LUDLUM MODEL 2241-4
SURVEY METER WITH
NEUTRON DETECTOR

October 2022

Serial Number 170658 and Succeeding

Serial Numbers

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Model 2241-4 with
Model 42-31H Detector

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.

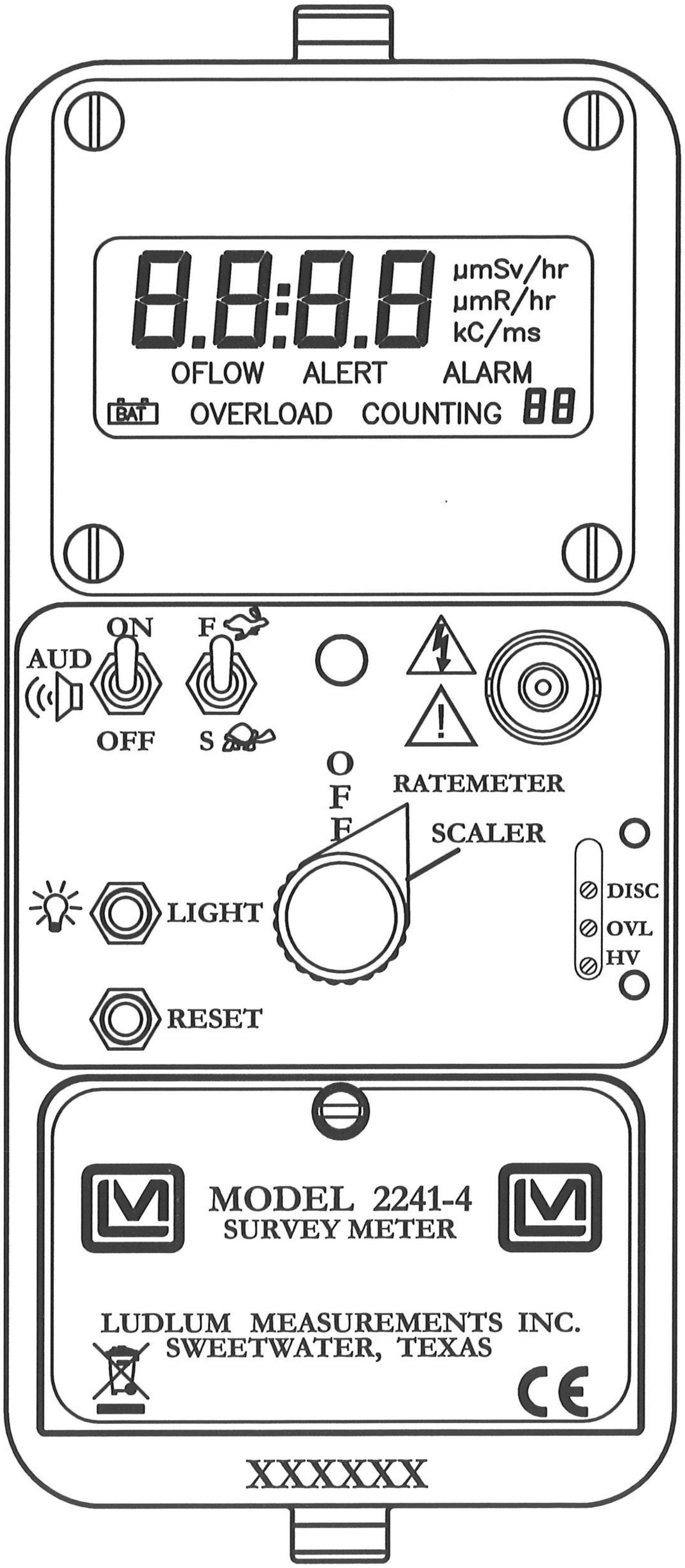
RETURN OF GOODS TO MANUFACTURER

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

REV #	ALTERATIONS	DATE	BY
1	VALID	2-28-06	CMC



DWN	DATE	CHK	DATE	APP	DATE
CMC	2-28-06			JWO	2-28-06

PART NUM: 4408-132 | SCALE: FULL ☒ OTHER

TITLE M 2241-4 SURVEY METER

LUDLUM MEASUREMENTS, INC. 501 OAK STREET SWEETWATER, TEXAS 79556 | SERIES 408 | SHEET 117

Table of Contents

Section

1

Introduction

The Model 2241-4 is a portable microprocessor-based digital Scaler/ Ratemeter coupled to a Model 42-31H Neutron Detector for use in measuring and monitoring neutron radiation. Data is presented on a four-digit (six digits in the scaler mode) Liquid Crystal Display (LCD) with moving decimal point. A three-position switch labeled "OFF/RATEMETER/SCALER" selects the desired operating mode for the instrument.

Similar Instrument with Model 42-31H Detector

Programmable display units (RATEMETER mode only) are represented in R/hr (normally represents roentgens/hr, but in this application represents rem/hr), Sv/h, cpm, or cps with multipliers of micro (μ) or milli (m) for R/hr and Sv/h and kilo (k) for cpm or cps. The display units are auto-ranging, enabling the readout to display a broad range of radiation levels. The display also offers lower limit capability. For example, the display can be set to show only values that are greater than or equal to1 μR/hr.

This instrument incorporates independent adjustable alarms for RATEMETER and SCALER operating modes. The RATEMETER mode has two alarm indicators. The first-level alarm is indicated by display of the word "ALERT" on the LCD. The second-level alarm is indicated by display of the word "ALARM" and by the emitting of a continuous audible tone. The SCALER alarm condition will also display the word "ALARM" and produce the same audible tone. Both audible alarms may be silenced (acknowledged) by depressing the RESET switch. All alarms are concurrent.

Other features include Dead Time Correction (DTC) to compensate for detector dead time; audible click-per-event with programmable 1, 10, 100, and 1000 divide-by; LCD backlight with programmable ON time; programmable fixed or variable response time; and count overflow visual alarm, indicating that the counting circuitry is nearing the maximum counting capability.

All of the features described above may be programmed manually using the internal switch board or by computer through the RS-232 port. Two different detector operating parameters may be stored in non-volatile memory. The switch board can be removed after entering or changing parameters to prevent tampering with setup parameters.

A regulated high-voltage power supply and independent set-point control, adjustable from 400 to 2400 volts, with detector overload detection and adjustable discrimination levels add versatility to the instrument. All of the calibration controls are covered to prevent any inadvertent adjustments to the detector operating parameters.

The instrument is powered by two standard ˝D˝ cell batteries. The unit body is made of cast-and-drawn aluminum with beige powder coating, which aids in the decontamination of surfaces.

The attached Ludlum Model 42-31H Neutron Detector is designed for detection of thermal and fast neutrons (0.025 eV to approximately 12 MeV). The neutrons are detected, not directly, but through nuclear reactions, which result in energetically charged particles, such as alpha particles. In many instances intense fields of gamma rays are also found with neutrons. Therefore, it is important to choose a method of neutron detection with the ability to discriminate against these gamma rays in the detection process.

A common reaction for the conversion of slow neutrons into directly detectable particles is $n + {}^{3}He \rightarrow {}^{3}H + {}^{1}H + 0.764$ MeV.

The Ludlum Model 42-31H utilizes this reaction in the form of helium-3(${}^{3}He$), which fills the gas proportional tube of the detector

The Model 42-31H is designed to be used with portable counting instruments and has a top bracket that allows for convenient mounting of a portable instrument. The Model 42-31H consists of a ${}^{3}He$ detector (1.6 cm diameter x 2.5 cm thick), surrounded by a cadmium-loaded polyethylene sphere, 22.9 cm (9 inches) in diameter. A study is available that shows that the 9-inch cadmium-loaded sphere has a response similar to that of a 10-inch diameter rem-responding sphere.

Section

2

Getting Started

Unpacking and Repacking

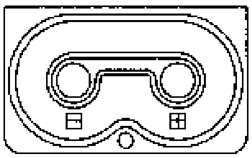
Remove the calibration certificates and place them in a secure location. Remove the instrument, detector, and accessories (batteries, cable, etc.), and ensure that all of the items listed on the packing list are in the carton. Check individual item serial numbers and ensure calibration certificates match. The Model 2241-4 serial number is located on the front panel below the battery compartment. To access the Model 42-31H detector identification, perform the following: (1) loosen the thumbscrews; (2) rotate counterclockwise and remove the polyurethane sleeve from the sphere; and (3) pull the detector from sleeve. The identification is located on the detector shaft. Reassemble in reverse order. Removal of the air-seal screw from the end of the polyurethane sleeve will facilitate reassembly. Replace the screw once the detector is completely reassembled.

Important!

If multiple shipments are received, ensure that the detectors and instruments are not interchanged. Each instrument is calibrated to a specific detector(s), and is 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. Include detector(s) and related cable(s) for calibration.

Every returned instrument must be accompanied by an **Instrument Return Form**, which can be downloaded from the Ludlum website at 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 OFF/SCALER/RATEMETER switch is in the OFF position. Open the battery lid by turning the quarter-turn thumb screw counterclockwise. 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.

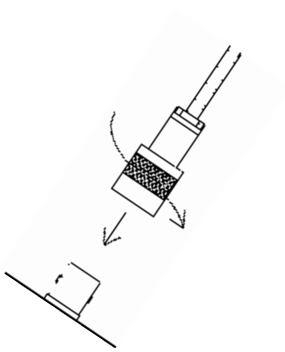
Note:

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

Detector Connection

Caution!

The detector operating voltage (HV) is supplied to the detector via the detector input connector. A mild electric shock may occur if bodily contact is made with the center pin of the input connector. Switch the instrument OFF before connecting or disconnecting the cable or detector.



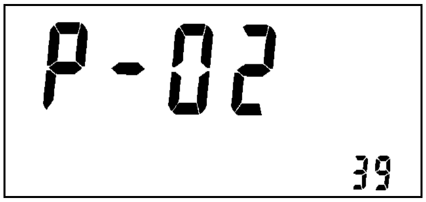
Using the cable provided, connect the Model 42-31H detector to the Model 2241-4; firmly pushing the connectors together while twisting clockwise until the connector latches (a quarter turn) as illustrated in the diagram to the left.

Operational Check

Note:

Performance of an operational check is an assurance of proper instrument and detector function. The check should be performed after instrument calibration or maintenance, as well as prior to each use.

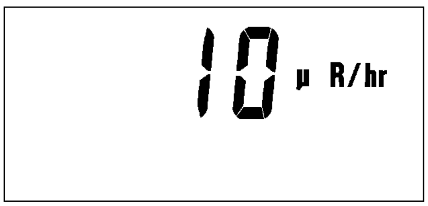
Turn the OFF/SCALER/RATEMETER switch to the RATEMETER position. Notice that the display goes through an initialization sequence. The display



will show all "8"s with decimal points. Ensure all segments display as illustrated in the diagram to the left.

The LCD then displays the firmware number in the format "P-XX YY." The "XX" is the firmware number, and the "YY" is the firmware version. (The figure to the left is for example only; to illustrate location of display.)

The minimum displayable value (for example, 00.0 μR/hr) should be shown. When switched to the SCALER position, a single "0" will be displayed.



The display will auto-range to the current level (see figure at left). When auto-ranging down, the Model 2241-4 uses multiples of 5. This technique keeps the decimal point from jumping between numbers when viewing values around multiples of 10.

If a neutron source is available, expose the detector to the source (at a repeatable distance) and record the reading. Daily source checks may then be performed by orienting the detector and source in identical fashion, ensuring an instrument reading of ±20% of the initial reading. Failure to meet the ±20% criteria may indicate a detector malfunction.

Switch the AUD ON/OFF switch to the ON position and confirm that the external unimorph speaker produces an audible click for each event detected (audio divide-by 1 parameter). The AUD ON/OFF switch will silence the clicks if in the OFF position; however, an audible alarm condition will still be heard.

Move the OFF/SCALER/RATEMETER switch to the SCALER position. Depress the COUNT switch located in the end of the carrying handle in order to initiate a count cycle. The word "COUNTING" should be flashing on the LCD during the count cycle and should disappear at the end of the predetermined count time. If a scaler ALARM condition occurs, the RESET switch can be depressed to acknowledge the alarm; however, the COUNT switch must be depressed to clear the visual ALARM and to restart the count cycle.

Depress and release the LIGHT switch. The backlight located behind the LCD should illuminate (for pre-programmed ON time). Select the desired F/S, AUD ON/OFF, and RATEMETER or SCALER parameters and proceed to use the instrument.

Section 3

Specifications

Instrument:

Warm-up Time: Unit may be used immediately after the LCD initialization sequence is completed (approximately five seconds after power-up).

Linearity: Readings are within 10% of true value with a detector connected.

Display: a four-digit Liquid Crystal Display (LCD) with digits 1.3 cm (0.5 in.) in height. Two additional 0.5 cm (0.2 in.) digits are used for the overflow counter (SCALER mode) and exponential powers (parameter setup). Enunciators are provided for display units, ALERT, ALARM, low battery, detector OVERLOAD, counting OVERFLOW, and scaler COUNTING.

RATEMETER: Depending upon how the instrument was calibrated, the RATEMETER can display in either R/hr, Sv/h, cpm, or cps when the control switch is in the RATEMETER position.

SCALER: activated by pushbutton in handle when the three-position switch is in the SCALER position. Count time is adjustable.

Calibration Controls: accessible from the front of the instrument (protective cover provided). These controls are preset at the factory or calibration lab and should not be adjusted by field personnel.

> **Discriminator / Input Sensitivity**: adjustable from 2 to 100 mV; negative pulse response
>
> **Overload**: indicated by OVERLOAD on the display; adjustable
>
> **High Voltage**: adjustable from 400-2500 Vdc; regulated within 0.2% at 1000 Vdc; maximum load of 50 µA

RESET: a pushbutton for zeroing the display, acknowledging and/or resetting the alarm

LIGHT: display backlight activated by pushbutton

Audio: built-in audio speaker (unimorph) with AUD ON/OFF switch; greater than 60 dB at 0.6 m (2 ft)

Alert/Alarm: indicated by either an ALERT or ALARM enunciator on the display (RATEMETER mode only) and by an audible tone

Power: two "D" cell batteries housed in an externally accessible sealed compartment. Current draw is approximately 35 mA with the backlight OFF. Minimum battery voltage is 2.2 ±0.1 Vdc.

Battery Dependence: Meter readings vary by less than 3% from fully charged batteries until the battery symbol appears, indicating the need for recharge or replacement.
Battery Life: typically 200 hours with alkaline batteries (display indicates low battery condition). Instrument will operate for approximately 24 hours after the battery symbol first appears.
Size: 16.6 x 8.9 x 21.6 cm (6. 5 x 3.5 x 8.5 in.) (H x W x D)
Weight: 1.6 kg (3.5 lb), including batteries

Removable Switchboard Adjustable Parameters:

Backlight ON Time: 5, 15, 30, 60, 90, 120, 180, or 240 seconds for the backlight to stay on when activated by the pushbutton; factory set at 5
Set Minimum Display: allows lower limit of the auto-ranging display to be fixed. For example, the display can be set to only show values above or equal to 1 µR/hr.
RS-232 Data Dump Mode: enables or disables dump mode to the RS-232 port (˝D˝ type connector). When enabled, the data will be dumped every two seconds.
RS-232 Detector Setup Mode: allows for input of detector parameters via the RS-232 port
Baud Rate: selects either 150, 300, 600, 1200, 2400, 4800, 9600, or 19200 bps
Detector Dead Time Compensation (DTC): adjustable from 0 to 9999 microseconds
Calibration Constant: adjustable from 0.001 to 280×10^9 counts/display unit
Display Units: can display in R/hr (representing rem/hr in this application), Sv/h, cpm, or cps
Time Base: can display in seconds or minutes
Audio Divide: 1, 10, 100, or 1000 events per click
Response Time: variable or fixed ratemeter response (All stated times correspond to a range of 10% to 90% of the final reading). The factory default is ˝variable˝ so that the instrument will automatically adjust the response time to the best setting for the current count rate.

