

**LUDLUM MODEL 12-4  
SURVEY METER WITH  
HE-3 NEUTRON DETECTOR**

**August 2019**

**Serial Number 227878 and Succeeding  
Serial Numbers**

# **LUDLUM MODEL 12-4 SURVEY METER WITH HE-3 NEUTRON DETECTOR**

**August 2019**

**Serial Number 227878 and Succeeding  
Serial Numbers**

This Manual also applies to Serial Numbers of Model 12-4 Instruments where the BF-3 detector has been modified to He-3.  
He-3 detectors, and those modified to be, are labeled with an "H."



**LUDLUM MEASUREMENTS, INC**  
501 OAK STREET, P.O. BOX 810  
SWEETWATER, TEXAS 79556  
325-235-5494, FAX: 325-235-4672



## STATEMENT OF WARRANTY

Ludlum Measurements, Inc. warrants the products covered in this manual to be free of defects due to workmanship, material, and design for a period of twelve months from the date of delivery. The calibration of a product is warranted to be within its specified accuracy limits at the time of shipment. In the event of instrument failure, notify Ludlum Measurements to determine if repair, recalibration, or replacement is required.

This warranty excludes the replacement of photomultiplier tubes, G-M and proportional tubes, and scintillation crystals which are broken due to excessive physical abuse or used for purposes other than intended.

There are no warranties, express or implied, including without limitation any implied warranty of merchantability or fitness, which extend beyond the description of the face there of. If the product does not perform as warranted herein, purchaser's sole remedy shall be repair or replacement, at the option of Ludlum Measurements. In no event will Ludlum Measurements be liable for damages, lost revenue, lost wages, or any other incidental or consequential damages, arising from the purchase, use, or inability to use product.

## RETURN OF GOODS TO MANUFACTURER

If equipment needs to be returned to Ludlum Measurements, Inc. for repair or calibration, please send to the address below. All shipments should include documentation containing return shipping address, customer name, telephone number, description of service requested, and all other necessary information. Your cooperation will expedite the return of your equipment.

**LUDLUM MEASUREMENTS, INC.  
ATTN: REPAIR DEPARTMENT  
501 OAK STREET  
SWEETWATER, TX 79556**

**800-622-0828    325-235-5494  
FAX 325-235-4672**

# Table of Contents

---

<b><i>Introduction</i></b>	<b>1</b>
<b><i>Getting Started</i></b>	<b>2</b>
Unpacking and Repacking	2-1
Battery Installation	2-1
Connecting the Detector to the Instrument	2-2
Battery Test	2-2
Instrument Test	2-3
Operational Check	2-3
<b><i>Specifications</i></b>	<b>3</b>
<b><i>Identification of Controls and Functions</i></b>	<b>4</b>
<b><i>Safety Considerations</i></b>	<b>5</b>
Environmental Conditions for Normal Use	5-1
Warning Markings and Symbols	5-1
Cleaning and Maintenance Precautions	5-2
<b><i>Calibration and Maintenance</i></b>	<b>6</b>
<b>Calibration</b>	<b>6-1</b>
Establishing an Operating Point	6-1
Equipment Required for Calibration	6-1
Initial Calibration Procedures	6-2
Detector Plateau	6-3
Gamma Rejection	6-4
Instrument Calibration	6-4
Electronic Calibration	6-5
<b>Maintenance</b>	<b>6-5</b>
Recalibration	6-6
Batteries	6-6

<b><i>Troubleshooting</i></b>	<b>7</b>
Troubleshooting Electronics that utilize a Proportional Detector	7-1
<b><i>Technical Theory of Operation</i></b>	<b>8</b>
Main Board (Drawing 464 × 275, 3 sheets)	8-1
Input	8-1
Amplifier	8-1
Discriminator	8-1
Audio	8-1
Scale Ranging	8-2
Digital Analog Converter	8-2
Ratemeter Drive Circuit	8-2
HV Meter Drive	8-2
Battery Test	8-2
HV Power Supply Board (Drawing 464 × 243)	8-3
Switching Convertor	8-3
Feedback	8-3
Voltage Control	8-3
Filtering	8-3
<b><i>Recycling</i></b>	<b>9</b>
<b><i>Parts List</i></b>	<b>10</b>
Model 12-4 Survey Meter	10-1
Main Board, Drawing 464 × 275	10-1
HV Power Supply Board, Drawing 464 × 243	10-4
Wiring Diagram, Drawing 464 × 309	10-5
Model 42-31H Neutron Detector	10-5
<b><i>Drawings and Diagrams</i></b>	<b>11</b>

**Section****1**

## Introduction

---



The Model 12-4 is a Survey Meter coupled to a Model 42-31H Neutron Detector; providing the required electronic circuitry and detector for measuring and monitoring of neutron radiation. The instrument provides four linear ranges used in combination with an exposure rate or CPM (counts per minute) meter dial. The instrument features a regulated HV (high-voltage) power supply, unimorph speaker with audio ON-OFF capability, fast-slow meter response, meter reset button and a six-position switch for selecting battery check or range multiples of  $\times 1$ ,  $\times 10$ ,  $\times 100$ , and  $\times 1000$ . Each range multiplier has its own calibration potentiometer. The unit body and meter housing are made of cast aluminum and the can is 0.23 cm (0.090 in.) thick aluminum.

The unit is powered by two "D" cell batteries for operation from  $-20$  to  $50$  °C ( $-4$  to  $122$  °F). For instrument operation below  $0$  °C ( $32$  °F), use very fresh alkaline or rechargeable NiCd batteries.

**Section****2**

## Getting Started

---

### Unpacking and Repacking

Remove the calibration certificate and place it in a secure location. Remove the instrument and accessories (batteries, cable, etc.) and ensure that all of the items listed on the packing list are in the carton. Check individual item serial numbers and ensure calibration certificates match. The Model 12-4 serial number is located on the front panel below the battery compartment. Most Ludlum Measurements, Inc. detectors have a label on the base or body of the detector for model and serial number identification.

**Important!**

If multiple shipments are received, ensure that the detectors and instruments are not interchanged. Each instrument is calibrated to specific detectors, and therefore not interchangeable.

To return an instrument for repair or calibration, provide sufficient packing material to prevent damage during shipment. Also provide appropriate warning labels to ensure careful handling.

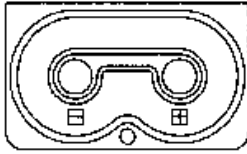
Every returned instrument must be accompanied by an **Instrument Return Form**, which can be downloaded from the Ludlum website at [www.ludlums.com](http://www.ludlums.com). Find the form by clicking the “Support” tab and selecting “Repair and Calibration” from the drop-down menu. Then choose the appropriate Repair and Calibration division where you will find a link to the form.

### Battery Installation

Ensure the Model 12-4 range selector switch is in the OFF position. Open the battery lid by pushing down and turning the quarter-turn thumbscrew



counterclockwise a quarter of a turn. Install two "D" size batteries in the compartment.



Note the (+) and (-) marks inside the battery door. Match the battery polarity to these marks. Close the battery box lid, push down, and turn the quarter-turn thumb screw clockwise a quarter of a turn.

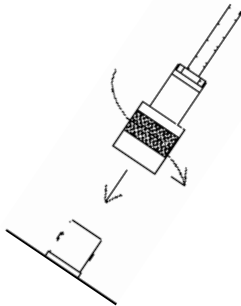
**Note:**

The center post of a flashlight battery is positive. The batteries are placed in the battery compartment in opposite directions.

## Connecting the Detector to the Instrument

**Caution!**

The detector operating voltage (also referred to as HV) is supplied to the detector via the detector input connector. A mild electric shock may occur if you make contact with the center pin of the input connector. Switch the Model 12-4 range selector switch to the OFF position before connecting or disconnecting the cable or detector.



Connect one end of a detector cable to the detector by firmly pushing the connectors together while twisting clockwise a quarter of a turn. Repeat the process in the same manner with the other end of the cable and the instrument.

## Battery Test

The batteries should be checked each time the instrument is turned on. Move the range switch to the BAT position. Ensure that the meter needle deflects to the battery check portion on the meter scale. If the meter does not respond, check to see if the batteries have been correctly installed. Replace the batteries if necessary.

