

# LM602 Series

## Inductive Loop Monitor Operations Manual

THIS MANUAL CONTAINS TECHNICAL INFORMATION FOR THE LM602 SERIES  
INDUCTIVE LOOP MONITOR.

REVISION: JULY 2005  
pn 888-0602-001



EBERLE DESIGN INC.

3819 East La Salle Street  
Phoenix, AZ 85040 USA  
www.EDIttraffic.com

Tel (480) 968-6407  
Fax (602) 437-1996



THE LM602 SERIES IS DESIGNED AND MANUFACTURED IN THE USA BY  
EBERLE DESIGN INC.  
PHOENIX, ARIZONA  
AN ISO 9001:2008 REGISTERED COMPANY

INFORMATION CONTAINED HEREIN IS PROPRIETARY TECHNICAL INFORMATION  
OF EBERLE DESIGN INC. PUBLICATION, REPRODUCTION OR USE IN WHOLE OR  
PART IS NOT PERMITTED EXCEPT UNDER TERMS AGREED UPON IN WRITING.  
DEFLECTOMETER IS A TRADEMARK OF EBERLE DESIGN INC.  
U.S. PATENT NO. 7,855,893

© COPYRIGHT 2011 EDI.

## Table of Contents

1.1 General Description .....	1
1.2 Installation and Adjustments .....	1
1.2.1 Set the Sensitivity .....	1
1.2.2 Set the Operational Mode .....	1
1.2.3 Set the Frequency .....	2
1.2.4 Miscellaneous .....	2
1.3 Loop Installation .....	2
1.4 Theory of Operation .....	3
1.4.1 System Description .....	3
1.4.2 Description of Circuit Operation .....	5
1.5 Maintenance .....	5
1.5.1 Fault Monitoring .....	5
1.5.2 Trouble Analysis .....	6
1.5.3 Trouble Shooting Sequence Chart .....	6
1.6 Specifications .....	7
1.6.1 Construction .....	7
1.6.2 Mechanical .....	7
1.6.3 Environmental .....	7
1.6.4 Electrical .....	8
1.6.5 Tuning .....	8
1.6.6 Environmental Tracking .....	8
1.6.7 Grounded Loop Operation .....	8
1.6.8 Lead-in Length .....	8
1.6.9 Loop Input (Lightning Protection) .....	8
1.6.10 Response Timing .....	8
1.7 Connector Pin Assignments .....	8
1.7.1 Polarization Keys .....	9
1.8 Parts List and Schematic .....	10

## 1.1 GENERAL DESCRIPTION

The LM602 Series TS-1 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. It meets or exceeds all requirements for as defined in **Nema Standard TS1-1989**. 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 LM602 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.

The unit will detect inductance changes as small as 0.010%  $\Delta L/L$ . Each channel is sequentially energized and sampled so as to negate the possibility of crosstalk between loops connected to different channels of the same detector.

## 1.2 INSTALLATION AND ADJUSTMENTS

### 1.2.1 SET THE SENSITIVITY

Sensitivity is set by moving the four DIP switches marked SENS to the desired position. Level 15 is the highest sensitivity, Level 0 disables the channel.

Sensitivity	$\Delta L / L$	SENS 8	SENS 4	SENS 2	SENS 1
Level 15	0.010%	ON	ON	ON	ON
Level 14	0.014%	ON	ON	ON	ON
Level 13	0.020%	ON	ON	OFF	ON
Level 12	0.028%	ON	ON	OFF	OFF
Level 11	0.040%	ON	OFF	ON	ON
Level 10	0.057%	ON	OFF	ON	OFF
Level 9	0.080%	ON	OFF	OFF	ON
Level 8	0.113%	ON	OFF	OFF	OFF
Level 7	0.160%	OFF	ON	ON	ON
Level 6	0.226%	OFF	ON	ON	ON
Level 5	0.320%	OFF	ON	OFF	ON
Level 4	0.453%	OFF	ON	OFF	OFF
Level 3	0.640%	OFF	OFF	ON	ON
Level 2	0.905%	OFF	OFF	ON	OFF
Level 1	1.280%	OFF	OFF	OFF	ON
Level 0	OFF	OFF	OFF	OFF	OFF

### 1.2.2 SET THE OPERATIONAL MODE

Operational mode can be set to presence or pulse mode. If presence mode is selected then short or long presence may be set. Use short presence unless the loop is expected to be continuously occupied for periods of time in excess of 30 minutes.

