LUDLUM MODEL 2224-1
SCALER / RATEMETER

July 2022

Serial Number 125559 and Succeeding

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LUDLUM MEASUREMENTS, INC
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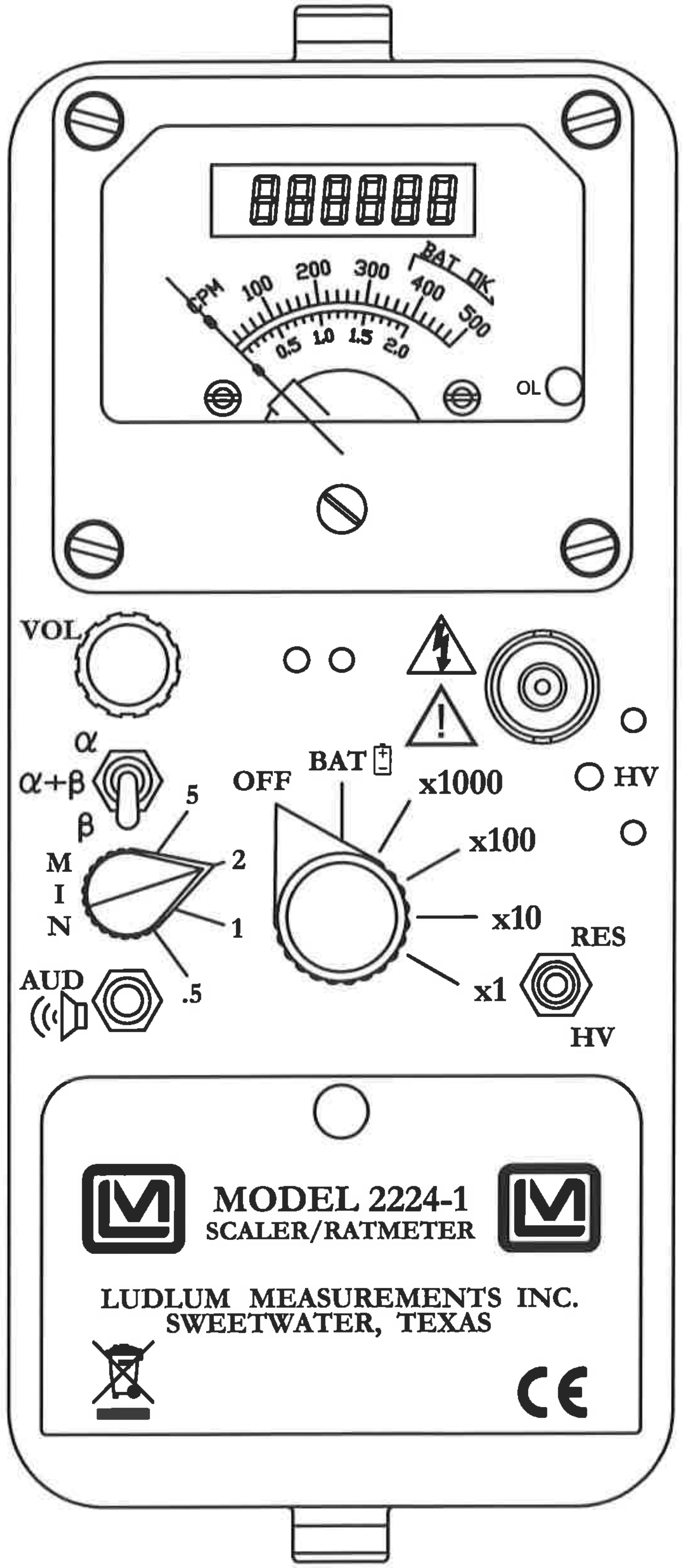
REV #	ALTERATIONS	DATE	BY
1	VALID	6/26/95	PW
2	UPDATED ARTWORK	5/15/06	CMC



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LUDLUM MEASUREMENTS, INC. 501 OAK STREET SWEETWATER, TEXAS 79556			SERIES 390		SHEET 115

Table of Contents

Section 1

Introduction

The Model 2224-1 is a portable microprocessor based radiation survey instrument used to measure and discriminate low-level alpha/beta radiation when used with an alpha/beta scintillation or proportional detector.

The data is displayed by an analog ratemeter and a six-digit liquid crystal display (LCD) counter. The ratemeter dial indicates 0-500 CPM with four linear range multipliers of ×1, ×10, ×100, and ×1000, producing an overall range of 0-500 kCPM. The LCD is used to display the counts accumulated during the preset count time. Four count times are available for selection through a front-panel switch. These count times are: 0.5, 1, 2 and, 5 minutes. The counter is reset and started by pressing the count button located in the end of the carrying handle.

The ratemeter and LCD can display alpha only, beta only, or alpha and beta by selecting the corresponding toggle switch selection. Audible click-per-event tones can also be selected to discriminate beta (low pitch tone) from alpha (high pitch tone) via the side-mounted speaker. Beta threshold, window, and alpha threshold are adjustable to optimize alpha/beta efficiency and count separation.

A regulated high-voltage power supply adjustable from 400 to 2000 volts with detector overload detection is utilized to operate a wide range of scintillation detectors. Other operating features of the instrument include programmable audio divide-by (beta channel only), a two-position switch (internal) for selecting the audio discrimination mode, audio headphone jack, adjustable volume, battery test pushbutton, high-voltage display pushbutton, and a ratemeter reset pushbutton.

The unit body is made of cast aluminum with a drawn aluminum can. The unit is operated with two ˝D˝ cell flashlight batteries for operation from -10 ºC to approximately 50 ºC (14 to 122 °F). For operation to -10 ºC (14 °F), either very fresh alkaline or rechargeable NiCd batteries may be used.

Section

2

Getting Started

Unpacking and Repacking

Remove the calibration certificate and place it in a secure location. Remove the instrument and accessories (batteries, cable, etc.) and ensure that all of the items listed on the packing list are in the carton. Check individual item serial numbers and ensure calibration certificates match. The Model 2224-1 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 is therefore not interchangeable.

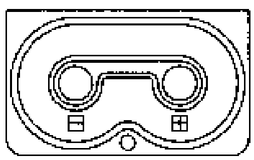
To return an instrument for repair or calibration, provide sufficient packing material to prevent damage during shipment. Also provide appropriate warning labels to ensure careful handling. Include detector(s) and related cable(s) for calibration. Include brief information as to the reason for return, as well as return shipping instructions:

- **Return shipping address**
- **Customer name or contact**
- **Telephone number**
- **Description of service requested and all other necessary information**

Internal Switches

Release the can latches and remove the cover from the instrument, taking care not to damage the speaker wires. Using a ball-point pen, set the switches for the desired AUDIO division and TONE as described on Page 4-3. Replace the cover and fasten the latches.

Battery Installation



Ensure that the range selector switch is in the ˝OFF˝ position. Open the battery lid by pushing down and turning the quarter-turn thumbscrew counterclockwise one-fourth of a turn. Install two ˝D˝ size batteries in the compartment.

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

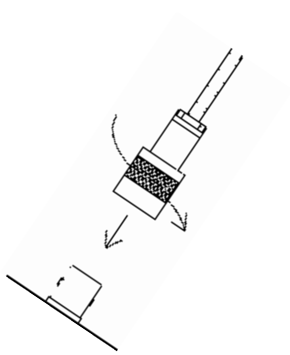
Note:

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

Connecting a Detector to the Instrument

Caution!

The detector operating voltage (HV) is supplied to the detector via the detector input connector. A mild electric shock may occur if you make contact with the center pin of the input connector. Switch the Model 2224-1 to the ˝OFF˝ position before connecting or disconnecting the cable or detector.



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

Battery Test

The batteries should be checked each time the instrument is turned on. Move the range selector switch to the BAT position. Verify that the overload (OL) LED on the front panel turns on briefly. The LCD should go through an initialization sequence displaying ˝88:8.8:8.8,˝ then the current sample number, and finally ˝0.˝ Ensure that the meter needle deflects to the battery check portion on the meter scale. If the meter does not respond, check to see if the batteries have been correctly installed. Replace the batteries if necessary.

Operating the Instrument

Connect a detector to the instrument if you have not already done so. Obtain a meter reading from a check source or calibrated source, if available. Verify that the reading falls within the expected range. Remove the source.

If a radiation source is available, increase the meter count to exceed the counting capability of the instrument, signified by the illumination of OL LED and full-scale needle deflection.

Depress the RESET pushbutton. The meter needle should drive to zero, and the alarm circuit should de-energize, shutting off the visual alarm.

Select the desire count channel display (α/α+β/β) and count cycle duration (MIN) and proceed with use.

Principle of Operation

The Model 2224-1 is to be used in combination with alpha/beta scintillation or proportional detectors. The instrument uses pulse heights discrimination to distinguish between alpha and beta pulses from the radiation detector.

The detected alpha count is displayed by selecting the α position on the three-position α, α + β, and β toggle switch. The sum of the alpha and beta counts are displayed in the α + β position, and beta counts are displayed in the β position. Multiply the CPM reading on the analog ratemeter by the range multiplier position. When using the LCD and count cycle selector switch (MIN), the counts are accumulated in each of the three channels during the count cycle. The alpha, alpha + beta, and beta counts can be displayed by selecting the appropriate α, α + β, β channel. The count cycle is started by depressing the pushbutton switch located in the end of the carrying handle.

The RESET pushbutton switch resets the meter pointer to zero. The detector operating voltage is displayed on the meter dial, 0-2 kV (kilovolts), by depressing the HV switch. The OL (overload) lamp, located in the lower right-hand corner of the meter dial, is to indicate that the detector is saturated either by a puncture in the detector face on a scintillation detector or an exposure to a radiation field above the counting capability of the instrument. The analog meter will deflect full-scale when the OL lamp is illuminated.