## Instrument Test

After checking the batteries, turn the instrument range switch to the  $\times 1000$  position. Place the AUD ON-OFF switch in the ON position. The instrument speaker should emit "clicks" relative to the rate of counts detected. The AUD ON/OFF switch will silence the audible clicks if in the OFF position.

It is recommended that the AUD ON/OFF switch be kept in the OFF position when not needed in order to preserve battery life.

Rotate the range switch through the lower scales until a meter reading is indicated. While observing the meter fluctuations, select between the fast and slow response time (F/S) positions to observe variations in the display. The "S" position should respond approximately 5 times slower than the "F" position.

### Note:

The slow response position is normally used when the instrument is displaying low numbers, which require a more stable meter movement. The fast response position is used at high rate levels.

Check the meter reset function by depressing the RES pushbutton switch and ensuring the meter needle drops to "0."

Once this procedure has been completed, the instrument is ready for use.

## Operational Check

To assure proper operation of the instrument – between calibrations and periods of nonuse – an instrument operational check, including battery test and instrument test (as described above), should be performed prior to use.

## Section

## 3

## Specifications

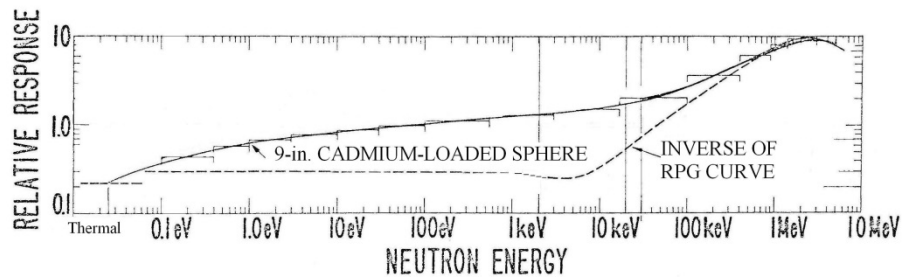
**Operating Voltage:** approximately 1200 Vdc

**Detector:** 2 Atm  $^3\text{He}$  tube – LND 25185 or equivalent – proportional detector, surrounded by a 22.9 cm (9 in.) diameter polyethylene sphere

**Detector Input Sensitivity:** -2 mV

**Sensitivity:** typically 10,000 cpm per  $\mu\text{Sv/h}$  (100 cpm/mrem/hr) ( $^{241}\text{AmBe}$  fast neutrons)

**Detection Range:** thermal to approximately 12 MeV, provides an approximate inverse RPG curve (see below)



**Meter:** 6.4 cm (2.5 in.) arc, pivot-and-jewel suspension.

**Meter Face:** 0-10 mrem/hr, 0-2.5 kV, BAT TEST (others available)

**Instrument Range:** typically 0-100 mSv/h (0-10,000 mrem/hr), depending on the meter face utilized

**Gamma Rejection:** typically 10 cpm or less through 0.1 Sv/h (10 R/hr) ( $^{137}\text{Cs}$ )

**Input Impedance:** 0.1 megohm

**Linearity:** reading within 10% of true value with detector connected

**Discriminator:** adjustable from 1 to 50 mV

**Audio:** built-in unimorph speaker with ON-OFF switch (greater than 60 dB at 61 cm {2 ft})

**Response:** toggle switch for FAST (4 seconds) or SLOW (22 seconds) from 10% to 90% of final reading

**Connector:** Series "C" (other available)

**Cable:** 99.1 cm (39 in.) with "C" connector (others available)

**Power:** two "D" cell batteries housed in a sealed externally accessible compartment

**Battery Life:** typically 600 hours with alkaline batteries (battery condition may be checked on the meter)

**End-of-Battery Life Warning:** At 2.1 Vdc (voltage direct current) the meter needle will drop to the edge of the BAT TEST or BAT OK area when the meter selector switch is moved to the BAT position. At 2.0 Vdc a steady audible tone will be emitted to warn the user of the low battery condition.

**Battery Dependence:** instrument calibration change less than 3% within battery check limits on the meter

**Size:** 43.2 x 22.9 x 26.7 cm (17 x 9 x 10.5 in.) (H x W x L)

**Weight:** 7.9 kg (17.5 lb)

**Construction:** cast and drawn aluminum with beige powder-coat finish

## Section

## 4

## Identification of Controls and Functions

---

**Meter:** 6.4 cm (2.5 in.) arc, 1 mA analog type with pivot-and-jewel suspension. Typical meter dial is 0-10 mrem/hr, 0-2.5 kV and BAT TEST.

**Connector:** Used to connect the detector to the instrument. Typically series "C," but can be "BNC", "MHV", "UHF," or others.

**Range Selector Switch:** a six-position switch marked OFF, BAT,  $\times 1000$ ,  $\times 100$ ,  $\times 10$ , and  $\times 1$ . Turning the range selector switch from OFF to BAT provides the operator with a battery check of the instrument. A BAT check scale on the meter provides a visual means of checking the battery-charge status. Moving the range selector switch to one of the range multiplier positions ( $\times 1000$ ,  $\times 100$ ,  $\times 10$ ,  $\times 1$ ) provides the operator with an overall range of 0 to 10,000 mrem/hr. Multiply the scale reading by the multiplier to determine the actual scale reading.

**Discriminator Adjustment:** allows the input sensitivity to be adjusted from 1 to 100 mV; factory set at -2 mV.

**HV Adjustment:** provides a means of varying the high voltage from 200 to 2500 V; factory set at 1100 V.

**Range Calibration Adjustment:** recessed potentiometers located under the calibration cover on the right side of the front panel. These adjustment controls allow individual calibration for each range multiplier.

**Battery Compartment:** sealed compartment to house two "D" cell batteries.

**AUD ON-OFF Toggle Switch:** In the ON position, it operates the unimorph speaker located on the left side of the instrument. The frequency of the clicks is relative to the rate of the incoming pulses. The higher the rate, the higher the audio frequency. This switch should be turned OFF when not required in order to reduce battery drain.

**RES Pushbutton:** When depressed, this button provides a rapid means of driving the meter needle to zero.

**Toggle Switch:** provides meter response. Selecting the fast, "F" position of the toggle switch provides 90% of full-scale meter deflection in four seconds. In the slow, "S" position, 90% of full-scale meter deflection takes 22 seconds. In the "F" position there is fast response and large meter deviation. The "S" position should be used for slow response and damped meter deviation.

**HV Pushbutton Switch:** When depressed, displays the detector high voltage on the meter. The output resistance of the high voltage-supply is 1.5 megohms with a typical scintillation voltage divider of 100 megohms. The actual detector voltage will be 98.5% of the indicated voltage.

**Section****5**

## Safety Considerations

---

### Environmental Conditions for Normal Use

Indoor or outdoor use

No maximum altitude

Temperature range of -20 to 50 °C (-4 to 122 °F); may be certified for operation from -40 to 65 °C (-40 to 150 °F)

Maximum relative humidity of less than 95% (non-condensing)

Pollution Degree 3 (as defined by IEC 664) (Occurs when conductive pollution or dry nonconductive pollution becomes conductive due to condensation. This is typical of industrial or construction sites.)

### Warning Markings and Symbols

**Caution!**

The operator or responsible party is cautioned that the protection provided by the equipment may be impaired if the equipment is used in a manner not specified by Ludlum Measurements, Inc.

**The Model 12-4 Survey Meter is marked with the following symbols:**



**CAUTION, RISK OF ELECTRIC SHOCK** (per ISO 3864, No. B.3.6): designates a terminal (connector) that allows connection to a voltage exceeding 1 kV. Contact with the subject connector while the instrument is on or shortly after turning off may result in electric shock. This symbol appears on the front panel.



**CAUTION** (per ISO 3864, No. B.3.1): designates hazardous live voltage and risk of electric shock. During normal use, internal components are hazardous live. This instrument must be isolated or disconnected from the hazardous live voltage before accessing the internal components. This symbol appears on the front panel. **Note the following precautions:**

#### **Warning!**

The operator is strongly cautioned to take the following precautions to avoid contact with internal hazardous live parts that are accessible using a tool:

1. Turn the instrument power OFF and remove the batteries.
2. Allow the instrument to sit for one minute before accessing internal components.



The “**crossed-out wheellie bin**” symbol notifies the consumer that the product is not to be mixed with unsorted municipal waste when discarding; each material must be separated. The symbol is placed on the battery compartment lid. See Section 9, “Recycling,” for further information.



