LUDLUM MODEL 2241-3 & 2241-3i
SURVEY METER

March 2024

Serial Number 299171 and Succeeding

Serial Numbers

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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.

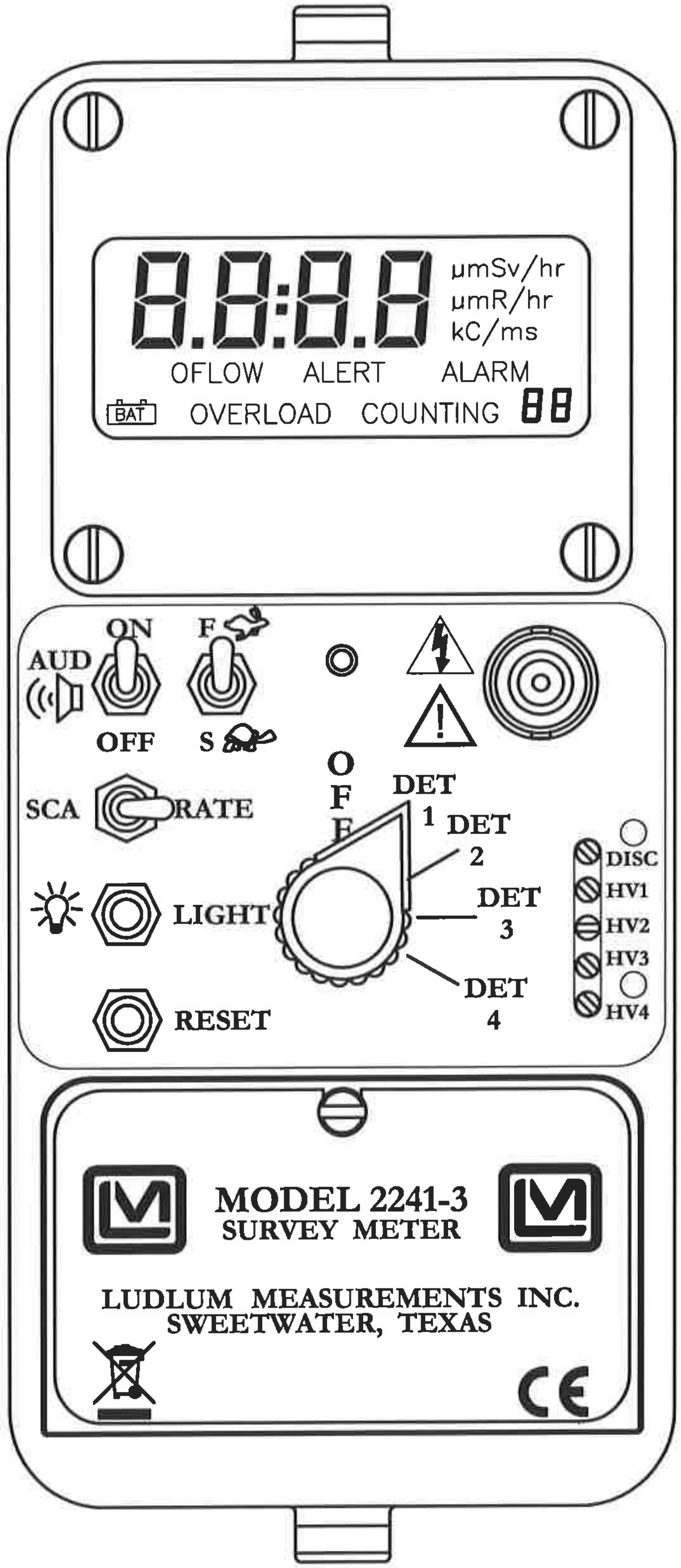
RETURN OF GOODS TO MANUFACTURER

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	02/19/04	CLW
2	ADDED DO NOT DISCARD SYMBOL	8/10/06	CMC
3	REMOVED CAL HOLE	10/17/06	CMC



CHG	NO.		DWN	CHK	APP
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TOL: SHOP STD ☐ OTHER		SCALE: FULL ☐ OTHER			
TITLE MODEL 2241-3					
LUDLUM MEASUREMENTS, INC. 501 OAK STREET SWEETWATER, TEXAS 79556		SERIES 408		SHEET 84	

REV #	ALTERATIONS	DATE	BY
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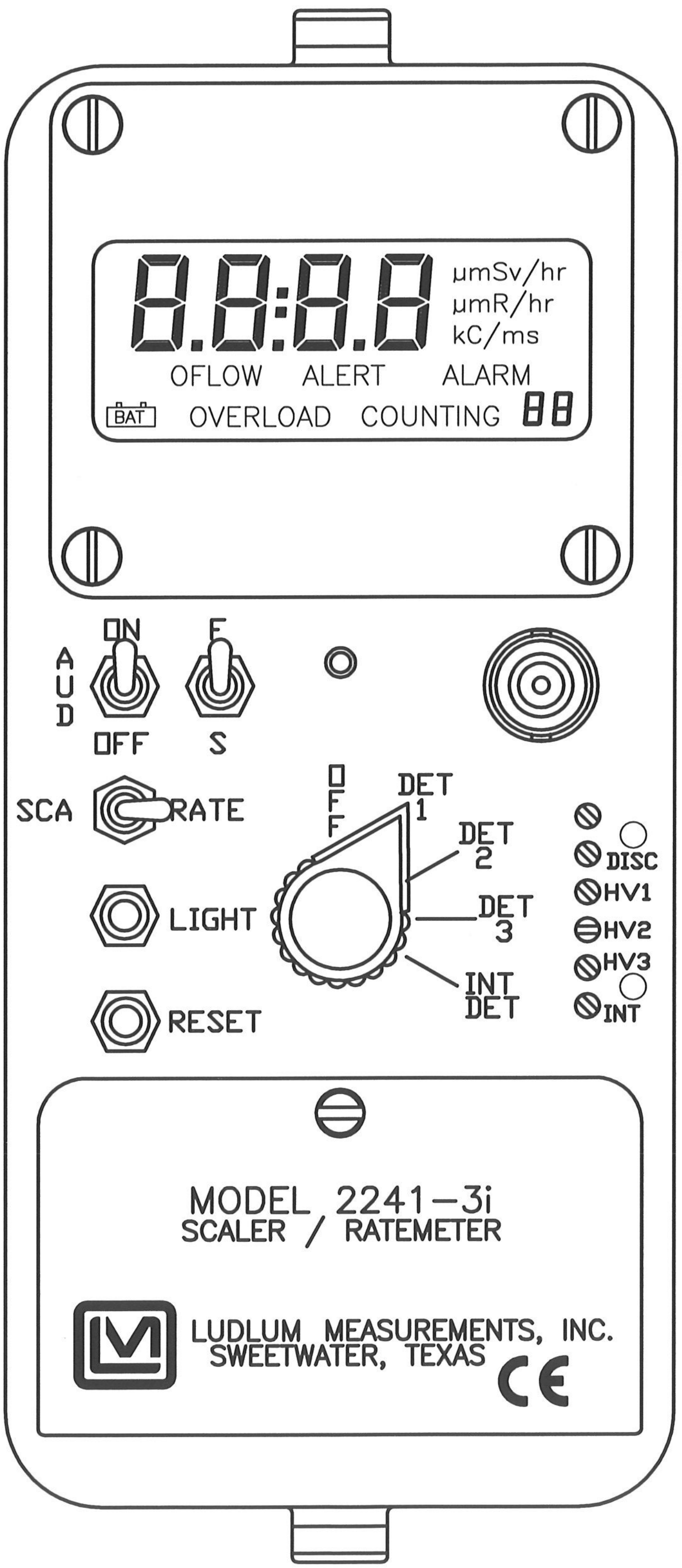


DWN	DATE	CHK	DATE	APP	DATE
CLW	8-20-04			PV	8-23-04

PART NUM: 4408-196	SCALE: FULL ☒ OTHER
TITLE M 2241-3i	
LUDLUM MEASUREMENTS, INC. 501 OAK STREET SWEETWATER, TEXAS 79556	SERIES 408 / SHEET 196

Table of Contents

Section 1

Introduction

The Model 2241-3 is a portable microprocessor-based digital Scaler/Ratemeter designed for use with scintillation, Geiger-Mueller (GM), and proportional-type detectors for measurement of ionizing radiation. Data is presented on a four-digit (six digits in the scaler mode) Liquid Crystal Display (LCD) with moving decimal point. A toggle switch labeled SCA/RATE selects the desired operating mode for the instrument. A five-position switch labeled "OFF/DET 1/DET 2/DET 3/DET 4" allows for a quick change of operating parameters when changing out detectors.

Programmable display units (RATEMETER mode only) can be represented in R/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: 1) Dead Time Correction (DTC) to compensate for detector dead time; 2) audible click-per-event with programmable 1, 10, 100, and 1000 divide-by; 3) LCD backlight with programmable ON time; 4) programmable fixed or variable response time; and 5) count overflow visual alarm, indicative of the counting circuitry 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. Four 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, four independent set-point controls adjustable from 400 to 2500 volts, and adjustable discrimination levels, add versatility to the instrument. This supports operation for a broad range of detectors and connecting cable lengths. All of the calibration controls are covered to prevent any inadvertent adjustment 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 **Model 2241-3i** is identical to the Model 2241-3 except for the following:

The five-position selector switch located on the front panel has been modified to provide for selection of an internal detector. When selected, the INT position (formerly DET4) switches detector operation to an internal, energy-compensated Geiger-Mueller detector. Appropriate wiring changes to accommodate the internal detector have been made; however, physical dimensions are the same as for a Model 2241-3.

