THICKNESS MONITORS

MODEL TM-100 SINGLE FILM
MODEL TM-200 MULTIPLE FILM
MODEL TM-300 SINGLE FILM, NEGATIVE AND POSITIVE READOUT

OPERATION AND SERVICE MANUAL

SERIAL NUMBER _____

MODEL NUMBER _____

CE

P/N 102800
REV J/FIJ

WARRANTY

Maxtek Inc. warrants the product to be free of functional defects in material and workmanship and that it will perform in accordance with its published specification:

Electronics for 12 months
Mechanical for 6 months

The foregoing warranty is subject to the condition that the product be properly operated in accordance with instructions provided by Maxtek Inc. or has not been subjected to improper installation or abuse, misuse, negligence, accident, corrosion, or damage during shipment.

Purchaser's sole and exclusive remedy under the above warranty is limited to, at Maxtek's option, repair or replacement of defective equipment or return to purchaser of the original purchase price. Transportation charges must be prepaid and upon examination by Maxtek the equipment must be found not to comply with tha above warranty. In the event that Maxtek elects to refund the purchase price, the equipment shall be the property of Maxtek.

This warranty is in lieu of all other warranties, expressed or implied and constitutes fulfillment of all of Maxtek's liabilities to the purchaser. Maxtek does not warrant that the product can be used for any particular purpose other than that covered by the applicable specifications. Maxtek assumes no liability in any event, for consequential damages, for anticipated or lost profits, incidental damage of loss of time or other losses incurred by the purchaser or third party in connection with products covered by this warranty or otherwise.

SAFETY

All standard safety procedures associated with the safe handling of electrical equipment must be observed. Always disconnect power when working inside the monitor. Only properly trained personnel should attempt to service the instrument.

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REV J/FIJ

1 General Description

The Thickness Monitor allows improved manual control of the vacuum film deposition process by providing a direct display of film thickness and deposition rate during deposition.

Semiautomatic control of film thickness can be accomplished by utilization of the shutter control relay in the Monitor. The shutter control relay allows for direct operator control of the system shutter and will also automatically close the shutter when the deposition thickness equals a preprogrammed value. The TM-200 has two shutter control relays which can be programmed to close on two separate set points.

The Monitor requires 4 operator supplied parameters in order to provide direct readout and shutter control. Entry, modification and display of these parameters is easy and straight forward. Parameter storage is not dependent on continuous AC power. Internal, self charging, Ni-Cad batteries provide parameter storage for a minimum of 60 days without external power.

1.1 Features

INDEPENDENT FILM DENSITY AND TOOLING FACTOR PARAMETERS

The tooling factor parameter allows the Monitor to compensate for deposition geometry effects such as different source to sensor and source to substrate distances which result in proportional but not equal film thicknesses at the sensor and the substrates. By utilizing the tooling factor, the Monitor can calculate and display film thickness and rate at the substrate rather than at the sensor.

ACOUSTIC IMPEDENCE CORRECTION

The Monitor corrects the thickness reading for acoustic impedance mismatch between the crystal and film material by taking into account the operator supplied Acoustic Impedance Parameter for the film. If not corrected for, errors result as the film thickness builds up on the sensor crystal. The sensitivity of quartz crystals to material buildup changes with the amount of material on the crystal if the deposited material has an acoustic impedance significantly different than that of quartz. With some materials this effect can lead to differences between indicated and actual thickness of up to 20% as material builds up on the sensor crystal.

PARAMETER DISPLAY

The Film Density, Tooling Factor, and Acoustic Impedance parameters are instantly viewable on demand for quick reference at any time.

AUTORANGED DISPLAY

All parameter displays and Rate and Thickness displays are fully autoranged.

LONG-TERM PARAMETER STORAGE

Parameters entered into the Monitor are maintained in memory for a period of at least 60 days without power. Short term power loss will not require parameters to be re-entered.

HIGH UPDATE RATE

The Monitor utilizes a dynamic updating scheme which provides an update rate of 5 measurements/sec at high deposition rates where response is important while still maintaining a static resolution of 0.01 microgram/sq. cm (1 Angstrom of material with density one) at low deposition rates.

OUTPUT PROTECTION

The Monitor incorporates output protection on both the shutter relay output and the DAC output in order to minimize the possibility of damage to the Monitor due to external system faults or miswiring.

DAC OUTPUT

A digital to analog converter output provides data for recording of the deposition process. Either Rate or Thickness data is selected for the DAC output.

UNIVERSAL APPLICABLILTY

The Monitor is designed to accept both 5 or 6 MHz sensor crystals and nominal A.C. line voltages of 100 through 120 or 200 through 240VAC at 50 to 60Hz.

BUILT IN TEST

The Monitor incorporates built in test functions to guarantee its operational integrity and to aid in fault isolation in the event of an internal failure.

1.2 SPECIFICATIONS

Table 1.1

Measurement Range:	Transducer Limited Typically 5,000 Microgram/sq cm As much as 20,000 Microgram/sq cm for well behaved materials. (1.0 Microgram/sq. cm = 37 Ang Al)
Rate Display:	TM-100 & TM-200: 3 Digit LED Autoranging from 00.0 to 999. Ang/sec TM-300: 3 Digit LED, Autoranging from 00.0 to +/- 999. Ang/sec
Thickness Display:	TM-100 & TM-200: 4 Digit LED Autoranging from 0.000 to 999.9 KAng TM-300: 4 Digit LED, Autoranging from 0.000 to +/- 999.9 KAng
Update Rate:	Automatically varied - .4 to 5 updates/sec
Static Thickness Resolution:	1 Ang at minimum Update Rate
Input Parameter:	Tooling Factor, Density, and Acoustic Impedance inputs allow readout directly in Angstroms.
Film No:	TM-100 & TM-300 allows input parameters for one film to be entered TM-200 allows input parameters for 1 to 100 films to be entered
Tooling Factor:	1.0 to 999.9%
Film Density:	0.800 to 99.99 gm/cubic cm
Film Acoustic Impedance:	1.500 to 99.99 X 10^5 gm/cm^2 sec
Shutter Control:	Dedicated relay. Internal 5 Amp fuse protection. One relay on TM-100/TM-300, two relays on the TM-200.

Thickness Set Point:	0.000 to 999.9 KAng Shutter closes when displayed thickness equals or exceeds set point.
Start Control:	Zeros thickness and opens Shutter.
Stop Control:	Closes Shutter
Shutter Position Indicator:	LED On indicates shutter relay activated.
Crystal Compatibility:	5 or 6 MHz, jumper selectable
Crystal Test Display:	Type of Crystal Being Used (5/6 MHz)
Crystal Health:	% of crystal life remaining. 0% life referenced to a film thickness of 925KA of aluminum.
Analog Output:	TM-100 & TM-200: 0 to +5 +/- .25V Full Scale corresponding to last 2 or 3 digits of selected display TM-300: +2.5 to +5 Full Scale Positive, +2.5 to 0 Full Scale Negative, 2.5VDC = ZERO, +/- .125V Full Scale corresponding to last 2 or 3 digits of selected display
Output Control:	TM-100 & TM-200: Rate or Thickness Select Decade Select selects for conversion of last 2 or 3 digits of display. TM-300: Rate or Thickness Select Decade Select selects for conversion of last 2 or 3 digits of display. Negative Full Scale, Positive Full Scale and Zero Calibration. Full Scale and Zero Scale Output Useful in calibrating recording equip ment.
Self Test:	Automatic detection and indication of: Oscillator Failure Power Line Failure Internal (Thickness Monitor) Failure
Power Requirement:	90 VRMS to 140 VRMS or 200 VRMS to 260 VRMS at 47 to 63 Hz, 15W

Size TM100/200/300:	3.5 H X 8.5 W X 9.3 D Inches
Size TM100R/200R:	3.0 H x 19.0 W x 8.7 D Inches
Operating Temperature Range:	0 to 50 Deg Centigrade
Weight TM100/200/300:	3.5 lbs.
Weight TM100R/200R:	8.0 lbs.