The “CE” mark is used to identify this instrument as being acceptable for use within the European Union.

## **Cleaning and Maintenance Precautions**

The Model 12-4 instrument and detector may be cleaned externally with a damp cloth, using only water as the wetting agent. Do not immerse the instrument in any liquid. Observe the following precautions when cleaning or performing maintenance on the instrument:

1. Turn the instrument OFF and remove the batteries.
2. Allow the instrument to sit for one minute before cleaning the exterior or accessing any internal components for maintenance.



**Section****6**

## Calibration and Maintenance

---

### Calibration

Calibration controls are located on the front of the instrument under the calibration cover. The controls may be adjusted with a 1/8-inch blade screwdriver.

**Note:**

Local procedures may supersede the following.

### ***Establishing an Operating Point***

The operating point for the instrument and detector is established by setting the detector voltage and instrument sensitivity (HV and DIS). The proper selection of this point is the key to instrument performance. Efficiency, background sensitivity, and noise are fixed by the physical makeup of the given detector and rarely vary from unit to unit. However, the selection of the operating point makes a marked difference in the apparent contribution of these three sources of count.

In setting the operating point, the final result of the adjustment is to establish the system gain so that the desirable signal pulses (including background) are above the discrimination level and the unwanted pulses from noise are below the discrimination level and are therefore, not counted.

Adjusting either the instrument gain or the HV controls the total system gain. Voltage affects control in the detector; DIS (Discriminator) controls the amplifier gain.

### ***Equipment Required for Calibration***

All instruments used in calibrating the Model 12-4 must be calibrated by standards traceable to the National Institute of Standards and Technology and must have a current calibration label attached.

- A Ludlum Model 500 Pulser or equivalent is required. If the pulser does not have an HV readout, use a high-impedance voltmeter with at least 1000 Megohm meter input resistance to adjust the detector voltage.
- A neutron source capable of yielding dose-equivalent rates ranging from 2 mrem/hr to 1 rem/hr is needed.
- A  $^{137}\text{Cs}$  source capable of yielding an exposure rate of 10 R/hr is needed.

### **Initial Calibration Procedures**

If any calibration procedure cannot be completed satisfactorily, the instrument shall be tagged and removed for proper disposition.

#### **Note:**

When placing the Model 12-4 into its can, orient the instrument so that the unimorph speaker is on the left side when reading the meter dial. Noise can be fed into the preamp of the instrument if it is placed backward into the can.

Ensure that the meter movement has proper mechanical zero. The adjustment is on the front of the meter bezel. It must be adjusted to "zero" with the Range Selector Switch in the OFF position.

Perform geotropism check.

Connect the Model 12-4 to the pulser or a certified high-impedance voltmeter.

Rotate the range selector switch to the BAT position. The meter pointer should remain in the BAT TEST area of the meter dial.

Rotate the Model 12-4 Range Selector Switch to  $\times 1000$ .

Adjust the CAL HV potentiometer on the Model 12-4 for a reading of 1.5 kV on the pulser HV meter.

**Warning!**

Avoid electrical shock! Do not allow any conductive material to come in contact with internal parts.

Depress the Model 12-4 HV pushbutton. The Model 12-4 meter pointer should be over the 1.5 mark on the kV dial scale. If it is not, remove the Model 12-4 from the can and adjust the HV potentiometer (R49) on the main board until the pointer is over the 1.5 kV mark. Place the Model 12-4 back in the can, with the unimorph speaker on the left side.

Depress the Model 12-4 HV button and adjust the Model 12-4 HV CAL potentiometer (front panel) until the Model 12-4 meter indicates 0.5 kV.

The pulser voltmeter should read  $0.5 \text{ kV} \pm 10\%$ .

Depress the Model 12-4 HV button and adjust the Model 12-4 HV CAL potentiometer (front panel) until the Model 12-4 meter indicates 2.0 kV.

The pulser voltmeter should read  $2.0 \pm 10\%$  kV.

Reset the Model 12-4 HV to 1100 volts.

Set the pulser for -2 mV.

Adjust DIS for a stable meter reading, and then back off the control until the meter reading declines 10%.

***Detector Plateau***

Secure a Model 2200 (or equivalent instrument) with input discrimination adjusted to -2 mV.

Connect the Model 12-4 detector to the Model 2200. Background count should be less than 1 cpm (counts per minute).

Place the Model 12-4 detector assembly in a neutron field. Expose the detector to a 20 mrem/hr neutron field. Run a plateau of cpm versus detector high voltage, within a suggested range of 1000-1250 volts.

Use 25-volt steps.

From your data, pick a high-voltage operating point between 2000 and 2800 cpm at 20 mrem/hr.

The operating point should show less than 10% deviation of count for  $\pm 25$  volt change.

Record this count at your selected operating point. Record the sensitivity in counts per minute/mrem/hr. Record the high-voltage operating point.

### ***Gamma Rejection***

Remove the Model 42-31H detector from the moderator and place in a 10 R/hr  $^{137}\text{Cs}$  gamma radiation field.

Take a one-minute count. If more than 10 counts are observed for the one-minute period, decrease the operating voltage until the count rate drops below 10 cpm; however, ensure that the HV remains in the plateau region determined above.

Ensure that sensitivity for the selected operating voltage is approximately 120 cpm/mrem/hr.

Return the Model 42-31H to the moderator.

### ***Instrument Calibration***

Connect the Model 12-4 counting instrument to a Model 500 Pulser.

Now adjust the Pulser to 4-6 mV.

Adjust the Model 12-4 HV control for a HV setting equal to the operating point HV from the previous paragraph.

Multiply the sensitivity in counts/minute/mrem/hr times 80 for the specific detector.

Adjust the Model 500 pulse rate to the calculated value. (Count rate should be 9600 cpm  $\pm 10\%$ .) Set the Model 12-4 range selector switch to  $\times 10$  and adjust the  $\times 10$  calibration potentiometer for a meter reading of "8".

Connect the Model 12-4 counter to the Model 12-4 detector assembly.

Expose the detector to an 80 mrem/hr neutron field.

Confirm that the meter reads 8 mrem/hr on the  $\times 10$  scale.

If the reading is not 8 mrem/hr  $\pm 5\%$ , make a slight adjustment to the HV supply to yield an 8 mrem/hr meter reading.

Expose the detector to a 20 mrem/hr field and confirm a meter reading of 20 mrem/hr  $\pm 10\%$ .

Proceed to calibrate all scales with a meter reading of 2 and 8 mrem/hr.

### **Electronic Calibration**

If your range is inadequate to equal all points between 2 mrem/hr and 800 mrem/hr, you may use a pulser to electronically calibrate the instrument.

Multiply the cpm/mrem/hr as determined on the plateau check by the range selection and meter reading. (i.e. typically,  $120 \text{ cpm/mrem/hr} \times 1000 \times 8 = 960,000 \text{ cpm}$  for 800 mrem/hr)

Set this calculated number in the pulser and calibrate the associated scale.

Note on the calibration certificate that this range was electronically calibrated.

## **Maintenance**

Instrument maintenance consists of keeping the instrument clean and periodically checking the batteries and the calibration. The Model 12-4 instrument may be cleaned with a damp cloth (using only water as the wetting agent). Do not immerse instrument in any liquid. Observe the following precautions when cleaning:

1. Turn the instrument OFF and remove the batteries.
2. Allow the instrument to sit for one minute before accessing internal components.

**Recalibration**

Recalibration should be accomplished after maintenance or adjustments have been performed on the instrument. Recalibration is not normally required following instrument cleaning, battery replacement or detector cable replacement of equal length.

**Note:**

Ludlum Measurements, Inc. recommends recalibration at intervals no greater than one year. Check the appropriate regulations to determine required recalibration intervals.

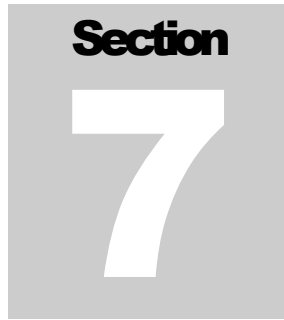
Ludlum Measurements offers a full-service repair and calibration department. We not only repair and calibrate our own instruments, but most other manufacturers' instruments. Calibration procedures are available upon request for customers who choose to calibrate their own instruments.

