LUDLUM MODEL 2241
DIGITAL RATEMETER

December 2000
Serial Nos. Listed Inside*;
Serial No. 170658 and Succeeding
Serial Numbers

Measuring Range: Auto-ranging with selectable units from:
μR/hr - R/hr, μSv/h - Sv/h, cpm - kcpm, cps - kcps

Power Requirement: two standard "D" cell batteries

Firmware Number for which this Instruction Manual is valid:
Firmware# 408-04, versions 01-05

LUDLUM MEASUREMENTS, INC.
501 OAK ST., P.O. BOX 810
SWEETWATER, TX 79556
915/235-5494 FAX: 915/235-4672

***NOTE: This manual (December 2000) also applies to the following serial numbers:**

163609
163610
163614
163618
163620
163625
163626
163627
163628
163640
163642
163645
163651
163652
163656
166935
166938
166953
166954
167591
167592
167594
167597
167600
167601
167604
167605
167607
167609
167610
167612
168435
168436
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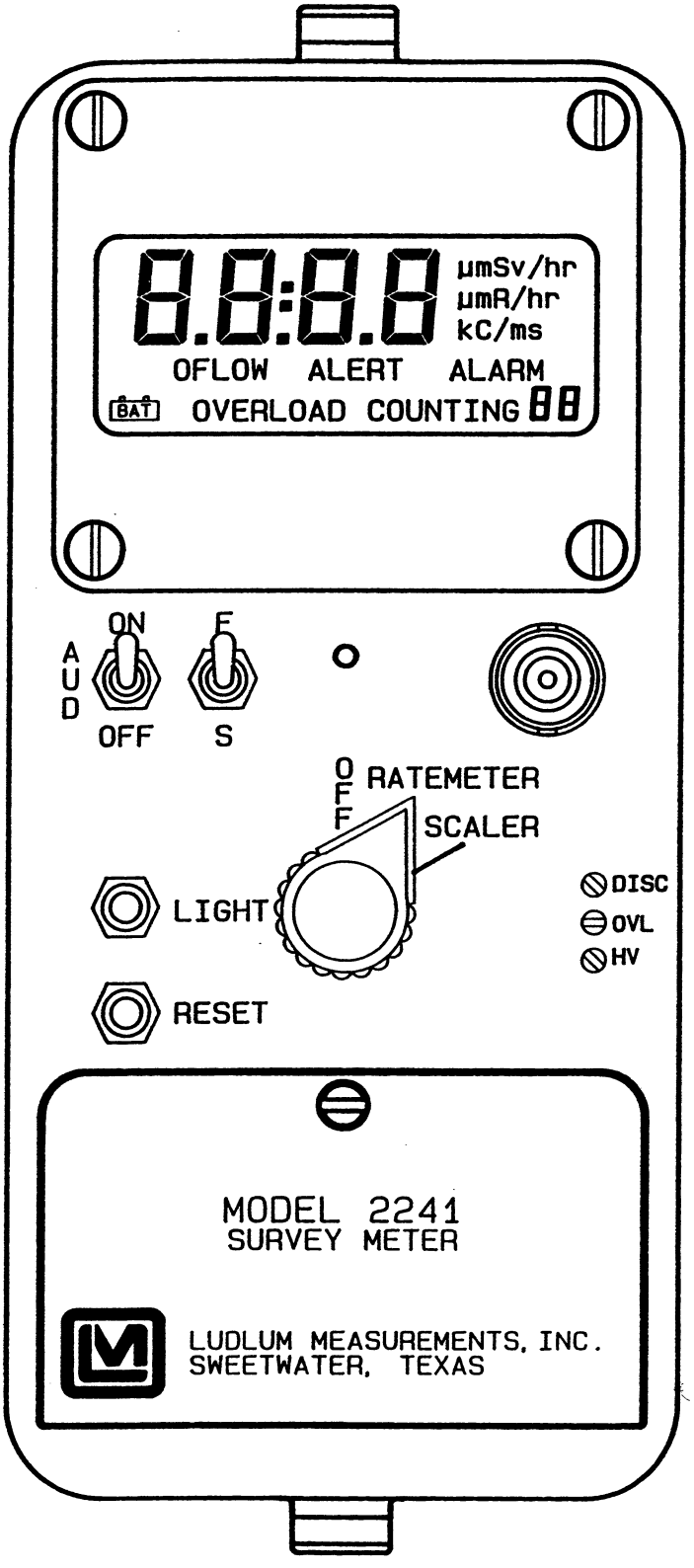
168466
169729
169737
169746



CHG	NO.				DWN	CHK	APP
DWN CKD	DATE 3/31/94	CHK	DATE	APP	DATE		
TOL: SHOP STD ☐ OTHER			SCALE: FULL ☐ OTHER				
TITLE M2241 SURVEY METER							
LUDLUM MEASUREMENTS, INC. 501 OAK STREET SWEETWATER, TEXAS 79556			SERIES 408		SHEET 15		

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Model 2241 Scaler/Ratemeter
December 2000

1. GENERAL

The Model 2241 is a portable microprocessor-based digital Scaler/Ratemeter designed for use with scintillation, Geiger-Mueller (G-M), and proportional type detectors for measurement of ionizing radiation. The data is presented on a 4-digit (6 digits in the Scaler mode) Liquid Crystal Display (LCD) with moving decimal point. A 3-position switch labeled "OFF/RATEMETER/ SCALER" selects the desired operating mode for the instrument. Programmable display units ("RATEMETER" mode only) are 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 activity.

The M2241 incorporates independent adjustable alarms for the "RATEMETER" and "SCALER" operating modes. The "RATEMETER" mode has 2 alarm indications. The first-level alarm is indicated by the word "ALERT" on the LCD. The second-level alarm is indicated by the word "ALARM" and a continuous audible tone. The Scaler alarm condition will also display the word "ALARM" and produce the same audible tone. Both of the audible alarms can be silenced (acknowledged) by depressing the "RESET" switch. All of the 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 via the internal Switch Board or by computer via the RS-232 port. Six different detector operating parameters may be stored in the non-volatile memory. The Switch Board can be removed after entering or changing parameters to prevent tampering with the setup parameters.

A regulated high voltage power supply, adjustable from 200 to 2500 volts with detector overload detection and adjustable discrimination level, adds 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 unit is operated with two "D" cell flashlight batteries. The unit body is made of cast and drawn aluminum with computer-beige polyurethane paint, which aids in decontamination of surfaces.

2. SPECIFICATIONS

- **POWER:** Two standard "D" size batteries; current drain approximately 35 mA (backlight off); minimum battery voltage 2.2 ± 0.1 Vdc

- **BATTERY DEPENDENCE:** Instrument calibration change less than 3% to battery endpoint

- **BATTERY LIFE:** Approximately 200 hours for alkaline batteries

- **OPERATING TEMPERATURE:** -4°F to 122°F (-20°C to 50°C)

- **WARM-UP TIME:** M2241 may be used immediately after the LCD initialization sequence is completed (approximately 5 seconds after turn-on)

- **DISPLAY:** 4-digit LCD with 0.5" (1.3cm) character height. Two additional 0.2" (0.5cm) digits are used for the overflow counter (Scaler mode) and exponential powers (parameter setup)

- **MEASURED RANGES:** Auto-ranging from 00.0 μR/hr - 999 R/hr, .000 μSv/h - 999 Sv/h, 000 cpm - 999 kcpm, or 000 cps - 999 kcps.

- **DISPLAY LINEARITY:** Within ± 10% of the true value

- **RESPONSE TIME:** Allows changing the time constant (TC) for the current detector setup.

Variable - Response time is varied in proportion to the incoming count rate. The 2-position "F/S" (Fast/Slow) toggle switch selects the maximum time constant (TC) for the variable mode. The "F" position varies the TC from 1-10 seconds, and the "S" position varies the TC from 1-30 seconds.

Fixed Response - The "F" (Fast) response position is programmable from 1-199 seconds. The slow response is 5 times the fast TC. For MDA-type measurements, the fixed response time mode is recommended.

NOTE

The TC is defined as a one-time constant which equals 63% of the final reading. To

convert to the 10-90% of-final-reading definition, the TC value will have to be multiplied by 2.25. The readout updates every 2 seconds, therefore response time measurements will be rounded to 2-second intervals. For example: fixed TC = 2 seconds X 2.25 = 4.5 seconds for 90% of final reading. It will take 6 seconds before the display will reach the 90% of final reading value (3 each: 2-second intervals).

- **ALERT/ALARM:** Visual and audible adjustable alarm points for both the Ratemeter and Scaler modes; alert annunciator for the Ratemeter mode only. The Ratemeter alert/alarm is adjustable from 1µR to 999 R/hr, 1µSv to 999 Sv/h, 1 to 999k cpm, 1 to 999 kcps. The Scaler alarm is adjustable from 1 to 999,999.

- **INPUT SENSITIVITY:** Adjustable from 2-100 millivolts; negative pulse response

- **HIGH VOLTAGE:** Externally adjustable from 200-2500 volts; regulated within ±0.2%@1000 Vdc; maximum load: 50µA @1000 Vdc

- **CALIBRATION CONSTANT:** 0.001 to 280 x 10^9 counts/unit

- **DETECTOR DEAD TIME COMPENSATION (DTC):** Adjustable from 0 to 9999 microseconds

- **RS-232 PORT:** 9-pin "D" type connector with programmable baud rate from 150 to 19,200 bps

- **CONNECTOR:** Series C; BNC, MHV, and other input connectors are available upon request

- **SIZE:** 7" (16.5cm) H X 3.5" (8.9cm) W X 8.5" (21.6cm) L, including handle

- **WEIGHT:** 3.5 pounds (1.6kg), including batteries

- **FINISH:** Drawn-and-cast aluminum, with computer-beige polyurethane enamel and silk-screened nomenclature

- **Backlight "ON" Time:** 5, 15, 30, 60, 90, 120, or 240 ±1 second

3. PRINCIPLE OF OPERATION

The M2241 utilizes microprocessor-based technology providing an extensive range of operating features. Exposure rate and count rate calibrations can be performed and saved with the appropriate G-M, proportional and/or scintillation detector. Up to 6 independent detector parameters can be stored in memory.

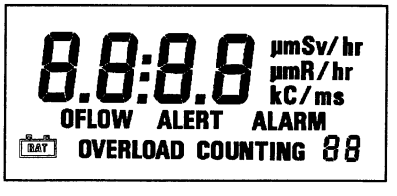
NOTE

All of the detector parameters listed on the Switch Board (refer to section 5.2.3) can be programmed and stored for each of the 6 detector selections. The Discriminator ("DISC"), Detector Overload ("OVL"), and Detector High Voltage ("HV"), located underneath the "CAL" cover on the front panel, must be manually adjusted for each detector.

The M2241 incorporates a detachable Switch Board, which is used to program detector and operating parameters into the non-volatile memory. (It retains the data even after the power is removed.) The Switch Board may be removed so that the operating parameters cannot be altered. If multiple units are to be used at one location, only a few Switch Boards need to be purchased in order to program all of the instruments. A 16 position rotary switch ("FUNCTION") selects each of the 16 operating and detector parameters. Three pushbutton switches provide the means to change and save the variables for each of the parameters.