Mode	MODE 1	MODE 2	Max Duration
Pulse	PL	--	--
Short Presence	PR	SH	30 minutes
Long Presence	PR	LG	120 minutes

When the jumper labeled SEL1 is inserted, the LM602 will limit the minimum presence time to 100 milliseconds.

### 1.2.3 SET THE FREQUENCY

Frequency setting needs to be changed only if interference occurs between adjacent loops connected to different sensor units. 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. 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. Four frequency positions are available on each channel to assist in alleviating interference affecting more than two units.

Frequency	FREQ 1	FREQ 0
High	OFF	OFF
Med. High	OFF	ON
Med. Low	ON	OFF
Low	ON	ON

### 1.2.4 MISCELLANEOUS

If a channel is not to be used, it may be switched off (disabled) by setting the Sensitivity to Level 0 (all SENS switches in the OFF position).

Check the front indicators. If both the DET and FLT indicators on a channel are flashing and no vehicles are present, there is a problem with the loop or the connections to the loop on that channel. Check the loop connections carefully.

Note: Each channel may be reset by momentarily changing any DIP switch for that channel.

### 1.3 LOOP INSTALLATION

The typical sensing height is 2/3 of the shortest leg of a loop (in feet). Therefore a 4' x 8' loop typically has a detection height of 2.6'.

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

$$L = P \times (T^2 + T) / 4 \quad \text{Where} \quad \begin{array}{l} L = \text{Loop Inductance in microHenries} \\ P = \text{Loop Perimeter in feet} \\ T = \text{Number of wires in saw slot} \end{array}$$

Therefore a 4' x 8' loop with 3 turns would be:

$$L = (4 + 8 + 4 + 8) \times (3^2 + 3) / 4$$

$$L = 24 \times (9 + 3) / 4$$

$$L = 24 \times 12 / 4$$

$$L = 72 \text{ microHenries}$$

Note: Loop feeder cable typically adds 0.22 microHenries of inductance per foot of cable.

The following are suggested guidelines for loop installation:

To begin, make sure that the pavement surface in the area that loops are to be installed is dry and free of debris. The outline of the loop(s) 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 2.0 inches deep and 0.25 inches wide. The saw slot should then be cleaned out 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.

As a general rule loops with circumference lengths less than 12 feet require 5 turns of wire, 12 to 60 feet require 3 to 4 turns of wire, loops with greater circumference lengths should have 2 to 3 turns.

Recommended loop wire is typically 14, 16, 18, or 20 AWG with cross-linked polyethylene insulation. Since moisture can cause significant changes in the dielectric constant of the insulation, which results in excessive loop (frequency) drift, choose insulation, which is most impervious to moisture. PVC, TFFN, THHN, and THHN-THWN should be avoided since they tend to absorb moisture and crack easily. XLPE (Cross Linked Polyethylene) is very resistant to moisture absorption and provides good abrasion resistance.

If long lead-ins are required, it is suggested that the loop cable be spliced onto shielded, pre-twisted, lead-in wire (IMSA specification 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. The inductance of the loop itself should be at least 50% of the sum of loop inductance plus lead-in inductance.

Start laying the loop wire 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. Leave the lead-in wire out of the slot so that it may be twisted together before being laid in the slot. Lead-ins should be twisted with a minimum of 4 to 6 twists per foot to prevent any separation of the lead-in wires.

Make sure that the loop wire is pushed fully to the bottom of the saw slot. Small pieces of foam rubber (backer rod) 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 and curing.

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 instructions concerning setting time should be noted especially when determining the length of time to wait before allowing vehicles to cross the loop area.

Consult the Eberle Design web site at [www.editraffic.com](http://www.editraffic.com) for further application information regarding loop design.

## **1.4 THEORY OF OPERATION**

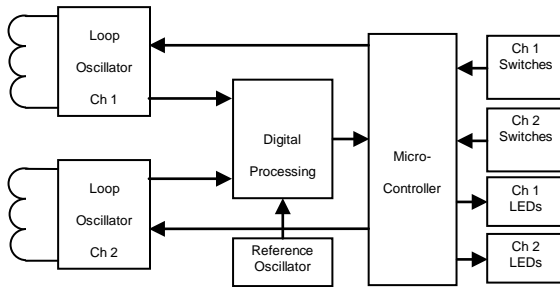
### **1.4.1 SYSTEM DESCRIPTION**

The LM602 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. The measurement is done by counting the number of cycles of a stable crystal oscillator reference that occur during the period to be measured. This scheme provides a high resolution measurement in a short period of time. Consecutive measurements are

compared with a reference that has been established 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 time.