Section 3

Specifications

Ranges: four linear range multiples of ×1, ×10, ×100 and ×1000; used in combination with the 0-500 CPM meter dial, providing an overall range of 0-500 kcpm

Thresholds: beta threshold (BT) is adjustable from -2 to -10 millivolts (mV); alpha threshold (AT) is adjustable from -50 to -150 mV

Window (beta only): Beta window (BW) is adjustable from 20-40 mV

Audio: dual or single-tone click-per-event (beta only) through a built-in speaker with an adjustable volume control located on front panel; headset jack located on the instrument ˝can˝

High Voltage: externally adjustable from 400 to 2000 Vdc

Linearity: within 10% of true value for the analog rate meter; within 2% for the LCD

Crosstalk: no more than 10% of gross alpha counts in beta channel; no more than 1% of gross beta counts in alpha channel

Response Time: ×1 range multiplier = 10 seconds, ×10 = 7 seconds, ×100 = 2 seconds, ×1000 = 1.5 seconds; all response times measured from 10-90% of full scale

Meter: rugged 1 milliamp (mA), with pivot-and-jewel suspension, 8.3 cm scale, 250 degree

LCD: six-digit direct-driven with 6.4 mm characters, a counter overflow arrow and colons for indicating a count in process

Connector: Standard series ˝C,˝ others available

Power: two standard ˝D˝ cell batteries

Battery Dependence: instrument calibration change less than 3% to battery endpoint

Battery Life: exceeds 350 hours with a fresh set of alkaline ˝D˝ cell batteries

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

Finish: drawn-and-cast aluminum, with beige powder coating

Size: 16.5 x 8.9 x 21.6 cm (6.5 x 3.5 x 8.5 in.) (H x W x L)

Weight: 1.6 kg (3.5 lb), including batteries

Section 4

Description of Controls and Functions

Operator Controls

OFF/BAT/X1000/X100/X10/X1 Switch (or Range Selector Switch): a six-position rotary switch to select the analog meter range multipliers and check the battery status. When switched to the BAT position, the meter pointer should deflect above the left vertical mark on the BAT OK or BAT TEST line. Moving the range selector switch to one of the range multiplier positions (×1, ×10, ×100, ×1000) provides the operator with an overall range of 0-500 kcpm. Multiply the scale reading by the multiplier to determining the actual reading.

During the initial turn-on, the meter is driven full-scale for about two seconds and then returns to zero. The LCD will then show "888888," display the processor program version, and then "0."

Liquid Crystal Display (LCD): six-digit display that shows the scaler count for the selected channel. The display also indicates when a count is in progress by displaying two colons. The colons are turned off when the count is completed. If the counter exceeds 999999, an arrow in the upper left corner of the display turns on to indicate the overflow, and the counter rolls over to zero and continues counting.

VOL: Turning this control clockwise will increase the speaker volume, and counterclockwise will decrease the volume.

> **Note:**
>
> The volume should be turned down, when not required, to reduce battery drain.

α / α+β / β Switch: a three-position toggle switch used to select the sum of both alpha and beta count channels (α+β), alpha count only (α), or beta count only (β) for display. This switch affects both the ratemeter and the counter. The separate ratemeter and counter channels are active regardless of the switch position and will continue to function when the channel is not selected for display. This allows the operator to view each channel separately or together by simply selecting the appropriate switch position.

Headphone Jack: 1/8 inch headphone jack for connection of external headphones. Connecting the headphones results in the disconnection of the external unimorph speaker from the audio circuitry. Use 1/8 inch mating plug (LMI part # 21-9653).

RESET/HV: a dual-position momentary toggle switch, which provides readout of the detector high voltage when the HV position is selected and provides a rapid means of driving the analog meter to zero when the RES position is selected. Use the 0-2 kV meter scale for high-voltage readings.

Count Pushbutton (located in the carrying handle): When depressed, the counter is reset to zero, and the timer is started. Colons on the display indicate a count cycle is in progress.

Remove the CAL cover to access the following:

HV Adjustment: provides a means to vary the high voltage from 400 to 2000 volts.

Internal Controls

Remove the instrument cover (can) to access the following dipswitches on S301:

Dipswitch1 & 2 (Audio-divide select): a two-pole DIP switch used to select the audio divide ratios of 1, 10, 100, and 1000.

Note:

The AUDIO divide function only affects the lower frequency beta tones. The higher frequency alpha clicks per events will be unaffected by the divide-by selection.

The ratio is selected from the following table. (O is open and C is closed)

SWITCH 1	SWITCH 2	DIVIDE BY RATIO
C	C	1
O	C	10
C	O	100
O	O	1000

Dipswitch 3 & 4 (SPARE): Not used

Dipswitch 5 (TONE): a one-pole DIP switch used to select tone discrimination between alpha and beta count channels. When in DUAL mode (C position), alpha and beta pulse tones will be audible in all selector switch positions (i.e. if in the α only position and β is detected, the β tones will be heard in addition to the α tones and visa versa).

When the SNGL tone position (O position) is selected, both alpha and beta pulse tones can be heard in the α+β selection, but alpha pulses cannot be heard in the beta only channel selection and beta pulse tones will not be heard in the alpha only channel selection.

Dipswitch 6 (SPARE): Not used

The following controls are utilized during calibration only and should only be adjusted by a qualified calibrator.

MTR: a multi-turn potentiometer used to calibrate the meter to the CPM reading.

AT: a multi-turn potentiometer used to vary the alpha pulse threshold from approximately -40 to -700 mV.

BW: a multi-turn potentiometer used to vary the beta pulse upper window limit from the beta threshold to the alpha threshold setting and anywhere in between those two parameters. The beta window can be disabled by adjusting the BW control to the maximum clockwise position, allowing the upper beta threshold limit to equal the alpha threshold.

BT: a multi-turn potentiometer used to vary the beta pulse threshold from approximately -2 to -15 millivolts.

OL: a multi-turn potentiometer that provides a means to vary the detector current overload set point.

LIM: a multi-turn potentiometer used to set the maximum HV limit to 2000 Vdc.

HV: a multi-turn potentiometer used to adjust the high-voltage test reading to correspond with the actual high-voltage output. HV must be selected on the RES/HV toggle switch during adjustment.

LB: a multi-turn potentiometer used to adjust the minimum battery voltage level, corresponding to the low-battery indication on the meter dial. The range selector switch must be in the BAT position during adjustment.

Section

5

Safety Considerations

Environmental Conditions for Normal Use

Indoor use only

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.)

Cleaning Instructions and Precautions

The Model 2224-1 Scaler/Ratemeter may be cleaned externally with a damp cloth, using only water as the wetting agent. Do not immerse the instrument in any liquid. Observe the following precautions when cleaning:

1. Turn the instrument range selector switch to the OFF position and remove the batteries.

2. Allow the instrument to sit for one minute before cleaning.

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.

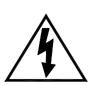
The Model 2224-1 Scaler / Ratemeter is marked with the following symbols:

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

Warning!

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

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



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.

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. This symbol is placed on the battery lid. See section 9, "Recycling," for further information.

CE

The "CE" mark is used to identify this instrument as being acceptable for use within the European Union. This symbol is located on the battery lid.

Section

6

Calibration and Maintenance

Calibration

Note:

Local procedures may supersede the following.

ESTABLISHING AN OPERATING POINT

The detector operating parameters are established by adjusting the detector operating voltage (HV), alpha threshold, and beta window to find an optimum efficiency for the alpha/beta scintillator or proportional detector.

The threshold and window parameters can be adjusted to optimize alpha/beta count discrimination, count efficiency, and minimize "cross talk" between channels. Refer to the specific detector Operation Manual or calibration certificate for the suggested threshold and window settings. Once the thresholds and window settings are established, an operating voltage versus count rate plot should be performed for both alpha and beta count channels with alpha and beta particle emission sources.

The following procedure is an example of determining the operating voltage for an alpha/beta scintillation or proportional detector:

1. Connect a Ludlum Model 500 Pulser or equivalent to the Model 2224-1.

2. Switch the Model 2224-1 channel selector to the β position. Adjust the beta threshold (BT) for 3.5 mV and the window (BW) for 30 mV. The pulser counts should be detected on the Model 2224-1 ratemeter above 3.5 ±1 mV and should shut off above 30 mV.

3. Switch the channel selector switch to the α position. Adjust the pulser for a 120 mV pulse output and vary the AT control until counts are detected on the ratemeter.

4. Depress the HV switch and adjust the HV potentiometer for 0.4 to 0.5 kV on the 0-2.0 kV scale. Connect the scintillator and switch to the β only position. Place an alpha source on the detector face.

5. Slowly increase the HV potentiometer to observe an increase, then decrease, and increase again in count as the HV is increased. Decrease the HV until the ratemeter is in the "dip" of the observed count rate versus HV plot just performed. Depress the HV switch and note the HV setting.

6. Plot a HV versus count rate plateau in 25-volt increments, 50 volts each side of the HV reading found in the above step (ie, HV setting for count "dip" in the above step = 675 volts, start the plot at 625 volts and increase in 25-volt steps until 725 volts is reached). Plot alpha source, beta source, and background counts for both the α and β channel positions.

7. Find the optimum operating voltage from the plot, which gives the greatest alpha and beta source efficiency while maintaining no greater than the maximum acceptable level of "cross talk" between channels.

8. Select the desired count channel display, and proceed with use.

METER CALIBRATION

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.

1. Ensure that the meter movement has proper mechanical zero. The adjustment is on the front of the meter bezel. It must be adjusted to zero with the range selector switch in the OFF position.

2. Connect the Model 500 Pulser to the Model 2224-1 with the appropriate cable. Rotate the Model 2224-1 range selector switch to the ×100 position. Select the α+β channel position.

3. Adjust the pulser for 40,000 cpm and adjust the pulse amplitude to twice the beta threshold level (ie; beta threshold = 3.5 mV, adjust pulser to 7-10 mV).

4. Remove the instrument cover and adjust the MTR potentiometer until the meter reads 400 cpm. Adjust the pulser to 10,000 cpm and ensure ratemeter reads 100 ±10%. Decade the pulser and Model 2224-1 range multiplier switch to check meter linearity on the ×1000, ×10, and ×1 positions. Linearity should be within □10% of each reading.

5. Set the LCD count time for one minute. Adjust the pulser count rate to 40 kcpm. Depress the count button, and when the count cycle is complete, confirm that LCD reads within 2% of the incoming count rate.

6. Adjust the BT, BW, and AT controls for the appropriate set points as described in the previous subsection, "Establishing an Operating Point."

7. Connect high-impedance, high-voltage meter (may use the Model 500 Pulser if equipped with a HV meter), and adjust the HV control for a reading of 1000 Vdc on the voltmeter.

8. Depress the HV pushbutton and adjust the HV potentiometer located on the main circuit board for a reading of 1.0 kV on the meter dial. Adjust the HV output from 500 to 1500 Vdc and confirm that the Model 2224-1 HV meter corresponds to the external voltmeter within □10% of each reading.