A drawing of the front-panel of the 2241-3i is included at the beginning of this manual. A wiring diagram for the instrument is included in the back of the manual with the other drawings. The internal detector specifications can be found at the end of Section 3 of this manual.

Section

2

Getting Started

Unpacking and Repacking

Remove the calibration certificates and place them in a secure location. Remove the instrument, detectors, 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 2241-3 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!

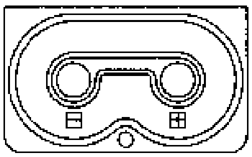
If multiple shipments are received, ensure that the detectors and instruments are not interchanged. Each instrument is calibrated to specific detectors, and are therefore, not interchangeable.

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/DET 1/DET 2/DET 3/DET 4 switch is in the OFF position. Open the battery lid by turning the quarter-turn thumb screw counter-



clockwise. 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.

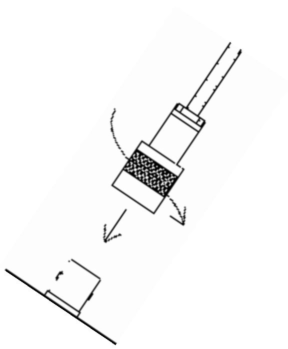
Note:

The center post of "D" size battery is positive.

Connecting a Detector

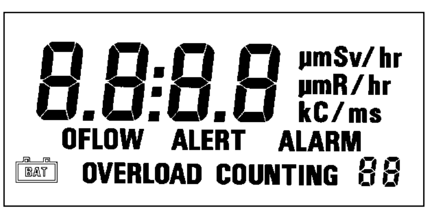
Caution!

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 2241-3 to the OFF position before connecting or disconnecting the cable or detector.

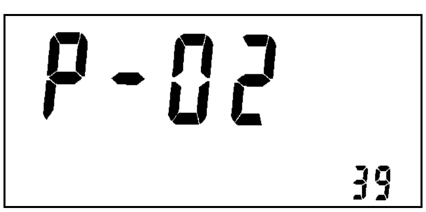


Connect a detector to the Model 2241-3 by using the cable provided; firmly pushing the connectors together while twisting clockwise until the connector latches (1/4 turn). The diagram to the left illustrates how this is done. Next, place the detector selector switch in the appropriate position.

Operational Check

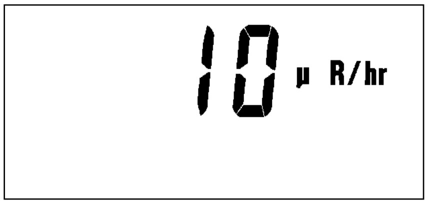


Place the SCA/RATE (scaler/ratemeter) switch in the RATE position. Notice that the display goes through an initialization sequence. The display will show all "8"s with decimal points. Check to make sure all segments display, as illustrated in the diagram to the left.



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 SCA 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 2241-3 uses multiples of 5. This technique keeps the decimal point from jumping between numbers when viewing values around multiples of 10.

Check for a proper background reading:

If using a Ludlum Model 44-9 detector, a typical reading would be 25-50 cpm or 8-15 µR/hr.

If using a Ludlum Model 44-2 detector, a typical reading would be 1.4-2.6 kcpm or 8-15 µR/hr.

If using a Ludlum Model 133-7 detector, a typical reading would be 0 cpm or 8-15 µR/hr.

A reference reading (or readings) with a check source should be obtained with the detector(s) in a constant and reproducible manner at the time of calibration or at the time the instrument is received in the field.

If at any time the instrument fails to read within 20% of the reference reading when using the same check source, it should be sent to a calibration facility for recalibration and/or repair. If desired, multiple readings may be taken at different distances and/or with different sources so that other ranges or scales are checked.

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.

Increase the source activity or lower the alert and alarm points to initiate an ALERT and ALARM condition. (Refer to Section 8, Subsection "Entering or Changing Switchboard Parameters.") Depress the RESET switch to acknowledge the audible alarm. Decrease the radiation activity below the ALERT and ALARM threshold and depress the RESET switch to clear the alarm conditions. If an alarm condition is not present, depressing the RESET switch the first time will reset the alert condition and zero the ratemeter.

Position a check source to produce a ratemeter reading of 100 to 2000 counts per minute or 10-100 µR/hr. While observing the ratemeter fluctuations, select between the fast and slow response time (F/S) positions to observe variations in the display. The S position should respond approximately five times slower than the F position (for fixed response mode) and three times slower when in variable response mode. The slow response position is normally used when the Model 2241-3 is displaying low numbers, which require a more stable display. The fast response position is used at high count levels.

Place the SCA/RATE switch to the SCA 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 RATE/SCA parameters and proceed to use the instrument.

Section

3

Specifications

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.) high 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 (not used), counting OVERFLOW, and scaler COUNTING.

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

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
>
> **High Voltage**: four independent controls, each adjustable from 400-2500 volts; four separate set points for each detector setup- HV 1, HV 2, HV 3, and HV 4, 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.

Note:

The RESET button only silences the alarm in the current mode that the instrument is in. For example, the RESET button will not affect the **scaler** alarm if the instrument is in the **ratemeter** mode.

Light: display backlight activated by pushbutton

Audio: built-in audio speaker (unimorph) with AUD ON/OFF switch; at maximum volume > 60 dB at 2 feet; internal adjustable volume

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

Power: two each, ˝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: 16.5 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, 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). 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**: dependent on the number of counts present, typically 4 to 25 seconds for FAST, and 4 to 60 seconds for SLOW
>
> **Fixed Response**: The parameter is adjustable from 1-25 seconds resulting in a FAST response from approximately 2-50 seconds. The SLOW response is approximately 10-250 seconds. 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

Internal Detector Specifications for Model 2241-3i:

Operating Voltage: recommended 550 volts

Input Sensitivity: -30 mV ±10 mV

Dead Time: typically 80 microseconds

Energy Reponse: within ±15%

Tube: 30 mg/cm^2 stainless steel (Halogen quench) GM

Size: 2.3 x 10.2 (0.9 x 4 in.) (Dia x L)

Temperature Range: -20 to 50 °C (-4 to 122 °F)

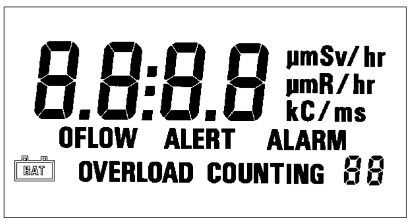
Section

4

Identification of Controls and Functions

Display

The Model 2241-3 utilizes a four-digit liquid crystal display (LCD) with a 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 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 (not used) enunciators 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 right corner) reaches "999999" and starts to roll over again.

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/DET 1/DET 2/DET 3/DET 4 Switch: a five-position rotary switch that applies power to the instrument and selects the desired set of detector parameters

SCA/RATE (Mode) Switch: a protected (locking) toggle switch that toggles between ratemeter or scaler counting modes. The user pulls up and then over to change modes.

AUD ON/OFF Switch: The click-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 click-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: 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 2241-3 handle.

Note:

The RESET button only silences the alarm in the current mode that the instrument is in. For example, the RESET button will not affect the **scaler** alarm if the instrument is in the **ratemeter** mode.

Scaler Count Switch: pushbutton switch located in the end of the Model 2241-3 carrying handle, which when depressed, initializes the start of the scaler count accumulation for the preset scaling time. The SCA/RATE switch must be in the SCA 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 potentiometers, make note of the following precautions: 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.

HV1, HV2, HV3, HV4: multi-turn potentiometers (approximately 20 revolutions) that vary the detector voltage from 400 to 2500 volts. The maximum high-voltage output is adjusted by the HV LIMIT potentiometer located on the internal main board.

Main Board Controls

Note:

To access the internal circuit boards, unlatch the latches at each end of the Model 2241-3. 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 2500 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 2241-3 batteries are removed. After the parameters are entered, the switch board can be removed and the Model 2241-3 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 2241-3 to the OFF position before connecting or disconnecting the cable or detector.

Warning Markings and Symbols

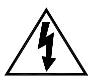
Caution!

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 2241-3 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.

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

Section

6

Maintenance

Instrument maintenance consists of keeping the instrument clean and periodically checking the batteries and the calibration. The Model 2241-3 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.

Operational Check

An instrument operational check should be performed prior to each use by exposing the detector to the supplied check source, confirming the proper reading on each scale. See Section 2, Subsection "Operational Check," for further details.

Recalibration

Recalibration should be accomplished after any maintenance or adjustment of any kind has been performed on the instrument. Battery and cable replacements (of same length) and exterior cleanings do not normally require the instrument be recalibrated.

Note:

Ludlum Measurements, Inc. recommends recalibration at intervals no greater than one year. Check the appropriate local state and federal 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.

See Section 8 "Instrument Setup & Calibration," for further details on instrument calibration.

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, more frequent battery servicing should be used. 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 Principle 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 with 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.

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, meaning 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 2241-3. The switch selects the parameters using the hexadecimal numbering system via buss lines SW1-SW4.

S2-S4

S2-S4 are pushbutton switches which 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 2241-3 to a computer.