The sensor circuitry can be broken down into four major blocks. The loop oscillators, digital processing circuitry, switch controls and the outputs/indicators. Each oscillator input incorporates a transformer to isolate the loop from the internal oscillator circuitry. Surge arrestors are provided to protect the unit from transient electrical damage. The Loop oscillator frequency may be modified to avoid crosstalk problems by switching capacitors into or out of the oscillator circuit. The output signals from the oscillators are fed through squaring circuits before being supplied to the digital processing circuit. Although the LM602 has two loop oscillators, a single digital processing section is used to measure the period of both oscillators in sequence.

The microcontroller determines the requisite number of loop oscillator cycles over which to perform the measurement. It then provides this number to the digital processing section and a measurement is initiated. When the sample period has ended, the sample value is collected and processed by the microcontroller while another sample is initiated.



The microcontroller checks the sample to confirm that it is still within acceptable operating limits and then determines whether the sample has changed sufficiently with respect to the stored reference to indicate the presence of a vehicle. It then controls the output and indicator appropriately. Small changes in period which occur over a relatively long time are considered due to the environment and are tracked out by altering the stored reference. In this fashion, the sensor unit can adjust for temperature changes and other long term effects such as the expansion and contraction of the pavement. The microcontroller maintains the time that a channel has been in the presence condition and will tune out a continuous presence after 30 minutes (Short Presence mode) or 120 minutes (Long Presence mode).

The microcontroller first determines the status of the front panel switches. The Operational mode determines whether the detection calls are to be momentary pulse or continuous. The Presence and the Sensitivity settings determine the length of the sample to ensure that the sensitivity will be sufficient to detect the desired types of vehicles and that the response time will be correct.

The microcontroller then begins the oscillator period measurement process by energizing the loop oscillator for the channel to be measured. During period measurement the digital processing circuit and the microcontroller count the number of cycles of the crystal based reference frequency.

When the sample 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. Larger changes are deemed to be caused by the presence of a vehicle or vehicles and a detection signal is initiated.

Detection output calls are made via optically isolated transistors. These isolate the traffic controller input from the sensor unit circuitry. Output calls are indicated on the front panel by means of high intensity LEDs labeled "DET".

#### **1.4.2 DESCRIPTION OF CIRCUIT OPERATION**

The following description is valid for both channels of the LM602. Reference designators are shown for channel 1 with those relating to channel 2 in parentheses.

Each loop oscillator is based upon two transistors, Q8 (Q9) and Q11 (Q13), loop transformer T1 (T2) and primary capacitor C12 (C11). The oscillator is enabled by transistor Q7-A (Q7-B). Frequency modification capacitors C16 and C18 (C13 & C17) are switched in via Q10-A (Q12-A) and Q10-B (Q12-B). Transient protection is provided by surge arrestor CR5 (CR6). When loops are connected to the loop input terminals and the unit is under power, the oscillators will attain their natural frequency according to the inductance of the loop and the capacitance which has been added via the frequency modification capacitors.

The oscillator output signal is found on the collector of Q8 (Q9) and is sine wave at the oscillator frequency (while the oscillator is energized). Zener diodes CR13 (CR14) are used to limit any voltage surges which may appear on the circuit side of the loop transformer.

The loop frequency signals from both of the oscillators are fed into Schmitt circuits U5A (U5B) to form square wave signals. The outputs of the Schmitt triggers are fed into the digital processing circuitry integrated into the microcontroller.

The digital processing circuit determines the period of a predetermined number of loop oscillator cycles and stores this value for retrieval by the microcontroller firmware. This value represents the period of the loop oscillator waveform to a very high precision.

Front panel switch settings are read directly by the microcontroller parallel ports P3 and P4. The Call Output opto-isolator U1 (U2) is driven directly by the microcontroller port P1\_2 (P1\_3). The front panel LED indicators DS1 (DS2) are similarly driven by the microcontroller port P5.