9. Remove the batteries from the battery compartment and connect a DC power supply to the two screw terminals located at the rear of the battery compartment. The positive power supply lead should connect to the terminal with the red wire and the negative lead to the terminal with the black wire.

10. Adjust the power supply for 2.2 Vdc and switch the Model 2224-1 to the α+β position. Depress the BAT pushbutton and adjust the LB potentiometer to align the meter needle with the low-battery mark on the meter dial (vertical line to the left of BAT OK).

11. Replace the Model 2224-1 cover (can) and proceed with use.

DETECTOR OVERLOAD CALIBRATION

Note:

The detector operating voltage (HV) must be determined and set before the OL (overload) adjustment is performed. If the detector operating voltage is re-adjusted, the overload adjustment must be re-adjusted.

1. Adjust the OL control to the maximum counterclock-wise position.

Note:

Detector saturation is when the meter response no longer increases with increasing radiation field intensity.

2. For alpha/beta scintillators, expose the detector photomultiplier tube (PMT) to a small light leak by loosening the detector window. Some scintillation detectors incorporate a screw in the detector body, which when removed, will simulate a detector face puncture or light leak. The meter should start to decrease toward zero as light saturates the scintillation material.

3. Expose just enough light to where the meter starts to decrease. Adjust the OL control until the overload LED just begins to flicker on the meter dial. The ratemeter should deflect above full meter scale at this point.

4. Re-seal the detector window and expose the detector to a radiation source that will drive the meter near full scale. Confirm that the LED does not turn on and the meter remains on-scale.

Maintenance

Instrument maintenance consists of keeping the instrument clean and periodically checking the batteries and the calibration. The Model 2224-1 instrument may be cleaned with a damp cloth (using only water as the wetting agent). Do not immerse instrument in any liquid. Observe the following precautions when cleaning:

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

RECALIBRATION

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

Note:

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

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

BATTERIES

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

Note:

Never store the instrument over 30 days without removing the batteries. Although this instrument will operate at very high ambient temperatures, battery seal failure may occur at temperatures as low as 37 °C (100 °F).

Section

7

Technical Principle of Operation

Refer to the Amplifier/Power Supply Board Schematic, Drawing 390 × 104, for the following:

Detector Input/ Amplifier

Negative-going detector pulses are coupled from the detector through C021 to amplifier U021. R023 and CR021 protects the input of U021 from inadvertent shorts. Self-biased amplifier U021 provides gain in proportion to R021 divided by R022. Transistor pins 4, 5, and 6 of U021 provides amplification. Pins 12 and 15 of U021 are coupled as a constant current source to pin 6 of U021. The output self-biases 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 for the constant current source. Positive pulses from pin 7 of U021 are coupled to the discriminators through R011 and C011.

Alpha/Beta Discriminator

Positive pulses from amplifier U021 are coupled to comparator U012, pin 6, for alpha discrimination and pins 6 and 2 of U011 for beta discrimination. R103, alpha threshold, provides the reference voltage for alpha comparator U012. R106, beta threshold (defined as the lower threshold limit of the beta counting window), provides the reference voltage for beta threshold comparator pins 1, 2, and 3 of U011. R102, beta window (defined as the upper threshold limit of the beta counting window), provides the reference voltage for the beta window comparator pins 5, 6, and 7 of U011.

Alpha/Beta Discriminator Logic Circuit

Alpha pulses from U012 are coupled to univibrator U111. Pulses at pin 6 of U111 are inverted by Q111 for connection to reset (R) pins 3 and 13 of U101. Pin 9 of U111 provides the pulses to be counted by the microprocessor (μP). Pulses from pin 9 of U111 are connected to pin 3 of

U111 to provide a time delay for the µP clock cycle to complete before the next alpha pulse can be recognized by the µP.

Beta pulses from pin 1 of U011 are coupled to univibrator U101. Pulses are coupled to the µP from pin 7 of U101 as long as pins 3 and 13 of U011 remain high (+5 V). When an alpha and/or a beta window pulse is present, the reset (pins 3 and 13 of U101) function is enabled and 7 of U101 remains high. Pin 7 of µP is connected to pin 13 of U101 to provide a time delay for the µP clock cycle to complete before the next beta pulse can be recognized by the µP.

Low Voltage Supply

Battery voltage is coupled to switching regulator U201 and associated components to provide +5 V to power op-amps and logic circuitry. The charge pump (cp) output, C202, CR211, CR212, and C201 form a voltage doubler circuit to provide +9 V for U201 amplifier supply. U001 and related components provide +2.5 V reference HV SET and alpha/beta discriminator controls. R201, LO BAT, is adjusted so that the meter pointer is aligned with the left vertical mark on the BAT OK or BAT TEST line with 2.2-volt battery input.

High Voltage Supply

High voltage is developed blocking oscillator Q421, T321, C412, and rectified by voltage multiplier CR221-CR224, C221-C223, C211, and C114. High voltage increases as current through Q421 increases, with maximum output voltage with Q421 saturated.

High voltage is coupled back through R123 to op-amp pin 2 of U311. Resistor network R211-214 completes the HV division circuit to ground. R214 provides HV limit at 2.0 kV when the HV SET control on the calibration board is at maximum. The regulated HV output is controlled by HV potentiometer, located under the CAL cover on the front panel. This control provides the reference for comparator pin 3, U311. During stable operation, the voltage at pin 2 of U311 will equal the voltage at pin 3 of U311. Pin 1 of U311 will cause conduction of Q312 to increase or decrease until the HV finds a level of stability. R115, HV TEST, calibrates the analog meter to the HV output when HV is selected on the RES/HV momentary toggle switch.

Detector Overload

A voltage drop is developed across R121 and sensed by comparator U012 as detector current increases. When the voltage at pin 3 of U012 goes below pin 2, pin 1 goes low, illuminating the OL LED and driving the meter to full scale. R211, Overload, provides adjustment for the overload set point.

Meter Drive

Pulses are coupled from the μP board (refer to μP theory of operation) to the gate of Q302. Q302 inverts the pulses, and R403 and C401 provides integration. Integrated meter drive voltage is coupled from P1-13 via the battery (BAT) and HV test switch to pin 5 of U311. The meter is driven by the emitter of Q111, coupled as a voltage follower in conjunction with pin 6 and 7 of U311. R406, Meter Cal, is adjusted to calibrate the ratemeter reading corresponding to the incoming count rate. R407 and R408 provide temperature compensation for changes in the meter resistance due to temperature variations.

Refer to Processor Board Schematic, Drawing 390 × 107 for the following:

Power supply

Battery voltage is coupled to switching regulator U321 and associated components to provide +5 V to power the μP and display drivers U211, U212. R101, C101, Q101, and Q201 form a delay switch, which allows U321 to stabilize before the load current is connected to the +5 V supply.

Microproccessor (μP)

U311, Intel N87C51FA, controls all of the data, control inputs, and display information. The clock frequency is crystal controlled by Y211 and related components at 6.144 MHz. The μP incorporates internal memory (ROM), storing the program information. C311 resets the μP at power-up to initiate the start of the program routine. During the program loop, the μP looks at all of the input switches for initiation or status changes and responds accordingly.

The μP uses pulse-width modulation to control the analog ratemeter. The analog output, RATE (P3-3), is divided into 255 increments in a 166 μs period. At full meter deflection, the low pulse period, leading edge to leading edge, will be 166 μs, 500 cpm = 130 μs, 400 cpm = 104 μs, 200 cpm = 52 μs, 100 cpm = 26 μs, and 0 = no pulse or +5 V. The pulses are inverted by Q302 on the amplifier/power Supply board and then integrated by R403, C401.

LCD Drive

U211 and U212 make up the liquid crystal display drive circuitry. The display information is sent from the μP to U211 and 212 via BUS0-3 and ADD0-1 data lines. When the SELECT line is brought low by the μP, the data is transferred and latched into the drivers until the SELECT line is brought low again. The corresponding digits and segments are illuminated corresponding to the stored count information from the μP.

Audio

Alpha and/or beta audio pulse frequency is generated by the μP and coupled to Q202. Q202 then inverts the pulses and drives the low side of the audio transformer T201. Front-panel VOL control provides the bias voltage to the top of T210. Secondary winding of T201 is coupled to unimorph speaker via front-panel audio jack.

Section 8

Troubleshooting

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

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

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

Troubleshooting Electronics that utilize Proportional and Scintillator Type Detectors

SYMPTOM	POSSIBLE SOLUTION
No power (or meter does not reach BAT TEST or BAT OK mark)	1. Check batteries and replace if weak. 2. Check polarity (see marks inside battery lid). Are the batteries installed backwards?

SYMPTOM	POSSIBLE SOLUTION
No power (or meter does not reach BAT TEST or BAT OK mark) (continued)	3. Check battery contacts. Clean them with rough sandpaper or use an engraver to clean the tips.
	4. Check for loose or broken wires, especially between the main board and the calibration board.
Non-linear Readings	1. Check the high voltage (HV) by using a Ludlum Model 500 Pulser (or equivalent). If a multimeter is used to check the HV, ensure that one with high impedance is used, as a standard multimeter could be damaged in this process.
	2. Check for noise in the detector cable by disconnecting the detector, placing the instrument on the lowest range setting, and wiggling the cable while observing the meter face for significant changes in readings.
	3. Check for “sticky” meter movement. Does the reading change when you tap the meter? Does the meter needle “stick” at any spot?
	4. Check the “meter zero.” Turn the power OFF. The meter should come to rest on “0.”
Meter goes full-scale or “pegs out”	1. Replace the detector cable to determine whether or not the cable has failed, causing excessive noise.
	2. Check the HV and, if possible, the input threshold for proper setting.

SYMPTOM	POSSIBLE SOLUTION
Meter goes full-scale or "pegs out" (continued)	3. Open the instrument "can" and check for loose wires.
	4. Ensure that the instrument's "can" is properly attached. When attached properly, the speaker will be located on the left side of the instrument. If the can is on backwards, interference between the speaker and the input preamplifier may cause noise.
No Response to Radiation	1. Substitute a "known good" detector and/or cable.
	2. Has the correct operating voltage been set? Refer to the calibration certificate or detector instruction manual for correct operating voltage. If the instrument uses multiple detectors, confirm that the high voltage is matched to the current detector being used.
No Audio	1. Ensure that the VOL (volume) knob is turned up.
	2. Remove the instrument housing and check the connection between the circuit board and the speaker. Plug in the two-pin connector if necessary.