1.3 ACCESSORIES

Table 1.2

P/N 102218	Remote Start and Stop Switch.
P/N 103200-2	SC-101 Box of 5 each 6MHz gold sensor crystals.
P/N 103202	SC-102 Box of 5 each 6MHz silver sensor crystals.
P/N 103204	SC-150 Box of 5 each 5MHz gold sensor crystals.
P/N 103205	SC-151 Box of 5 each 5MHz silver sensor crystals.
P/N 103206	SC-152 Box of 5 each 5MHz gold Balzer crystals.
P/N 103207	SC-153 Box of 5 each 5MHz silver Balzer crystals.
P/N 123200-2	SH-100 Sensor Head, cable and crystals.
P/N 123214	SH-101 Right Angle Sensor Head, cable and crystals.
P/N 123200-5	SH-102 Sensor head, 38" cable and crystals (30" Tubes).
P/N 123213	BSH-150 Bakeable Sensor with 2 3/4" Feedthru.
P/N 123215	SS-103 Single Shutter Assy. (6" tubes).
P/N 158200	CPS-100 Crystal Position Selector (RSH).
P/N 123217	SS-104 Single Shutter Assembly (30" Tubes).
P/N 123202	Crystal Retainer Assembly for SH-100 Sensor Head.
P/N 123202-2	Crystal Retainer Assembly with Ceramic Insulator.
P/N 123204-1	Internal Coax Cable 30".
P/N 123204-2	Internal Coax Cable 60".
P/N 123205-1	SH-100 Sensor Head, SO-100 Oscillator and 30" coaxial cables, and box of 5 each 6MHz gold SC-101 sensor crystals.
P/N 124201-4	SO-100 Oscillator with 6" and 10' BNC Cables.
P/N 124202-1	BNC Cable Assembly 10'.
P/N 124202-2	BNC Cable Assembly 20'.
P/N 124204	BNC Cable Assembly 6".
P/N 130200-1	IF-110 Instrumentation Feedthrough, 1" O-Ring with coaxial cable and dual 1/8" water connections.
P/N 130200-2	IF-111 Instrumentation Feedthrough, 1" O-Ring with coaxial cable and dual 3/16" water connections.
P/N 130204-1	IF-275 Instrumentation Feedthrough, 2 3/4" Flange seal with coaxial cable and dual 1/8" water connections.
P/N 130204-2	IF-276 Instrumentation Feedthrough, 2 3/4" Flange seal with coaxial cable and dual 3/16" water connections.
P/N 130211	IF-121 1" Feedthrough for use with SS-103.
P/N 130207	IF-280 2 3/4" Flange Seal Feedthrough for DSH-200.
P/N 130208	IF-120 Dual 1" O-Ring Feedthroughs for DSH-200.
P/N 147200	DSH-200 Dual Sensor Head.
P/N 147202	PSV-100 Pneumatic Shutter Valve.
P/N 150201	SF-120 Combination Sensor Head/1" Feedthrough, Cables and Crystals.
P/N 150205	SF-120 Combination Sensor Head/ 1" Feedthrough, Cables, Crystals and Oscillator.

P/N 150207	SF-290 Combination Sensor Head/ 2 3/4" Feedthrough, Cables and Crystals.
P/N 150208	SF-290 Combination Sensor Head/ 2 3/4" Feedthrough, Cables, Crystals and Oscillator.
P/N 153200-1	RSH-600 Rotary Sensor Head (Adjust. to 6.6").
P/N 153200-2	RSH0601 Rotary Sensor Head (Adjust. to 12.5").

2 Unpacking and Inspection

Carefully inspect your Monitor and its shipping container for evidence of possible shipping damage or loss. If such evidence is present, a report should be filed with the carrier as soon as possible. Keep the shipping container as evidence if shipping damage is present or for possible future return of the unit. Check the material received against the packing list to be certain that all material is accounted for. The following items should have been included with your Monitor:

1	TM-100/200/300
1	Operator's Manual
1	Power cord
1	3 pin connector (2 with TM-200)
1	9 pin connector
12	Pin contacts (15 with TM-200)

2.1 Bench Check-Out

If there is no evidence of damage, the Monitor can now be bench checked. Make sure that the input power voltage requirement (See Figure 3.4) is correct for your installation. If not, see Section 3.2.4, Input Power Voltage Selection, and set up your Monitor for the correct voltage range.

Power is applied to the Monitor via the rear panel rocker switch. When power is first applied to the Monitor it goes through a short internal test routine during which time all of the numeric displays will show 8's and all decimal points will be lit. This condition lasts for 3 seconds after which time the Monitor will begin to flash a P FAIL message indicating that power has been interrupted for more than 250 msec. You may see an E FAIL or I FAIL message for a short time, this is normal. If the display stops on either of the messages an internal fault has been detected and the unit will remain inoperative until the fault has been corrected. Further details of error messages can be found in Section 8.1 Self Test Failure Detection.

If power has been off for more than 60 days, the Monitor may display a flashing C FAIL message, indicating that the unit has lost all or part of its stored parameters. This fault may be cleared by pressing the STOP button.

Pressing the STOP button will also preset the parameters as follows:

SET POINT	- 10.00
DENSITY	- 1.000
ACOUSTIC IMP.	- 8.830
TOOLING	- 100.

Clearing this fault should result in a flashing O FAIL message indicating that the sensor oscillator has failed, in this case because the oscillator is not hooked up.

If your Monitor responds as described above it is probably OK and is ready to be installed. If not, return the Monitor for repair or replacement.

If an oscillator, feedthrough, and sensor head are available, you may wish to bench check the total system at this time. Obviously good vacuum practice should be observed when handling those items which will later be installed in the vacuum system. Be careful not to touch the surface of the sensor crystal installed in the Crystal Holder. Connect the various components as follows: Use the 10' coaxial cable to connect the Monitor to the "Output" end of the Oscillator. Use the 6" coaxial cable to connect the "Input" end of the Oscillator to the atmosphere side of the Feedthrough. Use the 30" miniature coaxial cable to connect the vacuum side of the Feedthrough to the Sensor Head.

After all the components have been connected, pressing the STOP button should clear the O FAIL message.

Depressing the START button will set the thickness display to zero. Breathe lightly on the sensor crystal surface. The displayed thickness should increase due to condensed water vapor on the crystal. The O FAIL message may be reactivated if excessive water on the crystal causes it to fail. The message should clear itself as soon as sufficient water has evaporated allowing the crystal to recover. The displayed thickness should then decrease as additional water vapor evaporates from the surface. If operation seems abnormal check to see that the stored parameter values are reasonable. The following parameter values are suggested:

Set Point Thickness 10.00 KAng
Material Density 2.650 gm/cubic cm
Acoustic Impedance 8.830
Tooling Factor 100.0%

If everything responds as described above the total system is OK. If not, refer to Section 8, Troubleshooting.