Monolithic regulator VR1 provides a stable 5 volt DC power supply to the digital circuitry and loop oscillators. The LM602 will operate properly until the power input at pin J1-B drops below 8 VDC.

### **1.5 MAINTENANCE**

#### **1.5.1 FAULT MONITORING**

The LM602 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 value. If a fault is detected on a channel, the DET and FLT indicators will flash. The channel output will remain in the detect (call) state.

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

If the fault condition is removed, the DET indicator and the channel output will return to normal operation. The FLT indicator will continue to flash indicating that a fault had previously occurred. This previous fault indication may be reset by momentarily changing any DIP switch for the corresponding channel.



### 1.5.2 TROUBLE ANALYSIS

The following list should be used to trouble-shoot the LM602 installation. If the detector unit itself is suspect, see Section 1.5.3 for a complete internal testing sequence.

- a. Neither channel responds to vehicles.
  - a. Power supply fault.

The LM602 requires a 24VDC nominal supply. Each unit draws between 50mA and 80mA depending on detect status. The unit will operate at voltages as low as 8 Vdc, however, supply voltage below this may result in the unit entering a reset state. In this case, the unit will appear to be non-functional.
  - b. Reset line held low.

This fault is likely to affect all units in the rack since the external reset line is typically common to every rack position. Measure the voltage on the External Reset line (pin J1-C). If it is below 15 volts, remove each unit one by one until the next line returns to the power supply level. The unit that was removed last should be checked carefully for other faults. See Section 1.5.3.
- b. Channel does not detect all vehicles.
  - a. Sensitivity too low.

Increase sensitivity by one setting and observe detection.
- c. Channel is noisy or chatters and outputs false detect calls.
  - a. Two or more units are interfering with each other (crosstalk).

Check frequency settings on units which are connected to loops closest to the one 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.
  - b. Poor connections.

Loop connections are very important to the satisfactory operation of the sensor unit. All connections whether they are in the cabinet or at the roadside must be secure, must be soldered and, in the case of connections made at the roadside, waterproofed to prevent shorting to ground.
  - c. Poor loops.

Loops which have become degraded due to the passage of traffic may cause the unit 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.

### 1.5.3 TROUBLE SHOOTING SEQUENCE CHART.

Apply 24 VDC power to the unit (pin J1-B) referenced to Logic Ground (pin J1-A). Connect 100 microhenry inductors to the loop inputs pins J1-D (J1-J) and J1-E (J1-K) to simulate the connection of loops. The following signal measurements are referenced to Logic Ground (pin J1-A):

- a. Unregulated Power Supply

Voltage at test point V\_UNREG should be  $24 \pm 1$  Vdc.  
Possible component faults are: diode CR11, resistor R7, capacitors C6-C7, or voltage regulator VR1.
- b. Regulated Power Supply

Voltage at test point VDD should be  $5 \pm 0.2$  Vdc.  
Possible component faults are: voltage regulator VR1.
- c. Microcontroller Clock

Waveform at pin 6 of U4 should be a square wave at 22.118 MHz.

Possible components at fault are: Crystal XTL1, U4.

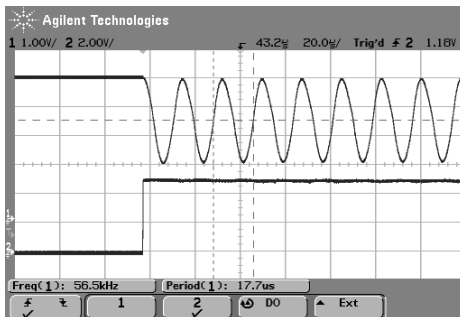
d. Reset Input to Microcontroller

Voltage at pin 35 of U3 should be less than 0.5 Vdc.

Possible components at fault are: U5-D, U4-C, microcontroller U3.

e. Loop Oscillator Output

Connect one channel of a dual channel oscilloscope to test point ENABLE1 (ENABLE2). Select trigger on the rising edge of this signal. Using the other channel of the oscilloscope, monitor test point LP1 (LP2). The signal should be as follows:



Repeat the above for the second loop detector channel. If the above waveform is not found on one or both channels of the detector, possible fault areas are Q8 (Q9), Q11 (Q13), Q7-A (Q7-B), CR13 (CR14), 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 DET indicator should illuminate and the output transistors Q5 (Q3) should be conducting.