An RS-232 port is also available via the Switch Board for computer connection. Communication baud rate may be set via the "FUNCTION" switch to correspond to the computer baud. The computer can adjust the detector parameters, retrieve the real time Ratemeter data, start and stop the Scaler counter, and retrieve the Scaler data.

An LCD provides the readout for the Ratemeter and Scaler data with the programmed units and multipliers; Alert/Alarm, Overload, and Overflow annunciators; "low battery" icon, and the Scaler counting mode indication ("COUNTING"). Four 0.5" digits are used for the Ratemeter and Scaler data with the addition of the two 0.2" digits in the lower right hand corner utilized as a 2-digit



overflow counter (equivalent to a 6-digit Scaler). The LCD also displays the variables during the manual programming sequence.

The Ratemeter mode is enabled by switching to the "RATEMETER" position and reading the displayed data in the programmed units of either **R/hr**, **Sv/h**, **C/m**, or **C/s**. The Scaler mode is selected by selecting the "SCALER" position. The Scaler count sequence is started by depressing the black pushbutton switch located in the end of the instrument handle. "COUNTING" will be displayed on the LCD during the counting sequence for the predetermined count time selected in the parameter setup. Once the Scaler count is started, the "RATEMETER/SCALER" switch can be switched back and forth without disturbing the Scaler counting sequence. Both the Ratemeter and Scaler ALERT and ALARM (ALARM only for Scaler) will initiate if the respective threshold level(s) is(are) exceeded. All of the alarms are concurrent; therefore it is not necessary to be in the related Ratemeter or Scaler operating mode to initiate an ALERT or ALARM condition.

4. PRELIMINARY INSTRUCTIONS

4.1 Unpacking and Repacking

- Remove calibration certificate and place in secure location. Remove instrument and accessories (batteries, cable, etc.) and ensure that all of the items listed on the packing list are in the carton. If more than 1 instrument is in the carton, refer to the calibration certificate(s) for serial number (S/N) match. The M2241 S/N is located on the front panel below the battery compartment. Most LMI detectors have a label on the base or body of the detector for the Model and S/N identification.

- To return instrument for repair or calibration, provide sufficient packing material to prevent damage during shipment. Provide appropriate warning labels to ensure careful handling. Include detector(s) and related cable(s) for calibration. Include brief information as to the reason for return and return shipping instructions (address, P.O.#, etc.).

  - return shipping address
  - customer name or contact
  - telephone number
  - description of service requested and all other necessary information

5. OPERATING INSTRUCTIONS

5.1 Safety Measures

CAUTION

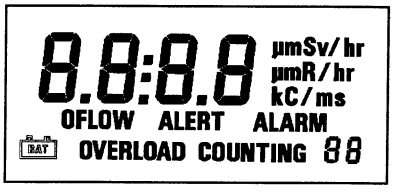
The detector operating voltage (HV) is supplied to the detector via the input connector. A mild electric shock may occur if you make contact with the center pin of the input connector. Switch the M2241 to the "OFF" position before connecting or disconnecting the cable or detector.

5.2 Descriptions of Controls and Functions

5.2.1 Operator Controls

- **OFF/RATEMETER/SCALER Switch:** A 3-position rotary switch which applies power to the instrument and selects the Ratemeter or Scaler counting modes.

- **DISPLAY:** A 4-digit LCD readout with 2-digit overflow (Scaler mode) and moving decimal point. The 2 smaller digits located in the lower right corner of the display indicate counter overflow when in the Scaler counting mode (equivalent to a 6-digit Scaler) or exponential power when in the parameter setup mode. The upper right of the LCD exhibits units and multiplier(s): R/hr, mR/hr, or µR/hr; Sv/h, mSv/h or µSv/h; C/m, kC/m, C/s, and kC/s. The bottom part of the readout displays the "ALARM," "ALERT," "OFLOW," and "OVERLOAD" annunciators and the "low battery" icon. "COUNTING" indicates that the Scaler 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 the "RESET" switch will acknowledge the audible Ratemeter and/or Scaler alarm. Depressing the

"RESET" switch 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, depress the "RESET" switch 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 reading that can be displayed each time the alert is reset.

- **OFLOW** (Overflow): Ratemeter mode - "OFLOW" 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 100k cps or if the dead time correction is greater than 75%.

An "OFLOW" will appear in the Scaler mode when the 6-digit display (4 digits + 2 overflow digits in 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 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 for each detector by adjusting the "OVL" control located underneath the CAL cover.

- **"low battery" icon**: Indicates that the batteries have decreased to the minimum operating voltage of 2.2 ±0.1 Vdc.

- **COUNTING**: Indicates that the Scaler count switch has been depressed and the Scaler is accumulating counts for the pre-determined count time.

- **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 2-position toggle switch which selects **F**ast or **S**low counting response time.

  - For the variable response mode, the **"F"** position allows the time constant (TC) to vary from 1 to 10 seconds. 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.

  - For the fixed response mode, the **"F"** position corresponds to the selected fixed response time - TC - and the **"S"** position is 5 times 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; and depressing "RESET" switch 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 M2241 handle.

- **Scaler Count Switch:** Pushbutton switch located in the end of the M2241 carrying handle which, when depressed, initializes the start of the Scaler count accumulation for the preset Scaling time. The "OFF/RATEMETER/SCALER" switch must be in the "SCALER" position to initiate the counting cycle. The Scaler display uses the 2 digits in the lower right hand corner for the two most-significant-digits of the 6-digit readout. Scaling time can be set from 1 to 9999 seconds in the parameter setup via the Switch Board. Depressing the "COUNT" switch after a Scaler ALARM will reset the Scaler display to "0," resetting the alarm condition.

■ Remove the CAL cover to access the following 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.

• **OVL (Detector Overload):** A multi-turn potentiometer (approximately 20 revolutions) located underneath the "CAL" cover which adjusts the detector current level that must be exceeded to initiate an OVERLOAD alarm. The control design current range is 0.5 to 40 microamperes, allowing overload setpoints specific to individual detectors. An overload condition indicates that the detector is being exposed to radiation intensities greater than the detector maximum operating limit. For alpha and/or beta scintillation detectors, an "OVERLOAD" message may indicate that the detector mylar has been punctured, allowing external light to saturate the photomultiplier tube inside the detector.

NOTE

Measure the HV at the detector connector with a Ludlum Model 500 Pulser or a high impedance voltmeter with a high voltage probe. The impedance of the voltmeter must be 1000 megohms or greater.

• **HV (High Voltage):** A multi-turn potentiometer (approximately 20 revolutions) which varies the detector voltage from 200 to 1500 volts for G-M and scintillation detectors and 200 to 2500 volts for proportional detectors. The maximum HV output is adjusted by the "HV LIMIT" potentiometer located on the internal Main Board.

NOTE

The M2241 is intended to be used with one detector at a time while performing a specific radiation survey. The M2241 stores 6 different detector setups. However, the "DISC," "OVL," and "HV" controls may have to be re-adjusted if the variables differ from the current detector setup when changing or substituting detectors. If the new parameters are predetermined during the initial calibration of the M2241 and the detector, the adjustments may be made by a QUALIFIED OPERATOR as long as the proper test equipment (Model 500 Pulser, etc.) is used.

5.2.2 Main Board (5408-110)

To access the internal circuit boards, unlatch the latches at each end of the M2241. Carefully separate the top chassis from the bottom cover (referred to as the "can"). The can has the audio speaker (unimorph) with a 2-conductor cable attached to the Main Board. The audio plug may be disconnected during the internal control adjustment(s).

• **HV LIMIT (R027):** A multi-turn potentiometer (approximately 20 revolutions) which 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) which varies audible clicks-per-event and alarm audio. Adjust the control to the maximum clockwise position for maximum volume.

NOTE

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.

5.2.3 Switch Board (5408-052)

■ The Switch Board (refer to component layout drawing–series 408, sheet 46 near the end of the manual) utilizes a 16-position rotary switch ("FUNCTION") to select the 16 setup parameters. All of the setup parameters are stored in the non-volatile EEPROM which will retain the data even after the M2241 batteries are removed. After the parameters are entered, the Switch Board can be removed, and the M2241 will operate from the programmed information for the specific detector setup prior to the removal of the Board.

ENTERING OR CHANGING SWITCH BOARD PARAMETERS:

☐ Select the desired parameter to enter or change by selecting the corresponding "FUNCTION" switch position. Depress the "ENTER" pushbutton switch, and a character will start to flash. The flashing character indicates that the program is in the parameter-change mode.

☐ To change the character, increment the "UP" switch to the desired variable. To shift to another character, increment the "LEFT" switch, which enables the operator to sequence through all the characters on the LCD associated with that particular parameter.

☐ Once the desired data is entered, depress the "ENTER" switch, and the LCD should quit flashing and display the new parameter data.

■ To read pre-programmed setup parameters, switch the "FUNCTION" switch to position "**A**" and select the pre-programmed detector setup number,

using the parameter change procedure above. Once the detector setup number is entered, sequence through the parameters by varying the "FUNCTION" switch to read the variables for that specific detector number.

NOTE

Once the detector setup number has been entered, the "FUNCTION" switch can be rotated in either direction to view the parameter variables.

- **FUNCTION Switch:** A 16-position rotary switch labeled "0-9" and "A-F". This switch selects a parameter setup mode for the M2241. If the board is not installed, the normal operation mode (counting mode) is selected. If the board is installed, then the selector switch must be set to the "0" position for normal operation. The following may be changed using this board:

  - detector parameters,
  - current detector setup in use,
  - RS-232 communication baud rate,
  - RS-232 data dump mode, and
  - RS-232 detector parameters set/read mode.

FUNCTION SWITCH POSITION DESCRIPTIONS AND VARIABLES:

- **POSITION 0:** NORMAL OPERATION, places the M2241 in the normal (counting) operating mode. Unplugging the Switch Board from the M2241 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. CC must be set to **"1"** to read out in cps or cpm.

$$CC = \frac{cps \times time\ base}{rate}$$

CC CONVERSION TABLE

Known Conversion Rate	Multiply by to get CC
cps/μR/hr	3.6×10^9
cps/mR/hr	3.6×10^6
cps/R/hr	3600
cpm/μR/hr	60×10^6
cpm/mR/hr	60,000
cpm/R/hr	60
cps/μSv/h	3.6×10^7
cps/mSv/h	36,000
cps/Sv/h	36
cpm/μSv/h	60×10^4
cpm/mSv/h	600
cpm/Sv/h	0.6

Example: Ludlum Model 44-9 G-M detector produces approximately 3300 cpm/mR/hr for ^{137}Cs: 60,000 x 3300 = 198×10^6 for CC

- **POSITION 3:** DISPLAY UNITS, selects the display units for the associated detector setup number. The M2241 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 M2241 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)
  - Sv/h (Sieverts)
  - C/time base (Counts)

The display is auto-ranging with the appropriate multiplier symbol appearing in front of the R, Sv, or C to indicate 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, 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 (e.g.; alpha scintillation detector has 25%, 2π efficiency - enter **250** $^{-3}$ 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 audio "ON/OFF" switch is off, no audio clicks 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 M2240 automatically calculates (Variable mode) the time constant based on the incoming cps. If a variable of "1-199" is entered for TC, then the response time becomes fixed:

Variable Response - Response time is varied in proportion to the incoming count rate; the 2-position "F/S" (Fast/Slow) toggle switch selects the maximum time constant (TC) for the variable mode. The "F" (Fast) position varies the TC from 1-10 seconds, and the "S" (Slow) position varies from 1-30 seconds.