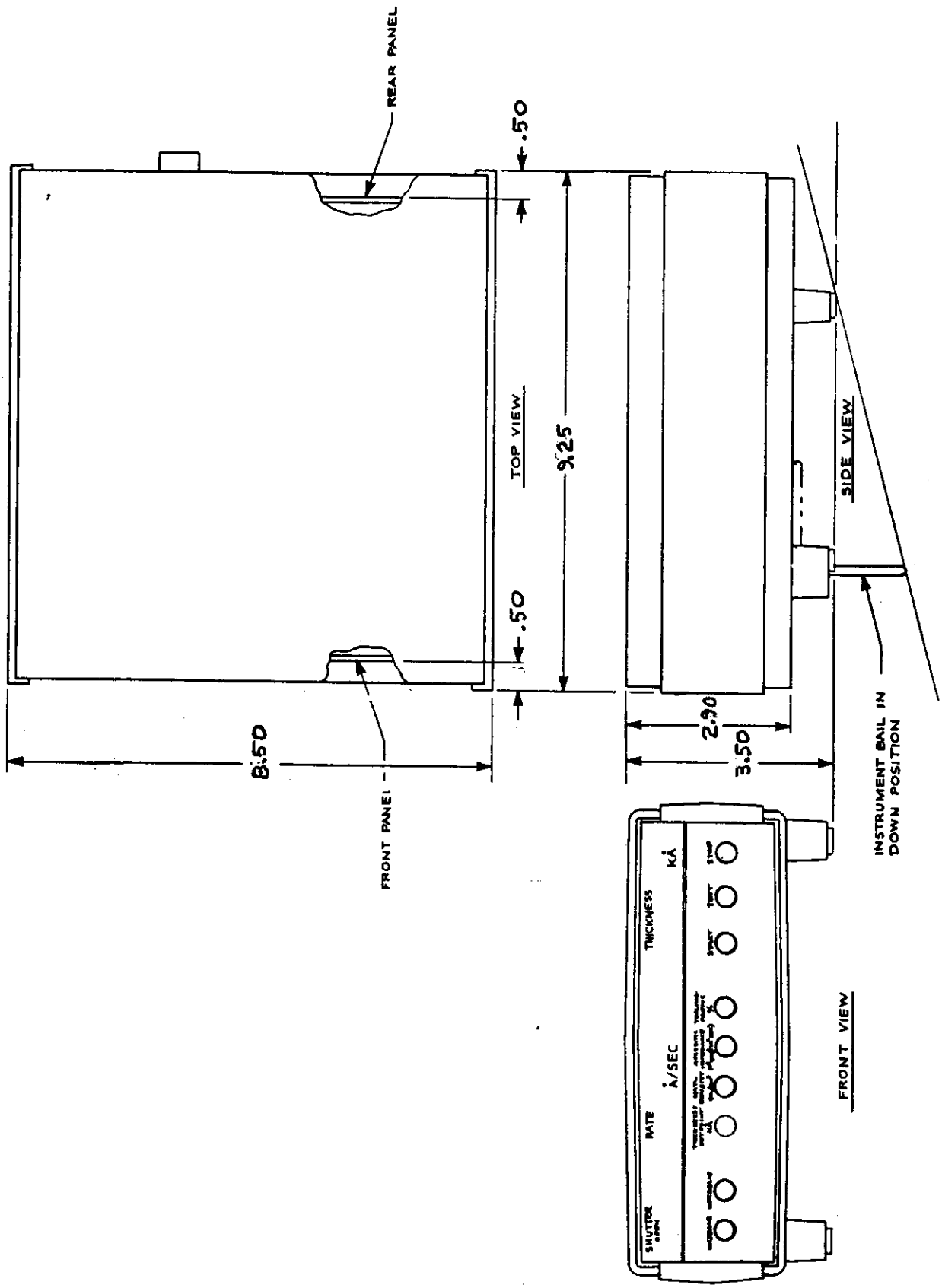


FIGURE 2.1 TM-100 OUTLINE

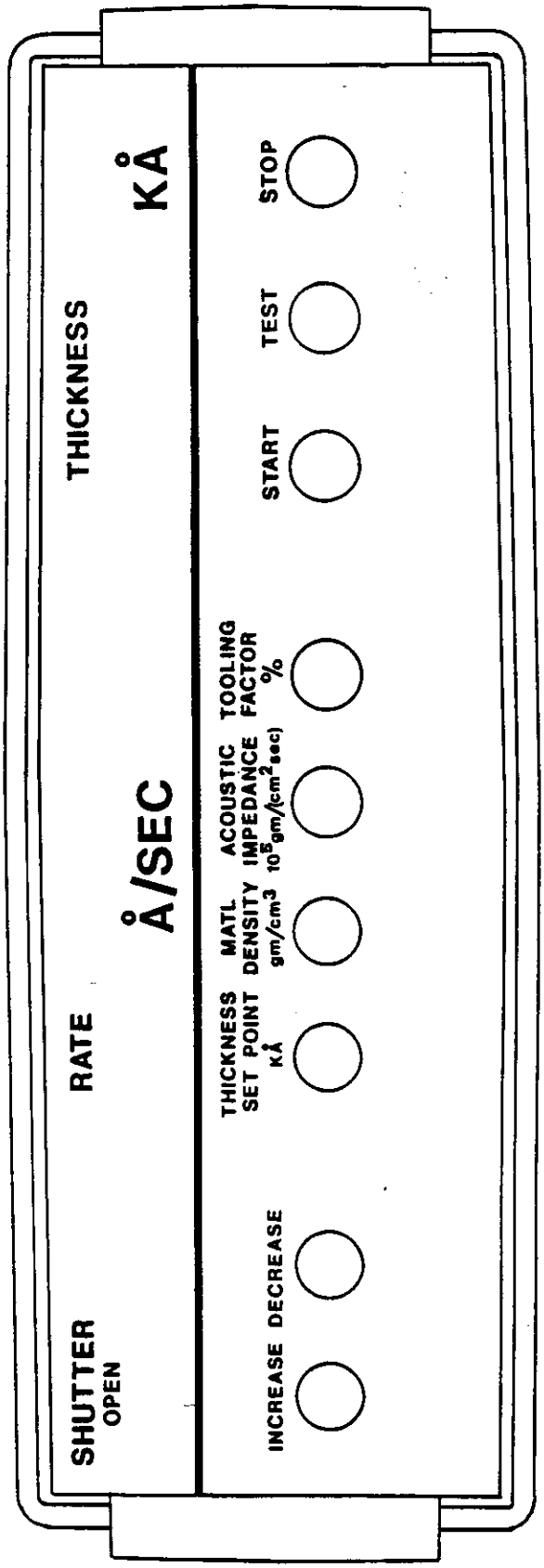


FIGURE 2.2 TM-100/300 FRONT PANEL OUTLINE

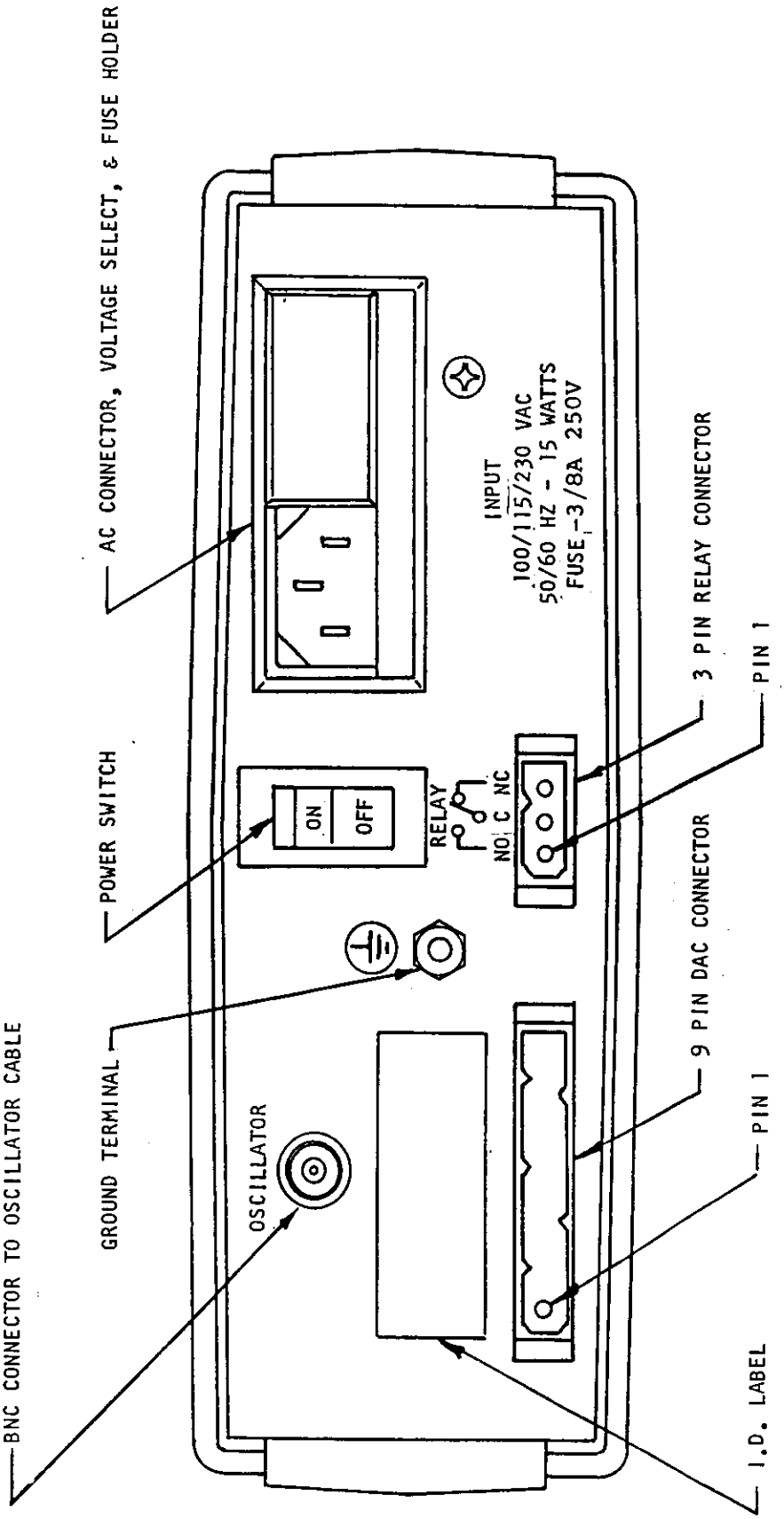


FIGURE 2.3 REAR PANEL OUTLINE (TM-100 & TM-300)