> **Variable Response**: dependant on the number of counts present, typically 4 to 25 seconds for FAST and 4 to 60 seconds for SLOW.
> **Fixed Response**: The FAST response position is adjustable from approximately 2 to 50 seconds. The SLOW response position is approximately five times slower than the FAST. For MDA-type measurements, the fixed response mode is recommended.

Ratemeter Alert/Alarm: set at any point corresponding to the pre-selected ratemeter range
Scaler Alarm: adjustable from 1 to 999999 counts
Scaler Count Time: adjustable from 1 to 9999 seconds

Model 42-31H Neutron Detector:

Detector: ^{3}He proportional tube
Energy Range: thermal to approximately 12 MeV
Moderator: 22.9 cm (9 in.) diameter cadmium-loaded polyethylene sphere
Sensitivity: typically 10 cpm per μSv/h (100 cpm per mrem/hr) (bare AmBe neutrons)
Gamma Rejection: typically 10 cpm or less through 10 R/hr (100mSv/h) (^{137}Cs).
Energy Response: provides appropriate inverse RPG curve for neutrons through 7 MeV, provides response up to 12 MeV
Input Sensitivity: -2 mV
Operating Voltage: approximately 1200 Vdc
Connector: series ˝C˝ (others available)
Size: 26.2 x 22.9 x 22.9 cm (10.3 x 9 x 9 in.) (H x W x D), including brackets
Weight: 6.56 kg (14.5 lb)

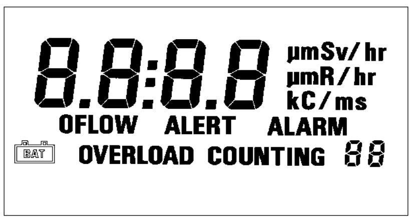
Section

4

Identification of Controls and Functions

Display

The Model 2241-4 utilizes a four-digit liquid crystal display (LCD) with two-digit overflow (SCALER mode) and moving decimal point. The two smaller digits located in the lower right corner of the display indicate counter OVERFLOW when in the scaler counting mode (equivalent to a six-digit scaler) or exponential power when in the parameter setup mode. The upper right corner of the LCD displays the following units and multiplier(s): R/hr, mR/hr, or µR/hr; Sv/h, mSv/h, or µSv/h; C/m, kC/m, C/s, or kC/s. The bottom part of the readout displays the ALARM, ALERT, OFLOW, OVERLOAD annunciators and the low-battery icon. COUNTING indicates that the scaler mode has been initiated and is in the counting process.



Display Status Definitions

ALARM: Ratemeter or scaler count has increased above the preset alarm threshold. An audible continuous tone will accompany the latching ALARM condition. Depressing RESET will acknowledge the audible ratemeter and/or scaler alarm. Depressing RESET a second time will reset the ratemeter reading and ratemeter alarm. To reset the scaler ALARM, depress the COUNT switch located in the carrying handle to re-initiate the scaler count cycle.

ALERT: Ratemeter count has increased above the preset alert threshold. To reset an ALERT condition, press RESET once if in the non-alarm condition, and twice if in an alarm condition. (The first depression in the alarm condition acknowledges the audible alarm.) The ratemeter will reset to the minimum displayable reading each time the alert is reset.

OFLOW (Overflow) [RATEMETER mode]: indicates that the incoming count exceeds the capability to display stable or reliable readings corresponding to the radiation level being measured. The overflow symbol will appear when the ratemeter exceeds 100 kcps or if the dead time correction is greater than 75%. OFLOW will appear in the SCALER mode when the six-digit display (four digits display and two overflow digits in the right corner) reaches 999999 and starts to roll over again.

OVERLOAD: indicates that the detector is being exposed to radiation intensities greater than the detector maximum operating limit. For alpha and/or beta-type scintillation detectors, an OVERLOAD may indicate that the detector face has been punctured allowing external light to saturate the photomultiplier tube inside the detector. The overload alarm point is set by adjusting the OVL control located underneath the calibration cover.

Low battery icon: indicates that the batteries have decreased to the minimum operating voltage of 2.2 ±0.1 Vdc. Instrument will continue to operate for approximately 24 hours thereafter

COUNTING: indicates that the scaler count switch has been depressed and that the scaler is accumulating counts for the pre-determined count time

Front Panel Controls

OFF/RATEMETER/SCALER Switch: a three-position rotary switch that applies power to the instrument and selects RATEMETER or SCALER counting mode

AUD ON/OFF Switch: The clicks-per-event audio may be silenced or enabled via this front-panel toggle switch. The audible alarm is independent of the AUD ON/OFF switch and will override the audible clicks-per-event. An audible alarm can only be silenced by depressing the RESET button.

F/S (Fast/Slow) Response Switch: a two-position toggle switch that selects fast or slow counting response time

Variable Response: The F position allows the time constant (TC) to vary from 1 to 10 seconds, while the S position varies from 1 to 30 seconds. The response time is automatically adjusted in proportion to the incoming count rate between the F/S TC variables.

Fixed Response: The F position corresponds to the selected fixed response time - TC. The S position is five times slower than the selected fast TC.

LIGHT (LCD Backlight): A pushbutton switch, when depressed, illuminates the LCD for a pre-programmed time. The backlight ON time can be selected between 5 and 240 seconds during the parameter setup.

RESET Pushbutton Switch: In the non-alarm condition, depressing the RESET switch resets the ratemeter display to the minimum display readout. In an alarm condition (ratemeter or scaler), depressing RESET will silence the audible alarm. Depressing RESET a second time will reset the ratemeter alarm and/or alert condition. The scaler alarm can only be reset by depressing the scaler COUNT switch located in the end of the Model 2241-4 handle.

Scaler COUNT Switch: pushbutton switch located in the end of the Model 2241-4 carrying handle, which when depressed, initializes the start of the scaler count accumulation for the preset scaling time. The SCALER/RATEMETER switch must be in the SCALER position to initiate the counting cycle. The scaler display uses the two digits in the lower right-hand corner for the two most significant digits of the six-digit readout. Scaling time can be set from 1 to 9999 seconds in the parameter setup by way of the switch board. Depressing the COUNT switch after a scaler ALARM will reset the scaler display to 0, resetting the alarm condition.

Front Panel Calibration Controls

Note:

Remove the front-panel calibration cover to expose the following calibration controls:

DISC (Discriminator): a multi-turn potentiometer (approximately 20 revolutions) used to vary the detector pulse-counting threshold from 2 to 100 millivolts. A Ludlum Model 500 Pulser or equivalent should be used in checking or adjusting the pulse discrimination parameter.

Note:

When making adjustments to the HV potentiometer, use a Ludlum Model 500 Pulser or high-impedance voltmeter with a high-voltage probe to measure the high voltage at the detector connector. If a Ludlum Model 500 Pulser is not available, ensure that the impedance of voltmeter used is 1000 megohms or greater.

HV: a multi-turn potentiometer (approximately 20 revolutions) that varies the detector voltage from 200 to 2500 volts. The maximum high-voltage output is adjusted by the HV LIMIT potentiometer located on the internal main board.

OVL (Detector Overload): a multi-turn potentiometer (approximately 20 revolutions), which adjusts the detector current level that must be exceeded to initiate an OVERLOAD alarm. This control adjusts the current level discrimination point from 0.5 and 40 microamperes, corresponding to the specific detector saturation point.

Main Board Controls

Note:

To access the internal circuit boards, unlatch the latches at each end of the Model 2241-4. Carefully separate the top chassis from the bottom cover (referred to as a can). The can has the audio speaker (unimorph) with a two-conductor cable attached to the main board. The audio plug may be disconnected during the internal control adjustments.

HV LIMIT (R027): A multi-turn potentiometer (approximately 20 revolutions) sets the maximum HV limit with the front-panel HV control adjusted to the maximum clockwise position. It is adjustable from 1250 to 2400 Vdc.

VOLUME (R002): A multi-turn potentiometer (approximately 20 revolutions) varies the audible click-per-event and alarm audio. Adjust the control to the maximum clockwise position for maximum volume. If the VOLUME control is adjusted to the maximum counterclockwise position, the clicks-per-event or the audible alarm(s) will not be audible when active.

Switch Board Controls

The switch board utilizes a 16-position rotary switch (FUNCTION) to select the 16 setup parameters. (Refer to schematics and component layout drawing near the end of the manual.) All of the setup parameters are stored in the non-volatile EEPROM, which will retain data even after the Model 2241-4 batteries are removed. After the parameters are entered, the switch board can be removed and the Model 2241-4 will continue to operate from the previously programmed information. Changing parameters and information on switchboard controls are covered in detail in Section 8 of this manual.

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)
Maximum relative humidity of less then 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.)

Detector Connector

Caution:

The detector operating voltage (HV) is supplied to the detector by way of the input connector. A mild electric shock may occur if contact is made with the center pin of the input connector. Switch the Model 2241-4 to the OFF position before connecting or disconnecting the cable or detector.

Warning Markings and Symbols

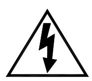
Caution!

The operator or responsible body 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.

Caution!

Verify instrument voltage input rating before connecting to a power converter. If the wrong power converter is used, the instrument and/or power converter could be damaged.

The Model 2241-4 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.

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 any internal components.

The "**crossed-out wheelie 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. See Section 9, "Recycling," for further information.

Section
6

Maintenance

Instrument maintenance consists of keeping the instrument clean and periodically checking the batteries and the calibration. The Model 2241-4 instrument may be externally cleaned 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:

1. Turn the instrument OFF and remove the batteries.

2. Allow the instrument to sit for one minute before performing any external cleaning or accessing internal components for maintenance.

Recalibration

Recalibration should be accomplished after any maintenance or adjustment of any kind has been performed on the instrument. Battery replacements are not considered to be maintenance and do not normally require the instrument to be recalibrated.

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 as well. Calibration procedures are available upon request.

Batteries

The batteries should be removed and the battery contacts cleaned of any corrosion at least every three months. If the instrument has been exposed to a very dusty or corrosive atmosphere, service the batteries more frequently. Use a spanner wrench to unscrew the battery contact insulators, exposing the internal contacts and battery springs. Removing 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 can occur at temperatures as low as 38 °C (100 °F).

Section

7

Technical Theory of Operation

Refer to the Main Board schematic for the following:

Detector Input/Amplifier

Negative-going detector pulses are coupled from the detector through C021 to amplifier U021. R024 and CR021 protect the input of U021 from inadvertent shorts. Self-biased amplifier U021 provides gain in proportion to R022, divided by R025. Transistor pins 4, 5, and 6 of U021 provide amplification. Pins 10-15 of U021 are coupled as a constant current source to pin 6 of U021. The output is self-biased to 2 Vbe (approximately 1.4 volts) at pin 7 of U021. This provides just enough bias current through pin 6 of U021 to conduct all of the current from the constant current source. Positive pulses from pin 7 of U021 are coupled to the discriminator (U011) through R031 and C012.

Discriminator

Positive pulses from amplifier U021 are coupled to pin 2 of U011 comparator. The discrimination level is set by the DISC control connected to pin 3 of U011. As the positive pulses at pin 2 of U011 increase above DISC reference at pin 3, pin 1 goes low, producing a low pulse. Pin 1 of U011 is normally held high (+5 volts) by R014.

The low pulse from pin 1 of U021 is coupled to univibrator U001. U001 shapes and fixes the pulse width to approximately 10 µs. The univibrator is configured in the non-retriggerable mode. Negative pulses from pin 9 of U001 are coupled to the µP for counting.

Low Voltage Supply

Battery voltage is coupled to DC-DC converter U231. U231 and related components provide +5 V to power the µP, op-amps, and logic circuitry. R135 and R136 provide voltage division for low-battery detection. Pin 6 of U231 provides a low signal when the battery voltage decreases to +2.2 ±0.1 Vdc. U121 provides the +2.5 Vdc reference for the HV and DISC control references.

High Voltage Supply

High voltage is developed by blocking oscillator Q241, T141, and C244 and rectified by voltage multiplier CR041-CR043, C041-C043, and C141. High voltage increases as current through R241 increases, with maximum output voltage and Q241 saturated. High voltage is coupled back through R034 to op-amp pin 2 of U131. Resistor network R027, R132 completes the HV division circuit to ground. R027 provides HV limit from 1250-2400 when the HV control on the calibration board is at maximum. The regulated HV output is controlled by the HV1 and HV2 potentiometers located under the CAL cover on the front panel. This control provides the reference for comparator pin 3, U131. During stable operation, the voltage at pin 2 of U131 will equal the voltage at pin 3 of U131. Pin 1 of U131 will cause conduction of Q141 to increase or decrease until the HV finds a level of stability.

Detector Overload

A voltage drop is developed across R031 and sensed by comparator pins 5, 6 and 7 of U131 as detector current increases. When the voltage at pin 5 of U012 goes below pin 6, pin 7 goes low, signaling U111 (µP) to send the OVERLOAD alarm to the LCD. OVL (underneath CAL cover) control provides adjustment for the overload set point.

Microprocessor (µP)

U111 controls all of the data, control inputs, and display information. The clock frequency is crystal-controlled by Y221 and related components at 6.144 MHz. The µP incorporates internal memory (ROM), storing the program information. U1 resets the µP at power-up to initiate the start of the program routine. During the program loop, the µP looks at all the input switches for initiation or status changes and responds accordingly. U122 is a 256 x 8 bit EEPROM used to store the setup parameters. The information is transferred serially from the µP. The EEPROM is non-volatile, meanting it retains memory even after power is removed.

Audio

Click-per-event, divide-by, and alarm audio pulse frequency is generated by the µP and coupled to Q101. Q101 then inverts the pulses and drives the bottom of T101. Bias voltage is provided by the volume control (R002) to the top of T101.

Refer to the Switch Board schematic for the following:

S1 (FUNCTION)

S1 is a 16-position binary rotary switch, which selects the programmable parameters for the Model 2241-4. The switch selects the parameters using the hexadecimal numbering system via buss lines SW1-SW4.

S2-S4

S2-S4 are pushbutton switches that enter/change the variables for each of the 16 parameters.

U1

U1 is a +5 V powered RS-232 driver/receiver used to interface the Model 2241-4 to a computer.

Refer to Display Board schematic for the following:

LCD Drive

U1 and U2 are serial input 32-bit LCD drivers. The data is loaded serially into the 32-bit shift registers (internal) via the "D" IN input. The LOAD input instructs the shift register to receive data while the CLOCK input shifts the data through the 32-bit registers. After all the data is loaded, the LOAD line is pulsed by the µP, instructing the registers to transfer the data to the LCD drivers. The backplane (BP) signal from U2 provides the reference signal (approximately 125 Hz at 5 Vdc) to the LCD (DSP1) BP connection. When a segment is illuminated, the signal to that segment will be out-of-phase with the BP signal. If the segment is OFF, the signal will be in-phase with the BP signal.