Section 9

Recycling

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

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

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

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

The symbol appears as such: 

Section

10

Parts List

Model 2224-1 Scaler / Ratemeter

Reference	Description	Part Number
UNIT	Completely Assembled Model 2224-1 Scaler / Ratemeter	48-2679

Amplifier/Power Supply Board, Drawing 390 × 104

CAPACITORS

Reference	Description	Part Number
BOARD	Completely Assembled Amplifier/Power Supply Board	5390-099
C001	100PF, 100V	04-5661
C002	47PF, 100V	04-5560
C011-C012	0.1µF, 50V	04-5663
C013	0.01µF, 50V	04-5664
C014-C016	0.001µF, 100V	04-5659
C017	10µF, 20V	04-5655
C021	10PF, 100V	04-5673
C022	100PF, 3KV	04-5532
C101-C102	47PF, 100V	04-5560
C111-C113	47PF, 100V	04-5560
C114	0.0047µF, 3KV	04-5547
C121-C122	0.0047µF, 3KV	04-5547
C201-C202	10µF, 20V	04-5655
C203	330PF, 100V	04-5657
C211	0.0047µF, 3KV	04-5547
C212	68µF, 6.3V	04-5654
C213	1µF, 35V	04-5656
C214	0.01µF, 50V	04-5664
C221-C223	0.0047µF, 3KV	04-5547
C301	68µF, 6.3V	04-5654
C311	0.01µF, 50V	04-5620
C401	0.1µF, 50V	04-5663
C411	0.1µF, 50V	04-5663
C412	1µF, 35V	04-5656
C421	68µF, 6.3V	04-5654
C500	100pf, 3KV	04-5532

	Reference	Description	Part Number
TRANSISTORS	Q111	2N7002L	05-5840
	Q301	MMBT4403LT	05-5842
	Q302	2N7002L	05-5840
	Q311-C312	MMBT3904T	05-5841
	Q421	MJD210	05-5843
INTEGRATED CIRCUITS	U001	LM285M-2.5	06-6291
	U011-U012	TLC372ID	06-6290
	U021	CMX3906TRLF	05-5890
	U022-023	CMX3904TRLF	05-5888
	U101	CD74HC4538M	06-6297
	U111	CD74HC4538M	06-6297
	U201	MAX631AESA	06-6285
	U301	CD74HC4066M	06-6323
	U311	TLC27M7ID	06-6292
DIODES	CR021	MMBD7000LT1	07-6355
	CR111-CR112	MMBD914L	07-6353
	CR211-CR212	BAT54	07-6354
	CR221-CR225	GI250-2	07-6266
	CR411	MMBD914L	07-6353
THERMISTOR	RT407	03006-165.9-55G100	07-6366
POTENTIOMETERS	R102	10K, BETA THRESH	09-6907
	R104	1M, BETA WIN	09-6921
	R115	1M, (HV) HV READOUT	09-6906
	R201	50k, ALPHA THRESH	09-6920
	R202	200K, LO BAT (LB)	09-6908
	R211	1M, OVERLOAD	09-6906
	R214	1M, HV LIMIT	09-6906
	R406	5K, METER CAL (MTR)	09-6907
RESISTORS	R001	22.1K, 1%, 125mW	12-7843
	R002	249K, 1%, 125mW	12-7862
	R003	22.1K, 1%, 125mW	12-7843
	R004	1.0K, 1%, 125mW	12-7832
	R011	100, 1%, 125mW	12-7840
	R012	22.1K, 1%, 125mW	12-7843
	R013	33.2K, 1%, 125mW	12-7842
	R014	10.0K, 1%, 125mW	12-7839
	R015	22.1K, 1%, 125mW	12-7843

	Reference	Description	Part Number
	R016	10.0K, 1%, 125mW	12-7839
	R021	392K, 1%, 125mW	12-7841
	R022-R023	10.0K, 1%, 125mW	12-7839
	R024	33.2K, 1%, 125mW	12-7842
	R025	22.1K, 1%, 125mW	12-7843
	R026	1M	10-7028
	R101	100K, 1%, 125mW	12-7834
	R103	4.75K, 1%, 125mW	12-7858
	R105	22.1K, 1%, 125mW	12-7843
	R106	100K, 1%, 125mW	12-7834
	R107	5.11K, 1%, 125mW	12-7909
	R108	274K, 1%, 125mW	12-7963
	R111	100, 1%, 125mW	12-7840
	R112	1G	12-7686
	R113-R114	100K, 1%, 125mW	12-7834
	R116	249K, 1%, 125mW	12-7862
	R121	4.7M, 125mW	10-7030
	R122	1M	10-7028
	R123	1G	12-7686
	R212-R213	1M, 1%, 125mW	12-7844
	R215	1M, 1%, 125mW	12-7844
	R301	2.21K, 1%, 125mW	12-7835
	R302-R303	22.1K, 1%, 125mW	12-7843
	R311	10.0K, 1%, 125mW	12-7839
	R312	22.1K, 1%, 125mW	12-7843
	R313	2.21K, 1%, 125mW	12-7835
	R314	10.0K, 1%, 125mW	12-7839
	R401	200, 1%, 125mW	12-7846
	R402	221K, 1%, 125mW	12-7845
	R403	7.5K, 1%, 125mW	12-7847
	R404	1K, 1%, 125mW	12-7832
	R405	1M, 1%, 125mW	12-7844
	R408	301, 1%, 125mW	12-7863
	R411	200, 1%, 125mW	12-7846
	R412	10.0K, 1%, 125mW	12-7839
	R500	1M, 1%, 125mW	12-7844
INDUCTORS	L301	220μH	21-9678
TRANSFORMERS	T321	L8050	40-0902
MISCELLANEOUS	P1	CONN-1-640456-5, MTA100	13-8355
	P2	CONN-640456-3, MTA100	13-8081

	Reference	Description	Part Number
Processor Board, Drawing 390 × 107	BOARD	Completely Assembled Processor Board	5390-100
CRYSTAL	Y211	6.144 MHZ	01-5262
CAPACITORS	C101	0.15µF, 50V	04-5665
	C201	47µF, 10V	04-5666
	C211-C212	27PF, 100V	04-5658
	C221	68µF, 6.3V	04-5654
	C311-312	10µF, 20V	04-5655
	C321	330PF, 100V	04-5657
	C322	68µF, 6.3V	04-5654
TRANSISTORS	Q101	2N7002L	05-5840
	Q201	MMBT4403L	05-5842
	Q202	2N7002L	05-5840
	Q311	MMBT4403L	05-5842
INTEGRATED CIRCUITS	U211-U212	ICM7211AMIQH	06-6294
	U311	N87C51FA	06-6303
	U321	MAX631AESA	06-6285
SWITCHES	S301	90HBW06S	08-6710
RESISTORS	R101	1M, 1%, 125mW	12-7844
	R102	10K, 1%, 125mW	12-7839
	R211	2.21K, 1%, 125mW	12-7835
	R221	150K, 1%, 125mW	12-7833
	R222	100K, 1%, 125mW	12-7834
	R301-R306	22.1K, 1%, 125mW	12-7843
RESISTOR NETWORK	RN401	220K	12-7831
INDUCTOR	L311	150µH	21-9677
TRANSFORMER	T201	AUDIO	4275-083
MISCELLANEOUS	P3	CONN-1-640456-6, MTA100	13-8134
	P4	CONN-640456-2, MTA100	13-8073
	P6	CONN-640456-3, MTA100	13-8081
	*	SOCKET-44P	06-6293
Calibration Board, Drawing 390 × 112	BOARD	Completely Assembled Calibration Board	5390-104

	Reference	Description	Part Number
LED	DS1	HLMP4700, OVERLOAD	07-6356
	*	LED-SPACER 457-570	07-6357
POTENTIOMETER	R3	250K, HV SET	09-6819
MISCELLANEOUS	P7	CONN-640456-5 MTA100	13-8057
Display Board, Drawing 390 x 127	BOARD	Completely Assembled Display Board	5390-118
DISPLAY	DSP1	LCD 7728-365-481	07-6351
CONNECTOR	J6	CONN-52 POS CP50	13-8410
Interconnect Board, Drawing 390 x 124	BOARD	Completely Assembled Interconnect Board	5390-117
CONNECTOR	J5	CONN-52 POS CP50	13-8410
Wiring Diagram, Drawing 390 × 110	S1	PA-600-210	08-6501
SWITCHES	S2	55D36-01-2-AJN	08-6514
	S3	MPS-103F	08-6699
	S4	PHONE JACK TINI #42A	21-9333
	S5	7103SYZQE TOGGLE	08-6720
	S6	7103SYZQE TOGGLE	08-6720
POTENTIOMETER	R1	10K NON-LOCKING VOLUME	09-6753
CONNECTORS	J1	CONN-1-640442-5 MTA100	13-8383
	J2	CONN-640442-3 MTA100	13-8135
	J3	CONN-1-640442-6 MTA100	13-8187
	J4	CONN-640442-2 MTA100	13-8178
	J7	CONN-640442-5 MTA100	13-8140
	J8	Series "C" UG706/U	13-7751
	J9	CONN-640442-3 MTA100	13-8135
	J10	1/8 inch PHONE JACK	18-9080
AUDIO	DS1	UNIMORPH	21-9251
BATTERY	B1-B2	"D" Duracell Battery	21-9313
MISCELLANEOUS	M1	METER ASSY	4390-136
	*	HANDLE ASSY	4408-178

Section 11

Drawings and Diagrams

AMPLIFIER / POWER SUPPLY BOARD, Drawing 390 × 104

AMPLIFIER / POWER SUPPLY LAYOUT, Drawing 390 × 105A (2 sheets)

PROCESSOR BOARD, Drawing 390 × 107

PROCESSOR BOARD, LAYOUT, Drawing 390 × 108

CALIBRATION BOARD, Drawing 390 × 112

CALIBRATION BOARD LAYOUT, Drawing 390 × 113 (2 sheets)