Possible components at fault are: U1 (U2), Q5 (Q3), CR2 (CR7), or LED DS1 (DS2).

## 1.6 SPECIFICATIONS

### 1.6.1 CONSTRUCTION

Printed circuit boards are double sided 2 oz. (56.70 gm.) copper with plated through holes. Circuit boards are coated for environmental protection.

### 1.6.2 MECHANICAL

Height ..... 4.50 inches  
 Width ..... 1.14 inches  
 Depth (excluding handle) ..... 6.875 inches

### 1.6.3 ENVIRONMENTAL

Storage Temperature Range ..... -45 to +85 °C  
 Operating Temperature Range ..... -34 to +74 °C  
 Humidity Range (non-condensing) ..... 0 to 95% Relative

### 1.6.4 ELECTRICAL

DC Supply Voltage Minimum .....	10.8 Vdc
DC Supply Voltage Maximum .....	28.8 Vdc
DC Supply Current .....	100 mA Maximum
DC Inputs	
True (low).....	less than 8 Vdc
False (high).....	greater than 16 Vdc
Optically Isolated Outputs	
True (low, 50 mA).....	less than 1.5 Vdc
False (high).....	greater than 16 Vdc
Maximum Leakage Current (high) .....	less than 1 uA
Maximum Current.....	100 mA
Relay Outputs	
AC Contact Rating.....	5A @ 120 Vac
DC Contact Rating .....	5A @ 30 Vdc

### 1.6.5 TUNING

#### 1.6.5.1 LOOP INDUCTANCE (TUNING) RANGE

The detector will automatically tune to a loop and lead-in combination within the tuning range of 20 to 2500 microHenry with a Q factor greater than 5.

#### 1.6.6 ENVIRONMENTAL TRACKING

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

#### 1.6.7 GROUNDED LOOP OPERATION

Each detector channel will operate when connected to poor quality loops including those that have a short to ground at a single point.

#### 1.6.8 LEAD-IN LENGTH

The unit will operate with lead-in (feeder) lengths up to 5,000 feet (1,524 m.) with appropriate loops and proper lead-in cable.

#### 1.6.9 LOOP INPUT (LIGHTNING PROTECTION)

The loop input incorporates lightning and transient protection devices and the loop oscillator circuitry is transformer-isolated for each channel. The lightning protection will withstand the discharge of a 10uF capacitor charged to 2,000V across the loop inputs or between a loop input and Earth Ground for each channel. The transformer isolation allows operation with a loop which is grounded at a single point.

#### 1.6.10 RESPONSE TIMING

This table assumes that both channels are set to the same Sensitivity.

Sensitivity	Response	Sensitivity	Response	Sensitivity	Response
<b>15</b>	76-96 ms	<b>10</b>	13-17 ms	<b>5</b>	4-6 ms
<b>14</b>	57-75 ms	<b>9</b>	9-12 ms	<b>4</b>	4-6 ms
<b>13</b>	38-50 ms	<b>8</b>	7-9 ms	<b>3</b>	4-6 ms
<b>12</b>	26-35 ms	<b>7</b>	5-7 ms	<b>2</b>	4-6 ms
<b>11</b>	18-24 ms	<b>6</b>	5-6 ms	<b>1</b>	4-6 ms

### 1.7 CONNECTOR PIN ASSIGNMENTS

Pin	Function	Pin	Function
<b>A</b>	Logic Ground	<b>1</b>	Reserved
<b>B</b>	Detector Unit DC Supply	<b>2</b>	Reserved
<b>C</b>	External Reset	<b>3</b>	Reserved
<b>D</b>	Channel 1 Loop Input	<b>4</b>	Channel 1 Redundant Loop Input

Pin	Function	Pin	Function
E	Channel 1 Loop Input	5	Channel 1 Redundant Loop Input
F	Channel 1 Output (+)	6	Reserved
H	Channel 1 Output (-)	7	Channel 1 Status Output
J	Channel 2 Loop Input	8	Channel 2 Redundant Loop Input
K	Channel 2 Loop Input	9	Channel 2 Redundant Loop Input
L	Chassis Ground	10	Reserved
M	Reserved	11	Reserved
N	Reserved	12	Reserved
P	Reserved	13	Reserved
R	Reserved	14	Reserved
S	Reserved	15	Reserved
T	Reserved	16	Reserved
U	Reserved	17	Reserved
V	Reserved	18	Reserved
W	Channel 2 Output (+)	19	Reserved
X	Channel 2 Output (-)	20	Channel 2 Status Output
Y	Reserved	21	Reserved
Z	Reserved	22	Reserved