Backlight Drive

Depressing the LIGHT button instructs the µP to set the BACKLIGHT line, pin 31 on µP, "low" for the predetermined backlight ON time. (Refer to main board schematic for details.) A "low" condition on pin 31 causes Q212 to conduct sending +3 V to P8-3 on the display board with +3 V at P8-3 (refer to display board schematic). Backlight oscillator Q011, T011, and related components starts to oscillate, producing a 2.5 kHz, sine wave signal. The signal is amplified by T011 to 150 volts peak-to-peak to drive the LCD backlight.

Section 8

Instrument Setup & Calibration

Entering or Changing Switch Board Parameters

On the switch board, select the desired parameter to enter or change by using the corresponding FUNCTION switch position. Depress the ENTER button and a character on the LCD will start to flash. The flashing character indicates that the program is in the parameter change mode.

To change the character, press the UP button until the desired variable is reached. To shift to another character, increment the LEFT pushbutton until the desired character is reached. The LEFT pushbutton switch enables the operator to sequence through all the characters on the LCD associated with a particular parameter.

Once the desired data is entered, depress the ENTER button. The LCD characters should stop flashing and the new parameter data should display.

To read pre-programmed setup parameters, switch the FUNCTION switch to position A and select the pre-programmed detector setup number, using the parameters change procedure above. Once the detector setup number is entered, sequence through the parameters by varying the function switch to read variables for that specific detector number.

Note:
Once the detector setup number has been entered, the function switch can be rotated either direction to view the parameter variables.

Loading Default Parameters

To load the default parameters for all detector setups, hold down the UP pushbutton on the switch board while turning the instrument on until DEF is displayed on the LCD. The table on the following page shows the default values.

Model 2241	**cpm**	**cpm**	**cpm**	**cpm**	**cpm**	**cpm**
	Setup 01	**Setup 02**	**Setup 03**	**Setup 04**	**Setup 05**	**Setup 06**
Dead Time	0 s	0 µs	0 µs	0 µs	0 µs	0 µs
Cal Const	100e-2	100e-2	100e-2	100e-2	100e-2	100e-2
Rate Alarm	50.0 kcpm	50.0 kcpm	50.0 kcpm	50.0 kcpm	50.0 kcpm	50.0 kcpm
Scaler Alarm	85000	85000	85000	85000	85000	85000
Count Time	12 Secs	12 Secs	12 Secs	12 Secs	12 Secs	12 Secs
Time Base	Mins	Mins	Mins	Mins	Mins	Mins
Units	cpm	cpm	cpm	cpm	cpm	cpm
Audio Divide-By	1	1	1	1	1	1
Response	0	0	0	0	0	0
Check Source	0	0	0	0	0	0
Percent CS	0	0	0	0	0	0
Rate Alert	20.0 kcpm	20.0 kcpm	20.0 kcpm	20.0 kcpm	20.0 kcpm	20.0 kcpm
Min Display	0.00 cpm	0.00 cpm	0.00 cpm	0.00 cpm	0.00 cpm	0.00 cpm
Baud Rate	9600					
LCD Time Off	5 seconds					
Detector	0					

The Function Switch

FUNCTION Switch: A 16-position rotary switch labeled "0-9" and "A-F." This switch selects a parameter setup mode for the Model 2241-4. If the board is not installed, the normal operation mode (counting mode) is selected. If the switch board is installed, the selector switch must be set to the 0 position for normal instrument operation.

The following may be changed using the switch board, and are discussed in detail in this section:

Detector Parameters
Current Detector Setup in Use
RS-232 Communication Baud Rate
RS-232 Detector Parameters Set/Read Mode

Function Switch Position Descriptions and Variables

POSITION 0: NORMAL OPERATION places the Model 2241-4 in the normal (counting) operating mode. Unplugging the switch board from the Model 2241-4 main board defaults to the normal operating mode.

POSITION 1: DEAD TIME (µs) allows changing the detector dead time correction for the current detector setup. Setting this parameter to 0 disables dead time correction. The dead time adjusts from 0 to 9999 microseconds (µs). The incoming counts are adjusted for dead time using the following formula:

$$n = \frac{m}{1 - m\tau}$$

Where,

n = corrected counts per second
m = incoming count per second
τ = system dead time

POSITION 2: CALIBRATION CONSTANT allows changing the calibration constant for the current detector setup. The calibration constant (CC) adjusts from 0.001 to 280×10^9. The calibration constant converts counts/time base to units/time base. The CC must be set to 1 to read out in cps (counts per second) or cpm (counts per minute).

$$CC = \frac{cps \text{ x } time\ base}{rate}$$

CC CONVERSION TABLE

Conversion Rate	Multiply by to get CC
cps/µR/hr	3.6×10^9
cps/mR/hr	3.6×10^6
cps/R/hr	3.6×10^3
cpm/µR/hr	6.0×10^7
cpm/mR/hr	6.0×10^4
cpm/R/hr	6.0×10^1
cps/µSv/h	3.6×10^7
cps/mSv/h	3.6×10^4
cps/Sv/h	3.6×10^1
cpm/µSv/h	6.0×10^5
cpm/mSv/h	6.0×10^2
cpm/Sv/h	0.6

Example:

The Model 44-9 GM detector produces approximately 3300 cpm/mR/hr for ^{137}Cs: $\rightarrow 6.0 \times 10^4 \times 3300 = 198 \times 10^6$ for CC.

POSITION 3: DISPLAY UNITS selects the display units for the associated detector setup number. The Model 2241-4 and detector may be calibrated in either exposure rate (R/hr or Sv/h) by entering the appropriate Calibration Constant (position 2) and Dead Time correction (position 1). The Model 2241-4 will automatically convert to the correct reading when switching between R and Sv.

The time base for count C is set independently in position 4. The display units may be set to:

R/hr (normally roentgens per hour, but in this case rem per hour)

Sv/h (Sieverts per hour)

C/time base (Counts per time)

The display is auto-ranging with the appropriate multiplier symbol appearing in front of the "R," "Sv," or "C" indicating the range:

μR/hr, mR/hr, R/hr

μSv/h, mSv/h, Sv/h

C/s, kC/s, C/m, kC/m

POSITION 4: TIME BASE CPS or CPM selects the display time base for the current detector setup. This time base only applies if the units are set to C/ (Counts/time). The time base for R/hr and Sv/h is fixed in "hr." For "true" reading (pulser calibration) cpm or cps calibrations, set the Calibration Constant (CC, parameter 2) to read "1." For geometry calibrations, the detector efficiency can be entered for CC.

Example:

For alpha scintillation detector with 25% 2π efficiency; enter "250 10_{-3}" in the CC parameter setup.)

The display time base may be set to:

seconds (**s**)

minutes (m)

POSITION 5: AUDIO DIVIDE BY selects the audible clicks-per-event division rate for the current detector setup. If the AUD ON/OFF switch is in the OFF position, no audible clicks-per-event will be heard.

This parameter ranges from:

0 / Divide By 1

1 / Divide By 10

2 / Divide By 100

3 / Divide By 1000

POSITION 6: RESPONSE TIME allows changing the time constant (TC) for the current detector setup. If the response is set to 0, the Model 2241-4 automatically calculates (for variable mode) the time constant based on the incoming cps. If a variable of 1-199 is entered for TC, the response time becomes fixed.

Variable Response - Response time is varied in proportion to the incoming count rate. The two-position F/S (Fast/Slow) toggle switch selects the maximum time constant (TC) for the variable mode. The fast position varies the TC from 4-25 seconds, and the slow position varies from 4-60 seconds.

Fixed Response - The Fast (F) response position is programmable from 2-50 seconds, and the slow response is 5 times slower than the fast TC. For MDA-type measurements, the fixed response time mode is recommended.

POSITION 7: RATEMETER ALARM/ALERT allows changing the ratemeter alarm for the current detector setup. The units of this alarm are the same as the units for the ratemeter display. The fifth push of the left button allows the decimal point to be moved. The ratemeter alarm adjusts from 1 to 999 R/hr (or Sv/h), 1 to 999 kcpm, or 1 to 100 kcps. The units of the alarm are determined by the units for the ratemeter.

POSITION 8: SCALER ALARM/COUNT TIME sets the scaler alarm variable from 1-999999, corresponding to the accumulated scaler count. After the scaler alarm variable is entered, the scaler count time is prompted. The scaler count time is adjustable from 1-9999 seconds.

POSITION 9: NOT USED

POSITION A: NOT USED

POSITION B: LCD Backlight ON TIME is the amount of time that the LCD backlight will stay on after pressing the front-panel switch labeled LIGHT. This value is stored in EEPROM.

Available values are:
5 seconds
30 seconds
60, 90 seconds
180, 240 seconds.

POSITION C: SET MINIMUM DISPLAY sets the ratemeter minimum displayable reading. Depressing the RESET button displays the minimum ratemeter units. The readout will auto-range up to the maximum displayable but will display "0" for ratemeter readings below the user-programmed minimum variable.

Minimum displayable values are:
00.0 µ, 000 µ, 0.00 m, 00.0 m, 000 m, 0.00, 00.0, 000 R/hr
.000 µ, 000 µ, 00.0 m, 000 m, 0.00, 00.0, 000 Sv/h
0.00, 00.0, 000, 0.00 k, 00.0 k, 000 kcpm or cps

POSITION D: RS-232 DATA DUMP MODE allows the RS-232 port to dump ratemeter data every two seconds. The Model 2241-4 is fully functional during RS-232 data dump with the exception of the audio function. The LCD will alternate between display of the ratemeter and the word "**dUP**" (representing "dump").

POSITION E: RS-232 DETECTOR PARAMETERS SETUP MODE allows the RS-232 port to accept/send a string of parameters corresponding to the current detector setup values.

POSITION F: BAUD RATE configures the RS-232 port for the following baud: 150, 300, 600, 1200, 2400, 4800, 9600, and 19200. The data is 8 data bits, 1 stop bit with no parity bit. This value is stored in EEPROM. The baud rate can only be programmed through the switch board.

RS-232 PORT CONNECTOR: This 9-pin "D" type connector is designed as a DCE port. A straight wire cable (extension cable) connects the Model 2241-4 to a computer's 9-pin RS-232 port.

RS-232 CONNECTOR PIN OUT:

PIN	FUNCTION
1	NC (No Connection)
2	DATA OUT
3	DATA IN
4	NC
5	NC
6	NC
7	HANDSHAKING IN
8	HANDSHAKING OUT
9	NC

Note:

Ludlum Measurements, Inc. offers a PC compatible software program, which incorporates the read/write commands necessary to communicate between the PC and the Model 2241-4. The program also incorporates an algorithm to calculate the detector Calibration Constant and Dead Time Constant. The software is offered in a DOS version (part number 1370-025) or a WINDOWS version (part number 1370-024). Read the Software License Agreement at the end of this section prior to installing any LMI software. If you cannot comply with the agreement, DO NOT install the software.

Calibration

The Model 2241-4 calibration routine consists of entering detector parameters into memory by way of the switch board and adjusting the CAL controls (HV and DISC) for the specific detector operating requirements.

The first subsection of calibration will give a general overview of detector setup, including the determination of various detector operating voltages (HV) and the adjustment of counter input sensitivity (DISC).

The next subsection deals with pulse generator counts-per-minute calibration. The counts-per minute-parameter setup is used in the initial instrument checkout procedure and the variables are saved under detector setup number “1” when shipped from Ludlum Measurements, Inc.

The following subsection deals with exposure rate calibration. The detector Calibration Constant (CC) and Dead Time Correction (DTC) are the two primary parameters used in the exposure rate calibrations (R/hr and Sv/h). These two constants are alternately varied to achieve linearity at the detector non-linear operating regions. An example of the Ludlum Model 44-9 GM detector calibration is given at the end of this section to illustrate the algorithm used in determining the CC and DTC variables.

GENERAL DETECTOR SETUP INFORMATION

The operating point for the instrument and probes is established by setting the probe voltage and instrument sensitivity (HV and DISC). 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 radiation) are above the discrimination level and the unwanted pulses from noise are below the discrimination level and are therefore not counted.

The total system gain can be controlled by adjusting either the instrument sensitivity or the high voltage. HV controls the gain of the detector; and DISC (Discriminator) controls the instrument counting threshold (sensitivity).

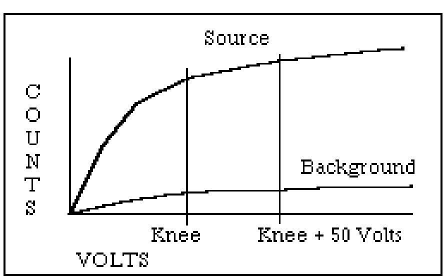
In the special case of GM detectors, a minimum voltage must be applied to establish the Geiger-Mueller characteristic. Further changes in HV will have little effect on this type of detector.

GM Detectors: The output pulse height of the GM detector is not proportional to the energy of the detected radiation. Adjusting DISC will have minimal effect on observed count rate unless the DISC setting is so low that the instrument will double-pulse.

For most GM detectors, set DISC for 30-40 millivolts and adjust HV to the GM detector recommended high voltage. Most GM detectors operate at 900 volts, although some miniature detectors operate at 450-550 volts. If a recommended setting is unavailable, plot count rate versus HV to produce a plateau graph. Adjust the HV for 25-50 volts above the knee or start of the plateau. For mixed detector use, both sensitivity and high voltage may be tailored for other detectors as long as the GM detector is operated within the recommended voltage range. Caution must be observed in lowering the input sensitivity to ensure that the counter does not double or multi-pulse.

Alpha Air-Proportional Detectors: For air proportional alpha detectors, set the DISC for 2 millivolt discrimination. Adjust HV until the detector just breaks down (shown by a rapid increase of count rate without a source present). Measure the HV output, then decrease the HV setting to operate 100 volts below breakdown.

Proportional Detectors: For proportional detectors, set the DISC control for 2-millivolt discrimination (near maximum clockwise). Expose the detector to a check source and plot count rate versus HV, similar to the one in the figure below. Refine the HV adjustment for optimum source efficiency with a minimum acceptable background count.



Scintillators: Set the DISC for 10 millivolts. Plot background and source counts versus HV to produce a plateau graph similar to the one in the figure. Adjust the HV to 25-50 volts above the knee or start of the plateau. This provides the most stable operating point for the detector.

COUNTS PER MINUTE (C/M) CALIBRATION

This procedure will set up the Model 2241-4 for the Counts/minute (C/m) mode of operation. Refer to Section 8, (Page 8-2 and following) for more information on setup parameter variables.

A Ludlum Model 500 Pulser or equivalent is required. If the pulser does not have a high-voltage display, use a high-impedance voltmeter with at least 1000 megohms input resistance to measure the detector high voltage.

Switch the SCA/RATE switch to the RATE position. Select position DET1 on the detector selector switch located on the front panel.

Select FUNCTION switch positions 1-6 and adjust for the following parameters:

Switch Pos.	Parameter	Function
1	0000 s_{-6}	Dead Time
2	0100 -2	Calibration Constant
3	c/	Display Units
4	m	Timebase
5	1	Audio Divide-by
6	000 s	Response Time

Position 7 selects the desired ratemeter ALERT and ALARM trip points.

If the parameters are undetermined, arbitrarily choose "0050 kC/m" for the alarm and "0045 kC/m" for the alert to confirm operation of the alert/alarm function.

Position 8 selects the scaler alarm parameter and the scaler count time.

If the values are unknown, set the scaler alarm to "4500_{ALARM00}" and the count time to "0060" (60 second count time).

Position 9 is not used, and position A is not used.

Switch to position B and enter "15" for a 15-second backlight ON time.

Switch to position C and enter "00.0 C/m" for the minimum displayable value.

Select position 0 to return to normal operation.