Refer to Display Board schematic for the following:

LCD Drive

U111 and U211 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 U211 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 start 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.

Note:

The DETECTOR SELECT switch allows the Model 2241-3 to have four sets of operating parameters.

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 2241-3	Cpm Setup 01	uR/hr Setup 02	R/Hr Setup 03	mR/hr Setup 04
Dead Time	0 µs	0 µs	0 µs	0 µs
Cal Const	100e-2	105e+8	108e+4	198e+6
Rate Alarm	50.0 kcpm	50 µR/hr	5 R/hr	5 mR/hr
Scaler Alarm	85000	85000	85000	85000
Count Time	12 s	12 s	12 s	12 s
Time Base	Minutes	Seconds	Seconds	Seconds
Units	cpm	R/hr	R/hr	R/hr
Audio Divide-By	1	1	1	1
Response	0	0	0	0
Check Source	0	0	0	0
Percent CS	0	0	0	0
Rate Alert	20.0 kcpm	20 µR/hr	2 R/hr	2 mR/hr
Minimum Display	0.00 cpm	00.0 µR/hr	00.0 µR/hr	00.0 µR/hr
Baud Rate	9600			
LCD Time Off	5 s			
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 2241-3. 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
Durrent detector setup in use
RS-232 communication baud rate
RS-232 data dump mode
RS-232 detector parameters set/read mode

Function Switch Position Descriptions and Variables

POSITION 0: NORMAL OPERATION places the Model 2241-3 in the normal (counting) operating mode. Unplugging the switch board from the Model 2241-3 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

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

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 readout in cps (counts per second) or cpm (counts per minute).

CC CONVERSION TABLE

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

Example:

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

POSITION 3: DISPLAY UNITS selects the display units for the associated detector setup number. The Model 2241-3 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 2241-3 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 (Roentgens 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 click-per-event division rate for the current detector setup. If the AUD ON/OFF switch is in the OFF position, no audible click-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 2241-3 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) or 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 2241-3 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 eight data bits, one 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 nine-pin "D" type connector is designed as a DCE port. A straight wire cable (extension cable) connects the Model 2241-3 to a computer's nine-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 2241-3. 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 before installing any LMI software.

Calibration

The Model 2241-3 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.

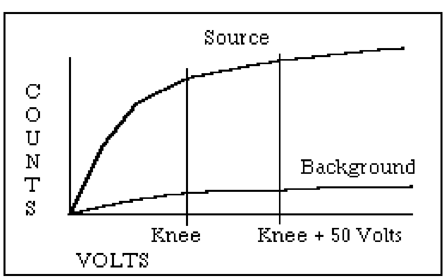
For most GM detectors, set DISC for 30-40 millivolts and adjust HV to the GM detector recommended high voltage. Most GM detectors operate at 900 volts, although some miniature detectors operate at 450-550 volts. If a recommended setting is unavailable, plot count rate versus HV to produce a plateau graph. 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.

Note:

If a Model 133-6 detector is used with a Model 2241-3 and calibrated to 1000 R/hr using series constant firmware, R031 on the 2241-3 main board must be changed from 4.7M to a 1M resistor (part # 10-7028).

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 2241-3 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$_{\text{ALARM00}}$" 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 2241-3 discrimination level.
- Adjust the pulser output to 800 cpm and confirm that the Model 2241-3 reads 800 cpm ±10% on the ratemeter setting.
- Adjust the pulser output to 200 cpm and confirm that the Model 2241-3 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 2241-3. 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

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

Equation 2

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

Equation 3

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

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

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

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

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

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

Equation 8

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

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

Example

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

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

Equation 9

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

Example

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

Solve for a_d:

Equation 10

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

Example

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

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

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

Solve for f_{cal}:

Equation 12

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

Example

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

Enter the result of equation (12) into:

Equation 13

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

and solve for CC:

Example

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

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 2241-3. 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 2241-3 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): Rick Srola **Date:** 20Jan06
Approved by: Ed [illegible] **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 2241-3 Survey Meter	UNIT	Completely Assembled Model 2241-3 Survey Meter	48-2864
Model 2241-3i Survey Meter	UNIT	Completely Assembled Model 2241-3i Survey Meter	48-3358
Main Circuit Board, Drawing 408 × 226	BOARD	Completely Assembled Main Circuit Board	5408-226
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	47uF, 10V	04-5666
	C121	47uF, 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

	Reference	Description	Part Number
	C139	0.001µF, 100V	04-5659
	C141	0.0047F, 3KV	04-5547
	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
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, VOLUME	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
	R023	10K, 1/4W, 1%	12-7839
	R024-R025	4.75K, 1/4W, 1%	12-7858

	Reference	Description	Part Number
	R026	8.25K, 1/8W, 1%	12-7838
	R031	4.75M, 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	100Ohm, 1/4W, 1%	12-7840
	R122	6.81K, 1/4W, 1%	12-7857
	R131	1M, 1/4W, 1%	12-7844
	R132	511K, 1/8W, 1%	12-7896
	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-P2	1-640456-3, MTA100X13	13-8100
	P3	640456-6, MTA100X6	13-8095
	P4	640456-2, MTA100X2	13-8073
	P5	1-640456-2, MTA100X12	13-8061

Calibration Board, Drawing 408 × 98

	Reference	Description	Part Number
	BOARD	Completely Assembled Calibration Board	5408-113
POTENTIOMETERS	R115	1M, HV1 SET	09-6814
	R116	100K, DISC.	09-6813
	R117	1M, HV2 SET	09-6814
	R118	1M, HV3 SET	09-6814
	R119	1M, HV4 SET	09-6814

	Reference	Description	Part Number
RESISTORS	R110	1M, 1/3W	12-7751
	R111	10K, 1/3W	12-7748
	R112	1M, 1/3W	12-7751
	R113	1K, 1/3W	12-7750
	R114	1M, 1/3W	12-7751
	R120	1M, 1/3W	12-7751
CONNECTOR	P7	CONN-640456-7, MTA100	13-8115
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	R1-R4	10.0K, 1%, 125mW	12-7839
	R5	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 for Model 2241-3, Drawing 408 × 101			
SWITCHES	S1	30-1-PB GRAYHILL	08-6517
	S2	PA-1012	08-6540
	S3-S4	7101-SYZ-QE C&K	08-6511
	S5	30-1-PB GRAYHILL	08-6517
	S6	7201KZQE Toggle	08-6749
	S7	MPS-103F	08-6699
	*	Switch Cap	08-6871
RESISTOR	R1	10 M, 1/4W, 5%	10-7031
CONNECTORS	J1 J2	CONN-1-640442-3, MTA100	13-8138
	J3	CONN-640442-6, MTA100	13-8171
	J4	CONN-640442-2, MTA100	13-8178
	J5	CONN-1-640442-2, MTA100	13-8407
	J6	CONN-1-640442-3, MTA100	13-8138
	J7	CONN-640442-7, MTA100	13-8172
	J8	CONN-640442-8, MTA100	13-8184
	J9	Series "C" -UG706/U	13-7777
	J10	JACK-09-9011-1-4193	18-9080
	P10	Handle Pin	7408-055

	Reference	Description	Part Number
AUDIO	DS1	UNIMORPH	21-9251
BATTERY	B1-B2	″D″ Duracell Battery	21-9313
MISCELLANEOUS	*	Model 2241 Switch Board Add On	4408-053
	*	Model 2241 Digital Bezel Assembly	4408-051
	*	Portable Battery Contact Set	2001-042
	*	Model 2241-3 Main Harness	8408-121
	*	Portable Harness Can Wires	8363-462
	*	Switch Board Harness	8408-027
	*	Portable Can Assembly (MTA)	4363-441
	*	Can Gasket	22-9773
	*	Portable Knob	08-6613
	*	Assembled Battery Lid	2363-191
	*	Portable Battery Gasket	7363-183
	*	Portable Calibration Cover with Screws	9363-200
	*	Model 2241-3 Flat Handle Assembly without Clip	4408-179
	*	Cable-C 1 meter (39 in.) only	40-1004
	*	Model 2241-3 Casting	7408-185

Chassis Wiring Diagram for Model 2241-3i, Drawing 408 × 263

(All parts are the same as those for the Model 2241-3 Wiring Diagram above, except for what is below.)