**Batteries**

The batteries should be removed any time the instrument is placed into storage. Battery leakage may cause corrosion on the battery contacts, which must be scraped off and/or washed using a paste solution made from baking soda and water. Use a spanner wrench to unscrew the battery contact insulators, exposing the internal contacts and battery springs. Removal of the handle will facilitate access to these contacts.

**Note:**

Never store the instrument over 30 days without removing the batteries. Although this instrument will operate at very high ambient temperatures, battery seal failure may occur at temperatures as low as 37.7 °C (100 °F).


 A gray square containing the word "Section" in a bold, black, sans-serif font at the top, and a large, white, bold number "7" in the center.

## Troubleshooting

---

Occasionally, you may encounter problems with your LMI instrument or detector that may be repaired or resolved in the field, saving turnaround time and expense in returning the instrument to us for repair. Toward that end, LMI electronic technicians offer the following tips for troubleshooting the most common problems. Where several steps are given, perform them in order until the problem is corrected. Keep in mind that with this instrument, the most common problems encountered are: (1) detector cables, (2) sticky meters, (3) battery contacts.

Note that the first troubleshooting tip is for determining whether the problem is with the electronics or with the detector. A Ludlum Model 500 Pulser is invaluable at this point, because of its ability to simultaneously check high voltage, input sensitivity or threshold, and the electronics for proper counting.

We hope these tips will prove to be helpful. As always, please call if you encounter difficulty in resolving a problem or if you have any questions.

### Troubleshooting Electronics that utilize a Proportional Detector

<u>SYMPTOM</u>	<u>POSSIBLE SOLUTION</u>
No power (or meter does not reach BAT TEST or BAT OK mark)	<ol style="list-style-type: none"> <li>1. Check batteries and replace if weak.</li> <li>2. Check polarity (See marks inside batter lid.). Are the batteries installed backwards?</li> </ol>

<b><u>SYMPTOM</u></b>	<b><u>POSSIBLE SOLUTION</u></b>
No power (or meter does not reach BAT TEST or BAT OK mark) (continued)	<ol style="list-style-type: none"><li>3. Check battery contacts. Clean them with rough sandpaper or use an engraver to clean the tips.</li><li>4. Check for loose or broken wires, especially between the main board and the high-voltage board.</li></ol>
Nonlinear Readings	<ol style="list-style-type: none"><li>1. Check the high voltage (HV) by pressing the HV TEST button. If a multimeter is used to check the HV, ensure that one with high impedance is used, as a standard multimeter could be damaged in this process.</li><li>2. Check for noise in the detector cable by disconnecting the detector, placing the instrument on the lowest range setting, and wiggling the cable while observing the meter face for significant changes in readings.</li><li>3. Check for “sticky” meter movement. Does the reading change when you tap the meter? Does the meter needle “stick” at any spot?</li><li>4. Check the “meter zero.” Turn the power OFF. The meter should come to rest on “0.”</li></ol>
Meter goes full-scale or “pegs out”	<ol style="list-style-type: none"><li>1. Replace the detector cable to determine whether or not the cable has failed, causing excessive noise.</li><li>2. Check the HV and, if possible, the input threshold for proper setting.</li></ol>



<u>SYMPTOM</u>	<u>POSSIBLE SOLUTION</u>
Meter goes full-scale or “pegs out” (continued)	<ol style="list-style-type: none"><li>3. Ensure that the instrument’s can is properly attached. When attached properly, the speaker will be located on the left side of the instrument. If the can is on backwards, interference between the speaker and the input preamplifier may cause noise.</li></ol>
No Response to Radiation	<ol style="list-style-type: none"><li>1. Substitute a “known good” detector and/or cable.</li><li>2. Has the correct operating voltage been set? Refer to the calibration certificate or detector instruction manual for correct operating voltage. If the instrument uses multiple detectors, confirm that the high voltage is matched to the current detector being used.</li></ol>
No Audio	<ol style="list-style-type: none"><li>1. Ensure that the AUD ON-OFF switch is in the ON position.</li><li>2. Remove the instrument housing and check the connection between the circuit board and the speaker. Plug in the 2-pin connector if necessary.</li></ol>

**Section****8**

## Technical Theory of Operation

---

### **MAIN BOARD (Drawing 464 × 275 3 sheets)**

#### **Input**

Detector pulses are coupled through C16 to emitter follower Q4. R42 provides 3.7 V bias. R41 couples to detector HV. CR3 protects the input from high-voltage transients.

#### **Amplifier**

A self-biased amplifier provides gain in proportion to R15 divided by R14 and R47. Transistor (pin 3 of U4) provides amplification. U6 is coupled as current mirror to provide a load for pin 3 of U4. The output self-biases to 2 V<sub>be</sub> (approximately 1.4 V) at emitter of Q1.

Positive pulses from Q1 are coupled to the discriminator U8. Amplifier gain is controlled by R47.

#### **Discriminator**

Comparator U8 has a fixed discrimination of 15 mV. Any pulse above 15 mV causes the output of U8 to go low. This negative pulse is coupled to pin 5 of U9A for meter drive and pin 12 of U9B for audio drive. The pulse is also available at pin 3 of P2 for special applications.

#### **Audio**

U9B develops a 22 millisecond pulse for each discriminator pulse if audio switch is ON, allowing pin 13 of U9B to be high. Pin 10 of U9B is normally low, preventing U12 from oscillating. When pulse goes high, U12 oscillates, driving the unimorph speaker. U7B is normally closed, but during low battery state, pin 5 of U7B opens, allowing R30 to pull pin 3 of U12 high causing a steady tone even though the audio is OFF.

## Scale Ranging

Detector pulses from the discriminator are coupled to univibrator pin 5 of U9A. For each scale, the pulse width of pin 6 of U9A is increased by a factor of 10 with the actual pulse width being controlled by the front-panel calibration controls and their related capacitors. This arrangement allows the same current to be delivered to C9 by one count on the  $\times 1$  range as 1000 counts on  $\times 1K$  range.

## Digital Analog Converter

U5 is coupled as a current mirror. For each pulse of current through R24 and equal current is delivered to C9. This charge is drained off by R25. The voltage across C9 is proportional to the incoming count rate.

## RateMeter Drive Circuit

Voltage across C9 is measured by voltage follower U10 and Q2. Q2 converts voltage input to a constant current output at Q2 collector. Current flow is controlled by R19. For slow time constant, C17 is switched from the output to parallel C9 at the input. Reset (SW2) shorts the input capacitor. R44 stabilizes U10. Meter current flows through analog switch U7A and U16B.

## HV Meter Drive

A V proportional to HV is converted to a constant current drain by voltage follower U13 and Q3. Current flow is controlled by R49. This current is converted to a constant current source by U15, and then coupled to the meter through analog switches U3B.

## Battery Test

Battery voltage is connected through R8 through analog switch U3A and U16B to the meter.

## ***HV Supply Board (Drawing 464 × 243)***

### **Switching Convertor**

HV is developed by voltage multiplier CR1 through CR10 and associated capacitors. This multiplier is driven by switching convertor U2 and T1. The convertor is powered by regulated 6 V from the main board.

### **Feedback**

The high-voltage output is reduced 99.9% by voltage dividers R4, R5, and R6. The remaining voltage is coupled to the HV meter circuit through R7 and pin 1 of P1. Also, the voltage is coupled through R8 to the switcher feedback input pin 8 of U2.

### **Voltage Control**

The switching convertor U2 and T1 will develop an output voltage at C3 and R4 such that the voltage at pin 8 of U2 stays at 1.24 V. If voltage at pin 2 is zero, voltage at pin 1 of U1 must be 2.541 V to maintain 1.24 V at pin 8 of U2. To obtain 2.541 V at pin 1 of U2 the output voltage must be 2.541 V. In like manner, as the voltage at pin 2 of P1 increases to 2.181 V, the HV output will be driven to zero.

### **Filtering**

The HV is filtered by R2, R3, C1, and C2. R2 and R3 cause the power supply to have an output resistance of 1.5 MEG. This will cause a metering error for heavy loads. For the typical 100 MEG detector, this error will only represent 1.5%.