Connect the Model 500 Pulser to detector input and adjust HV and DISC to the specific detector operating parameters.

- Adjust the pulser amplitude to 1.5 times the Model 2241-4 discrimination level.
- Adjust the pulser output to 800 cpm and confirm that the Model 2241-4 reads 800 cpm ±10% on the ratemeter setting.
- Adjust the pulser output to 200 cpm and confirm that the Model 2241-4 reads 200 cpm ±10% on the ratemeter setting.
- Adjust the pulser output to 800 cpm, take a one minute count and confirm that the digital scaler readout displays 800 cpm ±2%.
- Adjust the pulser output to 200 cpm, take a one minute count and confirm that the digital scaler readout displays 200 cpm ±2%.
- Confirm that the 20% and 80% readings for the upper decades are within the pulser input by decading the pulser count output.
- Confirm that the scaler readout is within 2% of the pulser input rate.
- Ensure that the ALERT and ALARMs function by inputting the preset alarm levels as to initiate the alert and alarm conditions.

R/hr CALIBRATION

The following calibration procedure assumes that detector Calibration Constant (CC) and Dead Time Constant (DTC) are already known. If these constants must be determined, reference the following subsection, "Determining CC and DTC."

Switch the toggle switch to DET2. Detector setup number "1" is usually reserved for the Counts/minute parameter calibration. Rotate the FUNCTION switch counterclockwise to position 1 and enter the detector Dead Time in µs. Rotate to position 2 and enter the Calibration Constant. Enter the desired parameters for positions 3-F. Switch to position 0 for normal operation.

Expose the detector to calibrated radiation fields extending from the lower to the upper operating range of the detector. Confirm that the linearity is within 10% of each respective reading. If the readings are off on the lower detector operating region, vary CC. If the readings are off at the upper end of the detector operating region, adjust DTC.

DETERMINING CC AND DTC

This procedure contains the algorithm (*hi-lo method)* for determining the CC (Calibration Constant) and the DTC (Dead Time Correction). An example of the Ludlum Model 44-9 GM detector calibration is used in conjunction with the algorithm calculations to aid in solving the equations.

Note:

Ludlum Measurements, Inc. offers a PC-compatible software program, which incorporates the read/write commands necessary to communicate between a PC and the Model 2241-4. The program also incorporates the algorithm to calculate the detector CC and DTC. The software is offered in a DOS version (part number 1370-025) or a WINDOWS version (part number 1370-024). Read the Software License Agreement at the close of this section prior to installing any LMI software.

Hi-Lo Method: The hi-lo method refers to the placement of the detector in a radiation field using a two-point (CC and DT) calibration to make linear the detector response, even in the non-linear operating regions of the detector. The low-radiation field (CC) should be a field that yields from 2 to 5 % count loss. The high radiation field (DT) should be a field that yields from 30 to 60 % count loss. The algorithm ignores background counts, and therefore, the low field must be at least ten times the background count.

The following summary lists the calibration constraints.

Calibration and Dead Time Calibration Constraints

FIELD	CONSTRAINT
BACKGROUND	*10 times less than low field
LOW FIELD	Yields from 2 to 5 % count loss
HIGH FIELD	Yields from 30 to 60 % count loss

* This constraint only applies when using two sources (two fields) or a radiation range calibrated without background consideration.

Preliminary CPS Setup

Refer to Section 8, Subsection "Function Switch Position Descriptions and Variables," for cps readout variables.

Select position DET1 on the detector selector switch located on the front panel. Starting with FUNCTION switch position 1, enter the following variables:

SWITCH POS.	PARAMETER	FUNCTION
1	0000s$_{-6}$	Dead Time
2	0100 -2	Calibration Constant
3	C/	Display Units
4	m	Timebase
5	N/A	Audio Divide-By
6	N/A	Response Time
7	N/A	Ratemeter Alm./Alert
8	0060 s	ScalerAlm./Count Time
9	Not Used	
A	Not Used	
B	N/A	LCD Backlight
C	000 C/s	Set Minimum Display
D-F	N/A	RS-232 Parameters

Equation 1

$$CPS^{LO2\%} = \frac{1}{49 \text{ x } DT}$$

Equation 2

$$CPS^{LO5\%} = \frac{1}{19 \text{ x } DT}$$

Equation 3

$$CPS^{HI30\%} = \frac{1}{2.3333 \text{x } DT}$$

Equation 4

$$CPS^{HI60\%} = \frac{1.5}{DT}$$

The equations to the left (Equations 1-4) determine the *hi* and *lo* radiation fields used to acquire counts for the CC and DTC algorithm. These calculations require an unknown variable, DT (Dead Time). Typical dead times for some of the standard LMI detectors are referenced in the table at the end of this section. The *lo* count field should be a field that yields between 2 and 5% count loss. The *hi* count field (CPS^{HI}) should be a field that yields between 30 and 60% count loss.

Reference the table at the end of this section to determine the cps/exposure rate (cps/ER). The conversion can be determined by placing the detector in a radiation field, which produces from 50 to 200 cps. Calculate the count/exposure rate using the equation to the left.

$$\frac{cps}{radiation\ \ field\ \ in\ \ exposure\ \ rate\ \ units} = cps\ /\ ER$$

For example, exposing an LMI Model 44-9 to a 2 mR/hr ^{137}Cs field yields approximately 110 cps so that:

$$\frac{110\,cps}{2\ mR/hr} = 55\ cps/mR/hr$$

The typical dead time for a Model 44-9 is approximately 85 μs. Therefore, using 85 μs for "DT" in equations 1-4, the *lo* field should be between 240 and 619 cps, and the *hi* field is between 5040-17,650 cps. Dividing the cps values by the 55 cps/mR/hr conversion equates to between 4-11 mR/hr for the *lo* field and 91-320 mR/hr for the *hi* field.

Select a calibrated field between the *lo* and *hi* data points determined above:

lo (CAL_{lo}) = 8 mR/hr

hi (CAL_{hi}) = 200 mR/hr

The following procedure outlines the hi-lo method

Abbreviations used:

units = Sv, R, counts.

CAL_{lo} = *lo* field calibration point.
CAL_{hi} = *hi* field calibration point.

$CORR_{lo}$ = recorded field at low calibration point.
$CORR_{hi}$ = recorded field at high calibration point.

DT = dead time constant entered into Model 2241.
CC = calibration constant entered into Model 2241.

f_d and a_d are intermediate steps in calculating DT.
f_{cal} is an intermediate step in calculating CC.

CC and DTC Algorithm

Equations (5) and (6) convert units per time (R/hr Display Units) to units per second:

$$\frac{\textbf{units}}{\textbf{time}} \Rightarrow \frac{\textbf{units}}{\textbf{second}}$$

Insert the cps *lo* data point (8 mR/hr for the Model 44-9 example) determined from equations (1) and (2):

Equation 5

$$CAL_{lo} = (0.008\frac{R}{h})\,x\,(\frac{1\,h}{60\,m})\,x\,(\frac{1\,m}{60\,s}) = \quad 2.22\,x\,10^{-6}\;\; s$$

Insert the cps hi data point (200 mR/hr for the Model 44-9 example) determined from equations (3) and (4):

Equation 6

$$CAL_{hi} = (0.200\frac{R}{h})x(\frac{1\,h}{60\,m})x(\frac{1\,m}{60\,s}) = \quad 55.6\,x\,10^{-6}\;\; s$$

Place the detector in the low field and enter the counts per second:

Equation 7

$$CORR_{lo} = \frac{SAMPL_{lo}}{count\,time} = \quad \frac{counts}{s}$$

Note:

The low field count sample should be ≥ 3000 counts. Use the scaler and adjust the count time to accumulate count ≥ 3000.

As an example, assume a 60-second count sample in a low field of 8 mR/hr:

Example

$$CORR_{lo} = \frac{26{,}427}{60} = 440\,C/s$$

Place detector in the high field and enter the counts per second:

Equation 8

$$CORR_{hi} = \frac{SAMPL_{hi}}{count\,time} = \frac{counts}{s}$$

Counts/second sample in high field of 200 mR/hr:

Example

$$CORR_{hi} = \frac{5830}{1} = 5830\,C/s$$

Insert the values calculated in equations (5), (6), (7), and (8) and solve for f_d:

Equation 9

$$f_d = CAL_{hi} - \frac{CORR_{hi} \, x \, CAL_{lo}}{CORR_{lo}} = \frac{units}{s}$$

Example

$$f_d = 55.6 \, x \, 10^{-6} - \frac{5830 \, x \, 2.22 \, x \, 10^{-6}}{440} = 26.2 \, x \, 10^{-6} \; \frac{R}{s}$$

Solve for a_d:

Equation 10

$$a_d = (CAL_{hi} \, x \, CORR_{hi}) - (CAL_{lo} \, x \, CORR_{hi}) = \frac{units \times count}{s^2}$$

Example

$$a_d = (55.6 \, x \, 10^{-6} \, x \, 5830) - (2.22 \, x \, 10^{-6} \, x \, 5830) = 31.1 \, x \, 10^{-2} \frac{RCount}{s^2}$$

Enter the results of equations (9) and (10) into equation (11) to solve for DT:

Equation 11

$$DT = \frac{f_d}{a_d} = \quad \frac{s}{count}$$

Example

$$DT = \frac{26.2x10^{-6}}{31.1x10^{-2}} = \quad 8.4x10^{-5}\frac{seconds}{count}$$ or $84 \text{ x } 10^{-6}$ sec

Solve for f_{cal}:

Equation 12

$$f_{cal} = CAL_{lo} - (CAL_{lo} \, x \, CORR_{lo} \, x \, DT) = \quad \frac{units}{s}$$

Example

$$f_{cal} = 2.22 \, x \, 10^{-6} - (2.22 \, x \, 10^{-6} \, x \, 440 \, x \, 84 \, x \, 10^{-6}) = \quad 2.14 \, x \, 10^{-6} \; \frac{R}{s}$$

Enter the result of equation (12) into:

Equation 13

$$CC = \frac{CORR_{lo}}{f_{cal}} = \quad \frac{count}{units}$$

and solve for CC:

Example

$$CC = \frac{440}{2.14 \, x \, 10^{-6}} = \quad 206 \, x \, 10^{6} \frac{counts}{R}$$

Enter the CC and DT values (positions 1 and 2 of the FUNCTION switch), derived from the equations above. Perform an "R/hr calibration" as described in the previous subsection in order to ensure that the instrument and detector have been correctly calibrated.

Model 44-9 Detector Parameter Setup

FUNCTION	PARAMETER
1	0084 s-6
2	0206 06
4	N/A
5-8	as desired
B-C	as desired
D-F	if applicable

Typical Count Rate and Dead Time for LMI Detectors

MODEL & TYPE	COUNT RATE	DEAD TIME in µs (microseconds)
44-6, GM	20 cps/mR/hr	90-110 µs
44-9, GM	55 cps/mR/hr	80-90 µs
44-7, GM	35 cps/mR/hr	240-290 µs
133-2, GM	17.5 cps/mR/hr	40-55 µs
133-4, GM	2 cps/mR/hr	40-55 µs
133-6, GM	0.3 cps/mR/hr	40-55 µs
44-2, Gamma Scint.	2800 cps/mR/hr	8-12 µs*
44-10, Gamma Scint.	15,000 cps/mR/hr	18-20 µs
44-3, Low-Energy Gamma Scint.	N/A, operated in Counts/units mode	8-12 µs*
44-21, Beta/Gamma Scint.	N/A, operated in Counts/units mode	8-12 µs*
43-5, Alpha Scint.	N/A, operated in Counts/units mode	20-28 µs

Note:

The data represented in the table above is typical. Actual values may vary among detector and instrument combinations. This table represents some of the common detectors operated with the Model 2241-4. Consult the LMI sales department for information concerning detectors not listed in the table above.

*The dead time values for these scintillation detectors are due to the dead time of the Model 2241-4 electronics.

LUDLUM MEASUREMENTS, INC.
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SWEETWATER, TX 79556
325/235-5494 FAX: 325/235-4672

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Rev. (number) 1.0
Written by (or Revised by): Rich Sprola **Date:** 20Jan06
Approved by: Ed Em **Date:** 20JAN06

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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. electronic 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, which have been placed on the market after August 13, 2005, have been labeled with a symbol recognized internationally as the "crossed-out wheelie bin." This 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

	Reference	Description	Part Number
Model 2241-4 Survey Meter	UNIT	Completely Assembled Model 2241-4 Survey Meter	48-2444
Main Circuit Board, Drawing 408 × 223	BOARD	Completely Assembled Main Circuit Board	5408-223
CAPACITORS	C1	0.1µF, 50V	04-5663
	C3	0.1µF, 50V	04-5663
	C001-C002	47pF, 100V	04-5660
	C011	0.001µF, 100V	04-5659
	C012	0.1µF, 50V	04-5663
	C021	100pF, 3KV	04-5532
	C031	0.0047µF, 3KV	04-5547
	C032	100pF, 3KV	04-5532
	C033	0.0047µF, 3KV	04-5547
	C041-C043	0.0047µF, 3KV	04-5547
	C101	47µF, 10V	04-5666
	C121	47µF, 10V	04-5666
	C122-C123	27pF, 100V	04-5658
	C131	0.0047µF, 3KV	04-5547
	C132-C133	0.1µF, 50V	04-5663
	C134	0.01µF, 50V	04-5664
	C135	47µF, 10V	04-5666
	C136	0.01µF, 50V	04-5664
	C137	47µF, 10V	04-5666
	C138	100pF, 100V	04-5661
	C139	0.001µF, 100V	04-5659
	C141	0.0047F, 3KV	04-5547

	Reference	Description	Part Number
	C241	1µF, 35V	04-5656
	C242	68µF, 10V	04-5654
	C243	0.1µF, 50V	04-5663
	C251	68µF, 10V	04-5654
TRANSISTORS	Q101	2N7002L	05-5840
	Q141	MMBT3904LT1	05-5841
	Q211	2N7002L	05-5840
	Q212	MMBT4403LT1	05-5842
	Q241	MJD210 RL	05-5843
INTEGRATED CIRCUITS	U1	MAX810LEUR	06-6424
	U001	CD74HC4538M	06-6297
	U011	TLC372ID	06-6290
	U021	CA3096M; 16=GND	06-6288
	U111	AT89C51RC2	06-6893
	U121	LM285MX-2.5	06-6291
	U122	X24C02S8T5	06-6299
	U131	LM358D	06-6312
	U231	LT1073CS8-5	05-5852
	*	SOCKET-44P	06-6613
DIODES	CR021	MMBD7000LT1	07-6355
	CR031	GI250-2	07-6266
	CR041-CR044	GI250-2	07-6266
	CR231	CXSH-4 EB33	07-6358
	CR241	MMBD914LT1	07-6353
	CR242	CXSH-4 EB33	07-6358
POTENTIOMETERS / TRIMMERS	R002	10K; 3269X1-103	09-6921
	R027	1M; 3269X1-105; HV LIMIT	09-6906
RESISTORS	R001	100K, 1/4W, 1%	12-7834
	R011-R012	10K, 1/4 W, 1%	12-7839
	R013	1K, 1/4W, 1%	12-7832
	R014	10K, 1/4W, 1%	12-7839
	R015	100K, 1/4W, 1%	12-7834
	R021	1M, 1/4W, 5%	10-7028
	R022	392K, 1/8W, 1%	12-7841