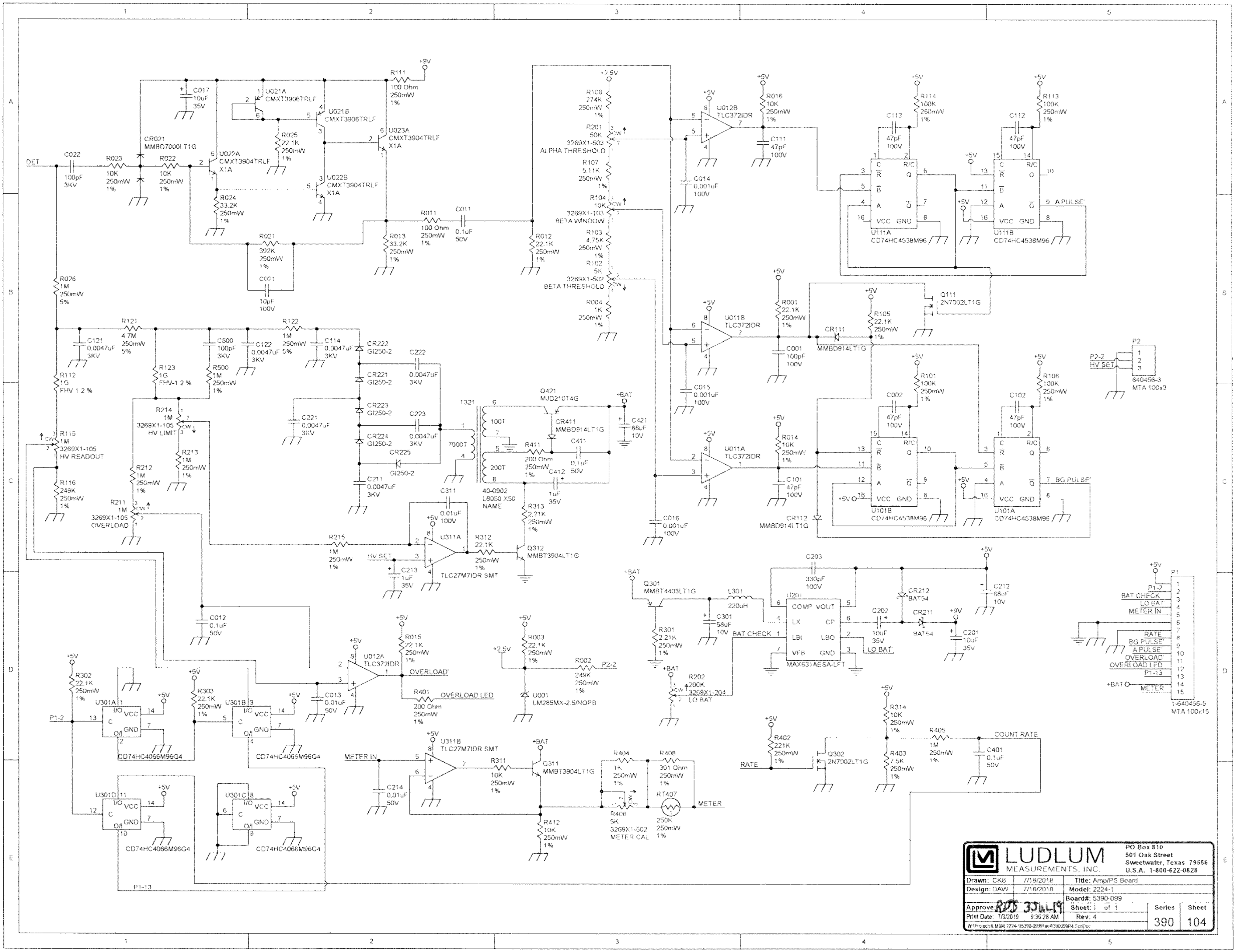
DISPLAY BOARD, Drawing 390 × 127

DISPLAY BOARD COMPONENT LAYOUT, Drawing 390 × 128 (2 sheets)

INTERCONNECT BOARD, Drawing 390 × 124

INTERCONNECT BOARD LAYOUT, Drawing 390 × 125

WIRING DIAGRAM, Drawing 390 × 110



LUDLUM MEASUREMENTS, INC.

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

Drawn: CKB	7/18/2018	Title: Amp/PS Board	
Design: DAW	7/18/2018	Model: 2224-1	
		Board#: 5390-099	
Approve: RDS 3JUL19		Sheet: 1 of 1	Series 390
Print Date: 7/3/2019	9:36:28 AM	Rev: 4	Sheet 104

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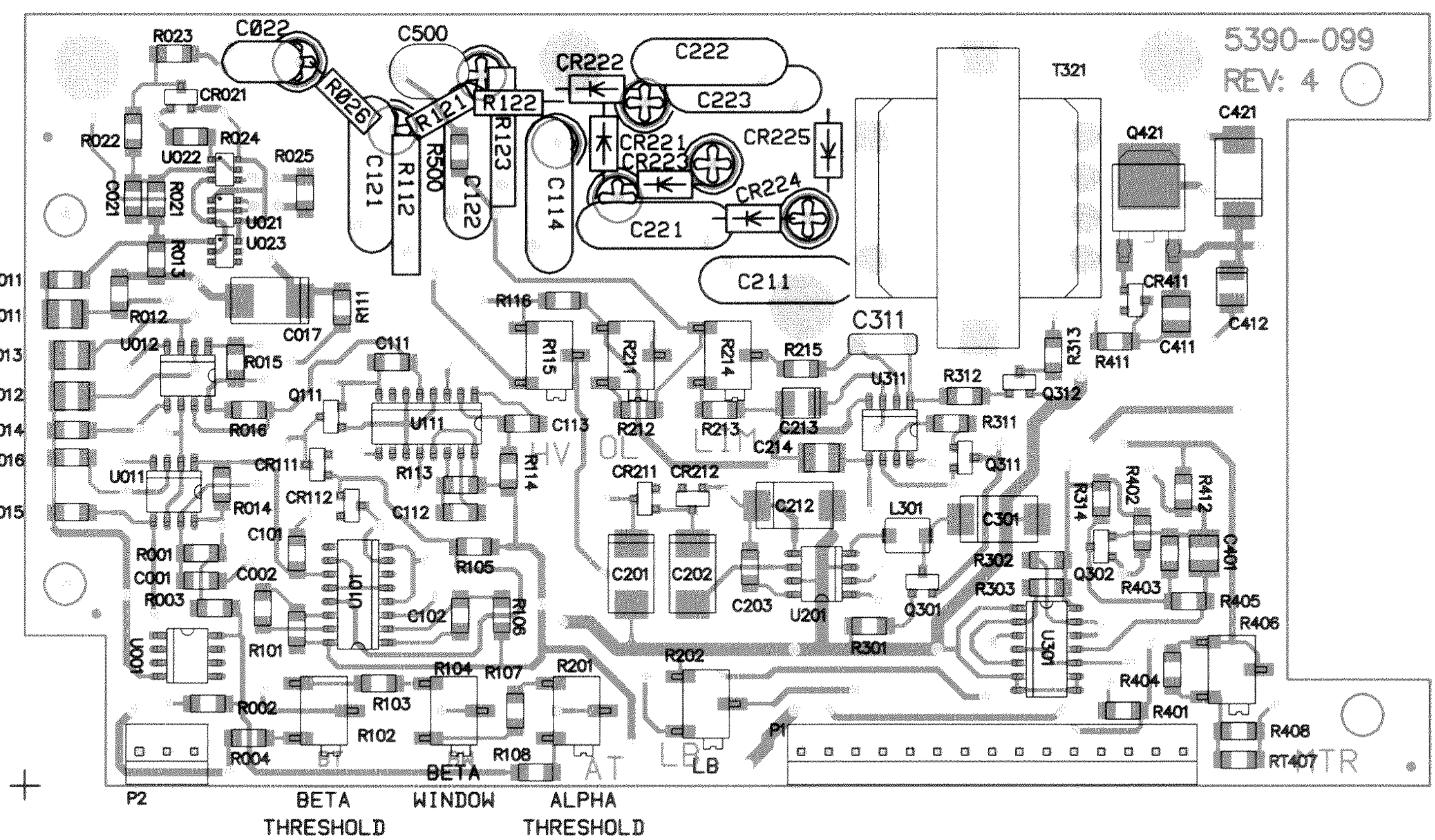

LUDLUM MEASUREMENTS, INC.

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

Title: Amp/PS Board				
Drawn: PAB	7/18/2018	Model: 2224-1		
Design: RDS	7/18/2018	Board#: 5390-099		
Approve: RDS	29JUL19	Rev: 4		
PCBA Drawing		SCALE: 1.08	Series	Sheet
Print Date: 7/29/2019	10:42:37 AM	Top Overlay	390	105A