## Section

## 9

## Recycling

Ludlum Measurements, Inc. supports the recycling of the electronic products it produces for the purpose of protecting the environment and to comply with all regional, national, and international agencies that promote economically and environmentally sustainable recycling systems. To this end, Ludlum Measurements, Inc. strives to supply the consumer of its goods with information regarding reuse and recycling of the many different types of materials used in its products. With many different agencies – public and private – involved in this pursuit, it becomes evident that a myriad of methods can be used in the process of recycling. Therefore, Ludlum Measurements, Inc. does not suggest one particular method over another, but simply desires to inform its consumers of the range of recyclable materials present in its products, so that the user will have flexibility in following all local and federal laws.

The following types of recyclable materials are present in Ludlum Measurements, Inc. electronics products, and should be recycled separately. The list is not all-inclusive, nor does it suggest that all materials are present in each piece of equipment:

Batteries	Glass	Aluminum and Stainless Steel
Circuit Boards	Plastics	Liquid Crystal Display (LCD)

Ludlum Measurements, Inc. products, placed on the market after August 13, 2005, have been labeled with a symbol recognized internationally as the “crossed-out wheelie bin,” which notifies the consumer that the product is not to be mixed with unsorted municipal waste when discarding. Each material must be separated. The symbol will be placed near the AC receptacle, except for portable equipment where it will be placed on the battery lid.

The symbol appears as such:



# Section 10

## Parts List

	<u>Reference</u>	<u>Description</u>	<u>Part Number</u>
<b>Model 12-4 Survey Meter</b>	UNIT	Completely Assembled Model 12 Survey Meter	48-1200
<b>Main Board, Drawing 464 × 275</b>	BOARD	Completely Assembled Main Circuit Board	5464-275
CAPACITORS	C1	47pF, 100V	04-5660
	C2	0.1μF, 35V-T	04-5755
	C3	0.0047μF, 100V	04-5669
	C4	NOT USED	
	C5	0.1μF, 35V-T	04-5755
	C6	2.2μF, 20V	04-5790
	C7	0.022μF, 50V	04-5667
	C8	1μF, 16V	04-5701
	C9	10μF, 10V-DT	04-5766
	C10	100pF, 100V	04-5661
	C11-C12	68μF, 10V	04-5654
	C13	2.2μF, 20V	04-5790
	C14	470pF, 100V	04-5668
	C15	0.1μF, 25V	04-5744
	C16	100pF, 3KV	04-5532
	C17	47μF, 10V	04-5666
	C18	470pF, 100V	04-5668
	C19	0.001μF, 3KV	04-5632
	C20	10μF, 10V	04-5766
	C21	0.01μF, 50V	04-5664
	C30	10μF, 10V	04-5766
	C31	1μF, 16V	04-5701
	C32	470pF, 100V	04-5668

	<u>Reference</u>	<u>Description</u>	<u>Part Number</u>
TRANSISTORS	Q1	MMBT3904LT1	05-5841
	Q2	MMBT4403LT1	05-5842
	Q3-Q4	MMBT3904LT1	05-5841
VOLTAGE REGULATOR	VR1	LT1460KC53-2.5	05-5867
	VR2	TPS76038	05-5912
INTEGRATED CIRCUITS	U1-U3	MAX4542ESA	06-6453
	U4-U5	CMXT3904	05-5888
	U6	CMXT3906	05-5890
	U7	MAX4541ESA	06-6452
	U8	MAX985EUK-T	06-6459
	U9	CD74HC4538M	06-6297
	U10	LMC7111BIM5X	06-6410
	U11	LT1304CS8	06-6394
	U12	MIC1557BM5	06-6457
	U13	LMC7111BIM5X	06-6410
	U14	TPS76050	05-5913
	U15	CMXT3906	05-5890
	U16	MAX4541ESA	06-6452
	DIODES	CR2	CMSH1-40M
CR3		CMPD2005S	07-6468
SWITCHES	SW1	CENTRAL-2P6P	08-6761
	SW2	TP11LTCQE	7464-186
	SW3-SW4	7101SDCQE	08-6781
	SW5	TP11LTCQE	7464-186
POTENTIOMETERS / TRIMMERS	R33	250K, 64W254, ×1000	09-6819
	R34	250K, 64W254, ×100	09-6819
	R35	500K, 64W504, ×10	09-6850
	R36	250K, 64W254, ×1	09-6819
	R38	100K, 64W104, HV SET	09-6813
	R47	1M, 64W105, NAME	09-6814
	R49	10K, 3266×1-103, HV METER ADJ	09-6822

	<u>Reference</u>	<u>Description</u>	<u>Part Number</u>
RESISTORS			
	R1-R5	200K, 1/8W, 1%	12-7992
	R6	8.25K, 1/8W, 1%	12-7838
	R7	10K, 1/8W, 1%	12-7839
	R8	2.37K, 1/8W, 1%	12-7861
	R9-R11	10K, 1/8W, 1%	12-7839
	R12	1K, 1/4W, 1%	12-7832
	R13	10K, 1/8W, 1%	12-7839
	R14	4.75K, 1/8W, 1%	12-7858
	R15	249K, 1/4W, 1%	12-7862
	R16	10K, 1/8W, 1%	12-7839
	R17	1K, 1/8W, 1%	12-7832
	R18	4.75K, 1/8W, 1%	12-7858
	R19	2K, 1/8W, 1%	12-7926
	R20	100K, 1/8W, 1%	12-7834
	R21	249K, 1/4W, 1%	12-7862
	R22	1M, 1/8W, 1%	12-7844
	R23	124K, 1/4W, 1%	12-7032
	R24	14.7K, 1/8W, 1%	12-7068
	R25	200K, 1/4W, 1%	12-7992
	R26	100K, 1/4W, 1%	12-7834
	R27	68.1K, 1/8W, 1%	12-7881
	R28	100K, 1/8W, 1%	12-7834
	R29	1K, 1/8W, 1%	12-7832
	R30	100K, 1/8W, 1%	12-7834
	R31	475K, 1/8W, 1%	12-7859
	R32	100K, 1/8W, 1%	12-7834
	R37	200K, 1/4W, 1%	12-7992
	R39	1M, 1/4W, 1%	12-7844
	R40	10K, 1/4W, 1%	12-7839
	R41-R42	100K, 1/4W, 1%	12-7834
	R43	10K, 1/4W, 1%	12-7839
	R44	1K, 1/4W, 1%	12-7832
	R45	475K, 1/4W, 1%	12-7859
	R46	10K, 1/4W, 1%	12-7839
	R48	1M, 1/4W, 1%	12-7844
	R50	1K, 1/4W, 1%	12-7832
CONNECTORS			
	P1	640456-5 - MTA100	13-8057
	P2	640456-6 - MTA100	13-8095
	P3	640456-2 - MTA100	13-8073



	<u>Reference</u>	<u>Description</u>	<u>Part Number</u>
	P4	640456-4 - MTA100	13-8088
	P5	DET PAD-RD120	7464-270
	P6	HV PAD-RD120	7464-270
INDUCTORS	L1	22 $\mu$ H	21-9808
<b>HV Power Supply Board, Drawing 464 x 243</b>	BOARD	Completely Assembled HV Power Supply Board	5464-243
CAPACITORS	C1-C2	0.01 $\mu$ F, 3KV, 2%	04-5762
	C3-C22	0.01 $\mu$ F, 500V	04-5696
	C23	0.1 $\mu$ F, 50V	04-5663
	C24	68 $\mu$ F, 10V	04-5654
	C25	NOT USED	*
INTEGRATED CIRCUITS	U1	LMC7111BIM5X	06-6410
	U2	LT1304CS8	06-6394
DIODES	CR1-CR10	CMPD2005S	07-6468
	CR11	CMSH1-40M	07-6411
RESISTORS	R2-R3	750K, 1/4W, 1%	12-7882
	R4-R5	500M, 3KV, 2%	12-7031
	R6	1M, 1/4W, 1%	12-7844
	R7	10K, 1/4W, 1%	12-7839
	R8	1M, 1/4W, 1%	12-7844
	R9	953K, 1/8W, 1%	12-7950
	R10	10 Ohm, 1W, 1%	12-7952
	R11-R12	150K, 1/4W, 1%	12-7833
	R13	100K, 1/4W, 1%	12-7834
CONNECTOR	P1	640456-4 MTA100x4	13-8088
	P2	CON 1	18-9238
TRANSFORMER	T1	31032R, Midcom	21-9925