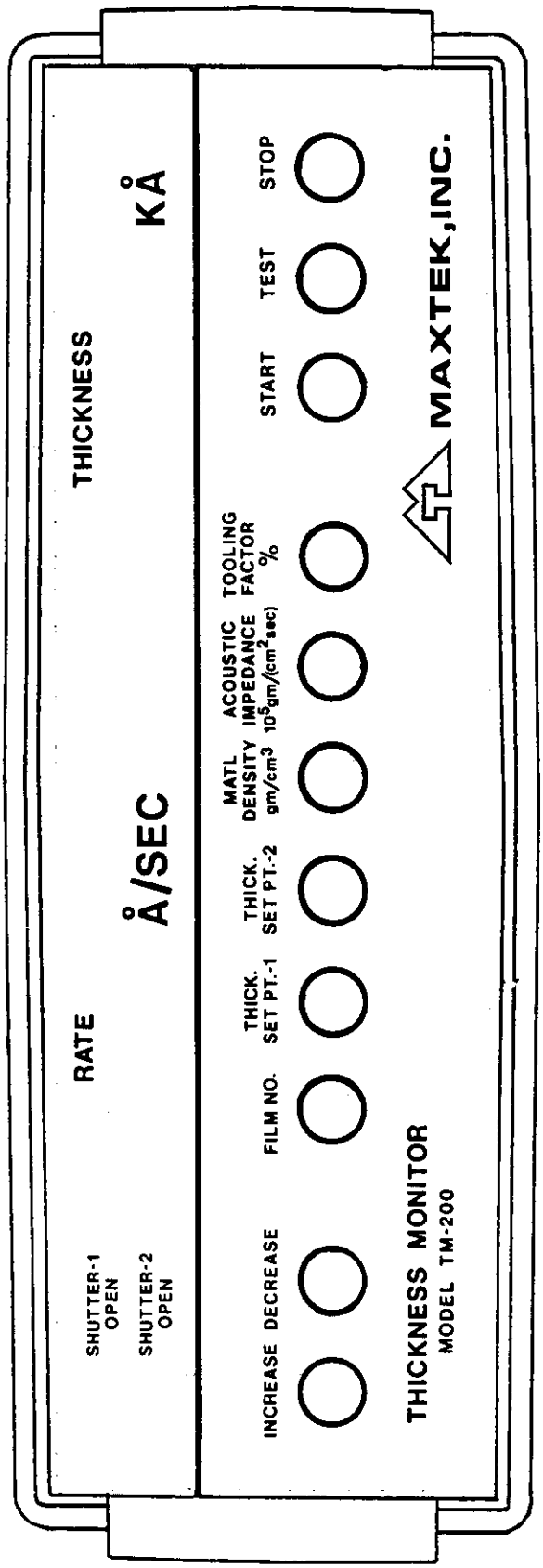


FIGURE 2.4 TM-200 FRONT PANEL

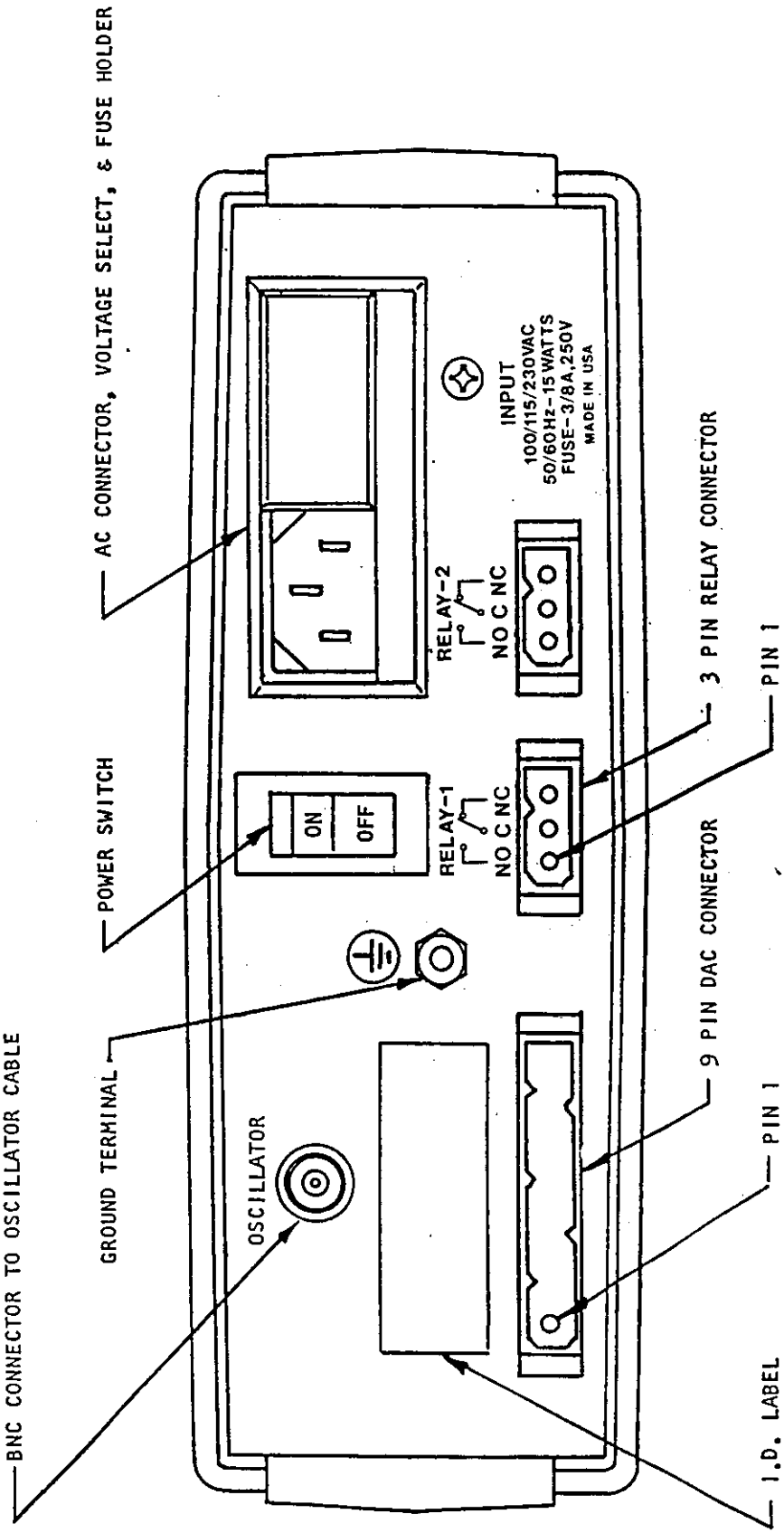


FIGURE 2.5 TM-200 REAR PANEL

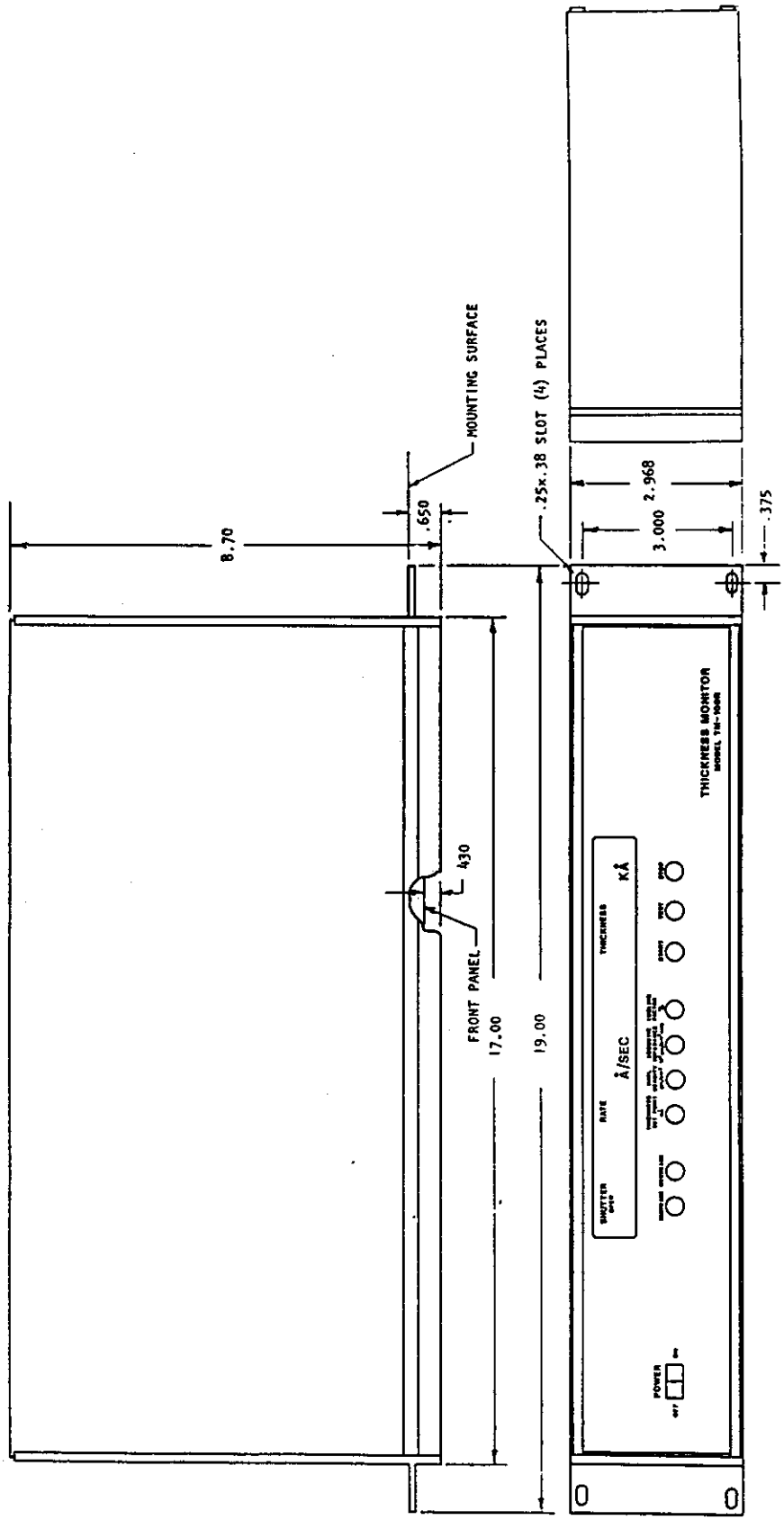


FIGURE 2.6 TM-100R/200R OUTLINE

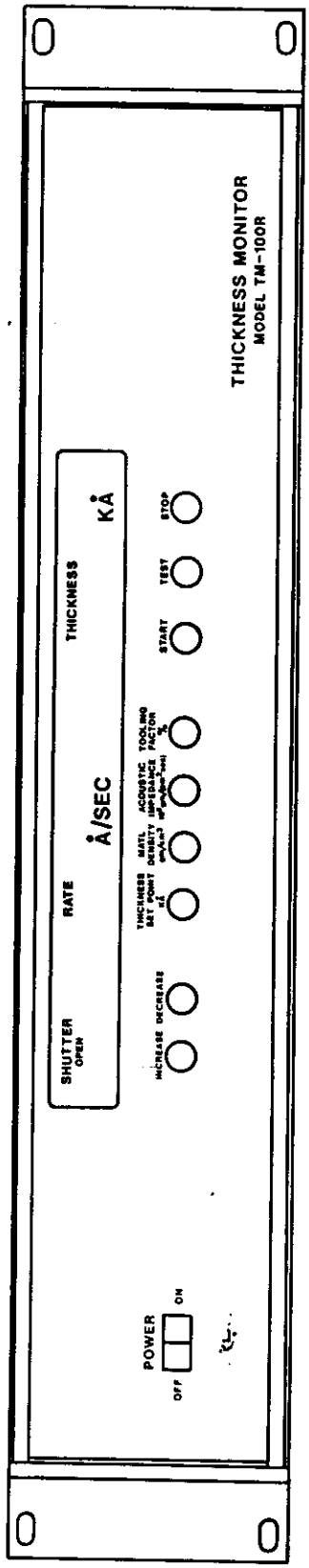


FIGURE 2.7 TM-100R FRONT PANEL

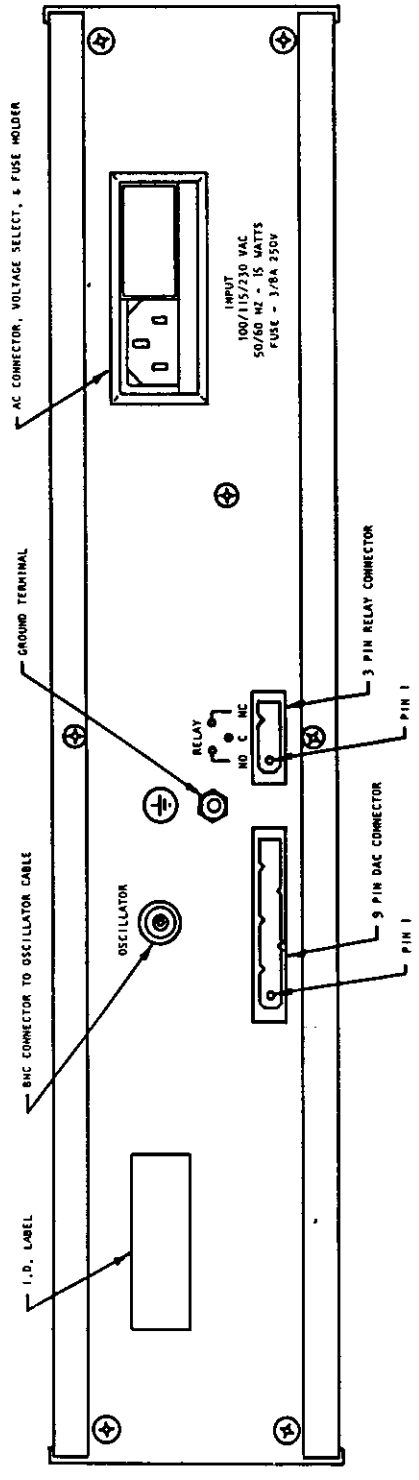


FIGURE 2.8 TM-100R REAR PANEL

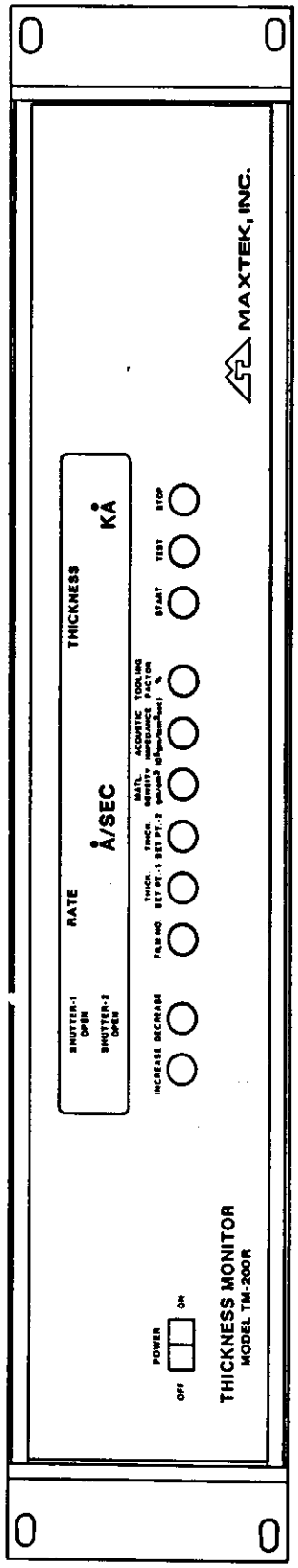


FIGURE 2.9 TM-200R FRONT PANEL

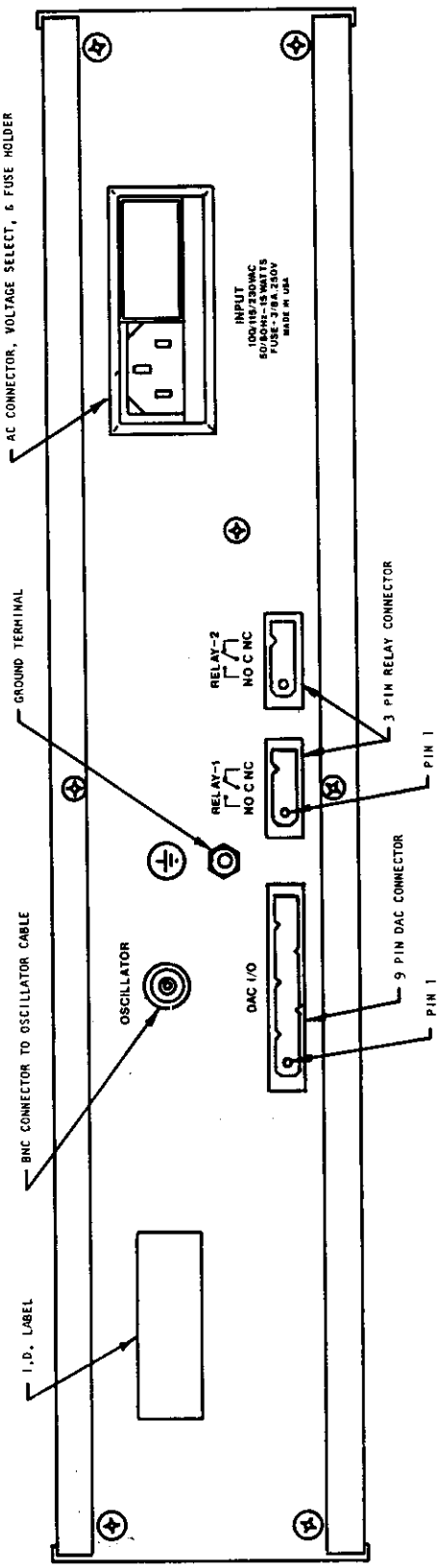


FIGURE 2.10 TM-200R REAR PANEL

3 Monitor Installation

3.1 Monitor Installation Precautions.

3.1.1 Proper Grounding

The Monitor was designed to operate in electrically noisy environments. In many cases no special grounding precautions will be required. Where noise susceptibility is suspected, use a short length of wire, wire braid or copper strap is recommended, to connect the Monitor to the equipment on which, or in which, the unit is mounted. Use the grounding lug provided on the back of the Monitor for this purpose. If trouble still persists, make sure that the equipment on which the Monitor is mounted, or the equipment rack in which the unit is mounted is adequately grounded to the vacuum frame. Use short copper straps or braid. It is a good idea to use several grounding straps attached to widely separated points on the vacuum system and equipment frame in order to minimize the inductance of the ground path.

3.1.2 Heat Dissipation