Fixed Response - The fast response position is programmable from 1-199 seconds. The slow response is 5 times the fast TC. For MDA-type measurements, the fixed response time mode is recommended.

REFER TO NOTE ON PAGE 2, REGARDING TIME CONSTANT

- **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 units. The fifth push of the left button allows the decimal point to be moved. The Ratemeter alarm adjusts from 1μ to 999 R/hr (Sv/h) or 1 to 999 kcpm or 1 to 999 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:** DETECTOR SETUP NUMBER, allows the current detector setup to be changed to 1 of the 6 different detector setups. The detector setups are stored in EEPROM. Enter the detector setup number first before entering or changing the related detector parameters.

- **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. The selectable values are:

  - 5 seconds
  - 30 seconds
  - 60, 90 seconds
  - 180, or 240 seconds

- **POSITION C:** SET MINIMUM DISPLAY, sets the Ratemeter minimum reading that can be displayed. Depressing the "RESET" switch displays the minimum Ratemeter units. The readout will auto-range up to the maximum value that can be displayed, but will display "0" for Ratemeter readings below the user-programmed minimum variable.

Minimum values that can be displayed:

00.0μ, 000μ, 0.00m, 00.0m, 000m, 0.00, 00.0, 000 R/hr
.000μ, 000μ, 0.00m, 00.0m, 000m, 0.00, 00.0, 000 Sv/h
0.00, 00.0, 000, 0.00k, 00.0k, 000k cpm or cps

- **POSITION D:** R-232 DATA DUMP MODE, allows the RS-232 port to dump Ratemeter data every 2 seconds. The M2241 is fully functional, except all audio is disabled during the data dump mode. The LCD will alternate between the Ratemeter and the word "dUP" (representing the word "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 by 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 M2241 to a computer 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

LMI offers a PC-compatible software program which incorporates the read/write commands necessary to communicate between the PC and M2241. The program also incorporates an algorithm to calculate the detector Calibration Constant and Dead Time Constant. The software is offered in a DOS version (DOS 6.0 or 6.2), LMI part# 1370-025, or a WINDOWS version (WIN 3.1), LMI part# 1370-024. Software is available on both 3.5" or 5.25" disks.

5.3 Operating Procedures

BATTERY INSTALLATION

☐ Ensure the M2241 power 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 a flashlight battery is positive. The batteries are placed in the battery compartment in opposite directions.

☐ Connect a detector to the M2241 with the appropriate cable.

☐ Turn the "OFF/RATEMETER/SCALER" switch to the "RATEMETER" position.

■ The display goes through an initialization sequence. The display will show all "8"s with decimal points. Check to make sure all segments are on as illustrated in Figure 3. The LCD then shows the firmware number in the format "P-XX YY." The "XX" is the firmware number and the "YY" is the firmware version. (Figure 4).

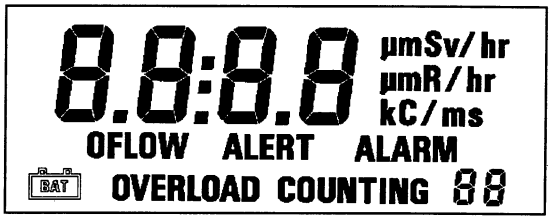


Figure 3. First screen after power up shows all symbols.

Figure 4. Second screen shows program number and version. This example shows program number 2, version 39.

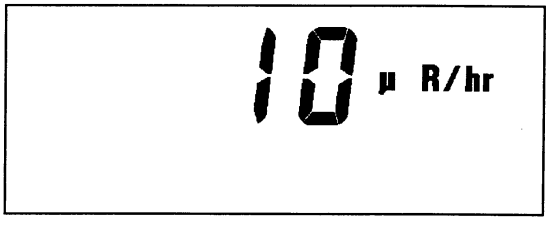


Figure 5. Typical operating screen showing 10 µR/hr.

■ The minimum value that can be displayed (for example: 0.00µR/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 (Figure 5). When auto-ranging down, the M2241 uses multiples of 5. This technique keeps the decimal point from jumping between numbers when viewing values around multiples of 10.

☐ Expose the detector to a check source if the background count is too low to generate a display reading. Switch the "AUD ON/OFF" to the "ON" position and confirm the external unimorph 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 (refer to section 5.2.3 for parameter change procedures) to initiate an ALERT and ALARM condition. 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 initiated, 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/minute or 10-100μR/hr. While observing the Ratemeter fluctuations, select between the fast and slow response time positions to observe different variations in the display. The "S" position should respond approximately 5 times slower (for fixed response mode) and 3 times slower (for variable response mode) than the "F" position. The slow response position is normally used when the M2241 is displaying low numbers which require a more stable display. The fast response is used at the high count levels.

☐ Switch to the Scaler position. Depress the Count switch located in the end of the carrying handle to initiate the count cycle. The word "COUNTING" should be visible in the display 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, but the "COUNT" switch will have to be depressed to clear the visual ALARM 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 instrument.

SPECIAL FREEZE SCREEN OPERATIONS

☐ Press the "RESET" button while turning the M2241 ON.

■ All of the segments will appear (Figure 3) until the "RESET" button is released. To "freeze" the firmware number and version (Figure 4), depress the "RESET" switch immediately after the first display is presented.

5.4 Calibration

■ The M2241 calibration routine consists of entering detector parameters into memory via the Switch Board and adjusting the "CAL" controls ("HV," "DISC". and "OVL") for the specific detector operating requirements.

• Section 5.4.1 is a general overview for determining various detector operating voltages ("HV") and adjustment of counter input sensitivity ("DISC").

• Section 5.4.2 sequences through the pulse generator Counts/minute calibration. The cpm parameter setup is used in the initial instrument checkout procedure, and the variables are saved under detector setup number 1 when shipped from LMI.

• Exposure rate calibration is covered in section 5.4.3. The detector Calibration Constant (CC) and Dead Time Compensation (DTC) are the 2 primary parameters used in the exposure rate calibrations (R/hr and Sv/h). These 2 constants are alternately varied to achieve linearity at the detector non-linear operating regions. An example of the Ludlum Model 44-9 G-M detector calibration is given at the end of section 5.4.3 to illustrate the algorithm used in determining the CC and DTC variables.

5.4.1 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 3 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 are above the discrimination level and the unwanted pulses from background radiation and noise are below the discrimination level and are 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 G-M detectors, a minimum voltage must be applied to establish the Geiger-Mueller characteristic. Further changes in "HV" will have little effect on this type detector.

■ G-M DETECTORS: The output pulse height of the G-M 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 G-M Detectors, set "DISC" for 30-40 millivolts and adjust "HV" to the G-M detector recommended high voltage. Most G-M 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 G-M 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 multiple-pulse.

■ 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.

■ 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 Figure 6. Refine the "HV" adjustment for an optimum source efficiency with a minimum acceptable background count.

■ For scintillators, set the "DISC" for 10 millivolts. Plot the background count rate and source count rate versus HV to produce a plateau graph similar to the one in Figure 6. 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.

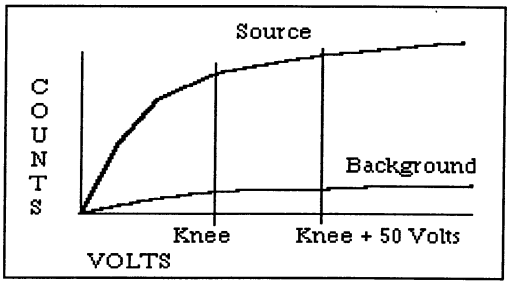


Figure 6.
Plateau Graph

5.4.2 Counts/minute (C/m) Calibration

■ This procedure will set up the M2241 for the Counts/minute (C/m) mode of operation. Refer to section 5.2.3, "*ENTERING OR CHANGING SWITCH BOARD PARAMETERS*," to enter setup parameter variables.

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

□ Switch the "OFF/RATEMETER/SCALER" switch to the "RATEMETER" position. Select position "**A**" on the "FUNCTION" switch located on the Switch board. Select detector setup "**1**" for the counts/minute mode.

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

Switch Position	Parameter	Function
1	0000 s-6	Dead Time
2	0100 -2	Calibration Constant
3	c/	Display Units
4	m	Timebase
5	1	Audio Divideby
6	000 s	Response Tme

□ 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. Position "A" was entered in the first step. 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 value that can be displayed. Select position "0" to return to normal operation.

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

☐ Adjust the pulser amplitude to 1.5 times the M2241 discrimination level. Adjust the pulser output to 800 cpm and confirm that the M2241 reads 800 C/m ±2%. Adjust count output to 200 cpm and confirm that the LCD displays 200 C/m ±2%. Confirm that the 20 and 80% readings for the upper decades are within ±2% of the pulser input by decading the pulser count output. Alternately switch to the Scaler mode to initiate the Scaler count accumulation.

☐ Ensure that the ALERT and ALARM function by inputting the preset alarm levels as to initiate the alert and alarm conditions.

5.4.3 R/hr Calibration

■ The following calibration procedure assumes that detector Calibration Constant (CC) and Dead Time Constant (DTC) are already known. If these 2 constants must be determined, reference section 5.4.4 to define CC and DTC.

☐ Rotate the "FUNCTION" switch to position "A" and select the desired detector setup number. 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 measured value is within ±10% of each respective reference value. 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.

5.4.4 Determining CC and DTC

■ This procedure contains the algorithm (*hi-lo method)* for determining the CC and DTC calibration constants. An example of the Ludlum Model 44-9 G-M detector calibration is used in conjunction with the algorithm calculations to aid in solving the equations.

LMI offers a PC-compatible software program which incorporates the read/write commands necessary to communicate between the PC and M2241. The program also incorporates the algorithm to calculate the detector CC and DT. The software is offered in a DOS version (DOS 6.0 or 6.2), LMI part# 1370-025, or a WINDOWS version (WIN 3.1), LMI part# 1370-024. Software is available on both 3.5" or 5.25" disks.

■ The *hi-lo method* refers to the placement of the detector in a radiation field using a 2-point (CC and DT) calibration to linearize 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 percent count loss. The high radiation field (DT) should be a field that yields from 30 to 60 percent count loss. The algorithm ignores background counts, therefore the low field must be at least 10 times the background count. The summary below 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 percent count loss
HIGH FIELD	■ Yields from 30 to 60 percent count loss

* This constraint only applies when using 2 sources (2 fields) or a radiation range calibrated without background consideration.

PRELIMINARY CPS SETUP

Refer to section 5.2.3, "*ENTERING OR CHANGING SWITCH BOARD PARAMETERS,*" to enter the cps readout variables.