	<u>Reference</u>	<u>Description</u>	<u>Part Number</u>	
<b>Wiring Diagram, Drawing 464 x 309</b> CONNECTORS	J1	MTA100×5, MAIN BOARD 5464-275	13-8140	
	J2	MTA100×6, OPTIONAL 5464-275	13-8095	
	J3	MTA 100×2, MAIN BOARD 5464-275	13-8073	
	J4	MTA100×4, MAIN BOARD 5464-275	13-8088	
	J5	MAIN BOARD 5464-275	**	
	J6	MAIN BOARD 5464-275	**	
	*	DETECTOR CONNECTOR, (RECPT-"C" SOLDERLESS)	4478-049	
	AUDIO	DS1	UNIMORPH, TEC-3526-PU	21-9251
	BATTERIES	B1-B2	"D" CELL BATTERY	21-9313
	METER	M1	PORT BEZEL W/ MVMNT ASSY	4363-188
MISCELLANEOUS	*	RANGE KNOB	08-6613	
	*	PORTABLE BATTERY NEGATIVE CONTACT ASSEMBLY	2001-065	
	*	PORTABLE BATTERY POSITIVE CONTACT ASSEMBLY	2001-066	
	*	CAN GASKET	22-9773	
	*	M12-4 DET. MNT. BLOCK.	7363-245	
	*	CBL "C" 39-inch	40-1004	
	<b>Model 42-31H Neutron Detector</b>	UNIT	Completely Assembled Model 42-31H Neutron Detector	47-3583
*	M 42-31 SPHERE ASSY.	47-1345		
*	Model 42-31H Probe Assembly	4005-140		

**Section**  
**11**

## **Drawings**

---

MAIN CIRCUIT BOARD, Drawing 464 × 275 (3 sheets)

MAIN CIRCUIT BOARD LAYOUT, Drawing 464 × 276 (2 sheets)

HV POWER SUPPLY BOARD, Drawing 464 × 243

HV POWER SUPPLY BOARD LAYOUT, Drawing 464 × 244

WIRING DIAGRAM, Drawing 464 × 309

1

2

3

4

5

A

A

B

B

C

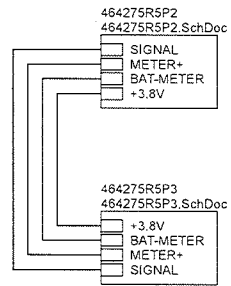
C

D

D

E

E



		PO Box 810 501 Oak Street Sweetwater, Texas 79556 U.S.A. 1-800-622-0828	
		Drawn: MC Design: DL	11/21/2007 11/21/2007
Approve: <i>DL</i>	11/21/07	Sheet: 1 of 3	Series: 464 Sheet: 275
Print Date: 7/17/2017 4:57:41 PM		Rev: 5	WIPProject\U\MMW 12545-275 Rev9\464275RSP1.SchDoc