INTERNAL DETECTOR ASSEMBLY	5408-160

Section

11

Drawings

Main Circuit Board, Drawings 408 × 226 (3 sheets)

Main Circuit Board Component Layout, Drawing 408 × 227

Calibration Board, Drawing 408 × 98

Calibration Board Component Layout, Drawings 408 × 99 (2 sheets)

Display Board, Drawing 408 × 259

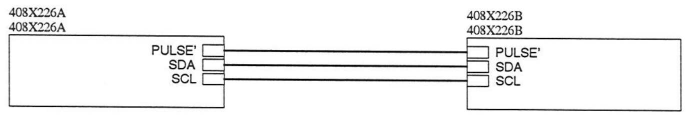
Display Board Component Layout, Drawings 408 × 260 (2 sheets)

Switch Board, Drawing 408 × 45

Switch Board Component Layout, Drawing 408 × 46

Wiring Diagram, Drawing 408 ×101

Wiring Diagram for Model 2241-3i, Drawing 408 × 263



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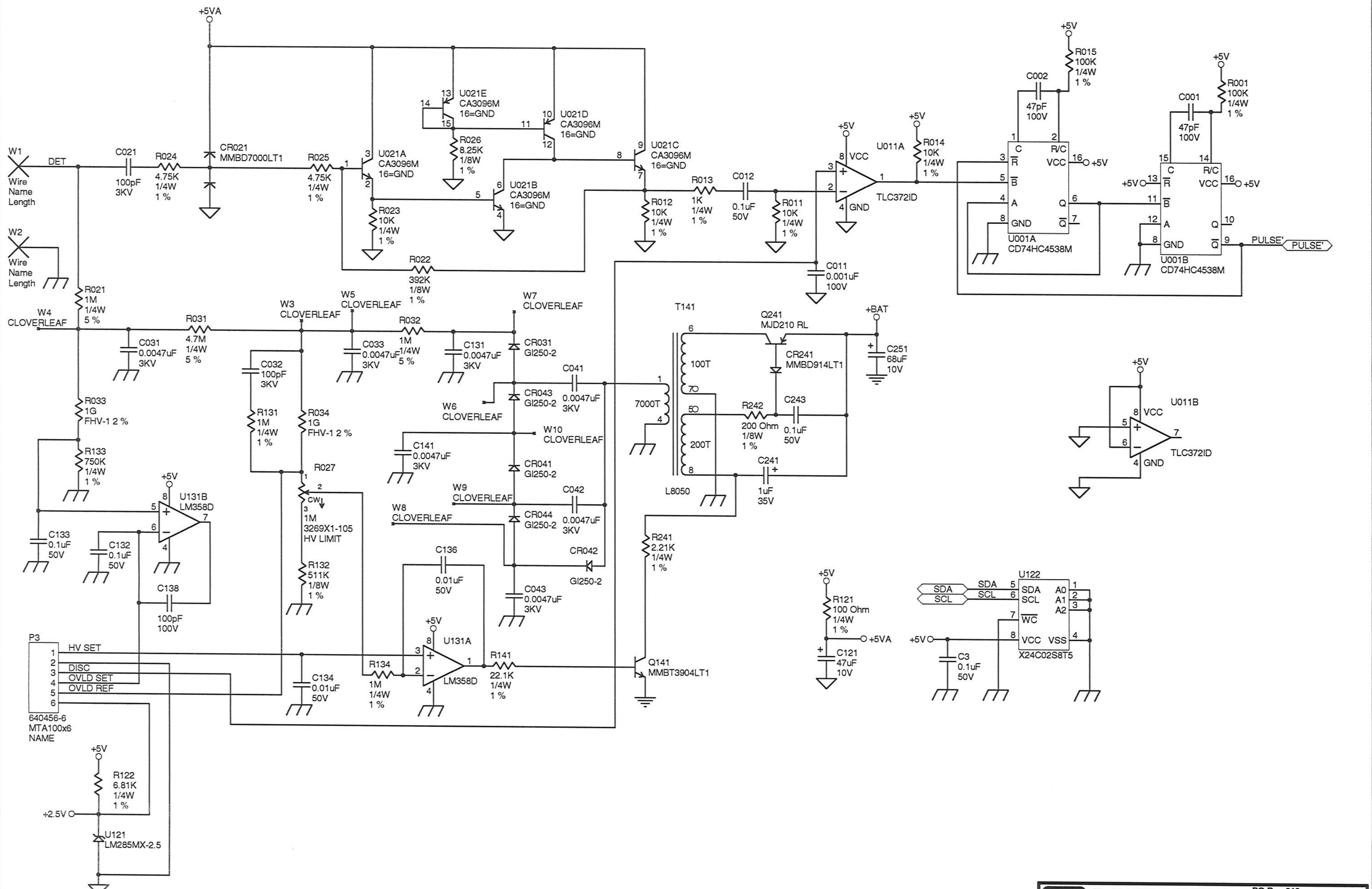
501 Oak Street
Sweetwater, Texas 79556
U.S.A. 1-800-622-0828

Drawn: SA	01/19/05	Title: MAIN BOARD	
Design: RSS	01/04/05	Model: 2241-3	
		Board#: 5408-226	
Approve: RSS	17 Jan 05	Sheet: 1 of 3	Series 408
14:13:35	19-Jan-2005	Rev: 1.0	Sheet 226
408x226			



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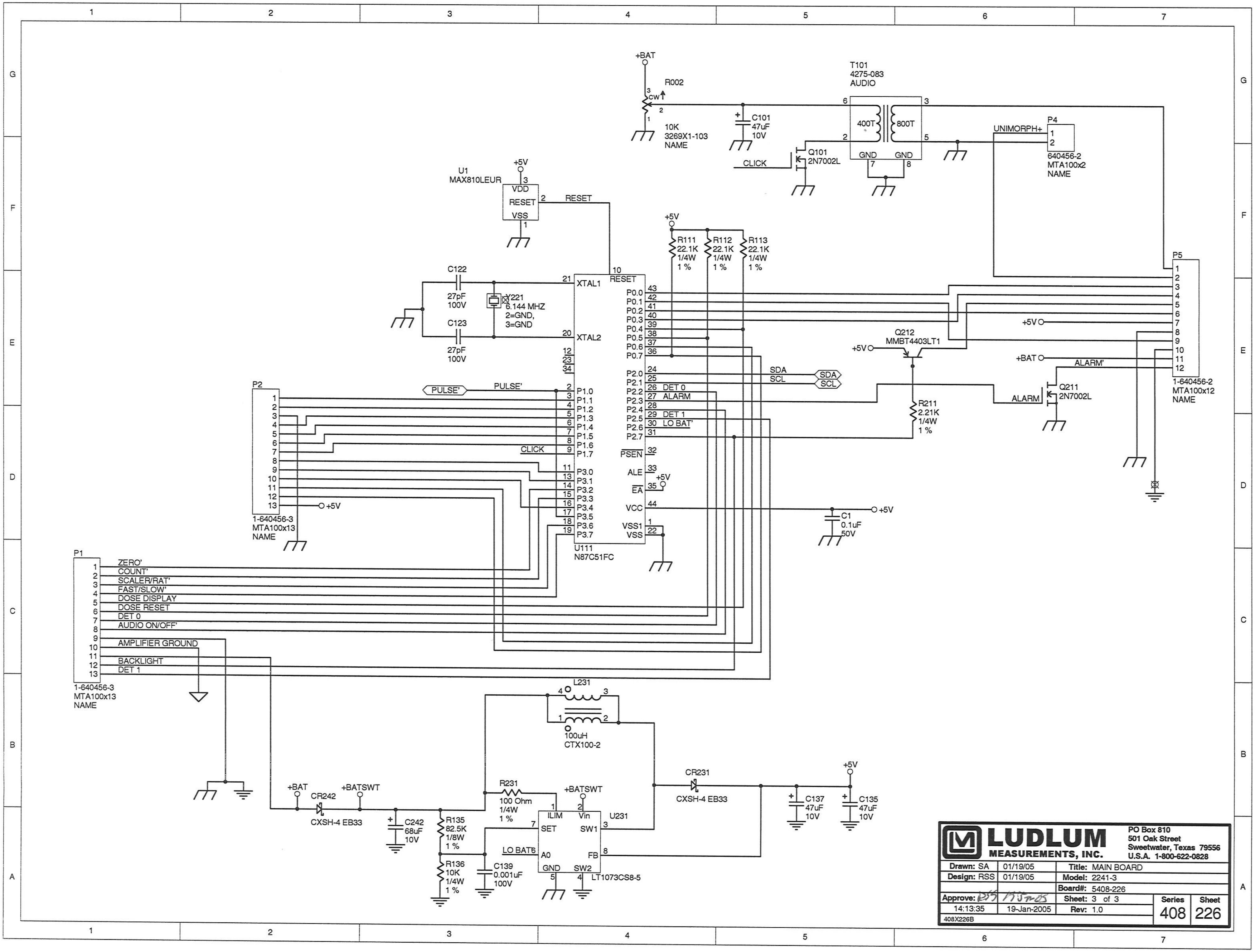
Drawn: SA	01/19/05	Title: MAIN BOARD	
Design: RSS	01/19/05	Model: 2241-3	
		Board#: 5408-226	
Approved:		Sheet: 2 of 3	Series 408 / Sheet 226
16:51:44	24-Oct-2005	Rev: 1.0	
408X226A			