Your Monitor dissipates very little heat. Even so the heat that is generated must be allowed to dissipate or the Monitor will overheat. Most of the heat generated in the Monitor is routed to the rear panel which is cooled by convection and radiation. Make sure that there is adequate clearance around the unit to allow air flow. If the unit is mounted in an enclosure, make sure that the air flow is enough to maintain a maximum temperature environment of 50 degrees centigrade for the Monitor. Overheating of the Monitor will ultimately cause
functional failures and may cause premanent failures.

3.2 Rear Panel Connections

3.2.1 Oscillator Connector

A BNC connector is provided on the rear panel of the Monitor for connection to the sensor oscillator. The Monitor's oscillator input buffer is designed to operate with coaxial cable of 50 ohm impedance. Cable lengths up to 50 feet may be installed using RG 58 cable or an equivalent. Cable lengths longer than the 10 ft. length supplied are available upon request. Refer to Section 4 for Sensor, Feedthrough, and Oscillator installation instructions.

3.2.2 Shutter Connection

A 3 pin Burndy QIKMATE^ connector is provided on the two connectors on the Monitor's rear panel for connection to a shutter activating device. The shutter relay provides a form C contact closure (SPDT, break before make). The contacts are rated for 8A

at 220VAC or 24VDC. A 3AG 5 Amp fuse is mounted inside the Monitor to protect the internal circuitry from possible damage due to miswiring. A mating connector and pins are supplied for connection to the rear panel connector. The pins can be crimped or soldered to the wires leading to the shutter actuator. Figure 3.2 shows the recommended method for connecting a shutter solenoid. Using this connection scheme results in the shutter closing in the event of power loss.

3.2.3 Digital to Analog Converter (DAC) Connection.

A nine pin connector is supplied on the Monitor rear panel for connection to the DAC.

The following list describes the DAC connector pin assignments.

Table 3.1
DAC Connector Pin Assignments

Pin Number	1	Analog Signal Output
	2	Analog Signal Return
	3	Not used
	4	Not used
	5	Thickness or Rate Select Input
	6	2 or 3 Decade Select Input
	7	Zero Scale Calibration Input
	8	Full Scale Calibration Input
	9	Logic Signal Return

A suggested wiring diagram for connecting a strip chart recorder to the DAC output is shown in Figure 3.3. It is suggested that the control switches be mounted near the recorder for convenience. Even though the Logic Signal Ground and the Analog Signal Return are tied to the Monitor ground internal to the Monitor it is suggested that the Analog Signal Output and Return be handled as a signal pair. In order to minimize noise pickup at the recorder it may be necessary to use a twisted, shielded pair for this signal.