☐ Switch the "FUNCTION" switch to the "A" position. Select and enter one of the 6 detector setup numbers which has not been preprogrammed. Starting with "FUNCTION" switch position "1," enter the following variables:

Switch Position	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 Alarm/Alert
8	0060 s	Scaler Alarm/Count
9	N/A	Check Source Size
A	setup in first step	Detector Setup Number
B	N/A	LCD Backlight
C	000 C/s	Set Minimum Display
D-F	N/A	RS-232 Parameters

The following equation determines 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 which yields between 2 and 5% count loss. The *hi* count field (CPS^{HI}) should be a field which yields between 30 and 60% count loss.

$$CPS^{LO_{2\%}} = \frac{1}{49 \times DT}$$

$$CPS^{LO_{5\%}} = \frac{1}{19 \times DT}$$

$$CPS^{HI_{30\%}} = \frac{1}{2.3333 \times DT}$$

$$CPS^{HI_{60\%}} = \frac{1.5}{DT}$$

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 following equation:

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

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

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

The typical dead time for a M44-9 is approximately 85 µs. Therefore, with 85 µs for "DT" in equations 1-4, the *lo* field should be between 240 and 619 cps and the *hi* field is between 5,040 - 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.*

Variables and units 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 M2241.
CC = calibration constant entered into M2241.

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 :

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

Insert the cps *lo* data point (8 mR/hr for the M44-9 example) determined from equations (1) and (2):

$$CAL_{lo} = (0.008\frac{R}{h}) \times (\frac{1\ h}{60\ m}) \times (\frac{1\ m}{60\ s}) = \qquad 2.22 \times 10^{-6}\ \ s \qquad \textbf{(5)}$$

Insert the cps *hi* data point (200 mR/hr for the M44-9 example) determined from equations (3) and (4):

$$CAL_{hi} = (0.200\frac{R}{h}) \times (\frac{1\ h}{60\ m}) \times (\frac{1\ m}{60\ s}) = \qquad 55.6 \times 10^{-6}\ \ s \qquad \textbf{(6)}$$

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

$$CORR_{lo} = \frac{SAMPL_{lo}}{count\ time} = \qquad \frac{counts}{s} \qquad \textbf{(7)}$$

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

60 second count sample in low field of 8 mR/hr:

$$CORR_{lo} = \frac{26{,}427}{60} = \qquad 440\ C/s \qquad \textbf{(Example)}$$

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

$$CORR_{hi} = \frac{SAMPL_{hi}}{count\ time} = \qquad \frac{counts}{s} \qquad \textbf{(8)}$$

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

$$CORR_{hi} = \frac{5830}{1} = \qquad 5830\ C/s \qquad \textbf{(Example)}$$

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

$$f_d = CAL_{hi} - \frac{CORR_{hi} \times CAL_{lo}}{CORR_{lo}} = \qquad \frac{units}{s} \qquad \textbf{(9)}$$

$$f_d = 55.6 \times 10^{-6} - \frac{5830 \times 2.22 \times 10^{-6}}{440} = \qquad 26.2 \times 10^{-6}\ \ s \qquad \textbf{(Example)}$$

Solve for a_d:

$$a_d = (CAL_{hi} \times CORR_{hi}) - (CAL_{lo} \times CORR_{hi}) = \frac{units \cdot count}{s^2} \quad \textbf{(10)}$$

$$a_d = (55.6 \times 10^{-6} \times 5830) - (2.22 \times 10^{-6} \times 5830) = 31.1 \times 10^{-2} \quad \textbf{(Example)}$$

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

$$DT = \frac{f_d}{a_d} = \frac{s}{count} \quad \textbf{(11)}$$

$$DT = \frac{26.2 \times 10^{-6}}{31.1 \times 10^{-2}} = 84 \times 10^{-6}\ s \quad \textbf{(Example)}$$

Solve for f_{cal}:

$$f_{cal} = CAL_{lo} - (CAL_{lo} \times CORR_{lo} \times DT) = \frac{units}{s} \quad \textbf{(12)}$$

$$f_{cal} = 2.22 \times 10^{-6} - (2.22 \times 10^{-6} \times 440 \times 84 \times 10^{-6}) = 2.14 \times 10^{-6}\ s \quad \textbf{(Example)}$$

Enter the result of equation (12) into:

$$CC = \frac{CORR_{lo}}{f_{cal}} = \frac{count}{units} \quad \textbf{(13)}$$

and solve for CC:

$$CC = \frac{440}{2.14 \times 10^{-6}} = 206 \times 10^{6} \quad \textbf{(Example)}$$

☐ Select a detector setup number from position "A" on the Switch bd. Enter the CC and DT (positions 1 and 2 of the FUNCTION switch) values derived from the equations above. Perform section 5.4.3 to confirm that the instrument and detector have been calibrated correctly.

NOTE

If the LCD reads EEEE's (error) between switching from the detector setup position "A" to position "1" to enter the DT value, switch the M2241 OFF and back ON to reset the program.

Model 44-9 Parameter Setup:

FUNCTION	Parameter
1	0084 S-6
2	0206 06
3	R/hr
4	N/A
5-9	as desired
A	determined above
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, G-M	20 cps/mR/hr	90-110 µs
44-9, G-M	55 cps/mR/hr	80-90 µs
44-7, G-M	35 cps/mR/hr	240-290 µs
133-2, G-M	17.5 cps/mR/hr	40-55 µs
133-4, G-M	2 cps/mR/hr	40-55 µs
133-6, G-M	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 Ener. 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 are typical values and may vary between detector and instrument combinations. This table represents some of the common detectors operated with the M2241. Consult the LMI Calibration Department for information concerning detectors not given in the table above.

*The dead time values for these scintillation detectors is due to the dead time of the M2241 electronics.

5.4.5 Detector Overload (OVL) Calibration

NOTE

The detector operating voltage (HV) must be determined and adjusted before the "OVL" adjustment is performed. If the HV is varied or another detector is substituted, the "OVL" must be readjusted. If the "OVL" feature is not used, adjust the control to the maximum counterclockwise position.

■ The detector overload circuit senses current flow through the detector. As the radiation intensity is increased, the detector may start to saturate (decrease pulse production) and the readout may decrease or read zero, but as the pulse output continues to decrease in the saturated field, the detector current drain continues to increase. This increase in current is detected by a comparator circuit which triggers the "OVERLOAD" annunciation on the LCD via the microcontroller.

■ For G-M and gamma scintillation detectors, the "OVL" trip point is adjusted to where the readout no longer increases with increasing radiation intensity. In the event that the overload point cannot be determined due to radiation field limitations, adjust the overload point from 5 to 10 times the upper operating range of the detector.

☐ Adjust the "OVL" control to the maximum counterclockwise position.

☐ Place the detector in an increasing radiation

field in which the readout no longer increases. Adjust the "OVL" control until the "OVERLOAD" alarm appears.

☐ Position the detector between the upper operating limit and the "OVL" set point and ensure the "OVERLOAD" alarm is defeated. Adjust the "OVL" control accordingly. Example: Ludlum Model 44-9 is calibrated with M2241 in the R/hr units display, utilizing DT. The upper linear operating point is 400 mR/hr for the M44-9. Place the detector at the 1000 mR/hr point and adjust the "OVL" control to initiate the "OVERLOAD" alarm. Place the detector in the 600-700 mR/hr field and ensure that the "OVERLOAD" is off.

■ The detector overload or saturation point for alpha and/or beta scintillation detectors is when the detector face (mylar) has been punctured, allowing light to saturate the photomultiplier tube (PMT). The pulse output will decrease or even appear non-responsive to any radiation activity, depending upon the size of the puncture and the light intensity to the PMT.

☐ Expose the detector PMT to a small light leak by loosening the detector window. Some scintillation detectors incorporate a screw in the detector body which, when loosened, will simulate a detector face puncture. The Ratemeter readout should start to decrease as the light saturates the PMT.

☐ Adjust the "OVL" control until the "OVERLOAD" alarm just appears. Reseal the light leak connection and expose the detector to a radiation source that will produce a near full-scale reading. Confirm that the "OVERLOAD" alarm does not initiate. Readjust the "OVL" control as required.

6. THEORY OF OPERATION

6.1 Main Board # 5408-110

Refer to schematic series 408, sheet 91 for the following:

6.1.1 Detector Input/Amplifier

Negative-going detector pulses are coupled from the detector through C021 to Amplifier U021. R024 and CR021 protects 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 self-bias to 2Vbe (approximately 1.4 volts) at pin 7 of U021 provides just enough bias current through pin 6 of U021 to conduct all of the current for the constant current source. Positive pulses from pin 7 of U021 are coupled to the discriminator (U011) through R031 and C012.

6.1.2 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 (+5V) 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.

6.1.3 Low Voltage Supply

Battery voltage is coupled to DC-DC convertor U231. U231 and related components provide +5V 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 ±0.1V.

U121 provides the +2.5V reference for the "HV" and "DISC" control references.

6.1.4 High Voltage Supply

High Voltage is developed by blocking oscillator Q241, T141, 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 1250-2500 when the "HV" control on the Calibration Board is at maximum. The regulated HV output is controlled by the "HV" potentiometer 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.

6.1.5 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 the "CAL" cover) control provides adjustment for the overload set point.

6.1.6 Microcontroller (C)

U111, Intel N87C51FC, 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. C102 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 – will retain memory even after power is removed.

6.1.7 Audio

Click/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.

6.2 Switch Board (5408-052)

Refer to schematic series 408, sheet 45 for the following:

S1 ("FUNCTION") is a 16-position binary rotary switch which selects the programmable parameters for the M2241. The switch selects the parameters using the hexadecimal numbering system via buss lines SW1-SW4.

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

U1 is a +5V powered RS-232 driver/receiver used to interface the M2241 to a computer.

6.3 Display Board (5408-091)

Refer to schematic series 408, sheet 79 for the following:

6.3.1 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 DIN 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 @ 5V) 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.

6.3.2 Backlight Drive

Depressing the "LIGHT" switch instructs the μP to set the BACKLIGHT (refer to Main Board schematic) line, pin 31 on μP, "low" for the predetermined backlight ON time. A "low" condition on pin 31 causes Q212 to conduct, sending +5V to P8-3 on the Display Board.

7. MAINTENANCE

Instrument maintenance consists of keeping the instrument clean and periodically checking the batteries and the calibration.

An instrument operational check should be performed prior to each use by exposing the detector to a known source and confirming the proper reading on each scale.

Re-calibration 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.

Ludlum Measurements recommends recalibration at intervals no greater than one year. Check the appropriate regulatory agencies' regulations to determine required recalibration intervals.

The batteries should be removed and the battery contacts cleaned of any corrosion at least every 3 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 BATTERIES. ALTHOUGH THIS INSTRUMENT WILL OPERATE AT VERY HIGH AMBIENT TEMPERATURES, BATTERY SEAL FAILURE CAN OCCUR AT TEMPERATURES AS LOW AS 100° FAHRENHEIT.