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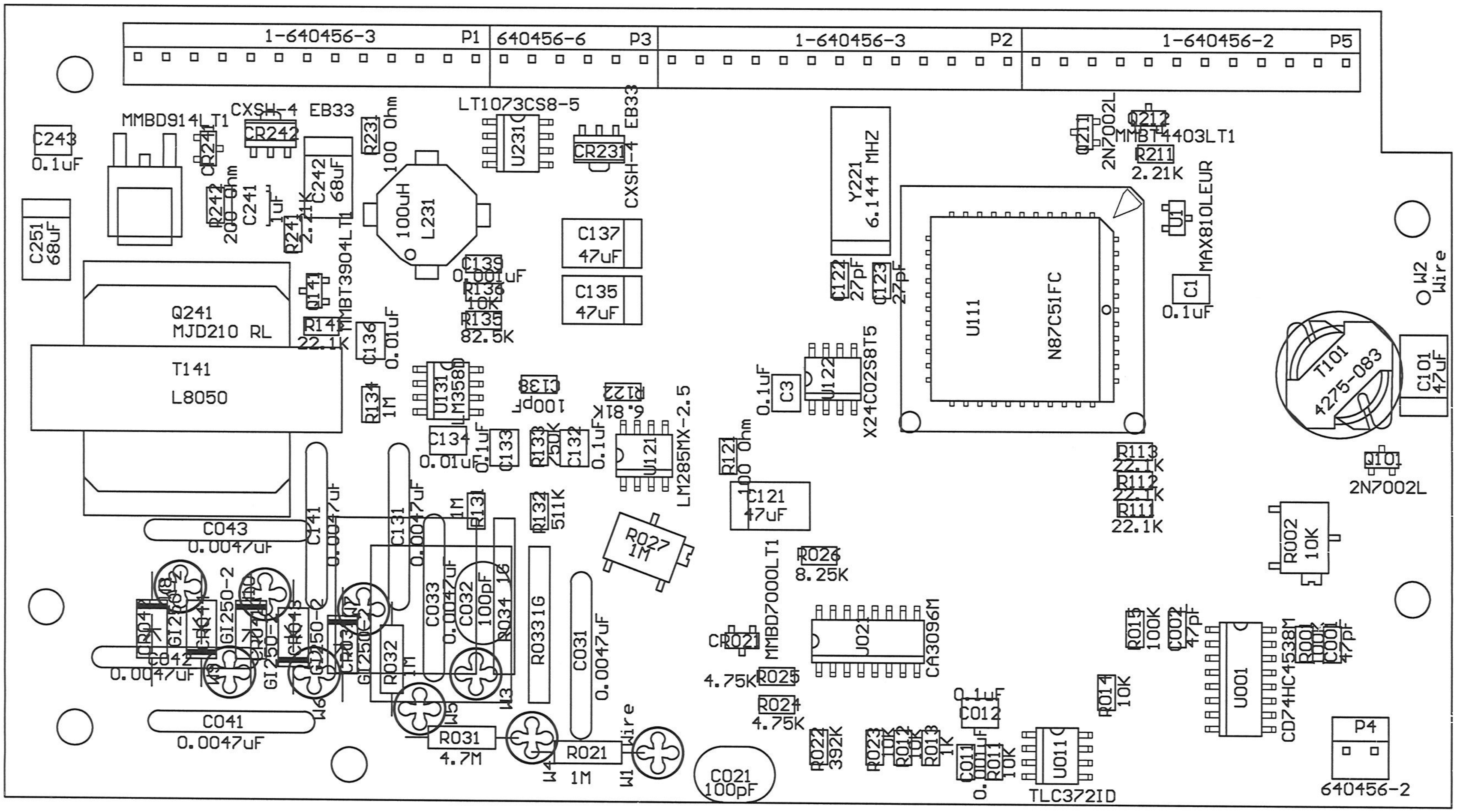
Sweetwater, Texas 79556
U.S.A. 1-800-622-0828

Drawn: SA	01/19/05	Title:	MAIN BOARD
Design: RSS	01/19/05	Model:	2241-3
		Board#:	5408-226
Approve: RSS	1-15-05	Sheet:	3 of 3
14:13:35	19-Jan-2005	Rev:	1.0

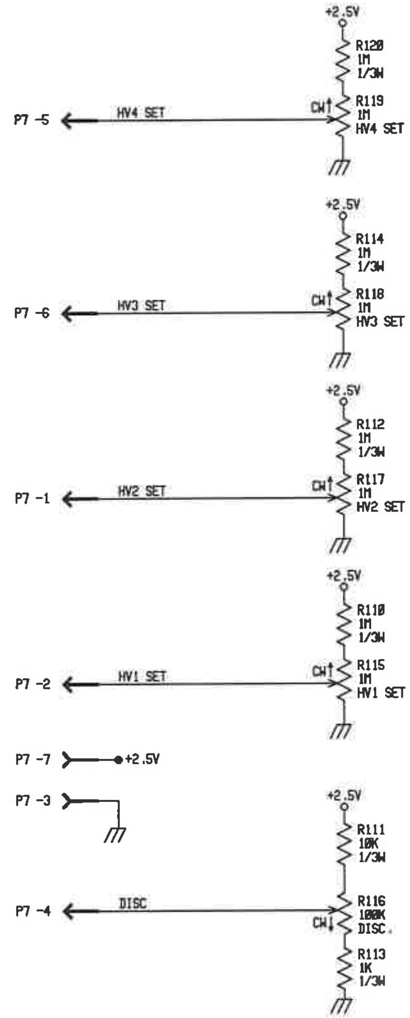
408X226B

Series 408 Sheet 226



Drawn: SA	01/19/05	Title: MAIN BOARD	
Design: RSS	01/19/05		
		Model: 2241-3	
Approve: *RBS*	*27 May 05*	Board#: 5408-226	
Layer: Mech.1 Mech.2	MID:	Rev: 1.0	Series 408
	11:23:14 27-May-2005	SCALE: 1.71	Sheet 227
BS408226			

EFF	AUTHORITY	ZONE	LTR	REVISIONS DESCRIPTION	DATE	APPROVED



UPDATED	-	
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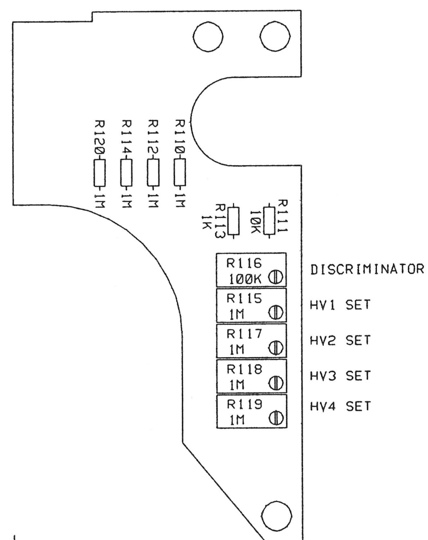
CHK RSS		6-23-97
DSGN RSS		09/24/96
APPD RDS		23 May 97
NEXT HIGHER ASSY.	-	
15:46:11		19-May-97

LUDLUM MEASUREMENTS INC.

TITLE : CALIBRATION BOARD

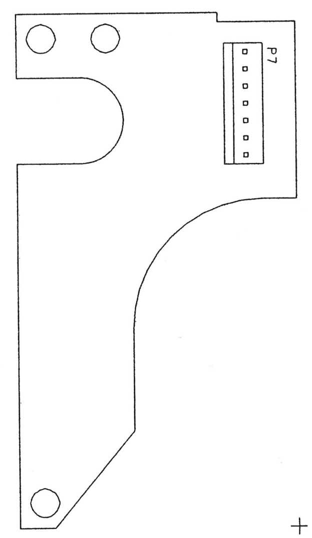
BOARD# 5408-113

SIZE	MODEL	SERIES	SHEET
C	2241-3	408	98
S9408113		SHEET 1	OF 1

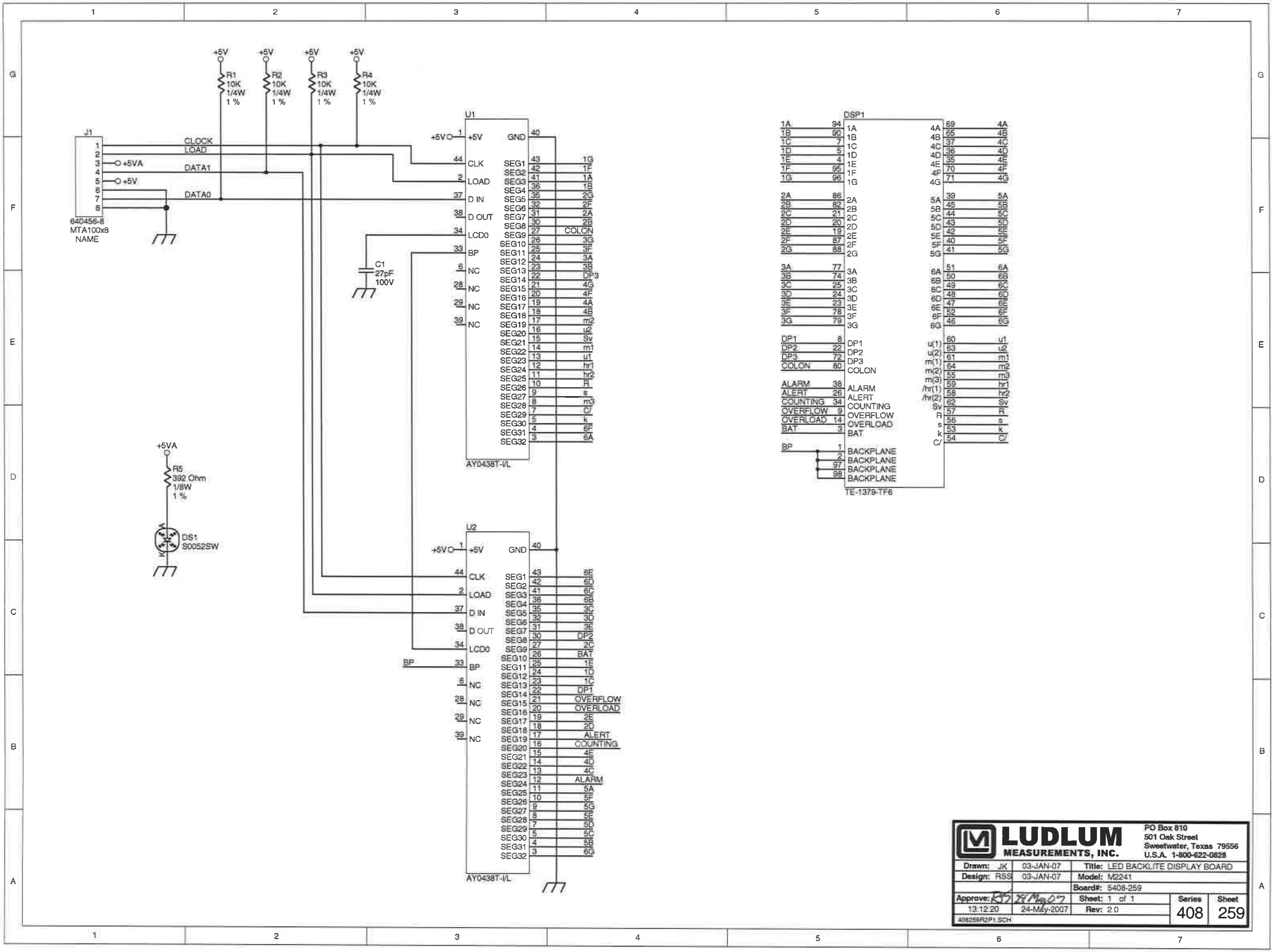


LUDLUM MEASUREMENTS INC. SWEETWATER, TX.