	Reference	Description	Part Number
	R023	10K, 1/4W, 1%	12-7839
	R024-R025	4.75K, 1/4W, 1%	12-7858
	R026	8.25K, 1/8W, 1%	12-7838
	R031	1M, 1/4W, 5%	10-7030
	R032	1M, 1/4W, 5%	10-7028
	R033-R034	1G, FHV-1, 2%	12-7686
	R111-R113	22.1K, 1/4W, 1%	12-7843
	R121	100 Ohm, 1/4W, 1%	12-7840
	R122	6.81K, 1/4W, 1%	12-7857
	R131-R132	1M, 1/4W, 1%	12-7844
	R133	750K, 1/4W, 1%	12-7882
	R134	1M, 1/4W, 1%	12-7844
	R135	82.5K, 1/8W, 1%	12-7849
	R136	10K, 1/4W, 1%	12-7839
	R141	22.1K, 1/4W, 1%	12-7843
	R211	2.21K, 1/4W, 1%	12-7835
	R231	100Ohm, 1/4W, 1%	12-7840
	R241	2.21K, 1/4W, 1%	12-7835
	R242	200Ohm, 1/8W, 1%	12-7846
CRYSTALS	Y221	6.144 MHZ, 2=GND, 3=GND	01-5262
INDUCTOR	L231	100uH, CTX100-2	21-9740
TRANSFORMERS	T101	4275-083, AUDIO	4275-083
	T141	L8050	40-0902
MISCELLANEOUS	P1	1-640456-2, MTA100×12	13-8061
	P2	1-640456-3, MTA100×13	13-8100
	P3	640456-6, MTA100×6	13-8095
	P4	640456-2, MTA100×2	13-8073
	P5	1-640456-2, MTA100×12	13-8061
	*	CLVRLF	18-8771
Calibration Board, Drawing 408 × 12	BOARD	Completely Assembled Calibration Board	5408-007
POTENTIOMETERS	R1	100K, DISC	09-6813
	R2	1M, OVERLOAD	09-6814

	Reference	Description	Part Number
	R3	1M, HV	09-6814
RESISTORS	R4	10K, 1/3W, 1%	12-7748
	R5-R6	1M, 1/3W, 1%	12-7751
	R7	1K, 1/3W, 1%	12-7750
CONNECTOR	P7	CONN-640456-6, MTA100×6	13-8095
Display Board, Drawing 408 × 259	BOARD	Completely Assembled Display Board	5408-259
CAPACITORS	C1	27PF, 100V	04-5658
INTEGRATED CIRCUITS	U1	AY0438-I/L	06-6358
	U2	AY0438-I/L	06-6358
RESISTORS	R001-R004	10.0K, 1%, 125mW	12-7839
	R005	392 Ohm, 1%, 1/8 W	12-7054
MISCELLANEOUS	J1	CONN-640456-8, MTA100	13-8039
	DS1	EL-BACKLIGHT-LED	07-6527
	DSP1	MAIN DISPLAY; LCD-8246-365-4E1-A/W-REV1	07-6383

	Reference	Description	Part Number
Switch Board, Drawing 408 × 45	BOARD	Completely Assembled Switch Board	5408-052
CAPACITORS	C1-C2	4.7µF, 10V	04-5578
	C3-C4	10µF, 20V	04-5592
	C5	4.7µF, 10V	04-5578
	C6	100µF, 10V	04-5576
INTEGRATED CIRCUITS	U1	MAX220EPE	06-6359
SWITCHES	S1	350134GSK; FUNCTION; 16 POS	08-6721
	S2	LEFT	08-6716
	S3	UP	08-6716
	S4	ENTER	08-6716
RESISTORS	R1-R2	22K	10-7070
MISCELLANEOUS	P6	CONN-1-640456-3, MTA100	13-8100
	P10	CONN-208006-2	13-8451
Chassis Wiring Diagram, Drawing 408 × 103 AUDIO	DS1	UNIMORPH	21-9251
CONNECTORS	J1	CONN-1-640442-2, MTA100×2	13-8407
	J2	CONN-1-640442-3, MTA100×3	13-8138
	J3	CONN-640442-6, MTA100×6	13-8171
	J4	CONN-640442-2, MTA100×2	13-8178
	J5	CONN-1-640442-2, MTA100×2	13-8407
	J6	CONN-1-640442-3, MTA100×3	13-8138
	J7	CONN-640442-6, MTA100×6	13-8171
	J8	CONN-640442-8, MTA100×8	13-8184

	Reference	Description	Part Number
	J9	Series "C" -UG706/U	13-7751
	J10	JACK-09-9011-1-419	18-9080
	P10	HANDLE PIN	7408-055
SWITCHES	S1	30-1-PB GRAYHILL	08-6517
	S3-S4	7101-SYZ-QE C&K	08-6511
	S5	30-1-PB GRAYHILL	08-6517
	S6	PA-600-210	08-6501
	S7	MPS-103F	08-6699
	*	SWTCH CAP, BLK C-22	08-6698
BATTERY	B1-B2	"D" Duracell Battery	21-9313
MISCELLANEOUS			
	*	DIGITAL BEZEL ASSY.	4408-020
	*	DIGITAL BEZEL W/GLASS	4408-051
	*	BEZEL BACK	7408-025
	*	BEZEL BACK GASKET	7408-026
	*	BATTERY CONTACT SET	40-1707
	*	MAIN HARNESS	8408-048
	*	Model 2241 CASTING	7408-043
	*	Portable HARNESS CAN WIRES	8363-462
	*	CAN ASSY.	4363-441
	*	PORTABLE KNOB	08-6613
	*	BATTERY LID WITH CNTCT	2363-191
	*	PORTABLE LATCH KIT W/O BATTERY LID	4363-349
	*	PORT CALIBRATION COVER W/SCREWS	9363-200
	*	Model 2241-2 RLLD HNDLE ASSY.	4408-178

Section 11

Drawings

Main Circuit Board, Drawings 408 × 223 (3 sheets)

Main Circuit Board Component Layout, Drawing 408 × 224 (2 sheets)

Calibration Board, Drawing 408 × 12

Calibration Board Component Layout, Drawing 408 × 13 (2 sheets)

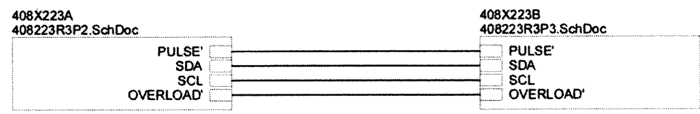
Display Board, Drawing 408 × 259

Display Board Component Layout, Drawings 408 × 260 (2 sheets)

Switch Board, Drawing 408 × 45

Switch Board Component Layout, Drawing 408 × 46

Wiring Diagram, Drawing 408 ×103



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

Drawn: PAB	6/21/2021	Title: Main Board		
Design: RSS	10/13/2015	Model: 2241		
		Board#: 5408-223		
Approve: RDS	21 JUN 21	Sheet: 1 of 3	Series	Sheet
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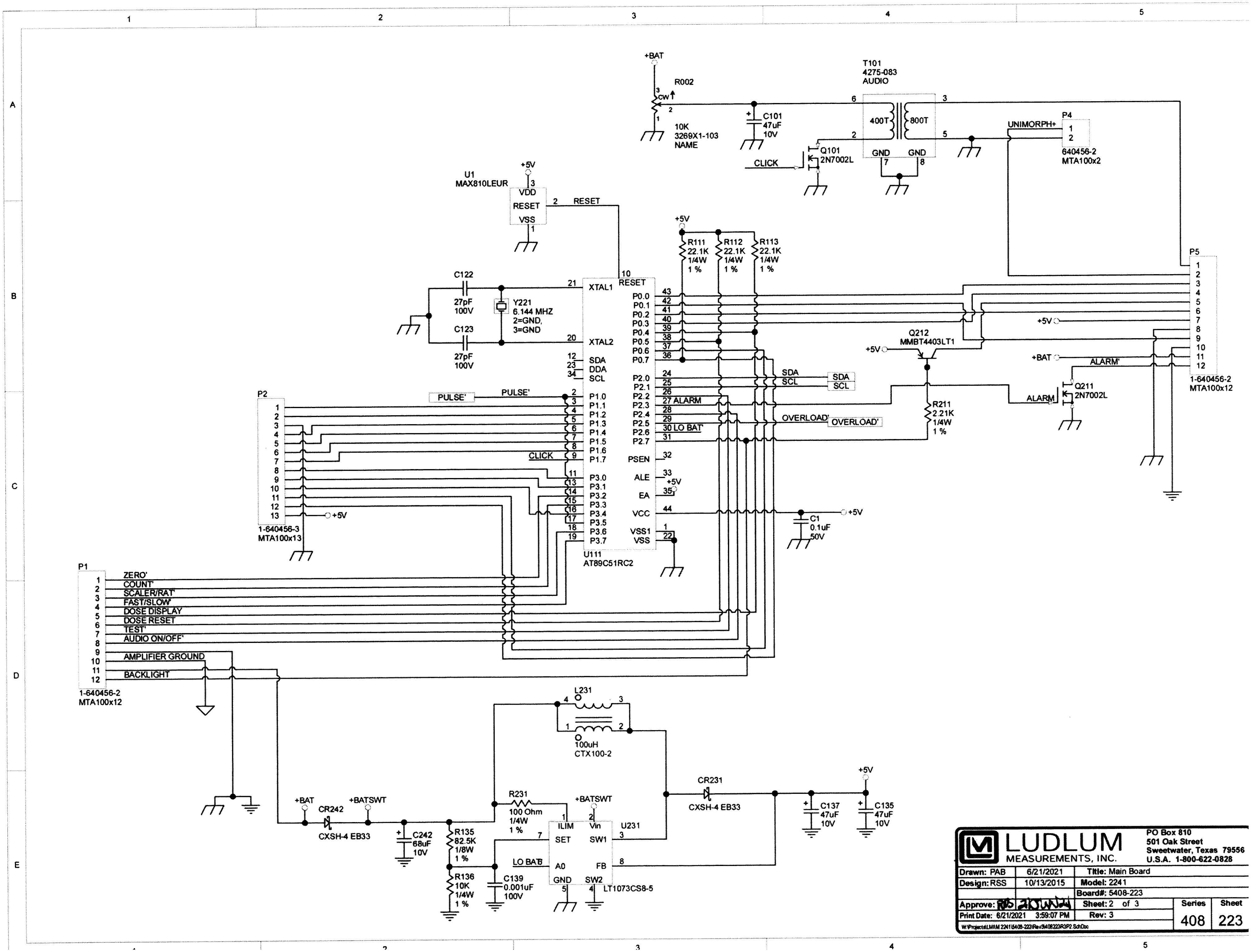

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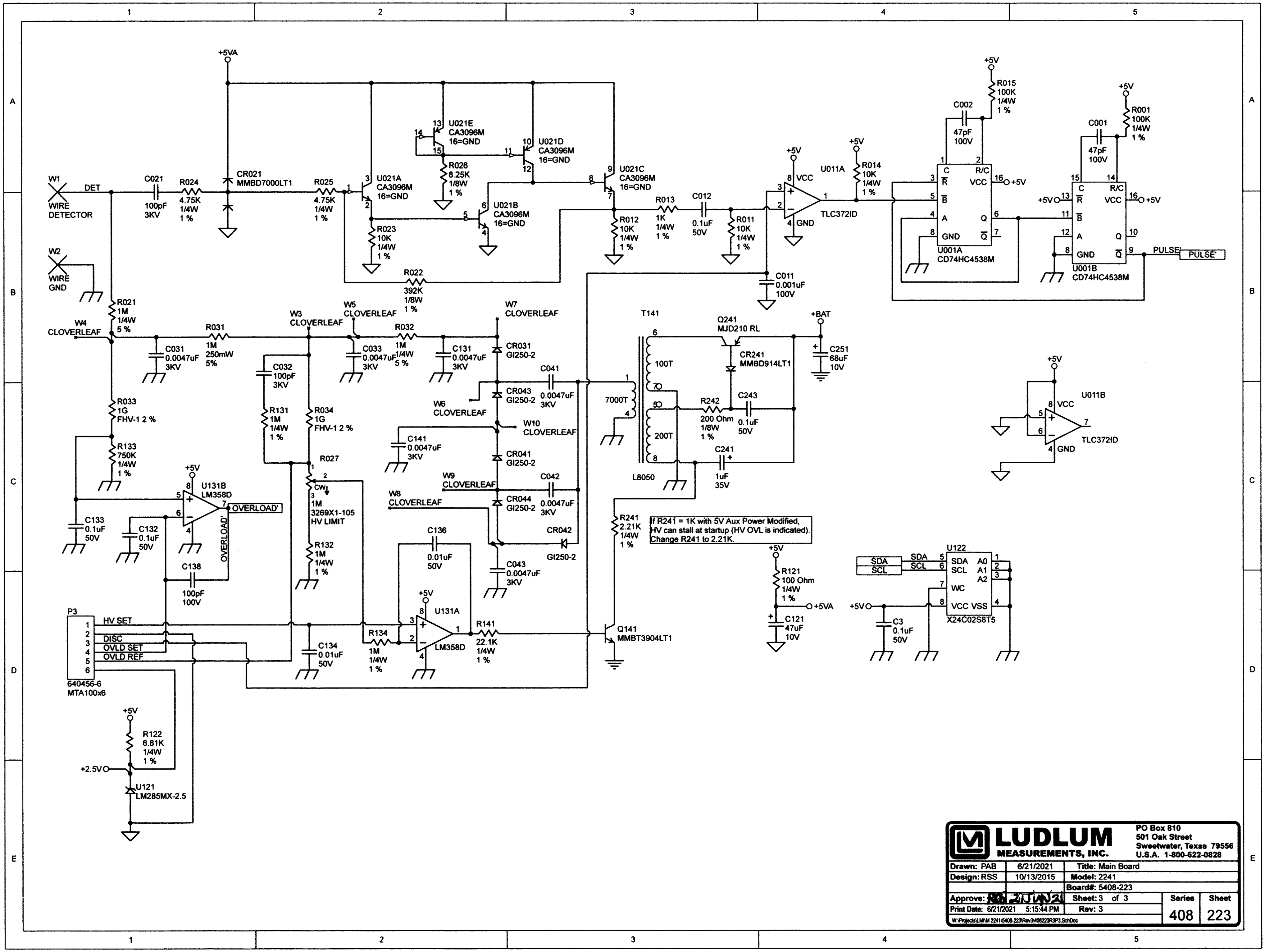
Drawn: PAB	6/21/2021	Title: Main Board
Design: RSS	10/13/2015	Model: 2241
		Board#: 5408-223
Approve:		Sheet: 2 of 3
Print Date: 6/21/2021	3:59:07 PM	Rev: 3

