI
36	2	Resistor CF 1/4W 22k Ohm	R7 R11	SEI
37	1	Resistor CF 1/4W 1M Ohm	R18	SEI
38	4	Resistor CF 1/4W 300 Ohm	R20- R23	SEI
39	1	Inductor, 0.33uH	T3	Dale
40	1	Heatsink	U3	AAVID
41	2	Loop Transformer	T1 T2	EDI
42	1	Socket 28 Pin	U5	RN

LM612 SERIES LAYOUT - MAIN PRINTED CIRCUIT BOARD REVISION S



9. Options

Circuit Reference	Diode Absent	Diode Present
CR1	No Minimum Presence	100ms Min Presence
CR2	No output call on fault	Output call during fault
CR3	15 sensitivity 0 - OFF	7 sensitivity & ON-OFF

Specifications

Power Supply:

24 VDC ±20%, 65 mA max, 35mA quiescent.

Loop Input:

The loop inputs incorporate lightning and transient protection devices and the loop oscillator circuitry is transformer isolated. The lightning protection will withstand the discharge of a 10µF capacitor charged to 2,000V across the loop inputs or between any loop input and earth ground. The transformer isolation allows operation with loops which are grounded at a single point.

Tuning:

Each channel of the LM612 series will automatically tune to any loop and lead-in combination within the tuning range upon application of power or when a valid reset signal is received. A channel may be retuned by adjusting mode, sensitivity or frequency and resetting to the desired value.

Tuning Range:

20 to 2500 microhenry with a Q factor greater than 5.

Lead-in Length:

The unit will operate with lead-in (feeder) lengths up to 5,000 feet with appropriate loops and proper lead-in cable.

Environmental Tracking:

The LM612 series automatically and continuously compensates for component drift and environmental effects throughout the tuning range and across the entire temperature range.

Grounded Loop Operation:

The LM612 series will operate when connected to poor quality loops including those that have a short to ground at a single point.

Sequential Scanning:

Only one channel is energized at any given time, thus reducing the possibility of crosstalk between adjacent loops connected to the same unit.

Fault Monitoring:

The Loop Monitor™ continuously checks the integrity of the loop. The system is able to detect shorted or open circuit loops, or sudden changes in inductance exceeding 25% of the nominal inductance. If a fault is detected on a channel, both the detect and fault LEDs emit a sequence of flashes followed by a pause. This signal is repeated until the fault is rectified. Each type of fault is identified by a different flash sequence. While the unit is in the fault condition, the channel output will remain in the detect (call) state.

Flash Sequence	Fault
1 flash	Open Circuit Loop.
2 flashes	Short Circuit Loop.
3 flashes	25% change in inductance.

If the fault condition is removed, both the detect LED and the output will return to normal operation. The fault LED will continue to emit the sequence signifying the type of fault that was last detected. In the case of the excessive inductance change fault, the channel will retune to the new inductance after a period of two seconds and continue operation. The fault condition will be indicated by the flash sequence of the fault LED.

High Intensity Color-Coded LED Indicators:

Each channel has two indicators, a red LED indicates the detect state and also the status of the delay and extension timers, a second yellow LED indicates the status of the fault monitor.

Front Panel Controls:

Each channel has a front panel mounted rotary and toggle switches to allow the user to set up sensitivity, operational mode and frequency independently on each channel.

Sensitivity:

One of fifteen settings may be selected to optimize detection on varying loop and lead-in configurations. Sensitivity is stated in terms of ΔL / L i.e. the minimum percentage change in the total inductance (loop plus lead-in) to which the unit will respond at the given level setting.

Sensitivity	DL/L	Sensitivity	DL/L	Sensitivity	DL/L	Sensitivity	DL/L
15	0.01%	11	.04%	7	.16%	3	.64%
14	.015%	10	.06%	6	.24%	2	.96%
13	.02%	9	.08%	5	.32%	1	1.28%
12	.03%	8	.12%	4	.48%	0	OFF

Channel ON-OFF:

When the sensitivity is set to 0, the channel will be disabled; the loop oscillator will be de-energized and the output will remain in the no-call state.

Operational Modes:

Pulse Mode: 125ms ±25ms momentary output.
 Short Presence: 15 minutes.
 Long Presence: 2 hours.

Note: When operating in pulse mode, a vehicle remaining over a loop will inhibit further pulse outputs from being issued for a period of 2 seconds after which time vehicles passing over the uncovered portion of the loop will be detected.

Frequency:

One of four settings may be selected to alleviate interference which may occur when loops connected to different detectors are located adjacent to one another.

Delay & Extension:

Delay times from 1 to 63 seconds and/or Extend times from .25 to 15.75 seconds may be selected using the board mounted DIP switches. Delay is overridden by the application of a ground true signal on the timer control input. Delay and Extend may be separately set up for each channel.

Reset Input:

The LM612 series may be reset by applying a ground true logic level to the reset input Pin C for a period exceeding 15 microseconds.

Response Times:

The following are typical response times at different sensitivity levels for units with optically isolated output.

Sens		Sens		Sens		Sens	
15	22 +5ms	11	12 +2ms	7	5 +1ms	3	5 +1ms
14	22 +5ms	10	12 +2ms	6	5 +1ms	2	5 +1ms
13	16 +3ms	9	12 +1ms	5	5 +1ms	1	5 +1ms
12	16 +3ms	8	12 +1ms	4	5 +1ms	0	OFF

Output Ratings:

Optically Isolated Output Versions: The output transistor is rated for a maximum collector voltage of 80 VDC. Maximum collector current is 100mA. In the saturated condition the collector voltage will be less than 1.5 VDC with a collector current of 50mA. Maximum off state leakage current is 1 microampere. Isolation exceeds 7,500 VAC. Relay Versions: contacts rated at 1A 28VDC/250VAC. Contacts are failsafe -- on power fail the contacts will assume the call state.

Mechanical:

Dimensions (Excl. Handle): 1.12" wide, 4.5" tall, 6.875" long.
 Weight: 7 oz.

Environmental:

Storage Temperature Range: -55°C to +85°C (-67°F to 185°F).
 Operating Temperature Range: -40°C to +80°C (-40°F to 176°F).
 Humidity Range: 0 to 95% relative.

Connections:

Edge Connector mates with connector type Cinch 50-44A-30.

PIN	LM612
A	Logic Ground
B	+24 V d.c.
C	Reset
D & 4	Loop Input CH 1
E & 5	Loop Input CH 1
F	CH 1 O/P Collector \ Relay O/P N.O.
H	CH 1 O/P Emitter \ Relay O/P Com.
J & 8	Loop Input CH 2
K & 9	Loop Input CH 2
L	Chassis Ground
W	CH 2 O/P Collector \ Relay O/P N.O.
X	CH 2 O/P Emitter \ Relay O/P Com.
1	CH 1 Timer Control Input (LM612t)
2	CH 2 Timer Control Input (LM612t)

Pins M,N,P,R,S,T,U,V,Y & Z have no connection.