DR	CKB	09/24/96	TITLE: CALIBRATION BOARD
			BOARD: 5408-113
DSGN	RSS	09/24/96	MODEL: 2241-3
APP	[illegible]	[illegible]	FILENAME: BS408113
COMPONENT		SOLDER	15:11:35 23-May-04
OUTLINE		OUTLINE	REVISION 1.0 / SERIES 408 / SHEET 99

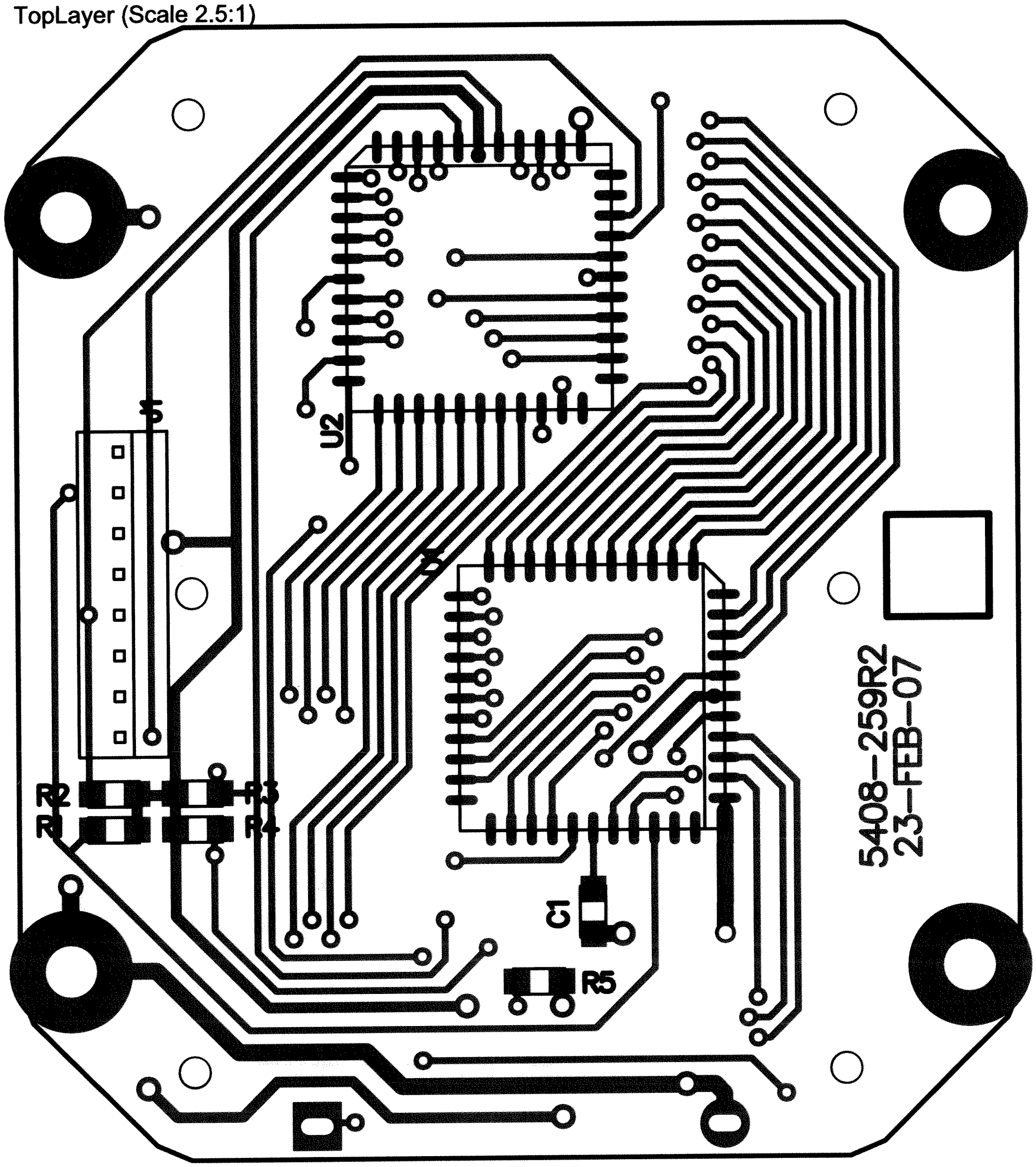


LUDLUM MEASUREMENTS INC. SWEETWATER, TX.		
DR CKB	09/24/96	TITLE: CALIBRATION BOARD
		BOARD# 5408-113
DSGN RSS	09/24/96	MODEL 2241-3 | SERIES 408 | SHEET 99
APP RS	31 Jul 12	COMP ARTWORK ☐ | SLDR ARTWORK ☐
		COMP OUTLINE ☐ | SLDR OUTLINE ☒
COMP PASTE ☐	COMP MASK ☐	SLDR PASTE ☐ | SLDR MASK ☐



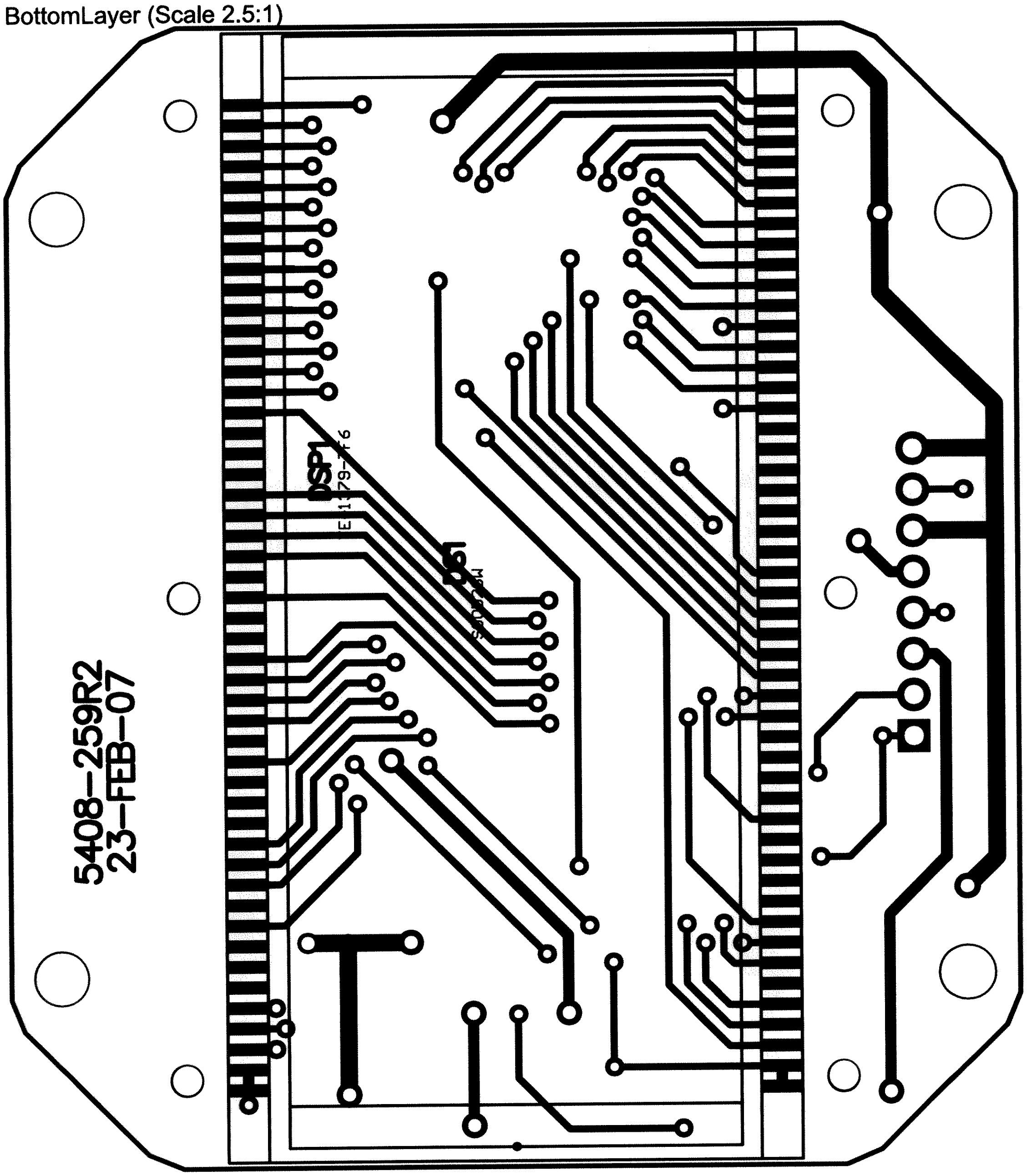
J1
640456-8
MTA100x8
NAME
CLOCK
LOAD
DATA1
DATA0
+5VA
+5V
R1 10K 1/4W 1 %
R2 10K 1/4W 1 %
R3 10K 1/4W 1 %
R4 10K 1/4W 1 %
C1 27pF 100V
R5 392 Ohm 1/8W 1 %
DS1 S0052SW
U1
AY0438T-I/L
U2
AY0438T-I/L
+5V
GND
CLK
LOAD
D IN
D OUT
LCD0
BP
NC
SEG1
SEG32
COLON
DP1
DP2
DP3
BAT
OVERFLOW
OVERLOAD
ALERT
COUNTING
ALARM
DSP1
TE-1379-TF6
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
Title: LED BACKLITE DISPLAY BOARD
Model: M2241
Board#: 5408-259
Sheet: 1 of 1
Rev: 2.0
13:12:20 24-May-2007
Series 408
Sheet 259
408259R2P1.SCH