Series 408 Sheet 223



+5VA
W1
WIRE DETECTOR
DET
C021 100pF 3KV
R024 4.75K 1/4W 1 %
CR021 MMBD7000LT1
R025 4.75K 1/4W 1 %
U021A CA3096M 16=GND
U021E CA3096M 16=GND
U021D CA3096M 16=GND
U021C CA3096M 16=GND
U021B CA3096M 16=GND
R026 8.25K 1/8W 1 %
R023 10K 1/4W 1 %
R022 392K 1/8W 1 %
R012 10K 1/4W 1 %
R013 1K 1/4W 1 %
C012 0.1uF 50V
R011 10K 1/4W 1 %
C011 0.001uF 100V
U011A TLC372ID
R014 10K 1/4W 1 %
C002 47pF 100V
R015 100K 1/4W 1 %
U001A CD74HC4538M
C001 47pF 100V
R001 100K 1/4W 1 %
U001B CD74HC4538M
PULSE'
W2
WIRE GND
W4 CLOVERLEAF
R021 1M 1/4W 5 %
R031 1M 250mW 5%
C031 0.0047uF 3KV
W3 CLOVERLEAF
W5 CLOVERLEAF
R032 1M 1/4W 5 %
C033 0.0047uF 3KV
C131 0.0047uF 3KV
W7 CLOVERLEAF
CR031 GI250-2
C041 0.0047uF 3KV
CR043 GI250-2
W6 CLOVERLEAF
W10 CLOVERLEAF
C141 0.0047uF 3KV
CR041 GI250-2
W9 CLOVERLEAF
C042 0.0047uF 3KV
CR044 GI250-2
W8 CLOVERLEAF
CR042 GI250-2
C043 0.0047uF 3KV
C032 100pF 3KV
R131 1M 1/4W 1 %
R034 1G FHV-1 2 %
R027 1M 3269X1-105 HV LIMIT
R132 1M 1/4W 1 %
R033 1G FHV-1 2 %
R133 750K 1/4W 1 %
U131B LM358D
OVERLOAD'
C133 0.1uF 50V
C132 0.1uF 50V
C138 100pF 100V
C136 0.01uF 50V
U131A LM358D
R134 1M 1/4W 1 %
R141 22.1K 1/4W 1 %
C134 0.01uF 50V
P3
HV SET
DISC
OVLD SET
OVLD REF
640456-6 MTA100x6
T141
100T
7000T
200T
L8050
Q241 MJD210 RL
CR241 MMBD914LT1
+BAT
C251 68uF 10V
R242 200 Ohm 1/8W 1 %
C243 0.1uF 50V
C241 1uF 35V
R241 2.21K 1/4W 1 %
If R241 = 1K with 5V Aux Power Modified, HV can stall at startup (HV OVL is indicated). Change R241 to 2.21K.
Q141 MMBT3904LT1
U011B TLC372ID
+5V
R121 100 Ohm 1/4W 1 %
C121 47uF 10V
U122 X24C02S8T5
SDA
SCL
WC
VCC VSS
C3 0.1uF 50V
R122 6.81K 1/4W 1 %
+2.5V
U121 LM285MX-2.5
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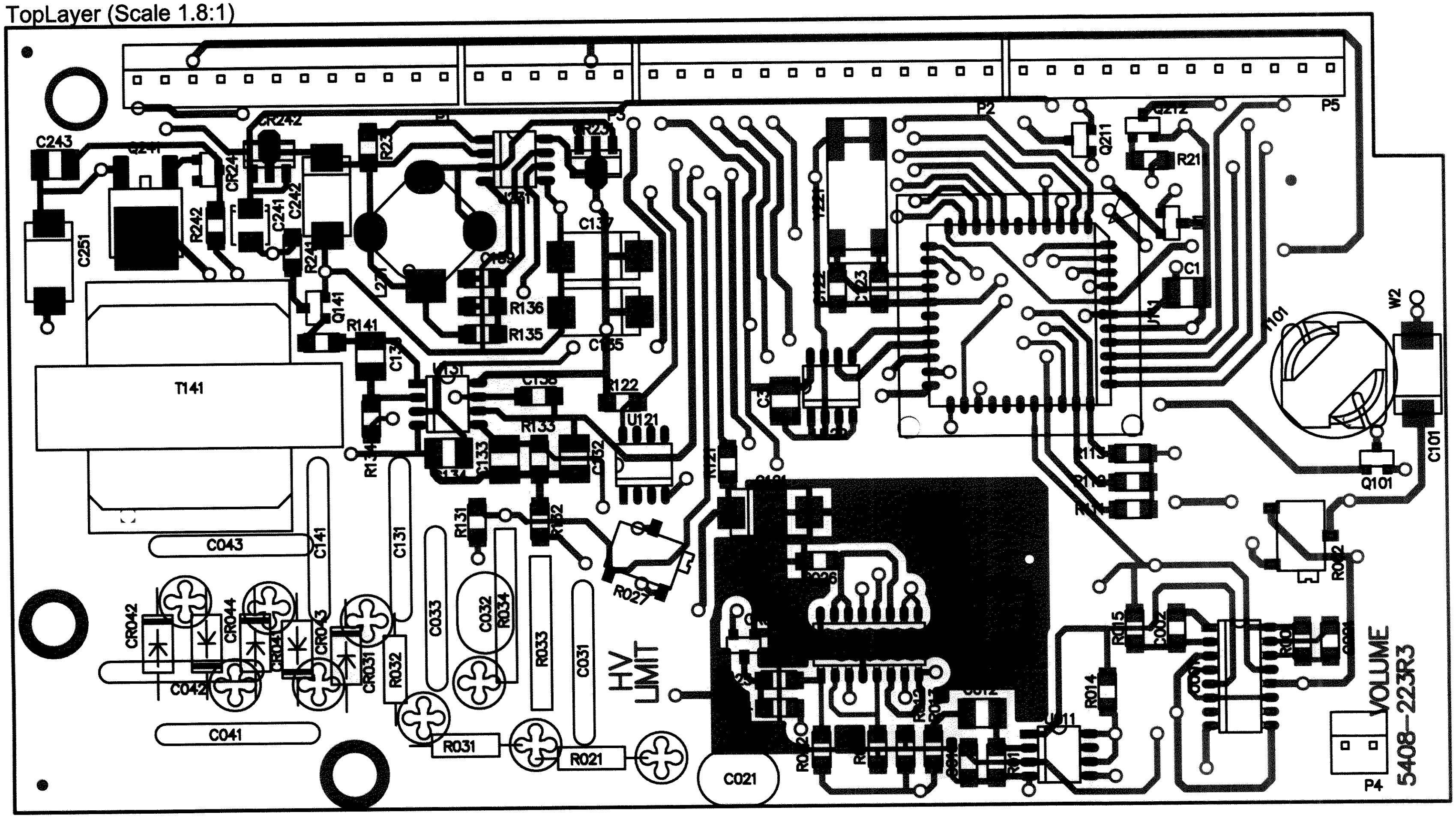
PO Box 810
501 Oak Street
Sweetwater, Texas 79556
U.S.A. 1-800-622-0828
Drawn: PAB 6/21/2021
Design: RSS 10/13/2015
Title: Main Board
Model: 2241
Board#: 5408-223
Approve:
Sheet: 3 of 3
Print Date: 6/21/2021 5:15:44 PM
Rev: 3
Series 408
Sheet 223

TopLayer (Scale 1.8:1)



LUDLUM MEASUREMENTS					
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Desc: Main Board					
Design: RSS	**Date:** 10/13/2015		**Rev:**	3	
Drawn: PAB	**Date:** 5/5/2022	**SHEET**	**SERIES**	**SHEET**	
Apr: JML	**Date:** 5/5/2022	1 of 3	408	224	
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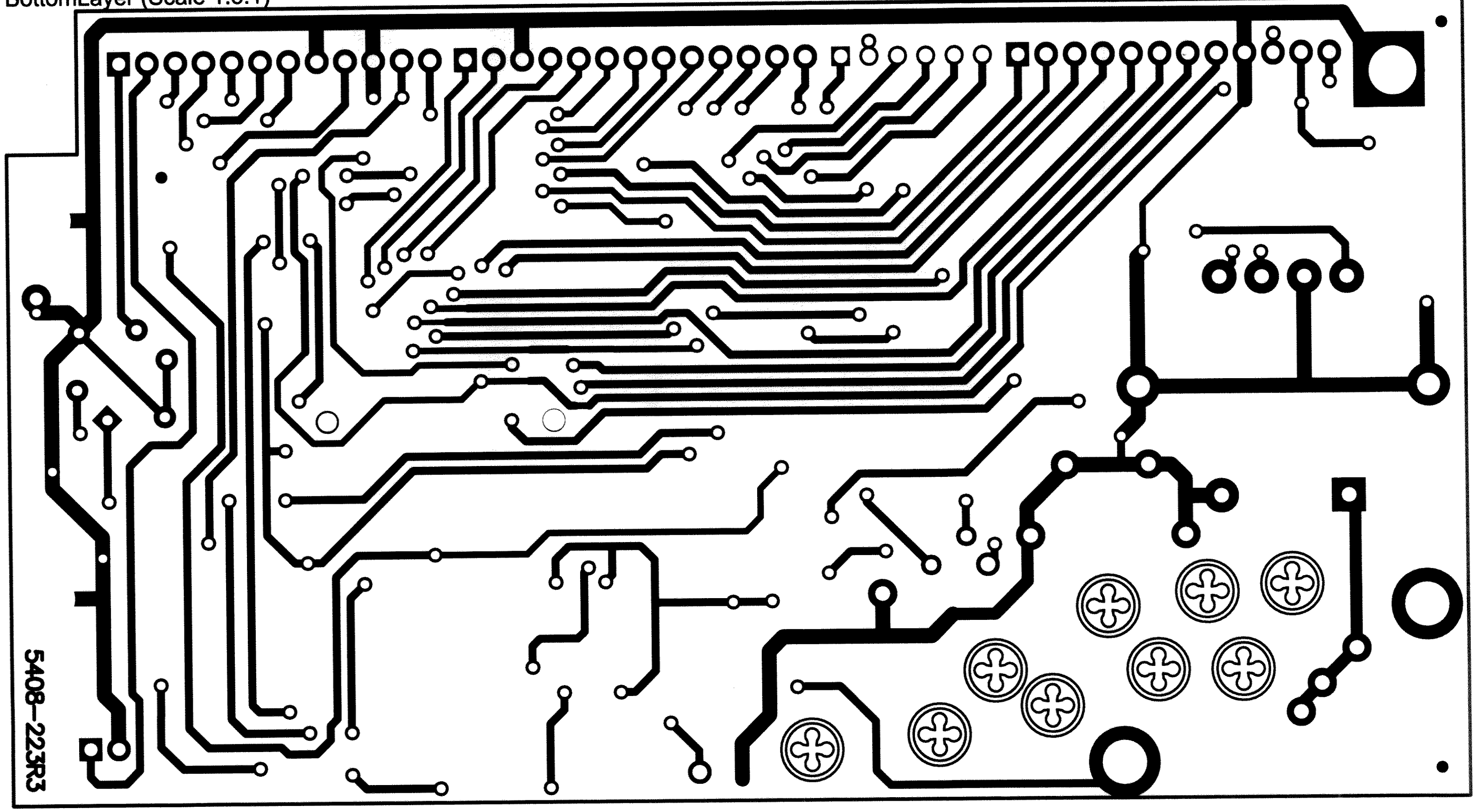
BottomLayer (Scale 1.8:1)



LUDLUM MEASUREMENTS			
Part: 5408-223	**Model:** 2241		
Desc: Main Board			
Design: RSS	**Date:** 10/13/2015	**Rev:**	3
Drawn: PAB	**Date:** 5/5/2022	**SHEET**	**SERIES**	**SHEET**
Apr: JMC	**Date:** 5/5/2022	2 of 3	408	224
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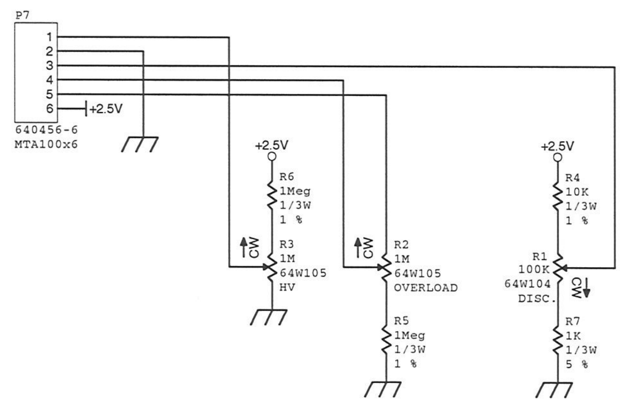
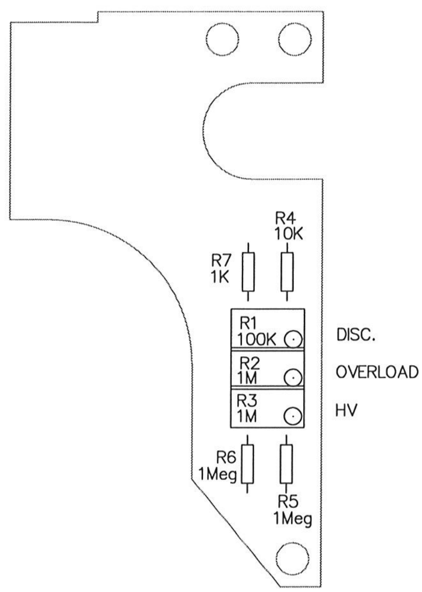


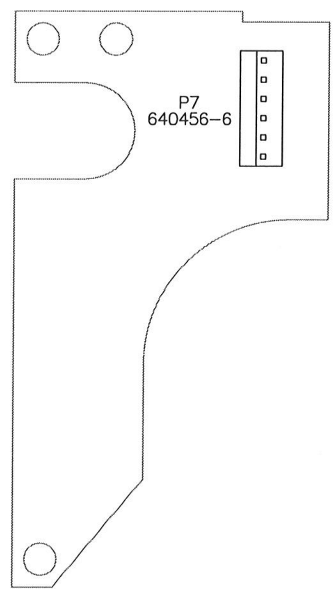
LUDLUM MEASUREMENTS, INC.