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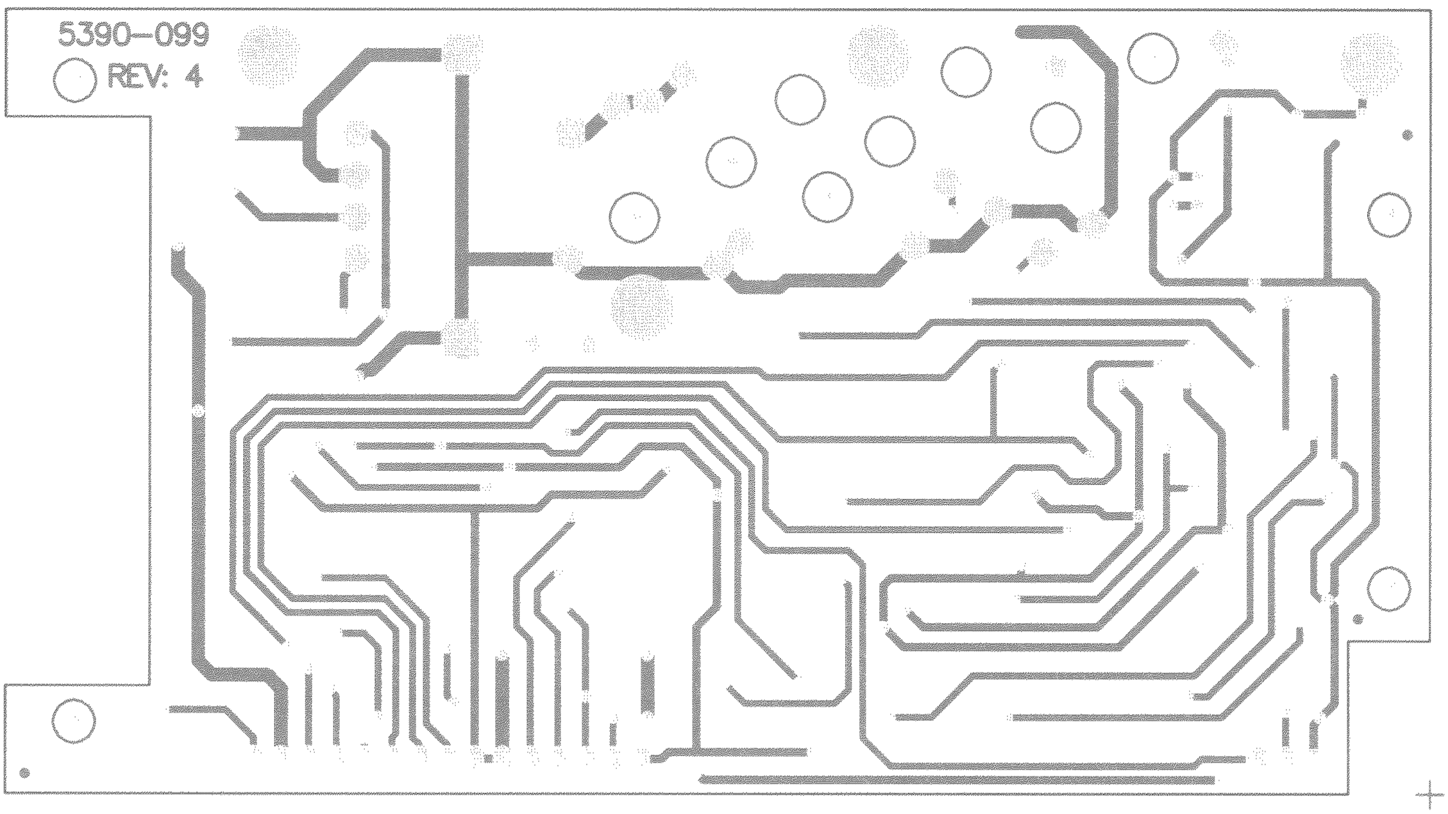

LUDLUM MEASUREMENTS, INC.

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

Title: Amp/PS Board				
Drawn: PAB	7/18/2018	**Model:** 2224-1		
Design: RDS	7/18/2018	**Board#:** 5390-099		
Approve: RDS	29 Jul 19	**Rev:** 4		
PCBA Drawing		**SCALE: 1.08**	**Series**	**Sheet**
Print Date: 7/29/2019	10:42:42 AM	Bottom Overlay	390	105A

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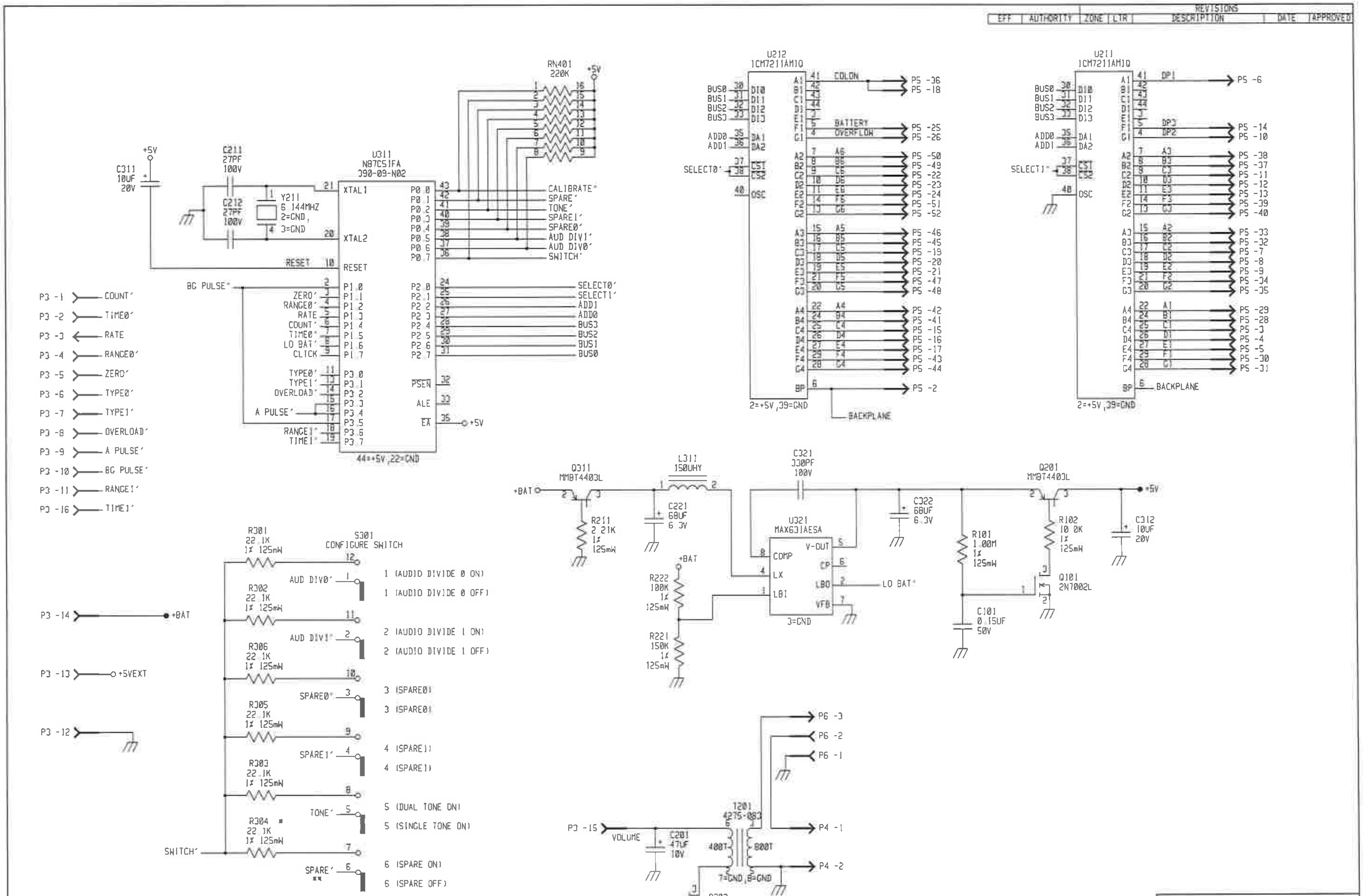
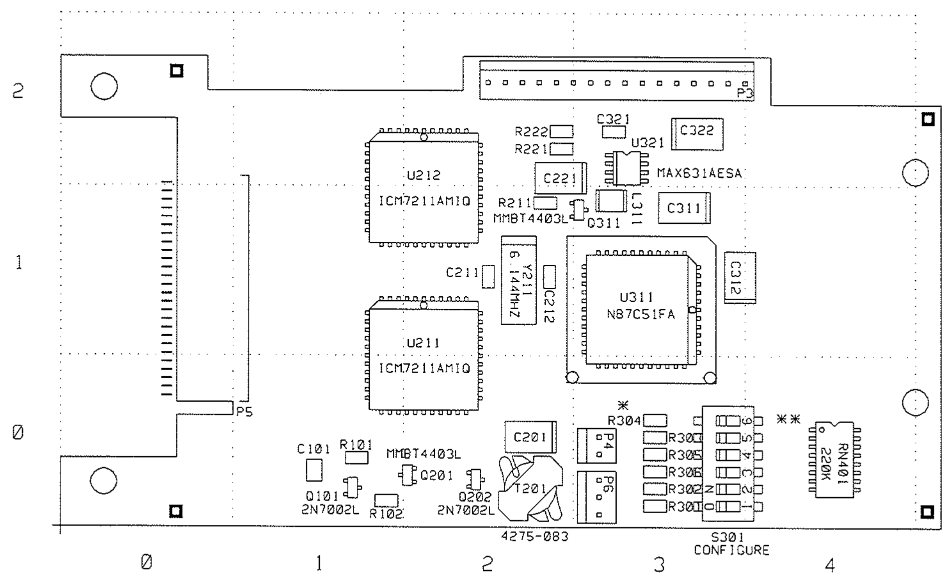


* REMOVE RESISTOR R304 FOR M2224-3

** JUMPER WIRE FROM PIN 6 (SPARE') TO SELECTOR SWITCH

UPDATED CKB	04-MAY-07	LUDLUM MEASUREMENTS INC.			
DR CKB	05/08/95	TITLE: PROCESSOR BOARD W/O E.L.			
DSGN DW	05/08/95	BOARD# 5390-100			
APPD	4May07	SIZE C	MODEL 2224-1/2224-3	SERIES 390	SHEET 107
NEXT HIGHER ASSY					
16:09:24	4-May-07	S8390100		SHEET 1	OF 1



* REMOVE RESISTOR R304 FOR M2224-3

** JUMPER WIRE FROM PIN 6 S301 TO SELECTOR SWITCH

REV: 1 BSS 2 May 13

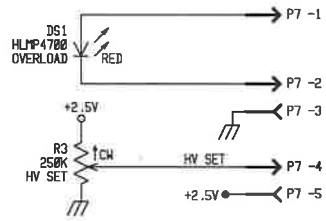
LUDLUM MEASUREMENTS INC. SWEETWATER, TX.

DR	CKB	4-MAY-07	TITLE: PROCESSOR BOARD W/O E.L		
CHK		/ /			
DSGN	DW	05/08/95	BOARD# 5390-100		B5390100
APP	BSS	4 May 07	MODEL 2224-1/2224-3	SERIES 390	SHEET 108
16:07:18		4-May-07	COMP SIDE ☐	SLDR SIDE ☐	OUTLINE ☒
COMP PASTE ☐		COMP MASK ☐	SLDR PASTE ☐	SLDR MASK ☐	

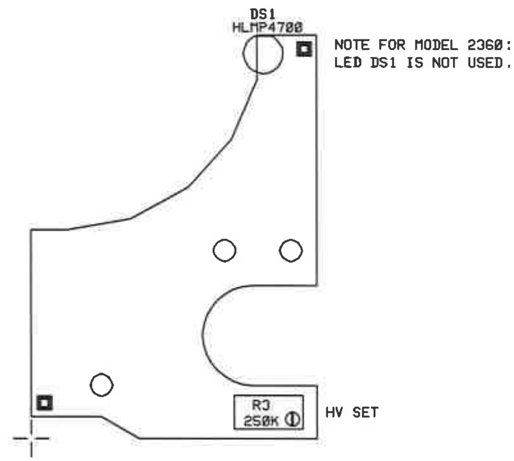
390 X 108

REVISIONS						
EFF	AUTHORITY	ZONE	LTR	DESCRIPTION	DATE	APPROVED

NOTE FOR MODEL 2360:
LED DS1 IS NOT USED.