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				

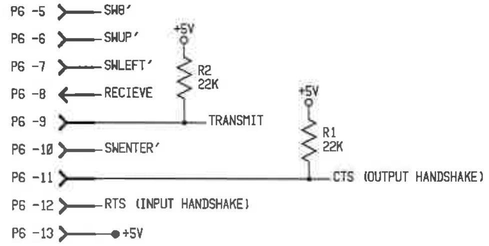
BottomLayer (Scale 2.5:1)

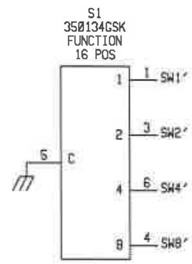


LUDLUM MEASUREMENTS

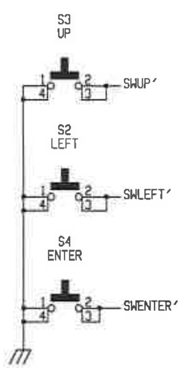
Part: 5408-259	**Model:** 2241		
Desc: LED BACKLITE DISPLAY BD			
Design: RSS	**Date:** 02/23/07	**Rev:**	2
Drawn: PAB	**Date:** 5/5/2022 **SHEET**	**SERIES**	**SHEET**
Apr: RDS	**Date:** 5 May 22 2 of 3	408	260
W:\Projects\LMI\M 2241\5408-259\Rev2			

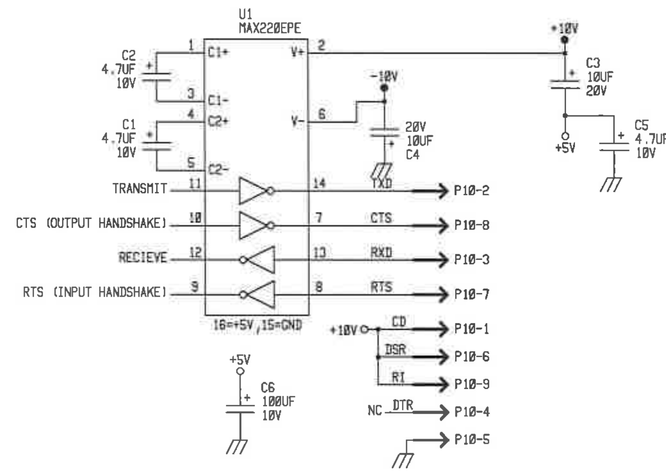
EFF	AUTHORITY	ZONE	LTR	REVISIONS DESCRIPTION	DATE	APPROVED





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





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

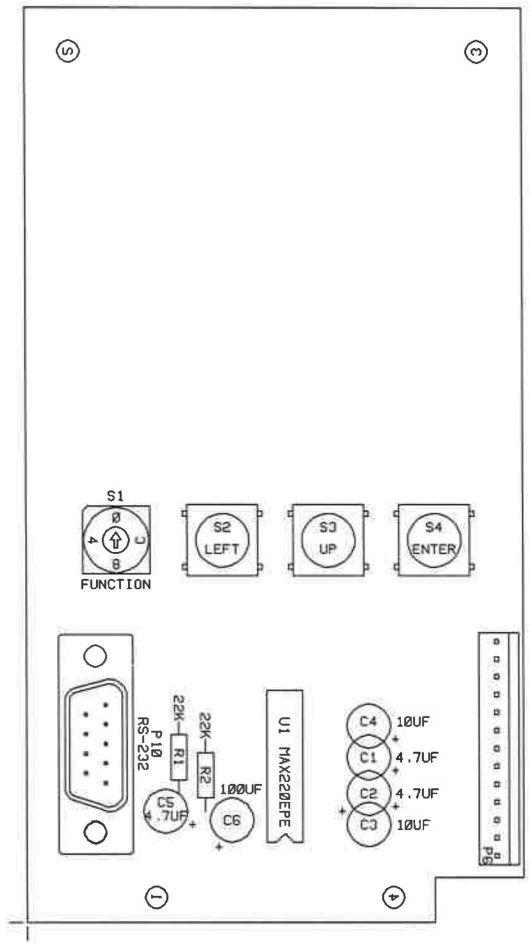
LUDLUM MEASUREMENTS INC.