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

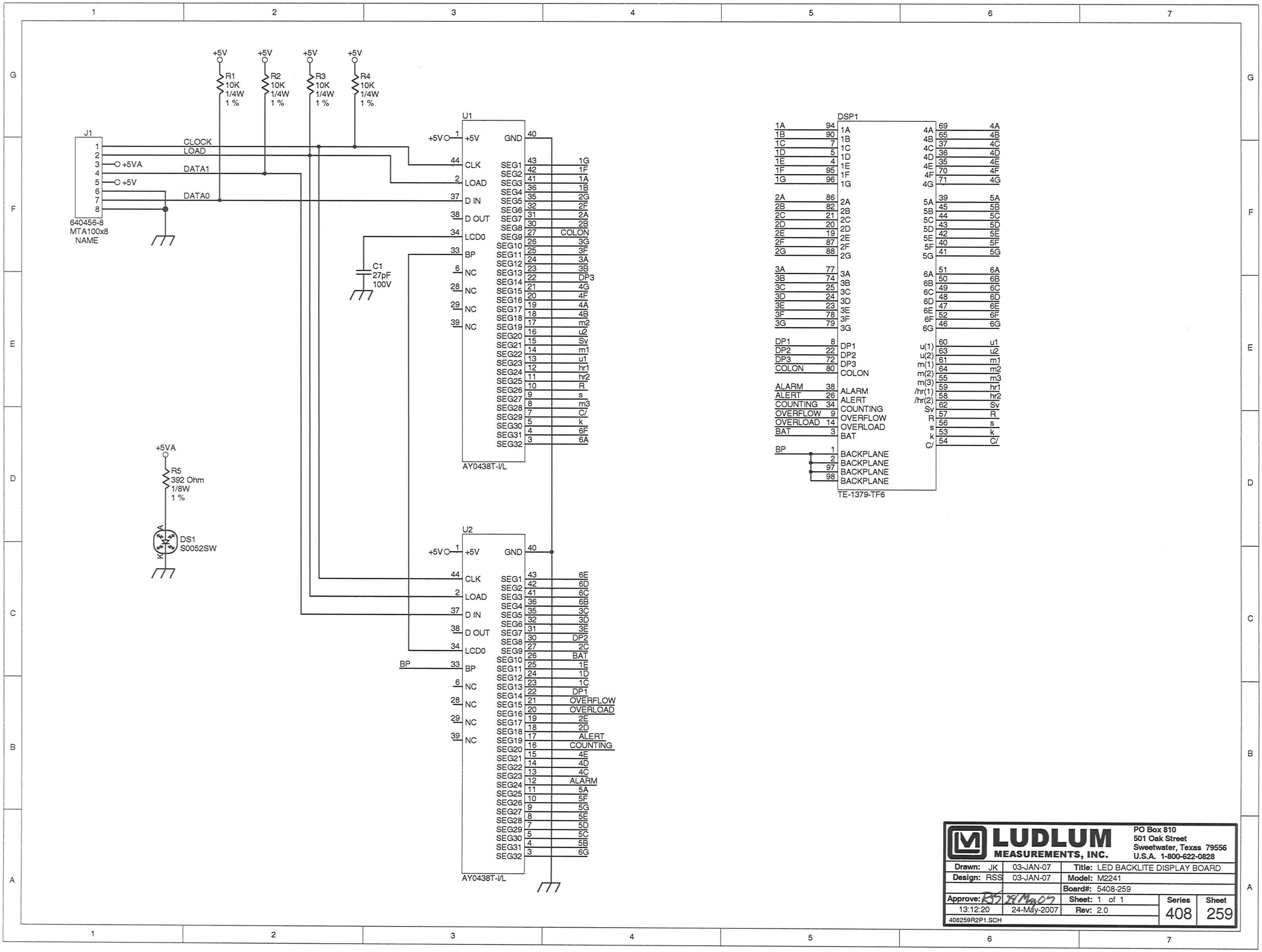
Drawn: CKB	30-Nov-99	Title: Calibration Board			
Design: LL	22-Mar-93	Model: 2240, 2241			
Check:		Board#: 5408-007			
Approve: JWS	18-Aug-05	Sheet: 0 of 0		Series	Sheet
14:30:37	6-Jun-2005	Rev: 1.0		408	12
408x12.sch					



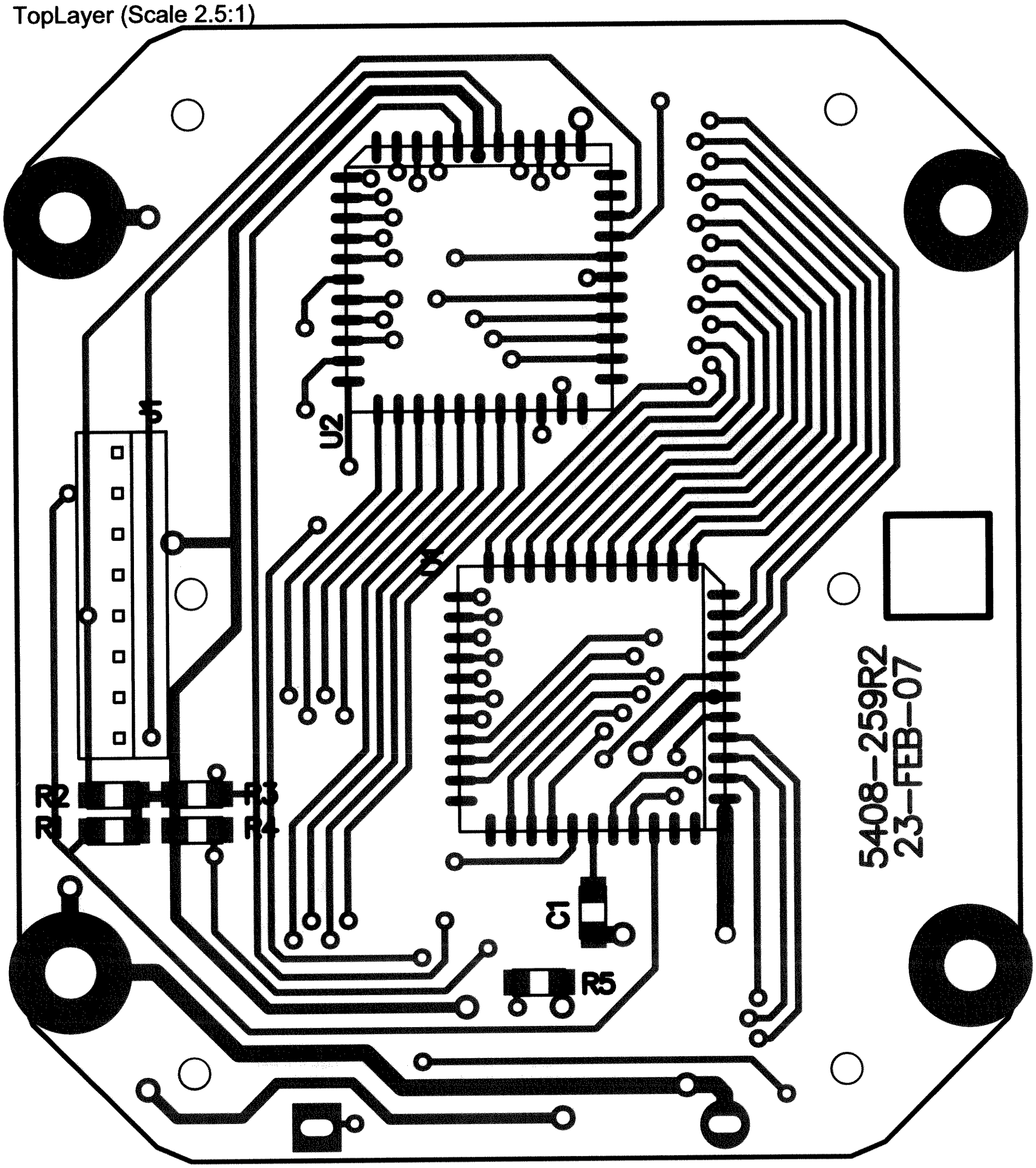
Drawn:	CKB	30-Nov-99	Title:		
Design:	LL	22-Mar-93	Calibration Board		
Check:			Model: 2240, 2241		
Approve:	JWS	18-Aug-2005	Board#: 5408-007		
Layer: Mech.1	MID:		Rev: 1.0	Series	Sheet
	14:50:59	6-Jun-2005	SCALE: 1.00	408	13
X:\Projects\LMI\M2240\m2240.Ddb\\Documents\5408-007\5408007.PCB					



Drawn:	CKB	30-Nov-99	Title:		
Design:	LL	22-Mar-93	Calibration Board		
Check:			Model: 2240, 2241		
Approve:	JWS	18-Aug-2005	Board#: 5408-007		
Layer: Mech.1 Mech.2	BottomPaste P1 P2 P3 P4		Rev: 1.0	Series	Sheet
	MID: 1 2 3 4 5 6 7 8 9 10 11 12 13 14				
	14:50:59	6-Jun-2005	SCALE: 1.00	408	13
X:\Projects\LMI\M2240\m2240.Ddb\\Documents\5408-007\Ver1_0\5408007.PCB					

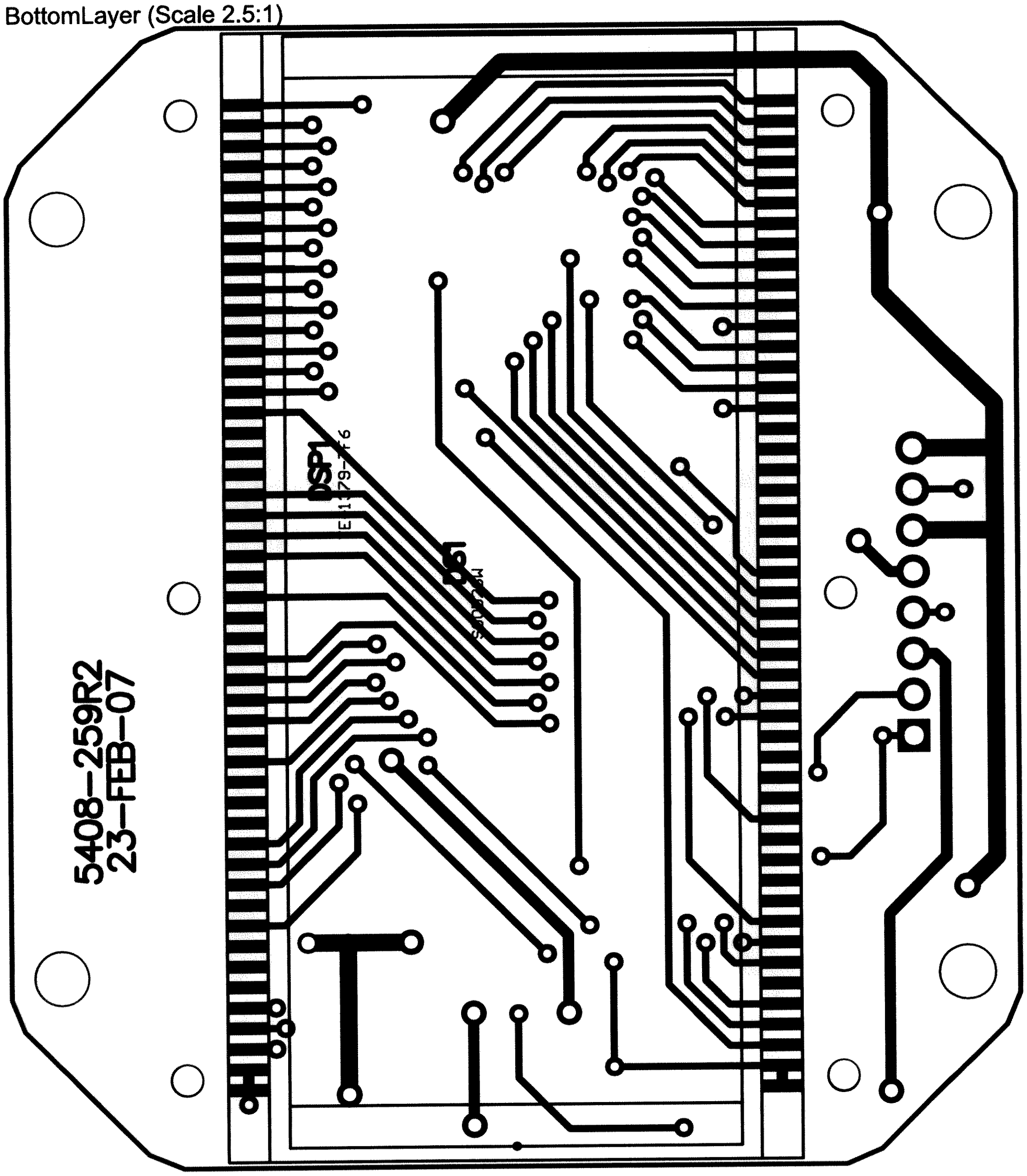

J1
640456-8
MTA100x8
NAME
CLOCK
LOAD
DATA1
DATA0
+5VA
+5V
R1 10K 1/4W 1 %
R2 10K 1/4W 1 %
R3 10K 1/4W 1 %
R4 10K 1/4W 1 %
C1 27pF 100V
R5 392 Ohm 1/8W 1 %
DS1 S0052SW
U1
AY0438T-I/L
U2
AY0438T-I/L
+5V GND CLK LOAD D IN D OUT LCD0 BP NC
DSP1
TE-1379-TF6
COLON
ALARM
ALERT
COUNTING
OVERFLOW
OVERLOAD
BAT
BACKPLANE
LUDLUM MEASUREMENTS, INC.
PO Box 810
501 Oak Street
Sweetwater, Texas 79556
U.S.A. 1-800-622-0828
Drawn: JK 03-JAN-07
Design: RSS 03-JAN-07
Approve: RSS 24 May 07
13:12:20 24-May-2007
408259R2P1.SCH
Title: LED BACKLITE DISPLAY BOARD
Model: M2241
Board#: 5408-259
Sheet: 1 of 1
Rev: 2.0
Series 408
Sheet 259

TopLayer (Scale 2.5:1)

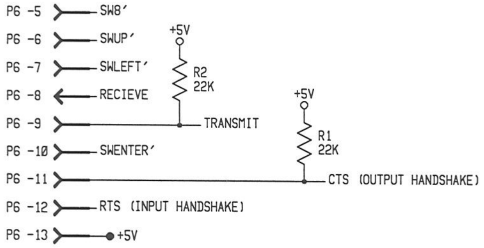


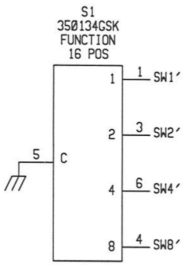
LUDLUM MEASUREMENTS				
Part: 5408-259	Model: 2241			
Desc: LED BACKLITE DISPLAY BD				
Design: RSS	Date: 02/23/07		Rev:	2
Drawn: PAB	Date: 5/5/2022	SHEET	SERIES	SHEET
Apr: RDS	Date: 5 May 22	1 of 3	408	260
W:\Projects\LMI\M 2241\5408-259\Rev2				

BottomLayer (Scale 2.5:1)

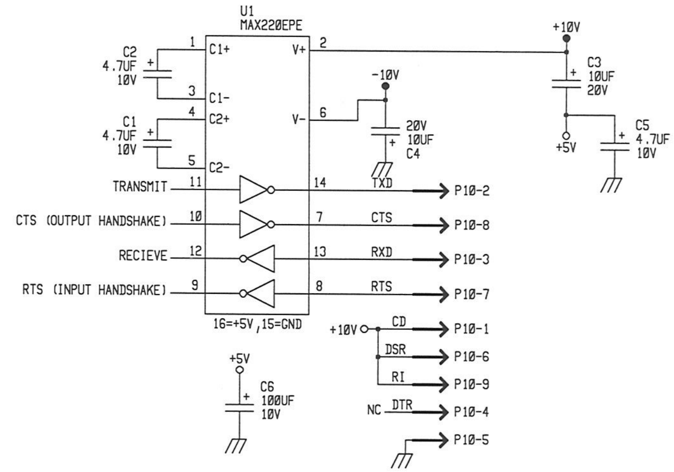


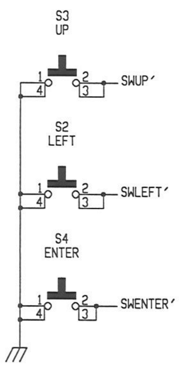
LUDLUM MEASUREMENTS				
Part: 5408-259	**Model:** 2241			
Desc: LED BACKLITE DISPLAY BD				
Design: RSS	**Date:** 02/23/07		**Rev:**	2
Drawn: PAB	**Date:** 5/5/2022	**SHEET**	**SERIES**	**SHEET**
Apr: RDS	**Date:** 5 May 22	2 of 3	408	260
W:\Projects\LMI\M 2241\5408-259\Rev2				





POS	FUNCTION
0	NORMAL OPERATION
1	DEAD TIME (us)
2	CALIBRATION CONSTANT
3	DISPLAY UNITS
4	TIMEBASE: CPS, CPM
5	AUDIO DIVIDE BY
6	RESPONSE TIME
7	RATEMETER ALARM / ALERT
8	SCALER ALARM / COUNT TIME
9	NOT USED
A	DETECTOR SETUP NUMBER
B	LCD BACKLIGHT ON TIME
C	SET MINIMUM DISPLAY
D	RS-232 DATA DUMP MODE
E	RS-232 DETECTOR SETUP MODE
F	RS-232 BAUD RATE





EFF	AUTHORITY	ZONE	LTR	REVISIONS DESCRIPTION	DATE	APPROVED

UPDATED	CKB	21-DEC-00
DR CKB		06/24/96
CHK	RSS	12-21-00
DSGN LL		3/17/93
APPD	RDS	21Dec00
NEXT HIGHER ASSY. -		
09:54:25		21-Dec-00

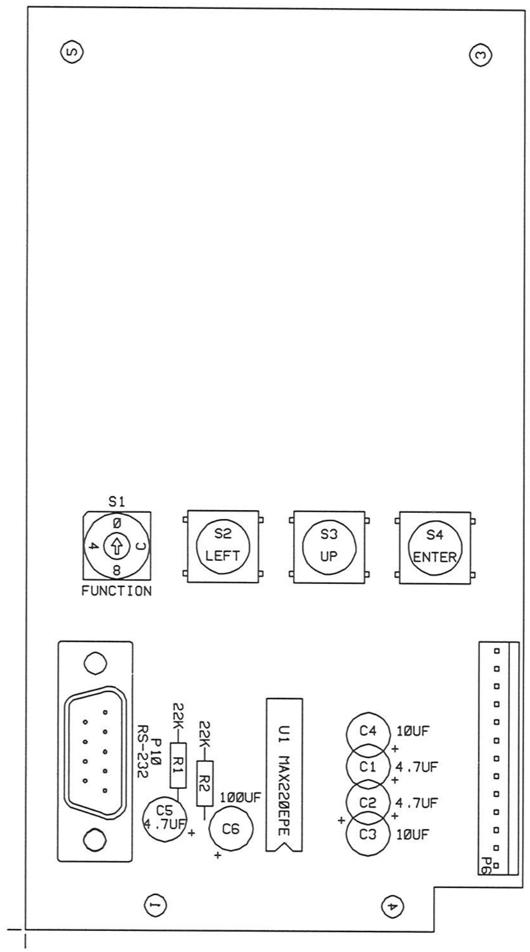
LUDLUM MEASUREMENTS INC.