### 1.7.1 POLARIZATION KEYS

Pin 1 through 22 is on the top (component) side and pin A through Z is on the bottom (solder) side. Polarization keys are located at three positions:

- Between B/2 and C/3
- Between M/11 and N/12
- Between E/5 and F/6

LM602 Loop Monitor  
Operations Manual

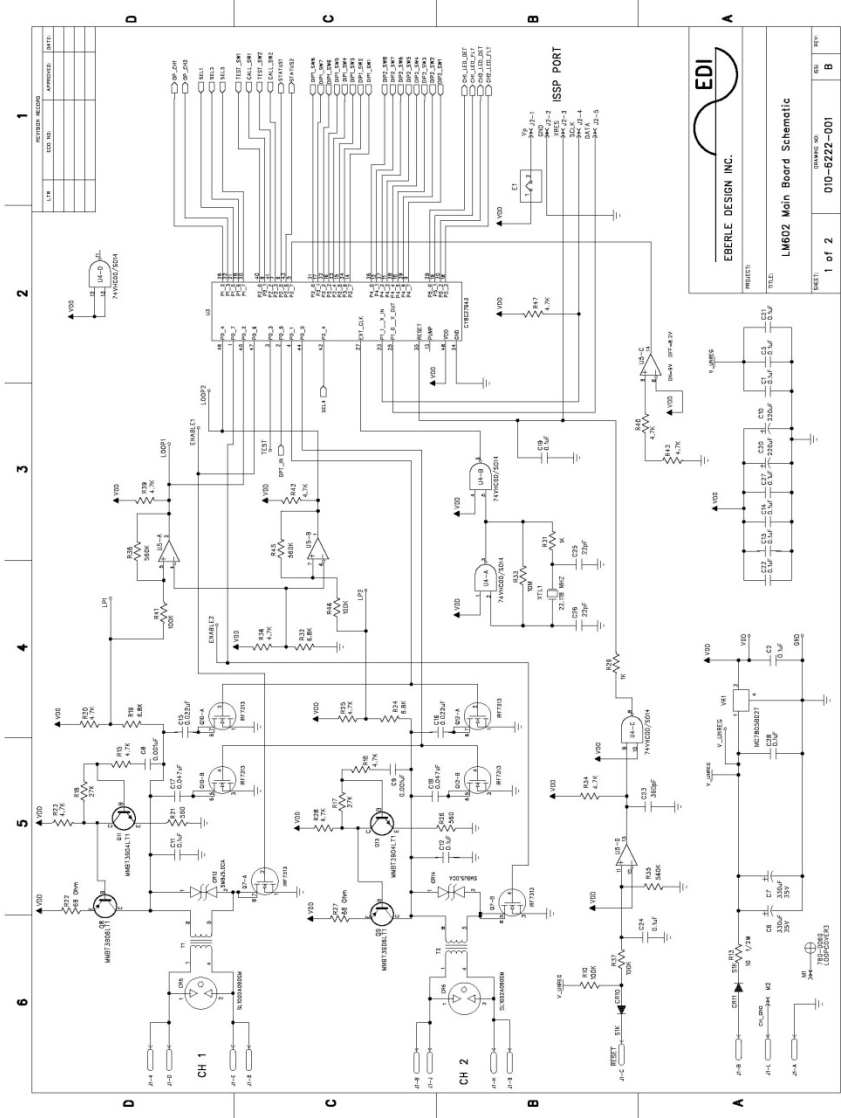
### 1.8 PARTS LIST AND SCHEMATIC

-----				
Bill Of Materials for LM602 Production Issue B				
-----				
Item	EDI Part Number	Qty	Description	Reference
-----				
1		1	(NO COMPONENT)	J1
2		10	(NO COMPONENT)	ENABLE1-2 GND LOOP1-2 LP1-2 TEST VDD V_UNREG
3		2		M1-2
4	215-1000-S	1	RESISTOR, 1/2W, 10 OHMS, 5%, 2010 surface mount	R13
5	255-0000-S	1	(NO COMPONENT)	SEL1
6	255-0000-S	5	RESISTOR, 1/8W, 0 OHMS, 5%, 1206 surface mount	E1 R2 R4 R9 R12
7	255-1020-S	4	RESISTOR, 1/8W, 1K, 5%, 1206 surface mount	R8 R14 R29 R31
8	255-1040-S	4	RESISTOR, 1/8W, 100K, 5%, 1206 surface mount	R10 R37 R41 R46
9	255-1060-S	1	RESISTOR, 1/8W, 10M, 5%, 1206 surface mount	R33
10	255-2730-S	2	RESISTOR, 1/8W, 27K, 5%, 1206 surface mount	R17-18
11	255-4720-S	15	RESISTOR, 1/8W, 4.7K, 5%, 1206 surface mount	R1 R5 R15-16 R20 R23 R25 R28 R34 R36 R39-40 R42-43 R47