TITLE: SWITCH BOARD

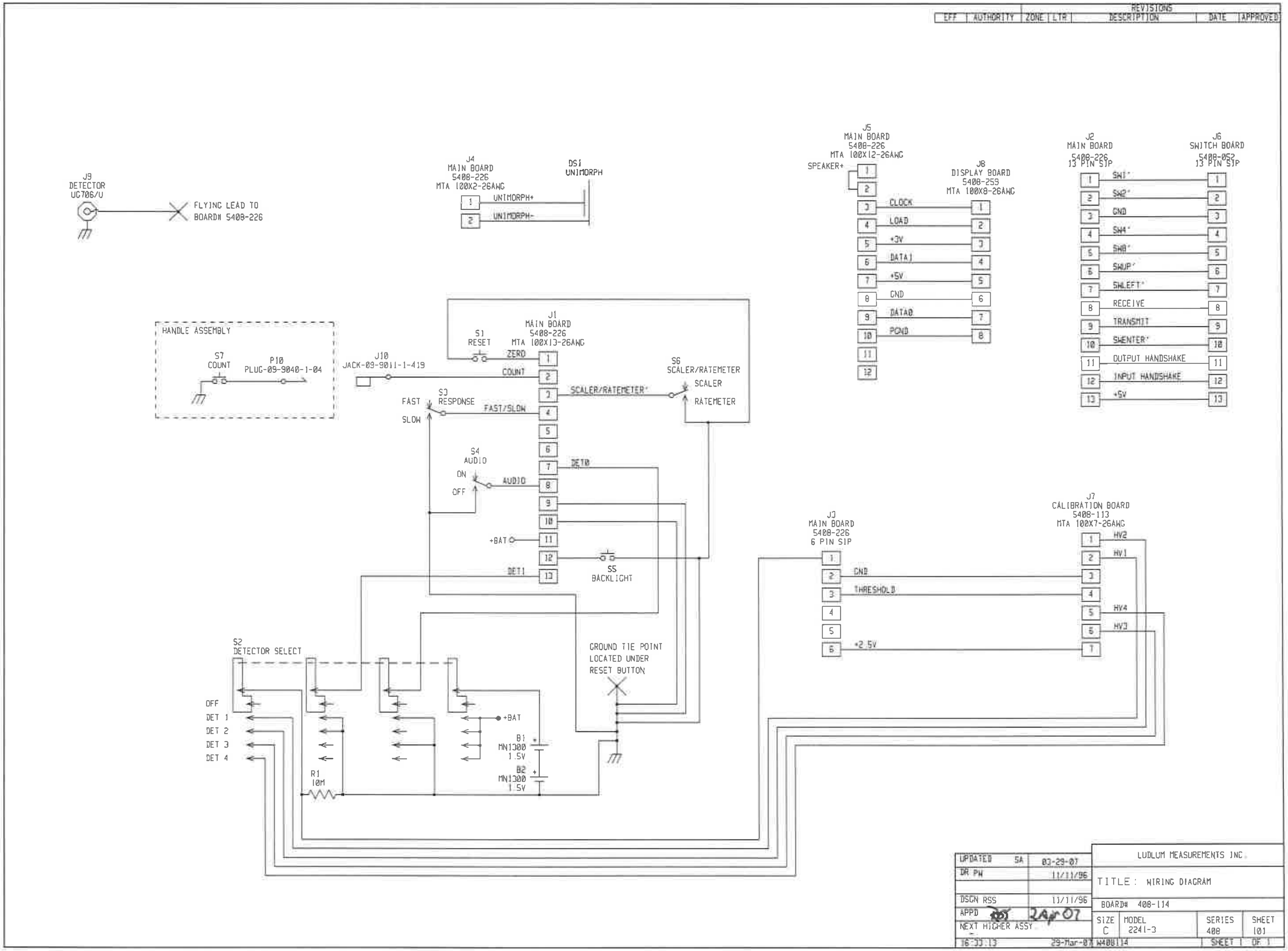
BOARD# 5408-052

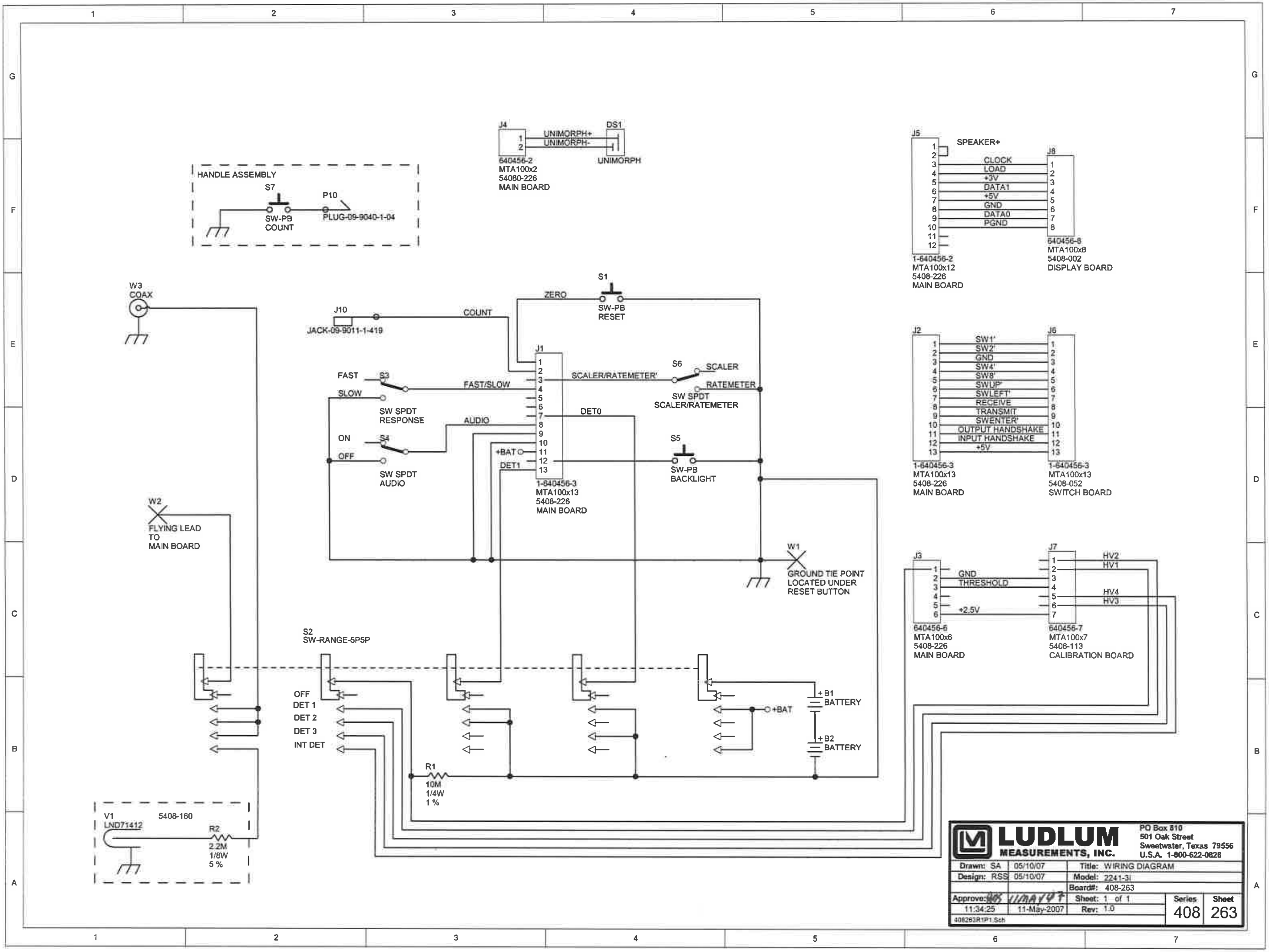
SIZE	MODEL	SERIES	SHEET
C	2241	408	45

S8408052 SHEET 1 OF 1



LUDLUM MEASUREMENTS INC. SWEETWATER, TX.			
DR CKB	06/24/96	TITLE: SWITCH BOARD	
CHK BS	12-21-00	BOARD: 5408-052	
DSGN LL	03/16/94	MODEL: 2241	
APP KDS	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# 5408-226
J4
MAIN BOARD
5408-226
MTA 100X2-26AWG
UNIMORPH+
UNIMORPH-
DS1
UNIMORPH
J5
MAIN BOARD
5408-226
MTA 100X12-26AWG
SPEAKER+
CLOCK
LOAD
+3V
DATA1
+5V
GND
DATA0
PGND
J8
DISPLAY BOARD
5408-259
MTA 100X8-26AWG
J2
MAIN BOARD
5408-226
13 PIN SIP
J6
SWITCH BOARD
5408-052
13 PIN SIP
SW1*
SW2*
GND
SW4*
SW8*
SWUP*
SWLEFT*
RECEIVE
TRANSMIT
SWENTER*
OUTPUT HANDSHAKE
INPUT HANDSHAKE
+5V
HANDLE ASSEMBLY
S7
COUNT
P10
PLUG-09-9040-1-04
J10
JACK-09-9011-1-419
S1
RESET
J1
MAIN BOARD
5408-226
MTA 100X13-26AWG
ZERO
COUNT
SCALER/RATEMETER*
FAST/SLOW
DET0
AUDIO
+BAT
DET1
S6
SCALER/RATEMETER
SCALER
RATEMETER
S3
RESPONSE
FAST
SLOW
S4
AUDIO
ON
OFF
S5
BACKLIGHT
S2
DETECTOR SELECT
OFF
DET 1
DET 2
DET 3
DET 4
R1
10M
+BAT
B1
MN1300
1.5V
B2
MN1300
1.5V
GROUND TIE POINT
LOCATED UNDER
RESET BUTTON
J3
MAIN BOARD
5408-226
6 PIN SIP
GND
THRESHOLD
+2.5V
J7
CALIBRATION BOARD
5408-113
MTA 100X7-26AWG
HV2
HV1
HV4
HV3
UPDATED SA 03-29-07
DR PW 11/11/96
DSGN RSS 11/11/96
APPD 2Apr07
NEXT HIGHER ASSY
16:33:13 29-Mar-07 W408114
LUDLUM MEASUREMENTS INC.
TITLE: WIRING DIAGRAM
BOARD# 408-114
SIZE C
MODEL 2241-3
SERIES 408
SHEET 101
SHEET 1 OF 1


HANDLE ASSEMBLY
S7
SW-PB
COUNT
P10
PLUG-09-9040-1-04
J4
UNIMORPH+
UNIMORPH-
DS1
UNIMORPH
640456-2
MTA100x2
54080-226
MAIN BOARD
J5
SPEAKER+
CLOCK
LOAD
+3V
DATA1
+5V
GND
DATA0
PGND
J8
1-640456-2
MTA100x12
5408-226
MAIN BOARD
640456-8
MTA100x8
5408-002
DISPLAY BOARD
W3
COAX
S1
ZERO
SW-PB
RESET
J10
JACK-09-9011-1-419
COUNT
J1
FAST
S3
SLOW
FAST/SLOW
SW SPDT
RESPONSE
SCALER/RATEMETER'
S6
SCALER
RATEMETER
SW SPDT
SCALER/RATEMETER
AUDIO
DET0
ON
S4
OFF
SW SPDT
AUDIO
+BAT
DET1
S5
SW-PB
BACKLIGHT
1-640456-3
MTA100x13
5408-226
MAIN BOARD
J2
SW1'
SW2'
GND
SW4'
SW8'
SWUP'
SWLEFT'
RECEIVE
TRANSMIT
SWENTER'
OUTPUT HANDSHAKE
INPUT HANDSHAKE
+5V
J6
1-640456-3
MTA100x13
5408-226
MAIN BOARD
1-640456-3
MTA100x13
5408-052
SWITCH BOARD
W2
FLYING LEAD
TO
MAIN BOARD
W1
GROUND TIE POINT
LOCATED UNDER
RESET BUTTON
J3
GND
THRESHOLD
+2.5V
J7
HV2
HV1
HV4
HV3
640456-6
MTA100x6
5408-226
MAIN BOARD
640456-7
MTA100x7
5408-113
CALIBRATION BOARD
S2
SW-RANGE-5P5P
OFF
DET 1
DET 2
DET 3
INT DET
+BAT
B1
BATTERY
B2
BATTERY
R1
10M
1/4W
1 %
V1
LND71412
5408-160
R2
2.2M
1/8W
5 %
LUDLUM
MEASUREMENTS, INC.
PO Box 810
501 Oak Street
Sweetwater, Texas 79556
U.S.A. 1-800-622-0828
Drawn: SA 05/10/07
Design: RSS 05/10/07
Approve:
11:34:25 11-May-2007
408263R1P1.Sch
Title: WIRING DIAGRAM
Model: 2241-3i
Board#: 408-263
Sheet: 1 of 1
Rev: 1.0
Series 408
Sheet 263

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)