TITLE: SWITCH BOARD

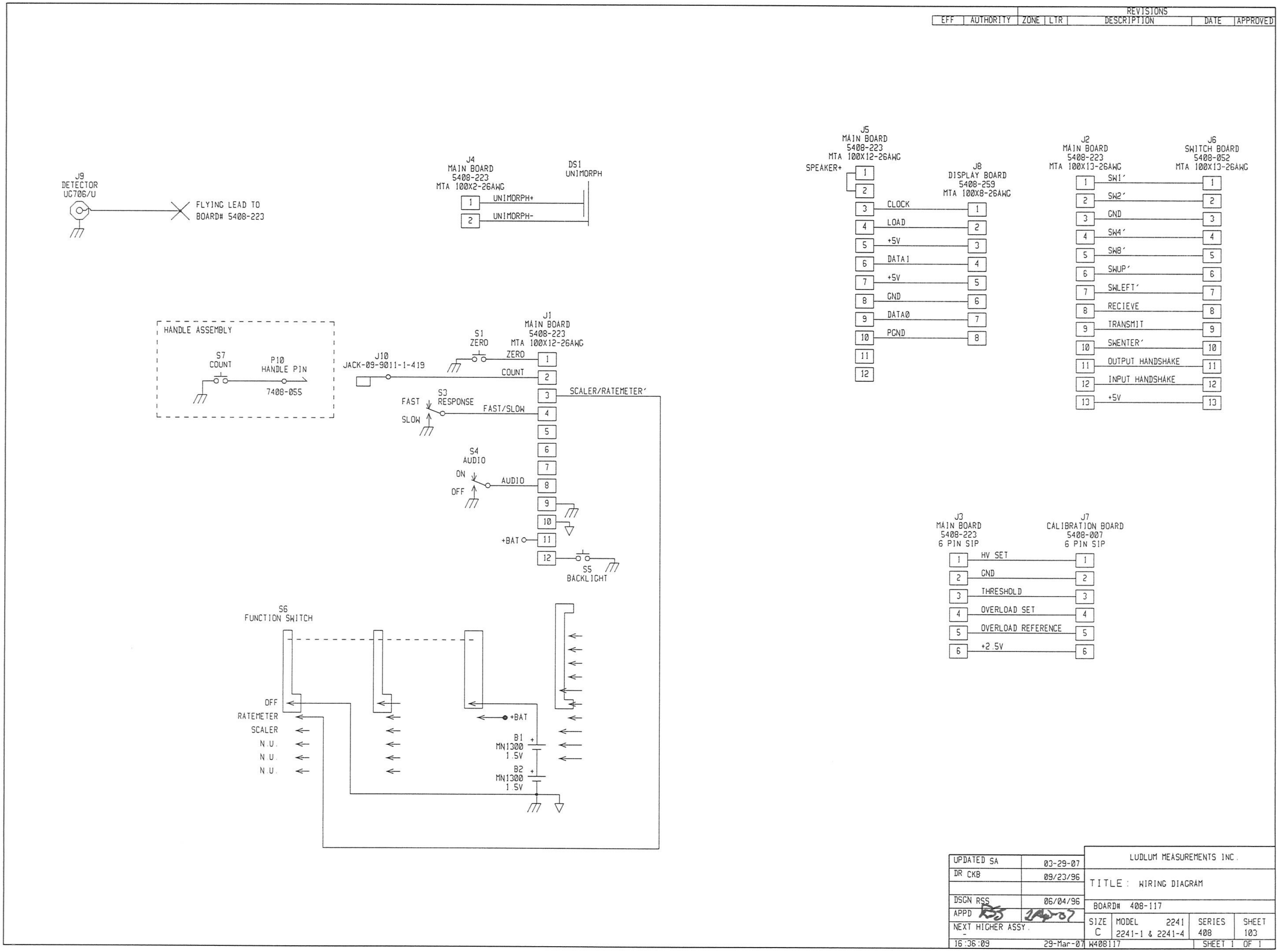
BOARD# 5408-052

SIZE	MODEL	SERIES	SHEET
C	2241	408	45

S8408052 SHEET 1 OF 1



LUDLUM MEASUREMENTS INC. SWEETWATER, TX.			
DR	CKB	06/24/96	TITLE: SWITCH BOARD
CHK	RSS	12-21-00	BOARD: 5408-052
DSGN	LL	03/16/94	MODEL: 2241
APP	RDS	21 Dec 00	FILENAME: BS408052
COMPONENT		SOLDER	09:52:54 21-Dec-00
OUTLINE		OUTLINE	REVISION 1.0 / SERIES 408 / SHEET 46


REVISIONS
EFF
AUTHORITY
ZONE
LTR
DESCRIPTION
DATE
APPROVED
J9
DETECTOR
UG706/U
FLYING LEAD TO
BOARD# 5408-223
J4
MAIN BOARD
5408-223
MTA 100X2-26AWG
UNIMORPH+
UNIMORPH-
DS1
UNIMORPH
J5
MAIN BOARD
5408-223
MTA 100X12-26AWG
SPEAKER+
CLOCK
LOAD
+5V
DATA1
+5V
GND
DATA0
PGND
J8
DISPLAY BOARD
5408-259
MTA 100X8-26AWG
J2
MAIN BOARD
5408-223
MTA 100X13-26AWG
SW1′
SW2′
GND
SW4′
SW8′
SWUP′
SWLEFT′
RECIEVE
TRANSMIT
SWENTER′
OUTPUT HANDSHAKE
INPUT HANDSHAKE
+5V
J6
SWITCH BOARD
5408-052
MTA 100X13-26AWG
HANDLE ASSEMBLY
S7
COUNT
P10
HANDLE PIN
7408-055
J10
JACK-09-9011-1-419
S1
ZERO
J1
MAIN BOARD
5408-223
MTA 100X12-26AWG
ZERO
COUNT
SCALER/RATEMETER′
FAST
S3
RESPONSE
SLOW
FAST/SLOW
S4
AUDIO
ON
OFF
AUDIO
+BAT
S5
BACKLIGHT
J3
MAIN BOARD
5408-223
6 PIN SIP
HV SET
GND
THRESHOLD
OVERLOAD SET
OVERLOAD REFERENCE
+2.5V
J7
CALIBRATION BOARD
5408-007
6 PIN SIP
S6
FUNCTION SWITCH
OFF
RATEMETER
SCALER
N.U.
N.U.
N.U.
+BAT
B1
MN1300
1.5V
B2
MN1300
1.5V
UPDATED SA 03-29-07
DR CKB 09/23/96
DSGN RSS 06/04/96
APPD RSS 2-Apr-07
NEXT HIGHER ASSY.
16:36:09 29-Mar-07 W408117
LUDLUM MEASUREMENTS INC.
TITLE: WIRING DIAGRAM
BOARD# 408-117
SIZE C
MODEL 2241 2241-1 & 2241-4
SERIES 408
SHEET 103
SHEET 1 OF 1

Appendix

A

RS-232 Output Formats

The Ludlum Model 2241 series of instruments has an RS-232 serial communications port that can be used to log readings and read or set instrument parameters. There are two formats available. Most Model 2241 instruments have the binary format outlined below, but some newer Model 2241-2 units have an ASCII output, which is also outlined below following the binary format explanation.

The RS-232 port is configured at 9600 baud, 8 data bits, no parity, and 1 stop bit (9600,8,N,1). Ludlum Measurements can supply a Windows-based software that can be used to help calibrate the instruments, but note that it will not communicate with the newer ASCII output Model 2241-2 units.

Binary Output Format (15 Bytes)

BYTE01	RatemeterCPS+0	MSB
BYTE02	RatemeterCPS+1	
BYTE03	RatemeterCPS+2	
BYTE04	RatemeterCPE+3	LSB
BYTE05	Scaler+0	MSB
BYTE06	Sclaer+1	
BYTE07	Scaler+2	
BYTE08	Scaler+3	
BYTE09	Scaler+4	LSB
BYTE10	CountTime+0	MSB
BYTE11	CountTime+1	LSB
BYTE12	CountTimeLeft+0	MSB
BYTE13	CountTimeLeft+1	LSB
BYTE14	Carriage Return (0DH)	
BYTE15	Line Feed (0AH)	

The ratemeter value is in cps and is scaled by a factor of 256. To get the ratemeter reading in cpm, take the value and divide by 256, and then multiply by 60.

RS-232 Commands

E – auto dump off

A – auto dump on

C – start scaler

F – set scaler count time

R – send parameters from instrument to computer

S – read parameters from computer to instrument

O – output once

All commands must be sent in upper case laters.

Output of "R" Command – Read Parameters

BYTE01	Detector+0	
BYTE02	DeadConstant+0	MSB
BYTE03	DeadConstant+1	LSB
BYTE04	CaConstant+0	MSB
BYTE05	CalConstant+1	
BYTE06	CalConstant+2	
BYTE07	CalConstant+3	
BYTE08	CalConstant+4	
BYTE09	CalConstant+5	LSB
BYTE10	RateAlarm+0	MSB
BYTE11	RateAlarm+1	
BYTE12	RateAlarm+2	
BYTE13	RateAlarm+3	
BYTE14	RateAlarm+4	LSB
BYTE15	ScalerAlarm+0	MSB
BYTE16	ScalerAlarm+1	
BYTE17	ScalerAlarm+2	
BYTE18	ScalerAlarm+3	
BYTE19	ScalerAlarm+4	LSB
BYTE20	CountTime+0	MSB
BYTE21	CountTime+1	LSB
BYTE22	Units+0	
BYTE23	TimeBase+0	
BYTE24	AudioDivideBy+0	
BYTE25	Response+0	
BYTE26	RateAlert+0	MSB
BYTE27	RateAlert+1	
BYTE28	RateAlert+2	
BYTE29	RateAlert+3	
BYTE30	RateAlert+4	LSB
BYTE31	CheckSource+0	MSB
BYTE32	CheckSource+1	
BYTE33	CheckSource+2	

BYTE34	CheckSource+3	
BYTE35	CheckSource+4	LSB
BYTE36	PercentCS+0	
BYTE37	MinDisplay+0	
BYTE38	Carriage Return (0DH)	
BYTE39	Line Feed (0AH)	

Input of "S" Command – Send Parameters

BYTE1	DeadCosntant+0	MSB
BYTE2	DeadConstant+1	LSB
BYTE3	CalConstant+0	MSB
BYTE4	CalConstant+1	
BYTE5	CalConstant+2	
BYTE6	CalCosntant+3	
BYTE7	CalConstant+4	
BYTE8	CalConstant+5	LSB
BYTE9	RateAlarm+0	MSB
BYTE10	RateAlarm+1	
BYTE11	RateAlarm+2	
BYTE12	RateAlarm+3	
BYTE13	RateAlarm+4	LSB
BYTE14	ScalerAlarm+0	MSB
BYTE15	ScalerAlarm+1	
BYTE16	ScalerAlarm+2	
BYTE17	ScalerAlarm+3	
BYTE18	ScalerAlarm+4	LSB
BYTE19	CountTime+0	MSB
BYTE20	CountTime+1	LSB
BYTE21	Units+0	
BYTE22	TimeBase+0	
BYTE23	AudioDivdeBy+0	
BYTE24	Response+0	
BYTE25	RateAlert+0	MSB
BYTE26	RateAlert+1	
BYTE27	RateAlert+2	
BYTE28	RateAlert+3	
BYTE29	RateAlert+4	LSB
BYTE30	CheckSource+0	MSB
BYTE31	CheckSource+1	
BYTE32	CheckSource+2	
BYTE33	CheckSource+3	
BYTE34	CheckSource+4	LSB
BYTE35	PercentCS+0	
BYTE36	MinDisplay+0	

Input of "F" Command – Set Count Time

BYTE1	CountTime+0	MSB
BYTE2	CountTime+1	LSB

Units 0 = R
1 = Sv
2 = cpm

Timebase 0 = min
1 = seconds

AudioDivide 0 = Auto
1 = Manual

ASCII Output Format

This special firmware changes the format of the auto-dump from binary to ASCII. The output interval remains the same (2 seconds).

2241	Special Firmware 40804n10	08/06/2003
2241-2	Special Firmware 40806n13	04/04/2003
2241-3	Special Firmware 40806n16	07/07/2004

The old format was (binary):

Byte 1	Ratemeter CPS + 0
Byte 2	Ratemeter CPS + 1
Byte 3	Ratemeter CPS + 2
Byte 4	Ratemeter CPS + 3
Byte 5	Scaler + 0
Byte 6	Scaler + 1
Byte 7	Scaler + 2
Byte 8	Scaler + 3
Byte 9	Scaler + 4
Byte 10	Count Time + 0
Byte 11	Count Time + 1
Byte 12	Count Time Left + 0
Byte 13	Count Time Left + 1
Byte 14	Carriage Return (0DH)
Byte 15	Line Feed (0AH)

and is now replaced with (ASCII):

byte 1	x	Ratemeter
byte 2	x	Raetemter
byte 3	x	Ratemeter
byte 4	x	Ratemeter
byte 5	x	Ratemeter
byte 6	y	Display units
byte 7	Carriage Return (0DH)	

byte 8	Line Feed (0AH)

The ratemeter is displayed as 5 ASCII digits with a decimal, if necessary, and matches the LCD display on the 2241-2.
The display mode is a value from 0 to 9 representing the display units.

CPS	0
KCPS	1
CPM	2
KCPM	3
μR	4
mR	5
R	6
μSv	7
mSv	8
Sv	9

Note: The LMI Model 2241 calibration software is not compatible with this firmware version.

Example output:

02.991	(=2.99 kcps)
01.801	(=1.80 kcps)
01.221	(=1.22 kcps)
00.831	(=0.83 kcps)
00.581	(=0.58 kcps)
004160	(=416 cps)