PARTS LIST

Ref. No.	Description	Part No.
	Model 2241 Digital Ratemeter	
UNIT	Completely Assembled Model 2241 Digital Ratemeter	48-2444
	Main Circuit Board, Drawing 408 X 91	
BOARD	Completely Assembled Main Circuit	5408-110
	• **CAPACITORS**	
C001	47pF, 100V	04-5660
C002	47pF, 100V	04-5560
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, C	04-5547
C041-C043	0.0047µF, 3kV, C	04-5547
C101	47µF, 10V	04-5666
C102	10µF, 20V	04-5655
C121	47µF, 10V	04-5666
C122	27pF, 100V	04-5658
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
C138	100pF, 100V	04-5661
C139	0.001µF, 100V	04-5659
C137	47µF, 10V	04-5666
C141	0.0047µF, 3kV	04-5547
C241	1µF, 35V	04-5656
C242	68µF, 6.3V	04-5654
C243	0.1µF, 50V	04-5663
C251	68µF, 6.3V	04-5654
	• **TRANSISTORS**	
Q101	2N7002L	05-5840
Q141	MMBT3904T	05-5841
Q211	2N7002L	05-5840
Q212	MMBT4403LT	05-5842
Q241	MJD210	05-5843

Ref. No.	Description	Part No.
	• **INTEGRATED CIRCUITS**	
U001	CD74HC4538M	06-6297
U011	TLC372ID	06-6290
U021	CA3096M	06-6288
U111	N87C51FC PLCC	06-6303
U121	LM285M-2.5	06-6291
U122	X24C02S8I	06-6299
U131	LM358D	06-6312
U231	LT1073CS8-5	05-5852
	SOCKET822068-4 44P	06-6293
	• **DIODES**	
CR021	MMBD7000LT1	07-6355
CR031	GI250-2	07-6266
CR041-CR044	GI250-2	07-6266
CR231	CXSH-4 EB33	07-6358
CR241	MMBD914L	07-6353
CR242	CXSH-4 EB33	07-6358
	• **RESISTORS**	
R001	100k, 1/8W, 1%	12-7834
R002	10k TRIMMER	09-6921
R011-R012	10k, 1/8W, 1%	12-7839
R013	1k, 1/8W, 1%	12-7832
R014	10k, 1/8W, 1%	12-7839
R015	100k, 1/8W, 1%	12-7834
R021	1 MEG	10-7028
R022	392k, 1/8W, 1%	12-7841
R023	10k, 1/8W, 1%	12-7839
R024-R025	4.75k, 1/8W, 1%	12-7858
R026	8.25k, 1/8W, 1%	12-7838
R027	1 MEG TRIMMER	09-6906
R031	4.7 MEG	10-7030
R032	1 MEG	10-7028
R033-R034	1G	12-7686
R111-R113	2.1k, 1/8W, 1%	12-7843
R121	100, 1/8W, 1%	12-7840
R122	6.81k, 1%	12-7857
R131-R132	1 MEG, 1%	12-7844
R133	750k, 1%	12-7882
R134	1 MEG, 1%	12-7844
R135	82.5k, 1%	12-7849
R136	10k, 1/8W, 1%	12-7839
R141	22.1k, 1/8W, 1%	12-7843
R211	2.21k, 1/8W, 1%	12-7835
R231	100, 1/8W, 1%	12-7840
R241	1k, 1/8W, 1%	12-7832
R242	200OHM, 1/8W, 1%	12-7846

- **CRYSTALS**

Y221	MICRO X-TAL-6.144 MHZ	01-5262

- **INDUCTORS**

L231	CTX100-2	21-9740

- **TRANSFORMERS**

T101	M 177 AUDIO	4275-083
T141	L8050	40-0902

- **MISCELLANEOUS**

P1	CONN-1-640456-2 MTA100	13-8061
P2	CONN-1-640456-3 MTA100	13-8100
P3	CONN-640456-6 MTA100	13-8095
P4	CONN-640456-2 MTA100	13-8073
P5	CONN-1-640456-2 MTA100	13-8061

Calibration Board, Drawing 408 x 12

BOARD	Assembled Calibration	5408-007

- **RESISTORS**

R1	100k TRIMMER	09-6813
R2-R3	1 MEG TRIMMER	09-6814
R4	10k, 1/3W, 5%	12-7748
R5-R6	1 MEG, 1/3W, 5%	12-7751
R7	1k, 1/3W, 5%	12-7750

- **CONNECTORS**

P7	CONN-640456-6 MTA100	13-8095

Display Board, Drawing 408 x 79

BOARD	Completely Assembled Display	5408-091

- **CAPACITORS**

C012	27pF, 100V	04-5658
C113	47pF, 100V	04-5660

- **INTEGRATED CIRCUITS**

U111	AY0438-I/L	06-6358
U114	SP4422N	06-6399
U211	AY0438-I/L	06-6358

- **RESISTORS**

R001	10k, 1/8W, 1%	12-7839
R002	8.25k, 1/8W, 1%	12-7838
R003-R004	10k, 1/8W, 1%	12-7839
R121	10k, 1/8W, 1%	12-7839

- **INDUCTORS**

L001-L002	20mH, 70 OHM	21-9792
L011-L012	20mH, 70 OHM	21-9792

- **MISCELLANEOUS**

*	CONN-640456-8 MTA100	13-8039
DS111	Backlight-EL QUANTEX	07-6382
DSP1	LCD-8246-365-4E1	07-6383

Switch Board, Drawing No. 408 x 45

BOARD	Assembled Switch	5408-052

- **CAPACITORS**

C1-C2	4.7µF, 10V, DT	04-5578
C3-C4	10µF, 20V, DT	04-5592
C5	4.7µF, 10V, DT	04-5578
C6	100µF, 10V	04-5576

- **INTEGRATED CIRCUITS**

U1	MAX220EPE	06-6359

- **SWITCHES**

S1	350134GSK	08-6721
S2-S4	3CTH9 PB	08-6716

- **RESISTORS**

R1-R2	22k, 1/4W, 5%	10-7070

- **MISCELLANEOUS**

P6	CONN-1-640456-3 MTA100	13-8100
P10	CONN-208006-2	13-8451

Chassis Wiring Diagram, Drawing No. 408 X 103

- **AUDIO**

DS1	UNIMORPH	21-9251

- **CONNECTOR**

J1	CONN-1-640442-2 MTA100	13-8407
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-640442-6 MTA100	13-8171
J8	CONN-640442-8 MTA100	13-8184
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

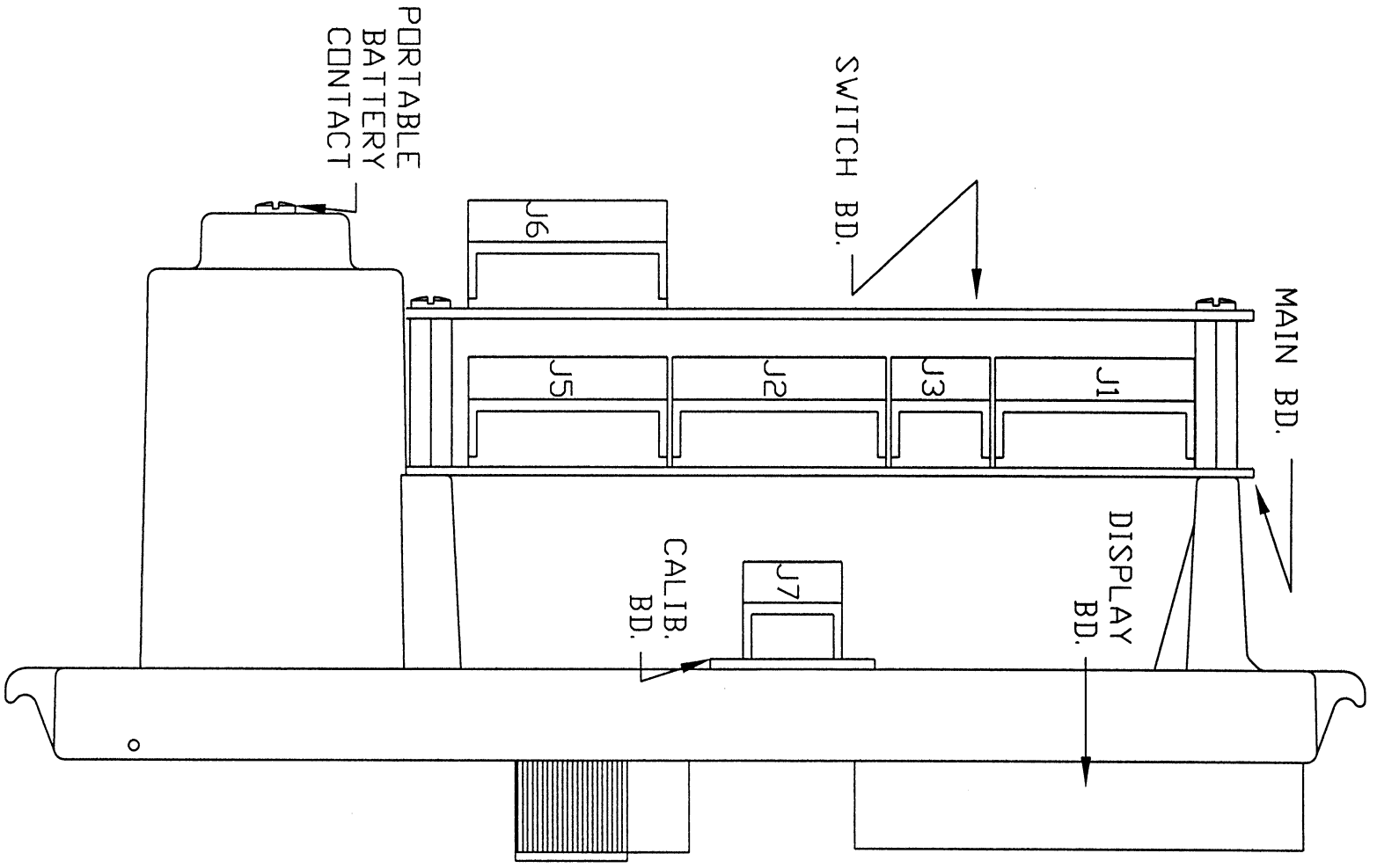
- **MISCELLANEOUS**

*	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
*	CASTING	9408-044
	Portable HARNESS CAN WIRES	8363-462
*	CAN ASSY.	4363-441
*	PORTABLE KNOB	08-6613
*	BATTERY LID W/LATCHSET	9408-033
*	PORT. LATCH KIT W/O BATT. LID	4363-349
*	PORT CALIB. COVER W/SCREWS	9363-200
*	HANDLE	7408-074
*	DIGITAL PUSHBUTTON MOUNT	7363-759

DRAWINGS AND DIAGRAMS

M2241 Assembled View, Drawing 408 x 50
Main Circuit Board, Drawing 408 x 91
Main Circuit Board Component Layout, Drawing 408 x 92
Calibration Board, Drawing 408 x 12
Calibration Board Component Layout, Drawing 408 x 13
Display Board, Drawing 408 x 79
Display Board Component Layout, Drawing 408 x 80
Switch Board, Drawing 408 x 45
Switch Board Component Layout, Drawing 408 x 46
Wiring Diagram, Drawing 408 x 103