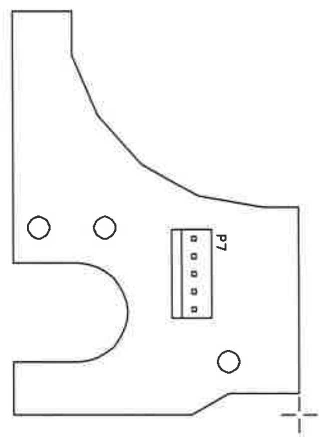


UPDATED -		LUDLUM MEASUREMENTS INC.			
DR CKB	05/31/95	TITLE: CALIBRATION BOARD			
CHK P.W.	6-2-99				
DSGN PW	05/22/95	BOARD# 5390-104			
APPD DSS	6-2-99	SIZE C	MODEL 2224-1	SERIES 390	SHEET 112
NEXT HIGHER ASSY. -					
16:32:08	2-Jun-99	5B390104		SHEET 1	OF 1



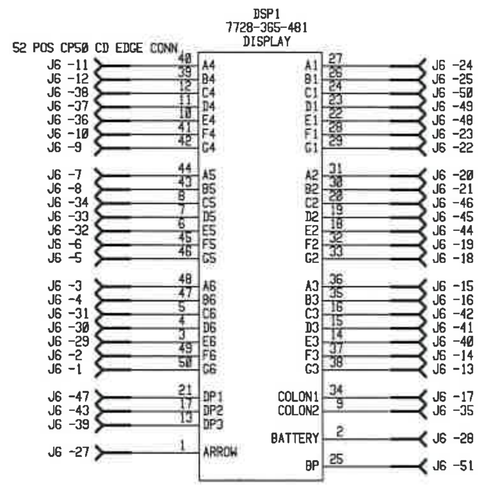
LUDLUM MEASUREMENTS INC. SWEETWATER, TX.

DR CKB	08/03/95	TITLE: CALIBRATION BOARD	
CHK PWU	6-2-99	BOARD: 5390-104	
DSGN		MODEL: 2224-1	
APP DS	6-2-99	FILENAME: BS390104	
COMPONENT	SOLDER	16:46:44	2-Jun-99
OUTLINE	OUTLINE	REVISION 1.0	SERIES 390 / SHEET 113



LUDLUM MEASUREMENTS INC. SWEETWATER, TX.				
DR CKB	03-AUG-95	TITLE: CALIBRATION BOARD		
CHK P.W.	6-27-99	BOARD# 5390-104		
DSGN		MODEL 2224-1	SERIES 390	SHEET 113
APP DS	6-2-99	COMP ARTWORK ☐	SLDR ARTWORK ☐	
		COMP OUTLINE ☐	SLDR OUTLINE ☒	
COMP PASTE ☐	COMP MASK ☐	SLDR PASTE ☐	SLDR MASK ☐	

REVISIONS						
EFF	AUTHORITY	ZONE	LTR	DESCRIPTION	DATE	APPROVED



UPDATED	-	
DR	ACF	02-JUN-99
CHK	P.W.	6-2-99
DSGN	JGW	17-JUL-95
APPD	RSS	6-2-99
NEXT HIGHER ASSY. -		
10:17:35		2-Jun-99

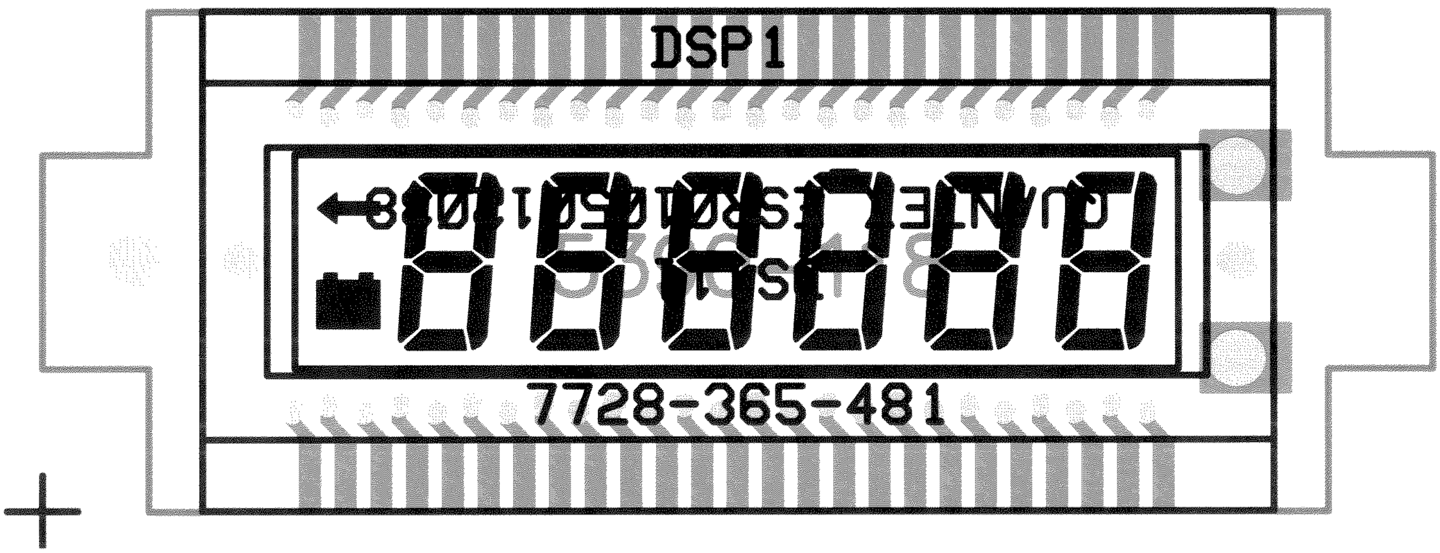
LUDLUM MEASUREMENTS INC.

TITLE: DISPLAY BOARD

BOARD# 5390-118

SIZE	MODEL	SERIES	SHEET
C	2224/2224-1	390	127

S0390118 SHEET 1 OF 1



LUDLUM MEASUREMENTS, INC.

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

Title: Display Board				
Drawn: PAB	2/12/2020	**Model:** 2224		
Design: JGW	2/12/2020	**Board#:** 5390-118		
Approve: [illegible]	[illegible]	**Rev:** 2		
PCBA Drawing		**SCALE: 1.08**	**Series**	**Sheet**
Print Date: 2/12/2020 9:43:11 AM		Top Overlay	390	128
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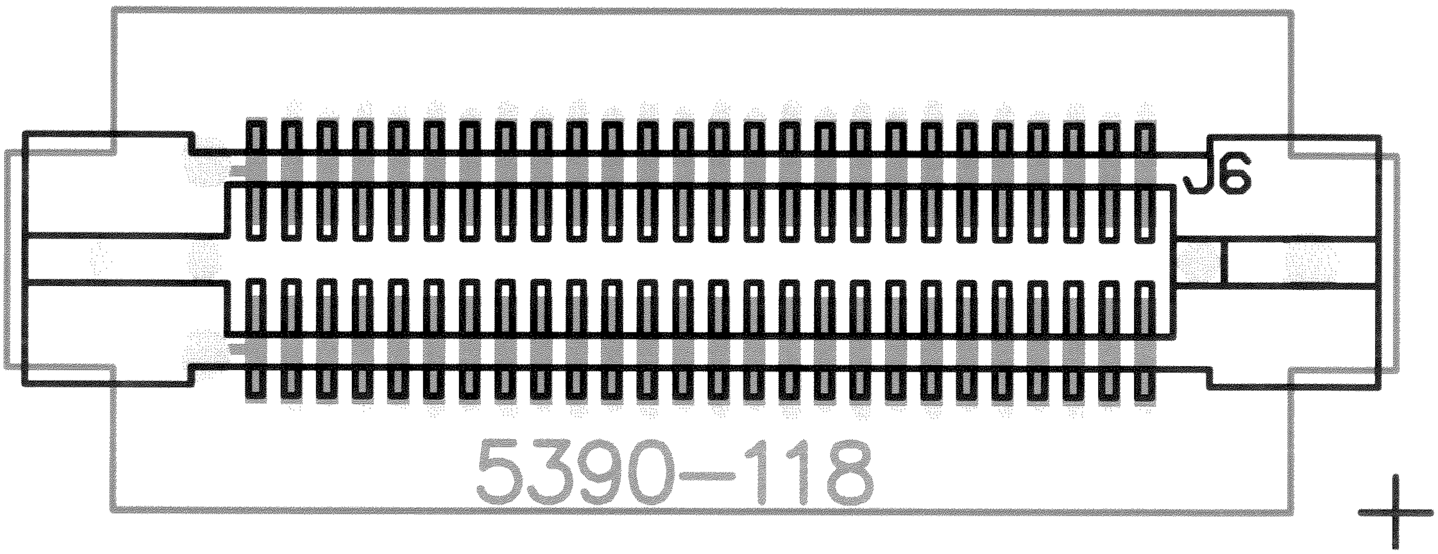


LUDLUM MEASUREMENTS, INC.

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

Title: Display Board				
Drawn: PAB	2/12/2020	**Model:** 2224		
Design: JGW	2/12/2020	**Board#:** 5390-118		
Approve: [illegible]	12Feb2020	**Rev:** 2		
PCBA Drawing		**SCALE: 1.08**	**Series**	**Sheet**
Print Date: 2/12/2020 9:43:15 AM		Bottom Overlay	390	128
\\freedom\pcb\Projects\LMI\M 2224\5390-118\Rev2\390118R2_Assy.PcbDoc				

EFF	AUTHORITY	ZONE	LTR	REVISIONS DESCRIPTION	DATE	APPROVED

5390-118 DISPLAY BOARD

M 2224 PROCESSOR BOARD 5390-095
M 2224-1 PROCESSOR BOARD 5390-100
52 POS. CP50 CD EDGE CONN.