12	255-5610-S	2	RESISTOR, 1/8W, 560, 5%, 1206 surface mount	R21 R26
13	255-5640-S	3	RESISTOR, 1/8W, 560K, 5%, 1206 surface mount	R35 R38 R45
14	255-6210-S	4	RESISTOR, 1/8W, 620 Ohm, 5%, 1206 surface mount	R48-51
15	255-6800-S	2	RESISTOR, 1/8W, 68, 5%, 1206 surface mount	R22 R27
16	255-6820-S	3	RESISTOR, 1/8W, 6.8K, 5%, 1206 surface mount	R19 R24 R32
17	300-2270-016S	2	CAPACITOR, ELECT,220uF,16WV, 20 %, LOW ESR,6.3mm SM	C10 C20
18	300-3370-035S	2	CAPACITOR, ELECTROLYTIC, 330uF, 35V, LOW ESR, 20%, SMT	C6-7
19	320-1020-050S	2	CAPACITOR, CER.MULT, 0.001uF, 50V, 10%, 1206 CHIP	C8-9
20	320-1040-050S	11	CAPACITOR, CER.MULT, 0.1uF, 50V, 10%, 1206 CHIP	C1-3 C13-14 C19 C21-22 C24 C27-28
21	320-2200-050S	2	CAPACITOR, CER.MULT, 22pF, 50V, 10%, 1206 CHIP	C25-26
22	320-3910-050S	1	CAPACITOR, CER.MULT, 390pF, 50V, 10%, 1206 CHIP	C23
23	330-1040-016S	2	CAPACITOR, 0.1uF, 5%, POLYPHENYLENE SULFIDE FILM, 16VDC, 1210	C11-12
24	330-2230-016S	2	CAPACITOR, 0.022uF, 5%, POLYPHENYLENE SULFIDE FILM, 16VDC, 1206	C15-16
25	330-4730-016S	2	CAPACITOR, 0.047uF, 5%, POLYPHENYLENE SULFIDE FILM, 16VDC, 1206	C17-18