REV #	ALTERATIONS	DATE	BY
	VALID	12-31-96	TJR



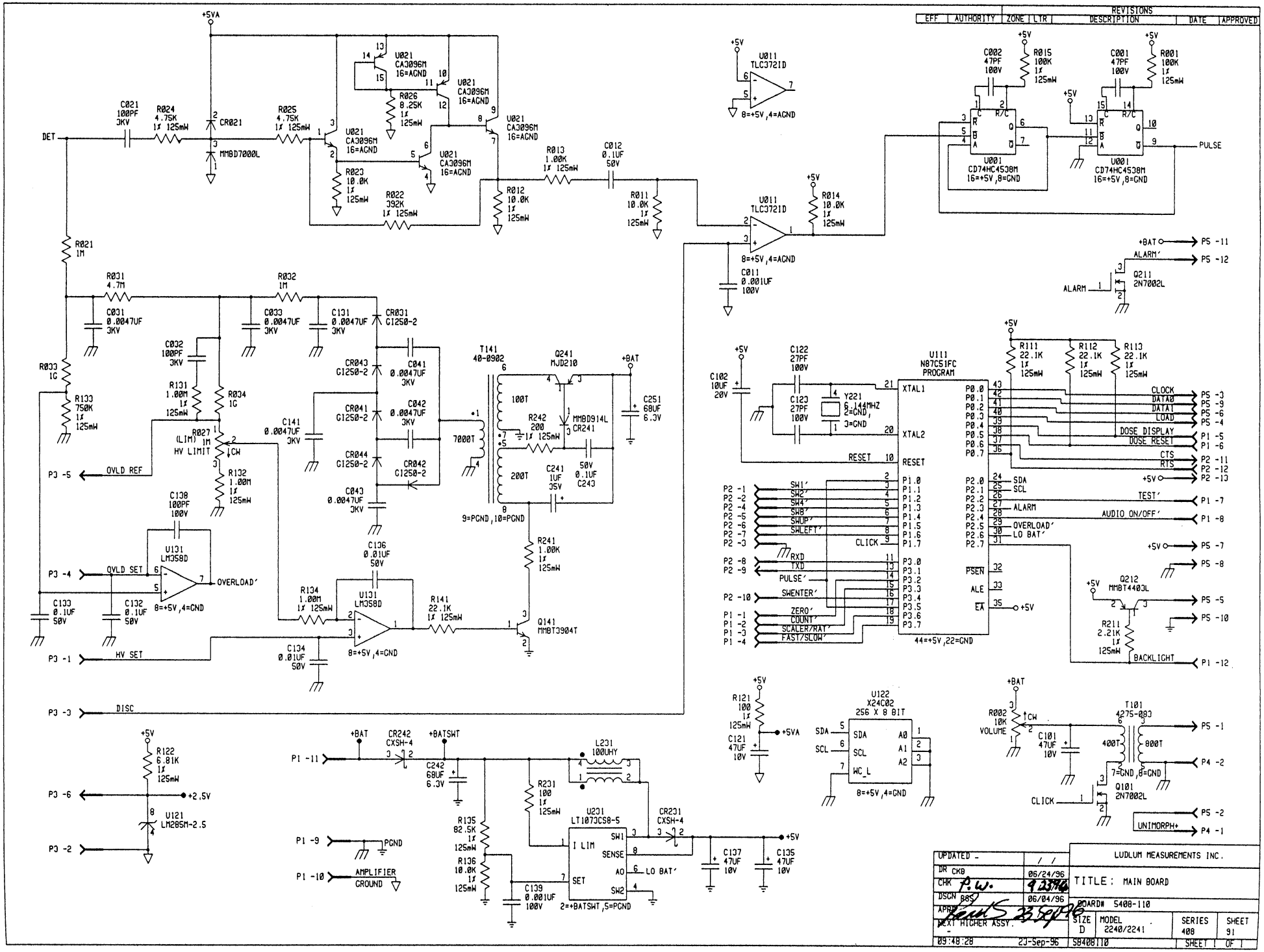
DWN	DATE	CHECKED	QC APPROVED
TJR	12-31-96	12-31-96 JGW	

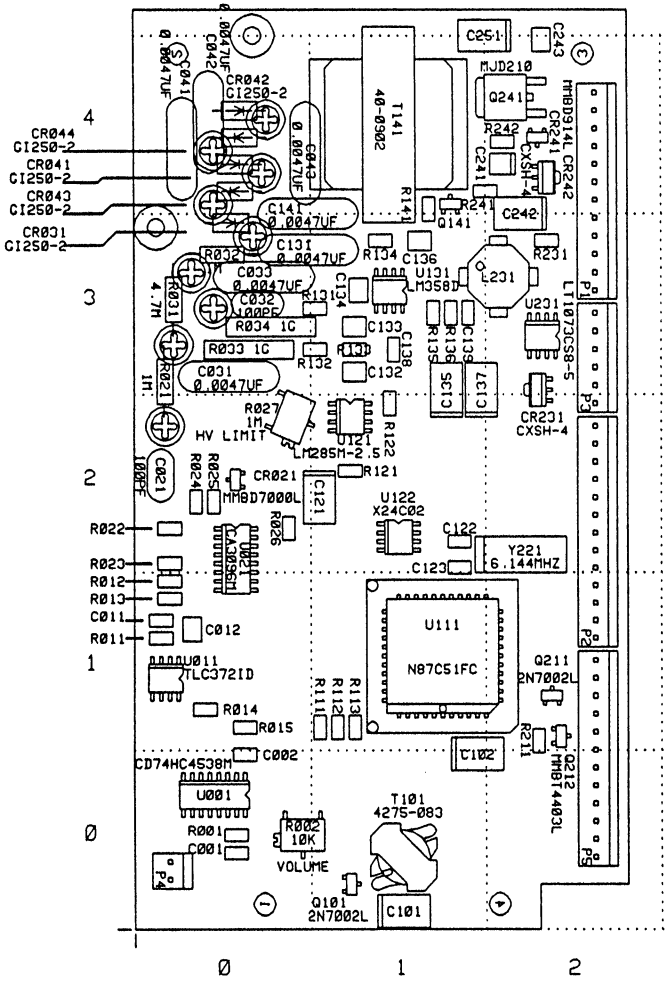
MODEL: MODEL 2241 / 2241-1

LUDLUM MEASUREMENTS, INC.
501 OAK STREET
SWEETWATER, TEXAS 79556

SERIES 408

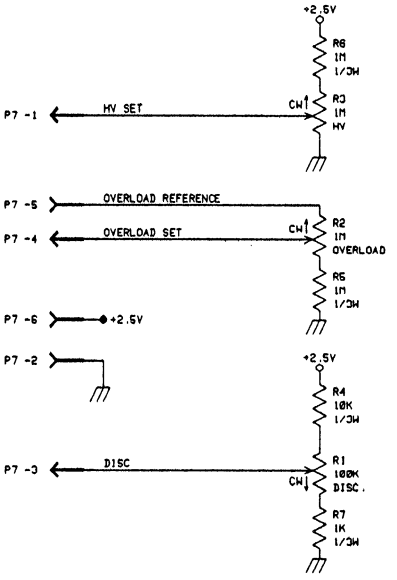
SHEET 50


REVISIONS
EFF | AUTHORITY | ZONE | LTR | DESCRIPTION | DATE | APPROVED
+5VA
DET
C021 100PF 3KV
R024 4.75K 1% 125mW
CR021
MMBD7000L
R025 4.75K 1% 125mW
U021 CA3096M 16=AGND
R026 8.25K 1% 125mW
R023 10.0K 1% 125mW
R022 392K 1% 125mW
R012 10.0K 1% 125mW
R013 1.00K 1% 125mW
C012 0.1UF 50V
R011 10.0K 1% 125mW
U011 TLC3721D
8=+5V,4=AGND
C011 0.001UF 100V
R014 10.0K 1% 125mW
C002 47PF 100V
R015 100K 1% 125mW
C001 47PF 100V
R001 100K 1% 125mW
U001 CD74HC4538M 16=+5V,8=GND
PULSE
+BAT
ALARM'
ALARM
Q211 2N7002L
PS -11
PS -12
R021 1M
R031 4.7M
R032 1M
R033 1G
R034 1G
C031 0.0047UF 3KV
C032 100PF 3KV
C033 0.0047UF 3KV
C131 0.0047UF 3KV
CR031 G1250-2
CR043 G1250-2
CR041 G1250-2
CR044 G1250-2
CR042 G1250-2
C041 0.0047UF 3KV
C042 0.0047UF 3KV
C043 0.0047UF 3KV
R131 1.00M 1% 125mW
R027 (LIM) 1M HV LIMIT
CW
R132 1.00M 1% 125mW
R133 750K 1% 125mW
C138 100PF 100V
C141 0.0047UF 3KV
T141 40-0902
100T
7000T
200T
9=PGND,10=PGND
Q241 MJD210
R242 200 1% 125mW
MMBD914L CR241
C241 1UF 35V
50V 0.1UF C243
C251 68UF 6.3V
P3 -5
OVLD REF
P3 -4
OVLD SET
P3 -1
HV SET
U131 LM358D
8=+5V,4=GND
OVERLOAD'
C133 0.1UF 50V
C132 0.1UF 50V
C136 0.01UF 50V
C134 0.01UF 50V
R134 1.00M 1% 125mW
R141 22.1K 1% 125mW
R241 1.00K 1% 125mW
Q141 MMBTJ904T
P3 -3
DISC
U111 N87C51FC PROGRAM
XTAL1
XTAL2
RESET
C102 10UF 20V
C122 27PF 100V
C123 27PF 100V
Y221 6.144MHZ 2=GND, 3=GND
R111 22.1K 1% 125mW
R112 22.1K 1% 125mW
R113 22.1K 1% 125mW
P2 -1 SW1'
P2 -2 SW2'
P2 -4 SW4'
P2 -5 SW8'
P2 -6 SWUP'
P2 -7 SWLEFT'
P2 -3 CLICK
P2 -8 RXD
P2 -9 TXD
PULSE'
P2 -10 SWENTER'
P1 -1 ZERO'
P1 -2 COUNT'
P1 -3 SCALER/RAT'
P1 -4 FAST/SLOW'
PSEN
ALE
EA
44=+5V,22=GND
CLOCK
DATA0
DATA1
LOAD
DOSE DISPLAY
DOSE RESET
CTS
RTS
SDA
SCL
TEST'
ALARM
AUDIO ON/OFF'
OVERLOAD'
LO BAT'
Q212 MMBT4403L
R211 2.21K 1% 125mW
BACKLIGHT
P1 -12
P5 -3
P5 -9
P5 -6
P5 -4
P1 -5
P1 -6
P2 -11
P2 -12
P2 -13
P1 -7
P1 -8
P5 -7
P5 -8
P5 -5
P5 -10
R122 6.81K 1% 125mW
U121 LM285M-2.5
+2.5V
P3 -6
P3 -2
R121 100 1% 125mW
C121 47UF 10V
U122 X24C02 256 X 8 BIT
SDA
SCL
WC_L
A0
A1
A2
8=+5V,4=GND
R002 10K VOLUME
C101 47UF 10V
T101 4275-080
400T
800T
7=GND,8=GND
Q101 2N7002L
CLICK
UNIMORPH+
P5 -1
P4 -2
P5 -2
P4 -1
P1 -11
+BAT
CR242 CXSH-4
+BATSWT
C242 68UF 6.3V
L231 100UHY
R231 100 1% 125mW
R135 82.5K 1% 125mW
R136 10.0K 1% 125mW
C139 0.001UF 100V
U231 LT1073CS8-5
I LIM
SENSE
SET
SW1
SW2
LO BAT'
2=+BATSWT,5=PGND
CR231 CXSH-4
C137 47UF 10V
C135 47UF 10V
P1 -9
PGND
P1 -10
AMPLIFIER GROUND
UPDATED - / /
DR CKB 06/24/96
CHK P.W. 9-23-96
DSGN BBS 06/04/96
APPR Kevin S 9-23-96
NEXT HIGHER ASSY. -
09:48:28 23-Sep-96
LUDLUM MEASUREMENTS INC.
TITLE: MAIN BOARD
BOARD# S408-110
SIZE D
MODEL 2240/2241
SERIES 408
SHEET 91
S8408110
SHEET 1 OF 1