3.2.4 Line Power Voltage Range Selection.

a) Remove AC cord and slide plastic cover to left, exposing fuse and voltage select p.c. board.
b) Remove fuse by moving "FUSE PULL" lever to the left.
c) Remove voltage select board by pulling with a suitable tool on the small hole in the center of the board.
d) Select the voltage by positioning p.c. board so that desired voltage is indicated on upper left hand corner. Insert board into place in this position.
e) Install fuse and slide cover to right. The selected voltage will be visible through the plastic window.

3.2.5 Crystal Type Selection

The Monitor is compatible with both 5 and 6 Megahertz sensor crystals. An internal plug-in (J5) jumper is used to set up the Monitor for the particular sensor crystal frequency to be used. As shipped the Monitor is set up for a 6 Megahertz sensor crystal frequency. To configure the Monitor for 5 Mhz operation the plug-in jumper must be removed. See Figure 8.3 for help in locating the jumper. It is suggested that the jumper be reinstalled over only one of the pins for storage so that it doesn't get lost. Refer to Section 3.3 for instructions on removal of the Monitor cover.

3.3 Monitor Cover Removal.

CAUTION

Under no circumstances should the Monitor cover be removed without first removing the line cord as dangerous voltages are present inside the case.

The cover of the Monitor is secured by 4 screws which are located in the feet on the bottom of the unit. The 2 rear screws are located under the soft rubber pads which plug into the plastic feet. Remove the 4 screws, grip the unit by the sides with the front panel facing you and carefully push the top cover up off the front panel with your thumbs. When the top edge of the front panel becomes visible, turn the unit around and do the same thing with the back cover facing you. The cover is tight and you will have to work it off slowly.

To reinstall the cover slide it down over the front and rear panels and into the side panels. Installation of the front two feet which constrain the bail is most easily accomplished by installing them with the bail in its extended position.

CAUTION

Be careful not to over tighten the screws as it is possible to pull the inserts out of the cover!

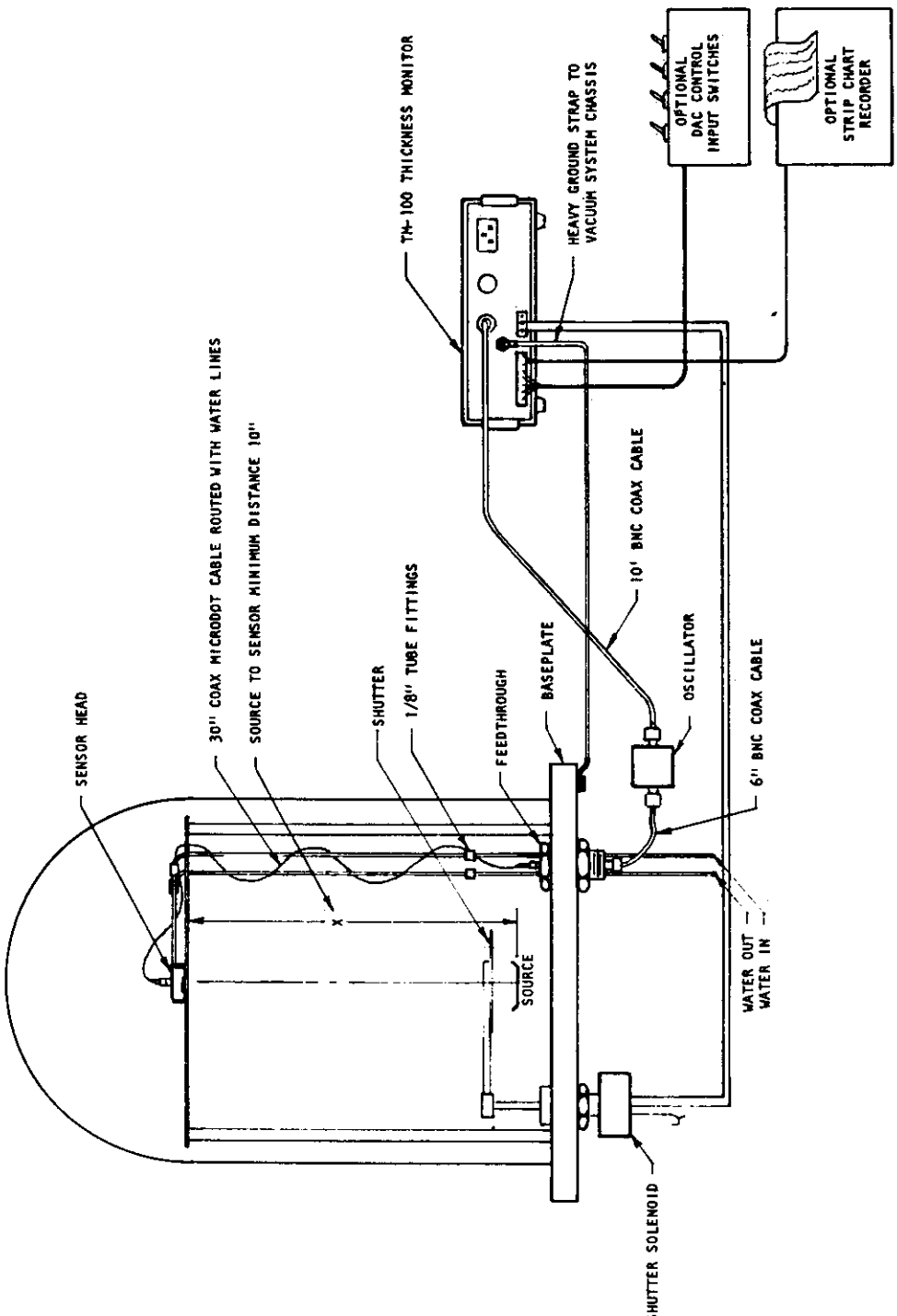
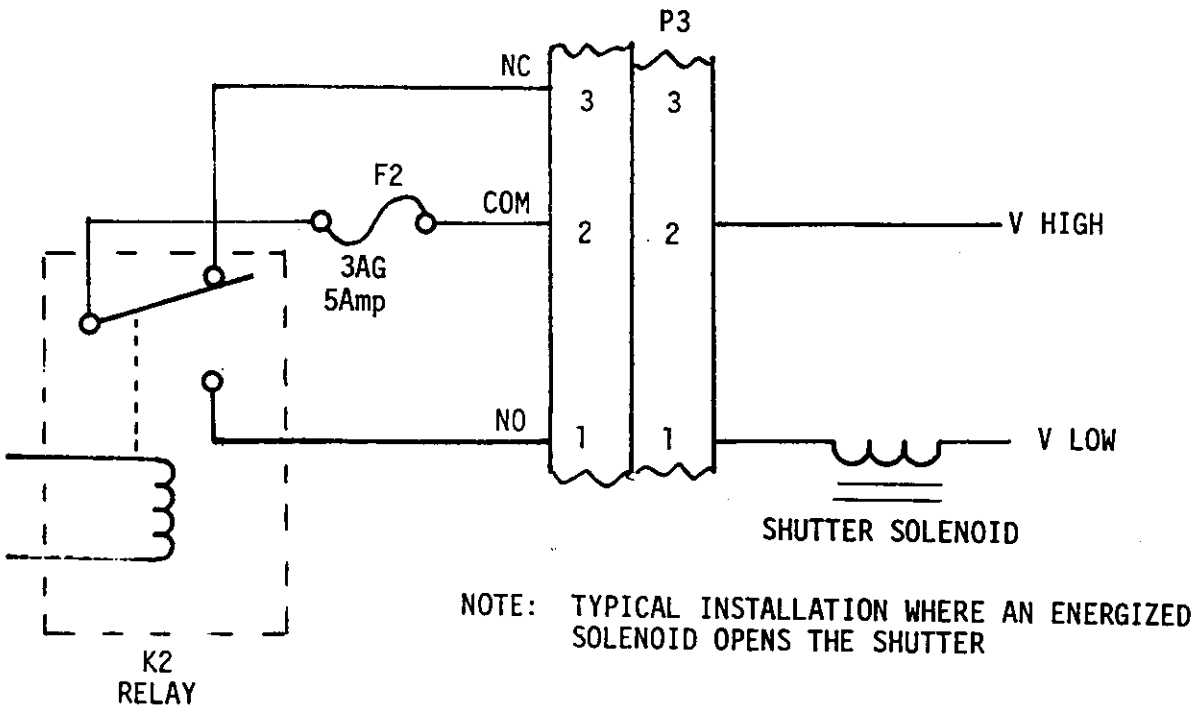
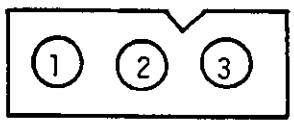