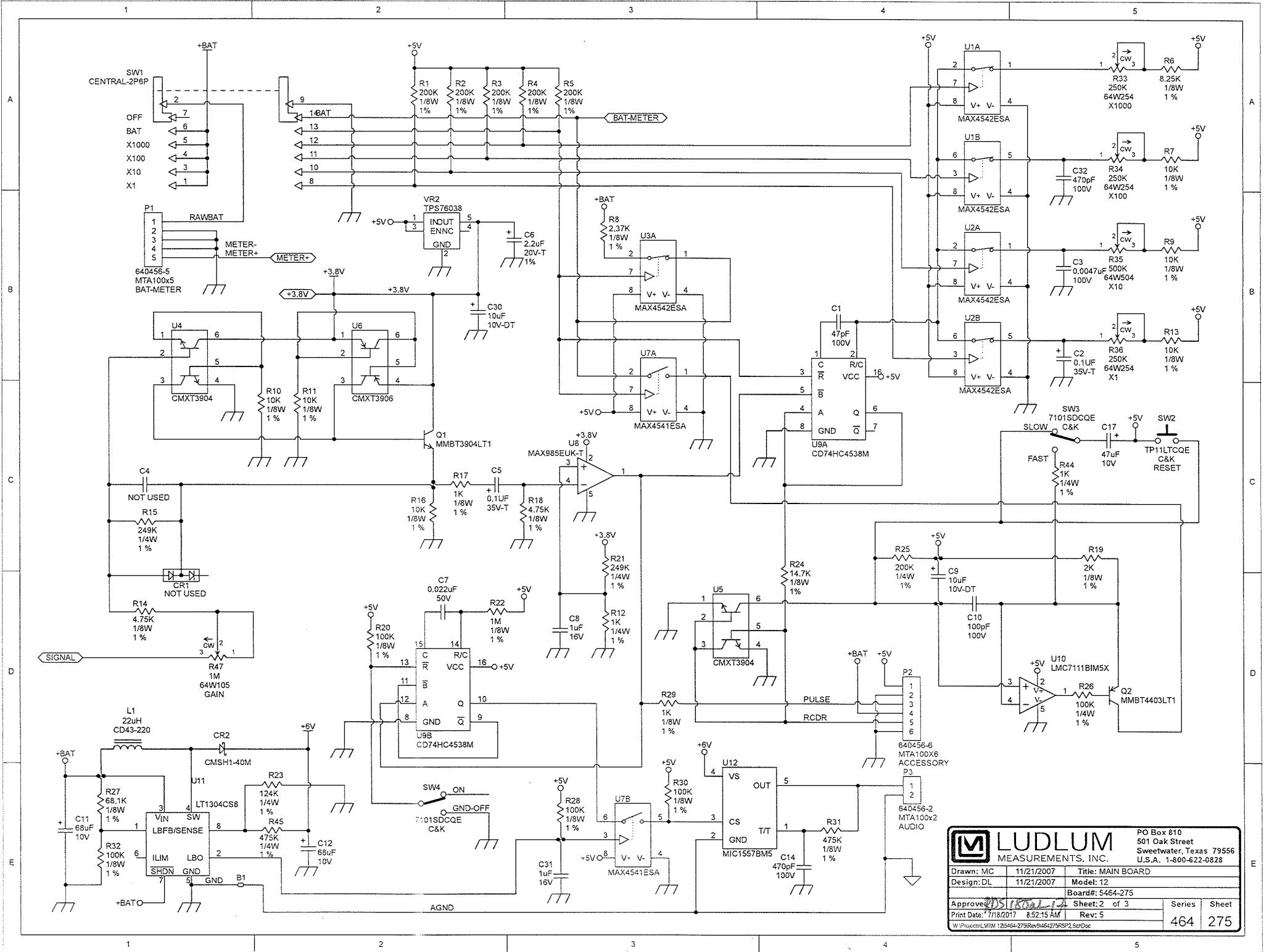
1

2

3

4

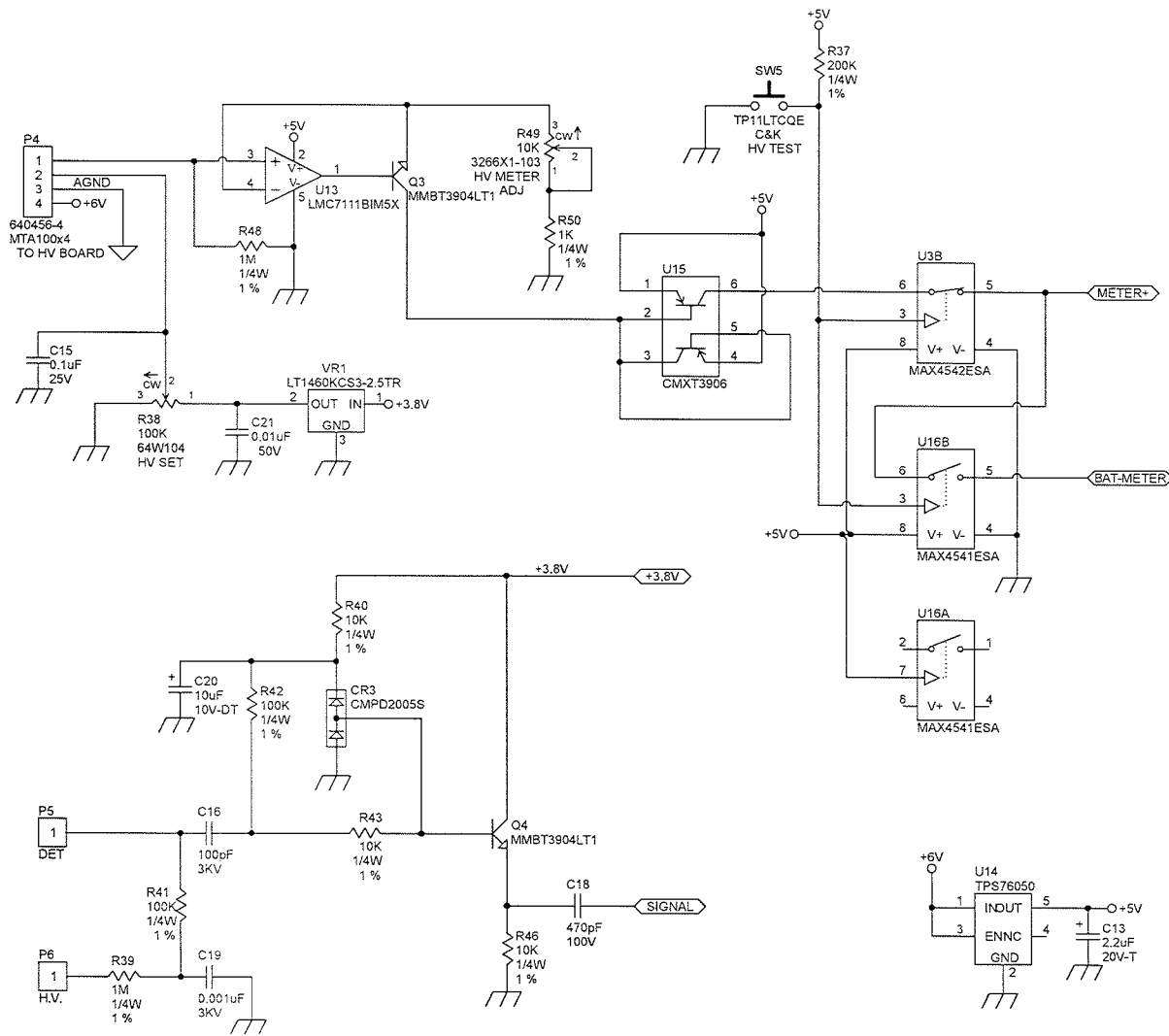
5



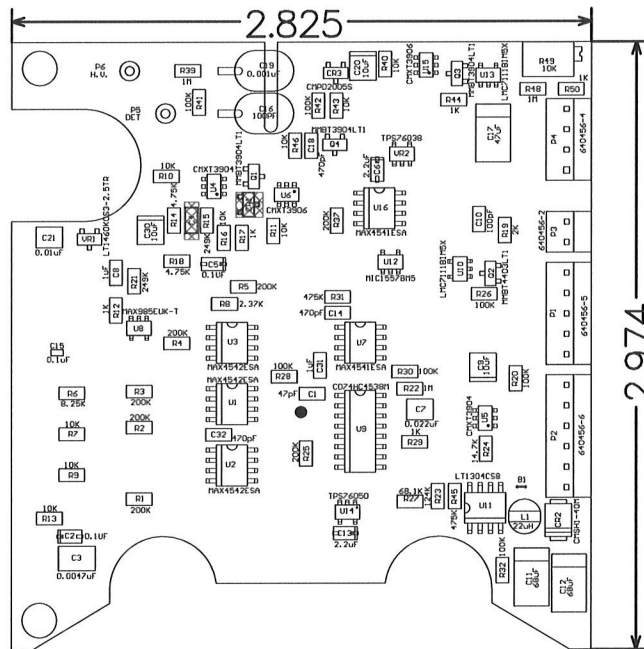
**LUDLUM**  
MEASUREMENTS, INC.


PO Box 810  
501 Oak Street  
Sweetwater, Texas 79556  
U.S.A. 1-800-622-0828

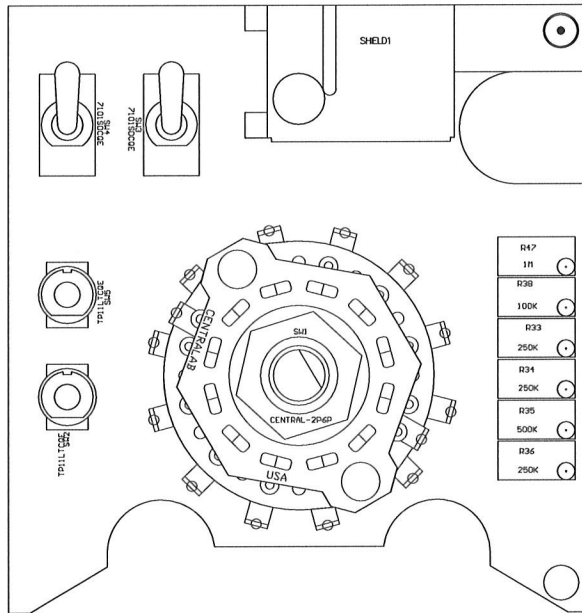
Drawn: MC	11/21/2007	Title: MAIN BOARD
Design: DL	11/21/2007	Model: 12
Approved: [Signature]	11/21/2007	Sheet: 2 of 3
Print Date: 7/18/2017 8:52:15 AM	Rev: 5	Series
W:\Projects\1215484-279\Rev04542\75RSP2_SchDoc		464 275




		PO Box 810 501 Oak Street Sweetwater, Texas 79556 U.S.A. 1-800-622-0828	
		Drawn: MC Design: DL Approved: <i>[Signature]</i> Print Date: 7/17/2017 4:57:42 PM W:\Projects\11M\125464-275\Rev9\4542\6RSP3.SchDoc	Title: MAIN BOARD Model: 12 Board#: 5464-275 Sheet: 3 of 3 Rev: 5