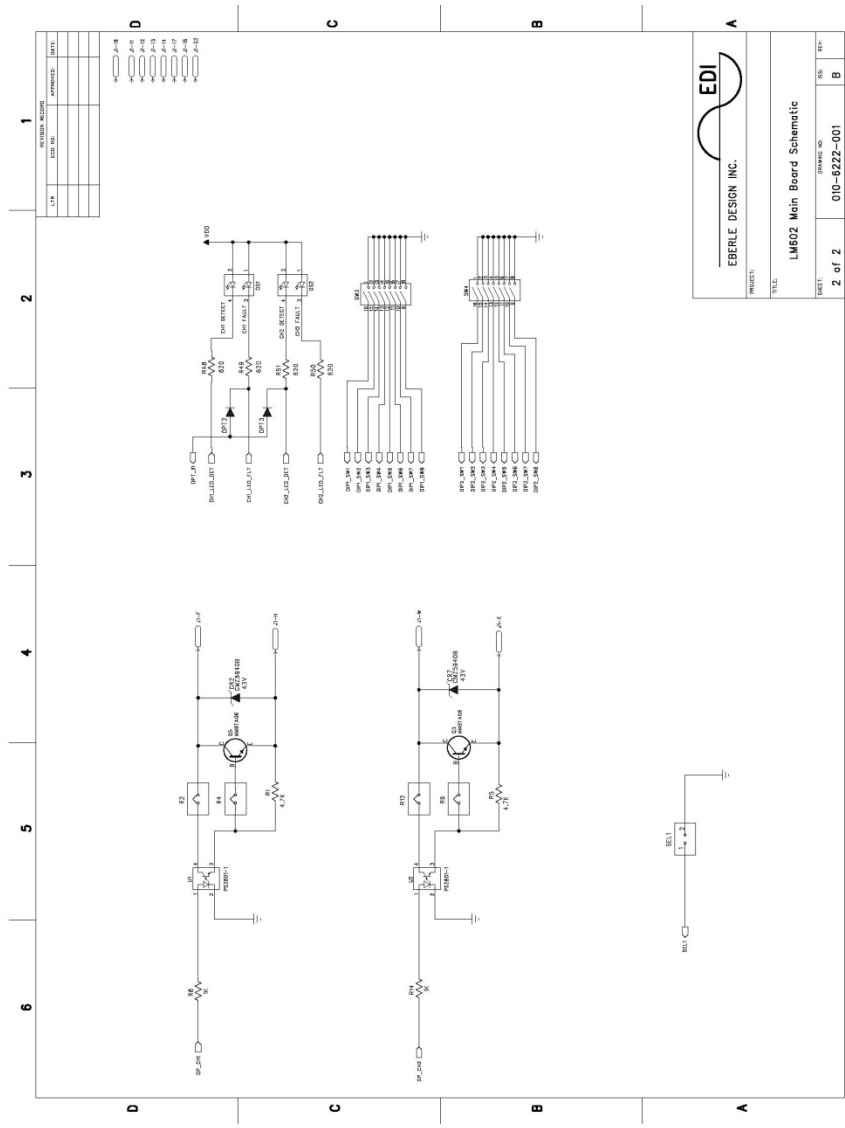
## LM602 Loop Monitor Operations Manual

26	405-3302-S	1	IC, LM3302N, QUAD COMPARATOR, SO14	U5
27	410-0050-S	2	DIODE, TRANSORB, SMBJ5.0CA, SMT	CR13-14
28	410-4005-S	2	DIODE, 1K, 800 PIV, 1A	CR10-11
29	410-4148-S	2	DIODE, LOGIC SIGNAL, 1N4148WS, SMT, SOD323	OPT2-3
30	410-4755-S	2	DIODE, ZENER, CMZ5941B, 1.0W, 5%, 43V, SMA	CR2 CR7
31	420-2811-S	2	OPTOCOUPLER, PS2801-1, 4 PIN SOP	U1-2
32	425-0318	2	DISPLAY, LED MODULE, DUAL, RA, HIGH BRIGHTNESS	DS1-2
33	430-0006-S	2	TRANSISTOR, MMBTA06LT1, NPN, 80V, 500 mA, SOT-23	Q3 Q5
34	430-3904-S	2	TRANSISTOR, MMBT3904LT1, NPN, SOT-23	Q11 Q13
35	430-3906-S	2	TRANSISTOR, PNP, MMBT3906LT1, SOT23	Q8-9
36	430-7313-S	3	Transistor, Dual N Channel FET, IRF7313, SO8	Q7 Q10 Q12
37	440-1002-S	2	GAS DISCHARGE TUBE	CR5-6
38	440-7805-S	1	MC7805BD2T, 5V REG., 1A, D2PAK	VR1
39	485-7643-S	1	MICROCONTROLLER, CY8C27643-24PVI	U3
40	490-1000-S	1	IC, 74VHC00, QUAD 2-INPUT NAND GATE, SO14	U4
41	520-0105-P	1	CONECTOR, HEADER, 5-PIN, ISSP PORT	J2
42	630-1080	2	SWITCH, DIP-SWITCH, 8 POS, RT. ANGLE	SW3-4
43	651-2212-S	1	CRYSTAL, 22.118 MHZ, 20pF, AT CUT, HC49, SMT	XTL1
44	780-0060	1		CVR2
45	800-0116-S	2	TRANSFORMER, LOOP, RM6, SMT	T1-2

# LM602 Loop Monitor Operations Manual



# LM602 Loop Monitor Operations Manual



**EBERLE DESIGN INC.**

---

PROJECT:	REV: <b>B</b>
TITLE:	ISS: <b>B</b>
LM602 Main Board Schematic	
SHEET:	DATE: <b>010-5422-001</b>
<b>2 of 2</b>	