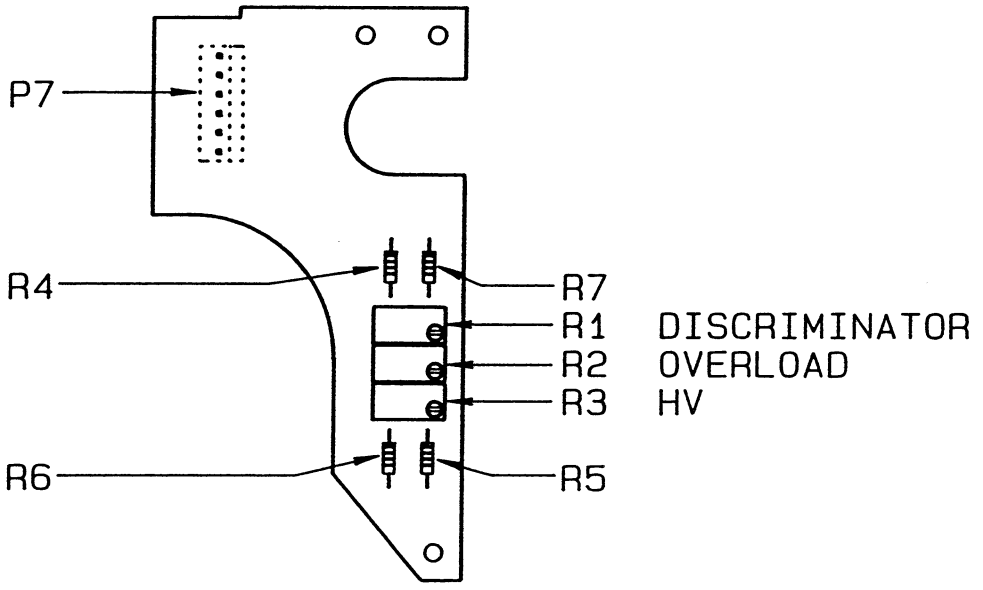


LUDLUM MEASUREMENTS INC. SWEETWATER, TX.				
DR CKB	06/24/96	TITLE: MAIN BOARD		
CHK RW	9/27/96	BOARD# 5408-110		BS408110
DSGN RSS	06/04/96	MODEL 2240	SERIES 408	SHEET 92
APP [illegible] 5235/96		COMP ARTWORK ☐		SLDR ARTWORK ☐
10:17:22	13-Sep-96	COMP OUTLINE ☒		SLDR OUTLINE ☐
COMP PASTE ☐	COMP MASK ☐	SLDR PASTE ☐		SLDR MASK ☐

REVISIONS						
EFF	AUTHORITY	ZONE	LTR	DESCRIPTION	DATE	APPROVED



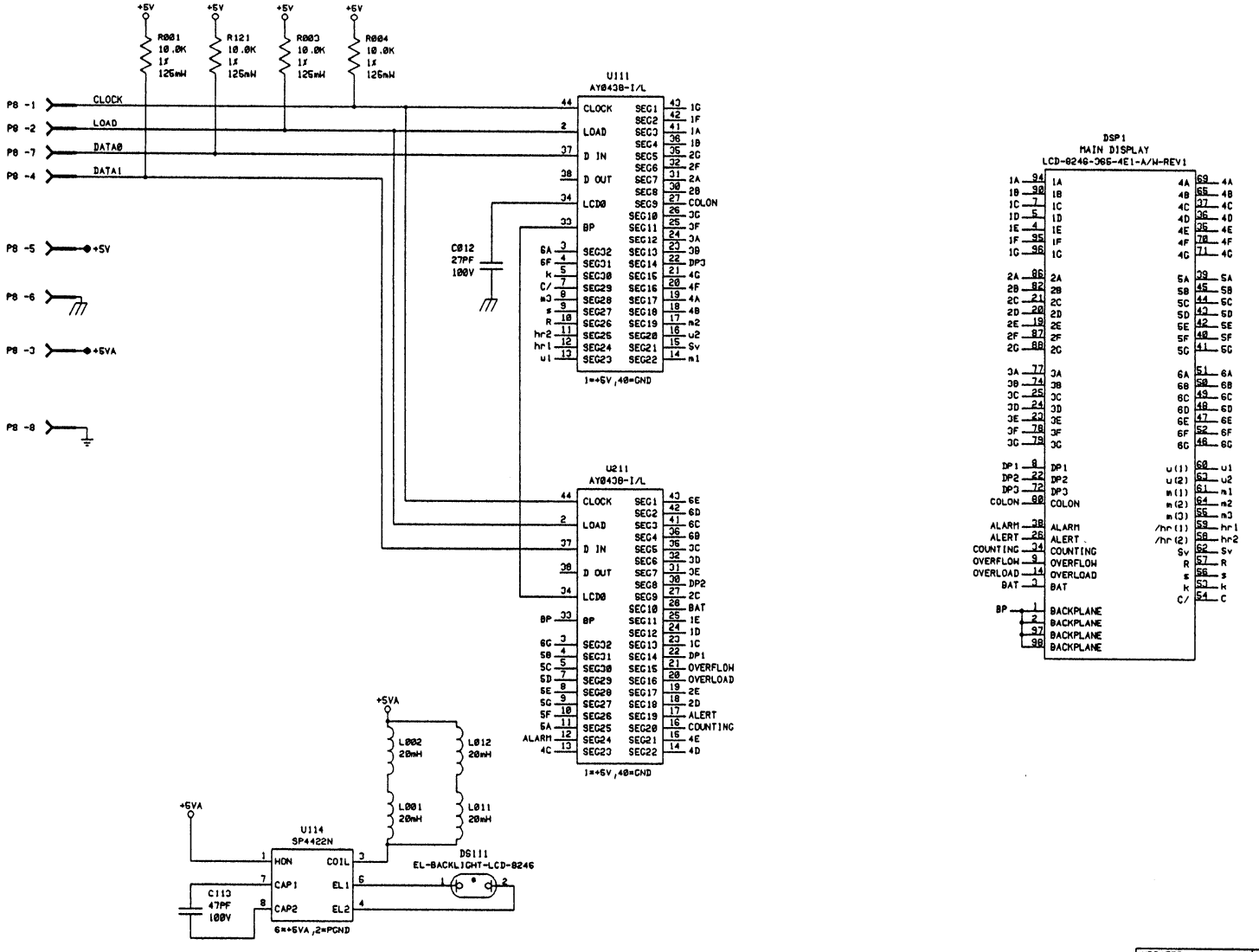
UPDATED -	/ /	LUDLUM MEASUREMENTS INC.
DR CKB	02/15/94	
CHK P.W.	1.3.97	TITLE: CALIBRATION BOARD
DSGN LL	3/22/93	BOARD# 5400-007
APPD ROS 03JAN97		SIZE D / MODEL 1900/2240/2241 / SERIES 400 / SHEET 12
NEXT HIGHER ASSY. -		
13:19:31	3-Jan-97	S8400007 SHEET 1 OF 1



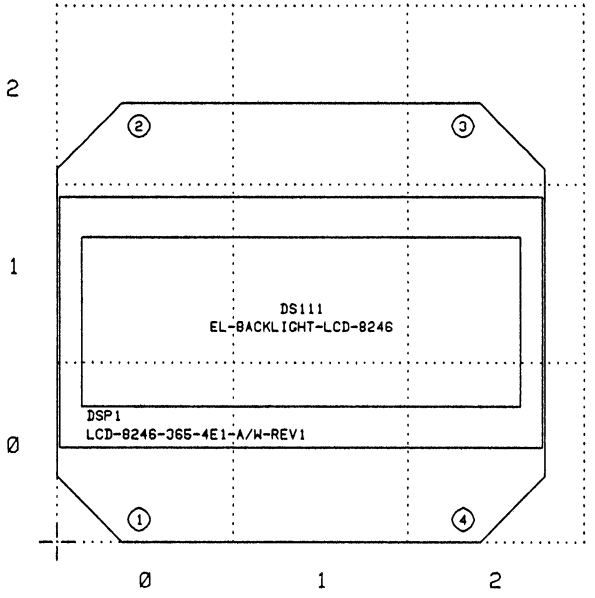
DESC: COMPONENT OUTLINES	
MODEL: 2240/2241	
PART #: 5408-007	
DWN: CKB	DATE: 02/15/94
DSGN:	DATE:

CHG	NO.					DWN	CHK	APP
DWN CKB	DATE 02/15/94	CHK MA	DATE 01/03/97	APP	DATE		
TOL: SHOP STD ☐ OTHER				SCALE: FULL ☐ OTHER			
TITLE MODEL 2240/2241 CAL BOARD							
LUDLUM MEASUREMENTS, INC. 501 OAK STREET SWEETWATER, TEXAS 79556				SERIES 408		SHEET 13	

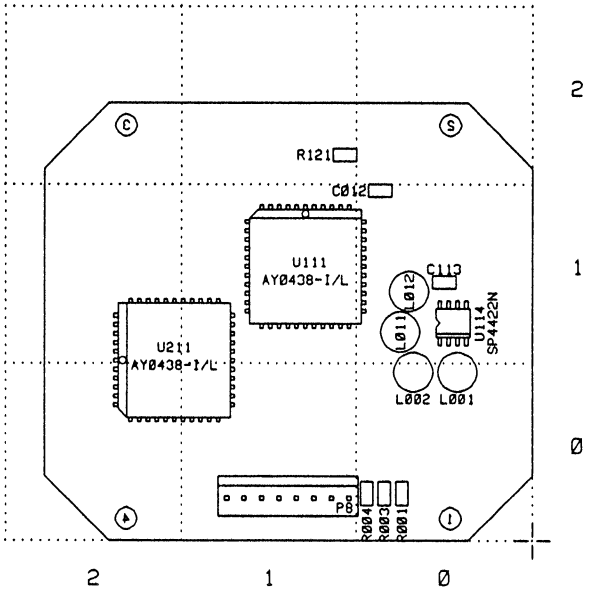
REVISIONS						
EFF	AUTHORITY	ZONE	LTR	DESCRIPTION	DATE	APPROVED



UPDATED -	/ /	LUDLUM MEASUREMENTS INC.
DR CKB	02/01/96	
CHK P.W.	1/3/97	TITLE: DISPLAY W/E.L.
DSGN RBS	01/12/96	BOARD# 5400-091
APPD RLS	03JAN97	
NEXT HIGHER ASSY. -		SIZE D / MODEL 2240/2241 / SERIES 400 / SHEET 79
13:18:34	3-Jan-97	S8400091 / SHEET 1 OF 1