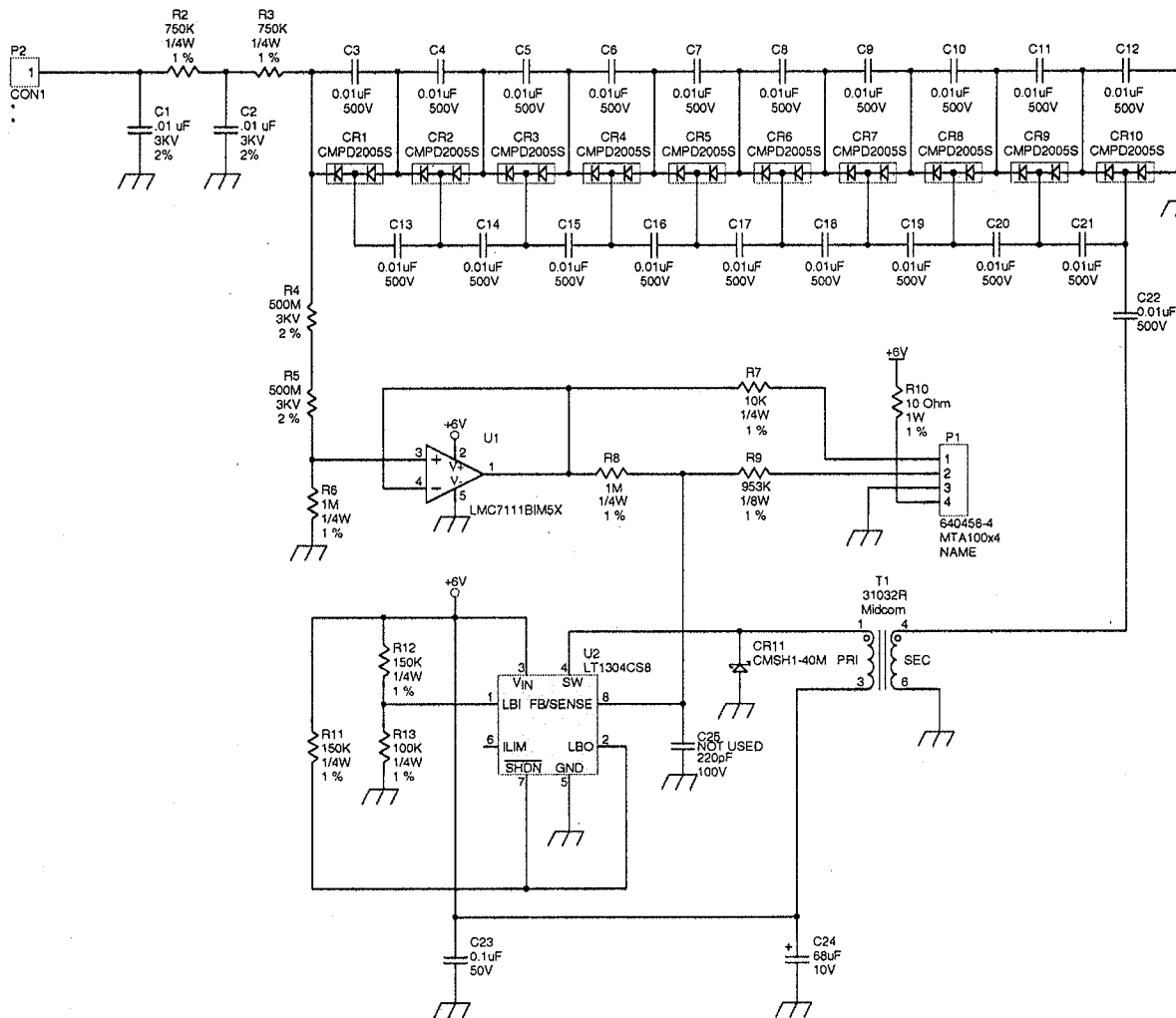


		PO Box 810 501 Oak Street Sweetwater, TX 79556 U.S.A. 1-800-622-0828	
<b>Title:</b> MAIN BOARD			
<b>Drawn:</b> MC	11/21/2007	<b>Model:</b> 12	
<b>Design:</b> DL	11/21/2007	<b>Board#:</b> 5464-275	
<b>Approve:</b> <i>RSS</i>	<i>11/21/2007</i>	<b>Rev:</b> 5	
<b>Print Date:</b>		<b>SCALE:</b> 1.00	<b>Series</b>
12/11/2012 5:27:42 PM		Top Overlay	464
			<b>Sheet</b>
			276
W:\Projects\LMM 12\5464-275\Rev5\464275R5_Manual.PcbDoc			

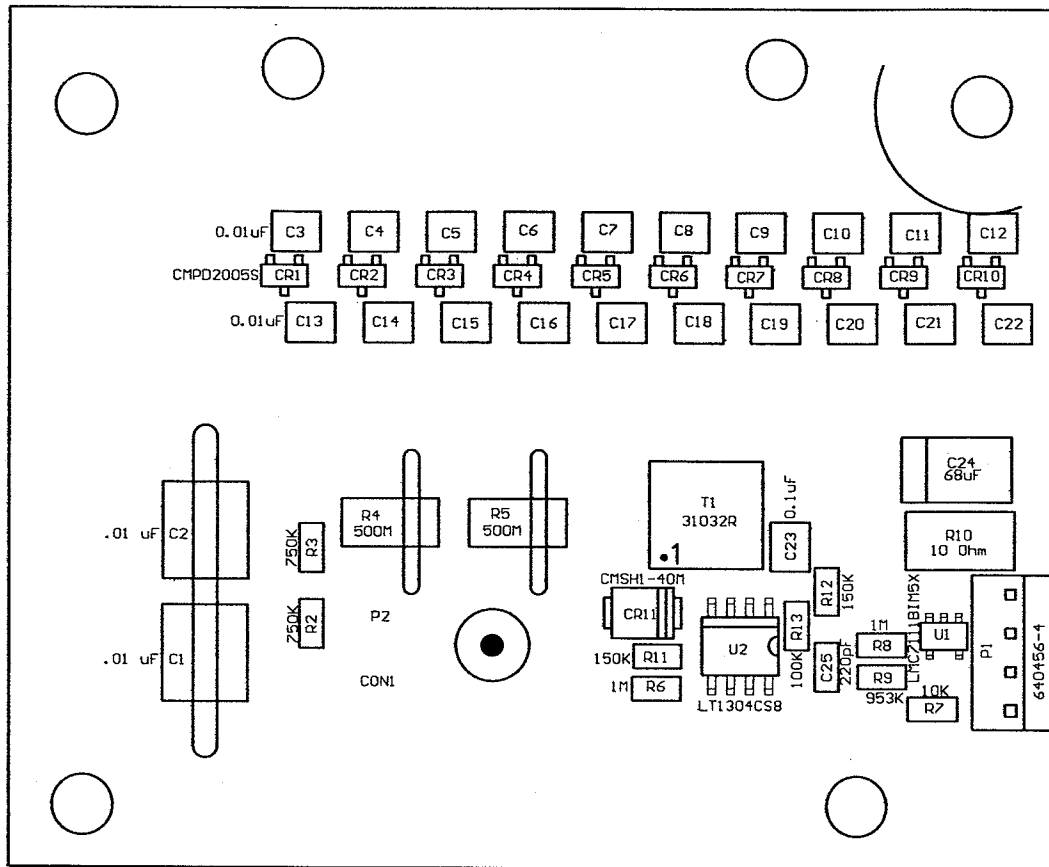


 <b>LUDLUM MEASUREMENTS, INC.</b>		PO Box 810 501 Oak Street Sweetwater, TX 79556 U.S.A. 1-800-622-0828	
		<b>Title: MAIN BOARD</b>	
<b>Drawn:</b> MC	11/21/2007	<b>Model:</b> 12	
<b>Design:</b> DL	11/21/2007	<b>Board#:</b> 5464-275	
<b>Approve:</b> <i>RSS</i>	<i>12/11/2012</i>	<b>Rev:</b> 5	
<b>Print Date:</b>		<b>SCALE:</b> 1.00	<b>Series</b>
12/11/2012 5:27:44 PM		Bottom Overlay	<b>Sheet</b>
464		276	
W:\Projects\LM\12\5464-275\Rev5\464275R5 Manual.PcbDoc			

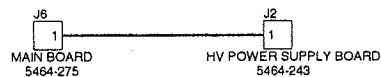
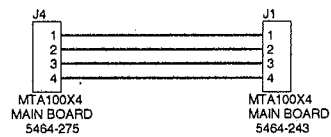
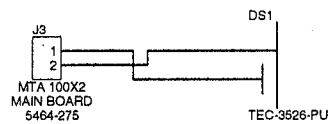
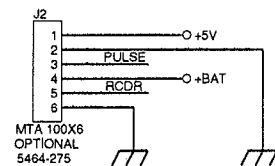
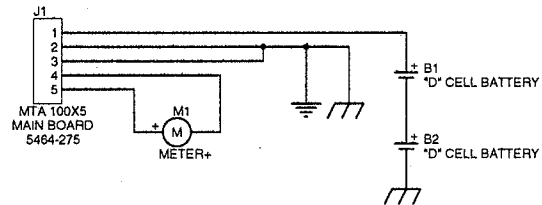




		PO Box 810 501 Oak Street Sweetwater, Texas 79556 U.S.A. 1-800-622-0828	
Drawn: JK	08-DEC-04	Title: HV POWER SUPPLY BOARD	
Design: DL	06-DEC-04	Model: M12/M12-4	
Check:		Board#: 5464-243	
Approve: <i>R. B. [Signature]</i>	11-Aug-2005	Sheet: 1 of 1	Series: 464
14:49:22	11-Aug-2005	Rev:	Sheet: 243
X:\Projects\LMF\Projects\M12.Dwg - Documents\5464-243\m2\27464-243.csh			



Drawn:	JK	06-DEC-04	Title: HV POWER SUPPLY BOARD		
Design:	DL	06-DEC-04			
Check:			Model: M12/M12-4		
Approve:	DL	8/12/05	Board#: 5464-243		
			Rev:	Series	Sheet
			SCALE: 2.02	464	244



			PO Box 810 501 Oak Street Sweetwater, Texas 79556 U.S.A. 1-800-622-0828		
Drawn:	JK	01-JUN-04	Title: WIRING DIAGRAM		
Design:	DL	01-JUN-04	Model: 12		
			Board#: 464-309		
Approve:			Sheet: 1 of 1	Series	Sheet
10:58:14		28-Dec-2005	Rev: 3.0	464	309
464X309.wd					