5390-118 DISPLAY BOARD	Signal	PROCESSOR BOARD
P6 -1	G6	J5 -52
P6 -2	F6	J5 -51
P6 -3	A6	J5 -50
P6 -4	B6	J5 -49
P6 -5	G5	J5 -48
P6 -6	F5	J5 -47
P6 -7	A5	J5 -46
P6 -8	B5	J5 -45
P6 -9	G4	J5 -44
P6 -10	F4	J5 -43
P6 -11	A4	J5 -42
P6 -12	B4	J5 -41
P6 -13	G3	J5 -40
P6 -14	F3	J5 -39
P6 -15	A3	J5 -38
P6 -16	B3	J5 -37
P6 -17	COLON1	J5 -36
P6 -18	G2	J5 -35
P6 -19	F2	J5 -34
P6 -20	A2	J5 -33
P6 -21	B2	J5 -32
P6 -22	G1	J5 -31
P6 -23	F1	J5 -30
P6 -24	A1	J5 -29
P6 -25	B1	J5 -28
P6 -26	EL BACKLIGHT 1	J5 -27
P6 -27	OVERFLOW	J5 -26
P6 -28	BATTERY	J5 -25
P6 -29	E6	J5 -24
P6 -30	D6	J5 -23
P6 -31	C6	J5 -22
P6 -32	E5	J5 -21
P6 -33	D5	J5 -20
P6 -34	C5	J5 -19
P6 -35	COLON2	J5 -18
P6 -36	E4	J5 -17
P6 -37	D4	J5 -16
P6 -38	C4	J5 -15
P6 -39	DP3	J5 -14
P6 -40	E3	J5 -13
P6 -41	D3	J5 -12
P6 -42	C3	J5 -11
P6 -43	DP2	J5 -10
P6 -44	E2	J5 -9
P6 -45	D2	J5 -8
P6 -46	C2	J5 -7
P6 -47	DP1	J5 -6
P6 -48	E1	J5 -5
P6 -49	D1	J5 -4
P6 -50	C1	J5 -3
P6 -51	BP	J5 -2
P6 -52	EL BACKLIGHT 2	J5 -1

UPDATED	-	
DR CKB	07/17/95	
CHK T.W.	6-16-99	
DSGN JGW	07/17/95	
APPD RDS	16JUN99	
NEXT HIGHER ASSY. -		
09:23:52	16-Jun-99	SB390117

LUDLUM MEASUREMENTS INC.

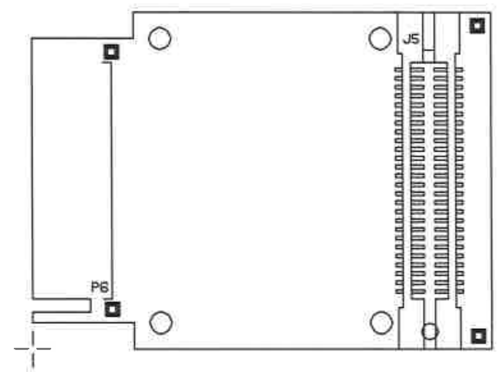
TITLE: DISPLAY INTERCONNECT BOARD

BOARD# 5390-117

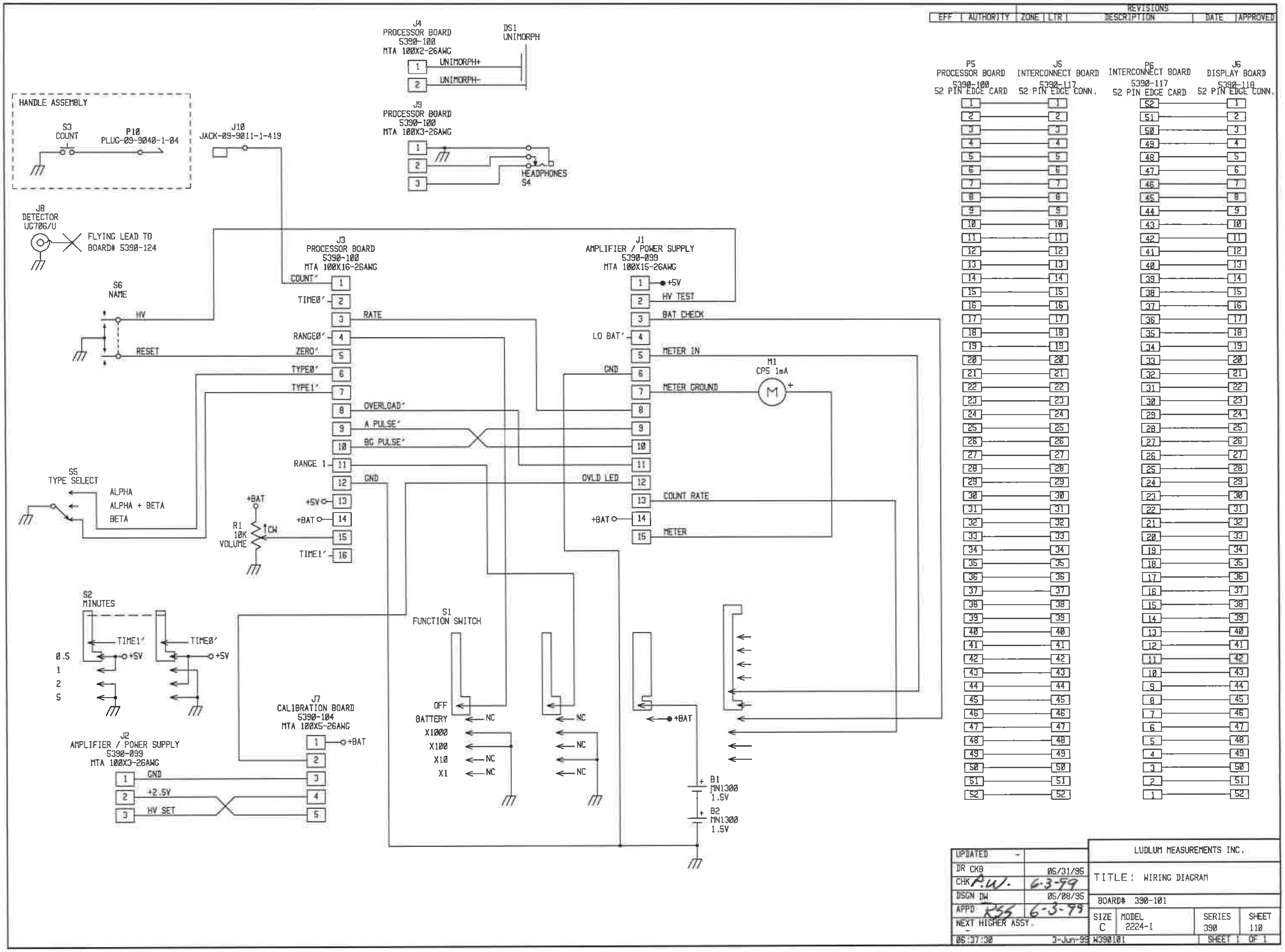
SIZE	MODEL	SERIES	SHEET
C	2224/2224-1	390	124

SHEET 1 OF 1

VF



LUDLUM MEASUREMENTS INC. SHEETWATER, TX.		
DR CKB	07/17/95	TITLE: DISPLAY INTERCONNECT BRD.
CHK PWL	6-2-99	BOARD: 5390-117
DSGN JGW	07/17/95	MODEL: 2224
APP DSS	6-2-99	FILENAME: BS390117
COMPONENT	SOLDER	13:34:28 — 1-Jun-99
OUTLINE	OUTLINE	REVISION 1.0 — SERIES 390 — SHEET 125


REVISIONS
EFF | AUTHORITY | ZONE | LTR | DESCRIPTION | DATE | APPROVED
J4
PROCESSOR BOARD
5390-100
MTA 100X2-26AWG
UNIMORPH+
UNIMORPH-
DS1
UNIMORPH
J9
PROCESSOR BOARD
5390-100
MTA 100X3-26AWG
HEADPHONES
S4
HANDLE ASSEMBLY
S3
COUNT
P10
PLUG-09-9040-1-04
J10
JACK-09-9011-1-419
J8
DETECTOR
UG706/U
FLYING LEAD TO
BOARD# 5390-124
J3
PROCESSOR BOARD
5390-100
MTA 100X16-26AWG
COUNT′
TIME0′
RATE
RANGE0′
ZERO′
TYPE0′
TYPE1′
OVERLOAD′
A PULSE′
BG PULSE′
RANGE 1
GND
+5V
+BAT
TIME1′
J1
AMPLIFIER / POWER SUPPLY
5390-099
MTA 100X15-26AWG
+5V
HV TEST
BAT CHECK
LO BAT′
METER IN
GND
METER GROUND
OVLD LED
COUNT RATE
+BAT
METER
M1
CPS 1mA
S6
NAME
HV
RESET
S5
TYPE SELECT
ALPHA
ALPHA + BETA
BETA
R1
10K
VOLUME
CW
S2
MINUTES
TIME1′
TIME0′
+5V
0.5
1
2
5
S1
FUNCTION SWITCH
OFF
BATTERY
X1000
X100
X10
X1
NC
+BAT
J7
CALIBRATION BOARD
5390-104
MTA 100X5-26AWG
J2
AMPLIFIER / POWER SUPPLY
5390-099
MTA 100X3-26AWG
GND
+2.5V
HV SET
B1
MN1300
1.5V
B2
MN1300
1.5V
P5
PROCESSOR BOARD
5390-100
52 PIN EDGE CARD
J5
INTERCONNECT BOARD
5390-117
52 PIN EDGE CONN.
P6
INTERCONNECT BOARD
5390-117
52 PIN EDGE CARD
J6
DISPLAY BOARD
5390-118
52 PIN EDGE CONN.
LUDLUM MEASUREMENTS INC.
TITLE: WIRING DIAGRAM
UPDATED -
DR CKB 05/31/95
CHK P.W. 6-3-99
DSGN DW 05/08/95
APPD RSS 6-3-99
NEXT HIGHER ASSY.
BOARD# 390-101
SIZE C
MODEL 2224-1
SERIES 390
SHEET 110
06:37:30 3-Jun-99 W390101
SHEET 1 OF 1