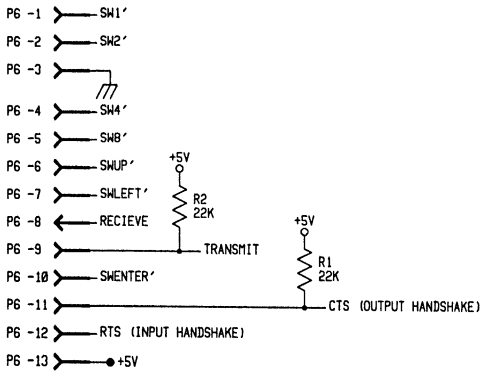


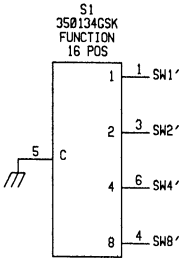
LUDLUM MEASUREMENTS INC. SWEETWATER, TX.				
DR CKB	01/15/96	TITLE: DISPLAY BOARD W/E.L.		
CHK R.C.	9/24/96	BOARD# 5408-091		BS408091
DSGN RSS	01/12/96	MODEL2240/2241	SERIES 400	SHEET 80
APP [illegible] 24Sep96		COMP ARTWORK ☐		SLDR ARTWORK ☐
16:20:09	24-Sep-96	COMP OUTLINE ☒		SLDR OUTLINE ☐
COMP PASTE ☐	COMP MASK ☐	SLDR PASTE ☐		SLDR MASK ☐



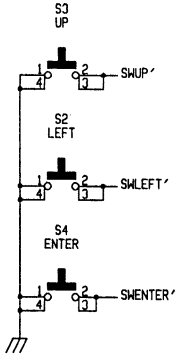
LUDLUM MEASUREMENTS INC. SWEETWATER, TX.					
DR CKB	01/15/96	TITLE: DISPLAY BOARD			
CHK R.C.	9/24/96	BOARD# 5408-091		BS408091	
DSGN RSS	01/12/96	MODEL 2240/2241	SERIES 408	SHEET 00	
APP Paul S 2 Sept 96		COMP ARTWORK ☐		SLDR ARTWORK ☐	
13:42:00	02-FEB-96	COMP OUTLINE ☐		SLDR OUTLINE ☒	
COMP PASTE ☐	COMP MASK ☐	SLDR PASTE ☐		SLDR MASK ☐	

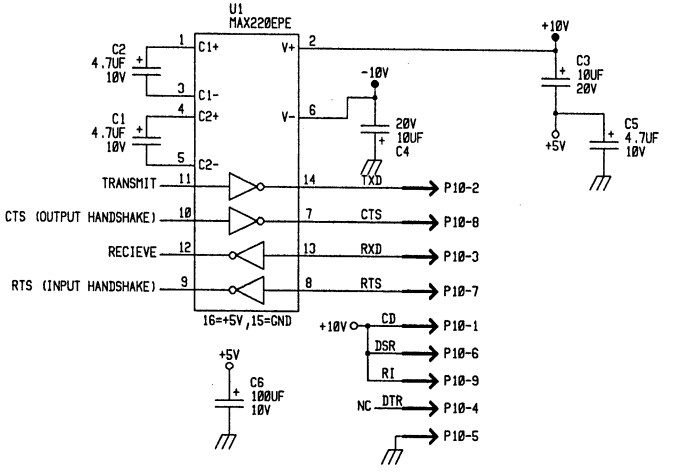
REVISIONS						
EFF	AUTHORITY	ZONE	LTR	DESCRIPTION	DATE	APPROVED



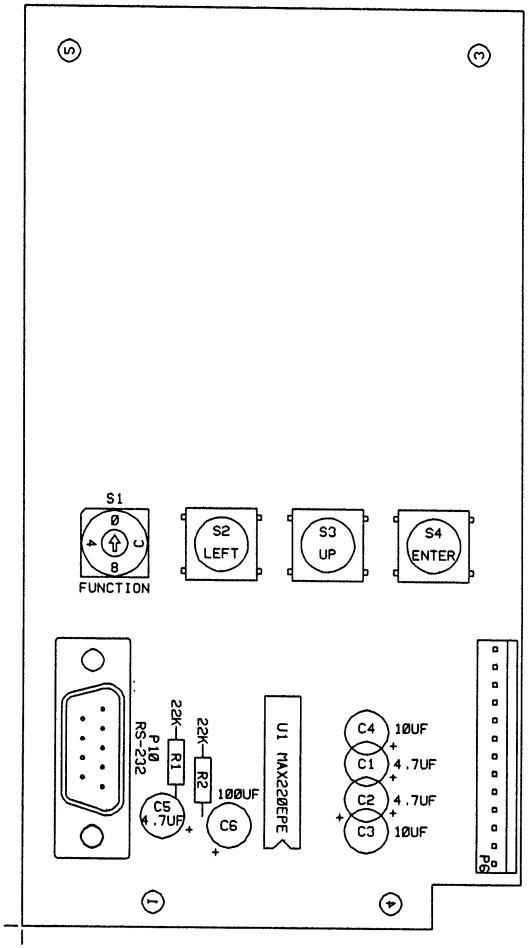


POS	FUNCTION
0	NORMAL OPERATION
1	DEAD TIME (us)
2	CALIBRATION CONSTANT
3	DISPLAY UNITS
4	TIMEBASE: CPS, CPM
5	AUDIO DIVIDE BY
6	RESPONSE TIME
7	RATEMETER ALARM / ALERT
8	SCALER ALARM / COUNT TIME
9	NOT USED
A	DETECTOR SETUP NUMBER
B	LCD BACKLIGHT ON TIME
C	SET MINIMUM DISPLAY
D	RS-232 DATA DUMP MODE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



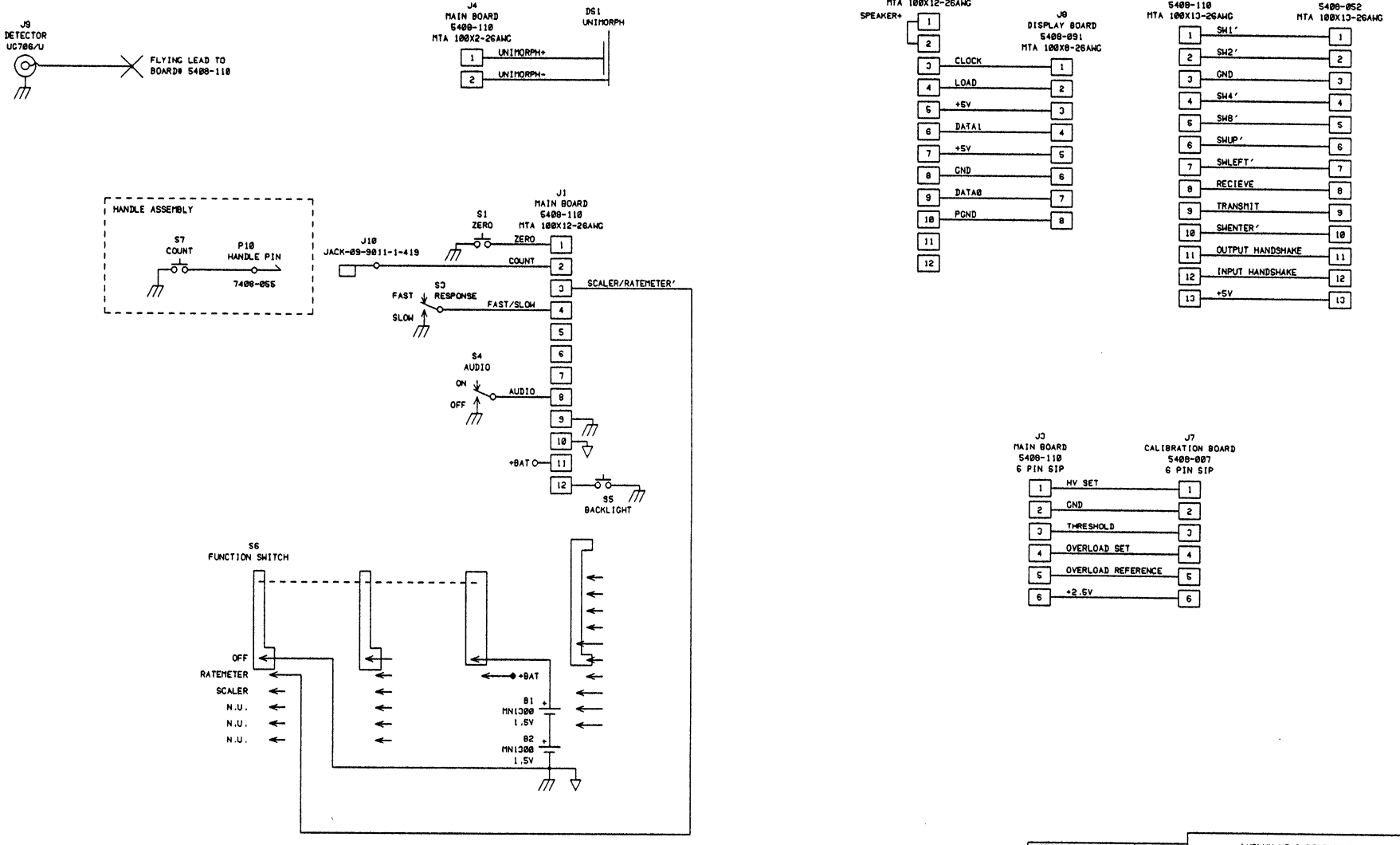


UPDATED CKB	21-DEC-00	LUDLUM MEASUREMENTS INC.
DR CKB	06/24/96	
CHK RSS	12-21-00	TITLE: SWITCH BOARD
DSGN LL	3/17/93	BOARD# 5408-052
APPD RDS	21Dec00	SIZE C / MODEL 2241 / SERIES 408 / SHEET 45
NEXT HIGHER ASSY. -		
09:54:25	21-Dec-00	S8408052 SHEET 1 OF 1



LUDLUM MEASUREMENTS INC. SWEETWATER, TX.					
DR	CKB	06/24/96	TITLE: SWITCH BOARD		
CHK	RDS	12-21-00	BOARD: 5408-052		
DSGN	LL	03/16/94	MODEL: 2241		
APP	RDS	21Dec00	FILENAME: BS408052		
COMPONENT		SOLDER	09:52:54		21-Dec-00
			REVISION	SERIES	SHEET
OUTLINE		OUTLINE	1.0	408	46

REVISIONS						
EFF	AUTHORITY	ZONE	LTR	DESCRIPTION	DATE	APPROVED



UPDATED RSS	12-30-96	LUDLUM MEASUREMENTS INC.
DR CKB	09/23/96	
CHK P.W.	11297	TITLE: WIRING DIAGRAM
DSGN RSS	06/04/96	BOARD# 408-117
APPD ROS ORIGINAL		SIZE D / MODEL 2241 AND 2241-1 / SERIES 408 / SHEET 103
NEXT HIGHER ASSY. -		
15:52:38	30-Dec-96	W408117 / SHEET 1 OF 1