FIGURE 3.1 TYPICAL VACUUM SYSTEM INSTALLATION





CONNECTOR PIN DESIGNATION

FIGURE 3.2 SHUTTER WIRING SCHEMATIC

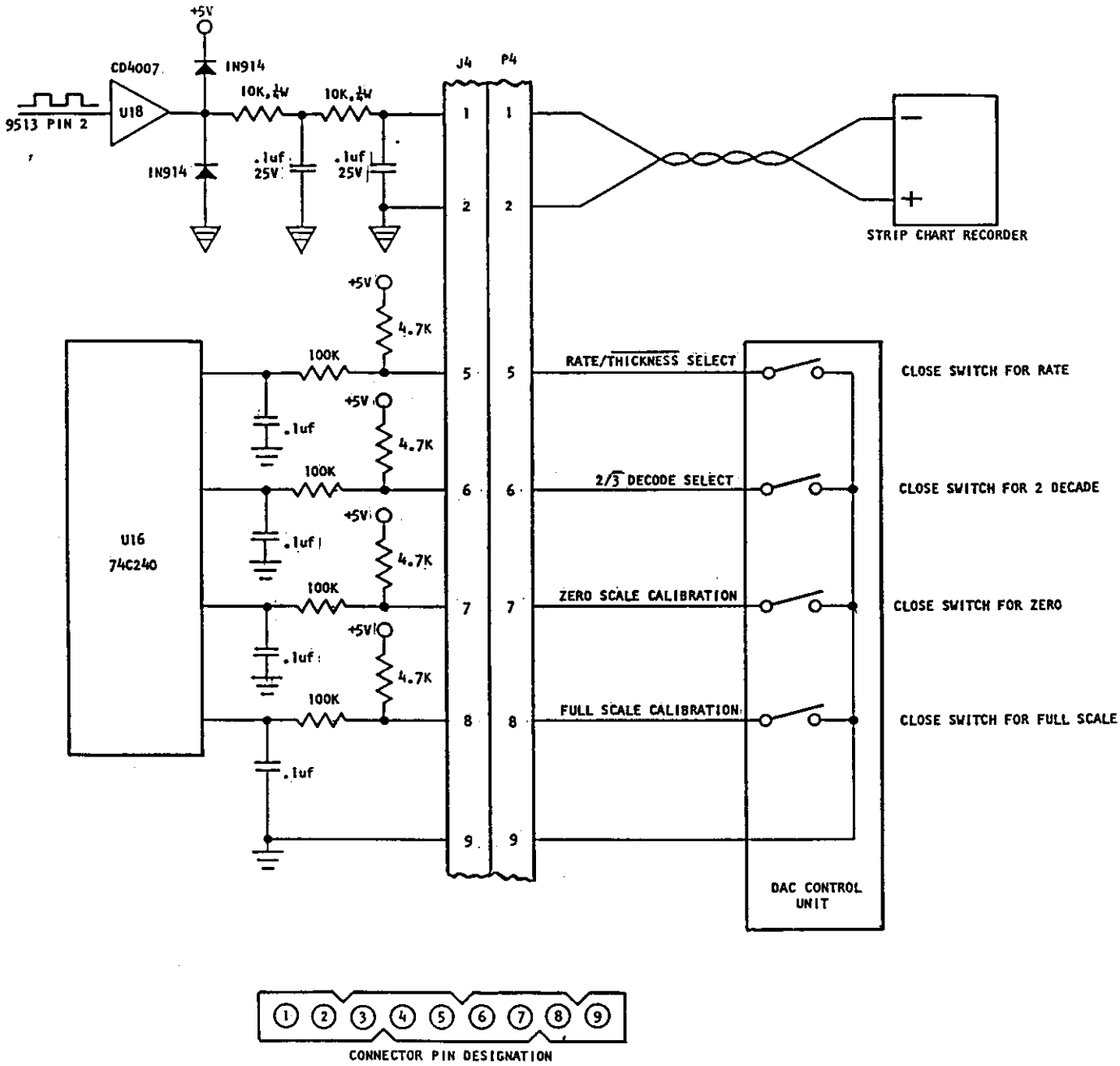


FIGURE 3.3 DAC WIRING SCHEMATIC

4 Sensor, Feedthrough, and Oscillator Installation

4.1 Sensor Head Installation

The sensor head can be installed in any appropriate location in the vacuum chamber. Preferably, the sensor should be located at least ten inches from the evaporation source and as close as possible to the center of the substrate area. The distance from the vapor source to the substrate is the recommended distance between the vapor source and the sensor crystal surface. The sensor head can be supported by its integral mounting bracket furnished with two #4-40 tapped holes. Make sure there is adequate clearance to allow for easy removal of the crystal drawer.

The microdot cable connects the sensor head to the dual water/electrical feedthrough. It is a good idea to wrap the coaxial cable loosely around the water cooling tubes. Teflon is used as the insulator in the coaxial cable and therefore will in many cases need no further shielding. However, if substrate heating is used or the system operates above 300 deg. C. for any other reason, the cable and water lines may be wrapped together in aluminum foil to extend the cable's useful life. Maxtek's crystal retainer with ceramic insulator (P/N 123202-2) should be used. If the system is to be baked out (up to 400 deg. C) then a Model BSH-150 Bakeable Sensor Head/Feedthrough shoud be used. The mounting tabs on the sensor head may be used to install a radiation shield to specifically protect the microdot cable connector at its attachment point to the head.

The cable length from the sensor head to the feedthrough connection should not exceed 60 inches. Cable lengths in excess of 40" requires a factory-modified oscillator. The water cooling tubes connect to the feedthrough by brazed or vacuum couplings.

Water cooling of the sensor head should always be provided except during short depositions at low temperatures. In all cases, sensor head temperature should not exceed 100 degrees centigrade. Sufficient cooling for thermal environments of up to 300 deg. C. can be provided by a water flow of approximately 0.2 gallons per minute. Excessively cold water may result in condensation of water on the crystal holder and crystal when the system is vented. Excessive moisture may cause the crystal to cease operating. This condition is only temporary and the crystal will function properly as soon as the moisture evaporates. Ideal water temperature is between 10 deg. C. and 25 deg. C.

Use a shutter to shield the sensor head during initial soak periods to protect the crystal from any sputtering that may occur. If a small droplet of molten material hits the crystal, the crystal may be damaged and oscillation will cease.

A complete description of the sensor head is provided in Appendix A.2

4.2 Instrumentation Feedthrough Installation

The feedthrough is installed in the vacuum chamber housing with the smaller Microdot S-50 connector exposed to the vacuum chamber. The sensor head is connected to the Microdot connector by a coaxial cable. This coaxial cable should not exceed 60 inches. Connect the 6 inch coaxial cable to the feedthrough's external BNC connector and the sensor oscillator's TRANSDUCER BNC connector. Water line connections to the feedthrough may be accomplished by brazing or vacuum couplings.

Refer to Appendix A.3 for a description of the feedthrough.

4.3 Combination Sensor/Feedthru Installation

With the combination Sensor/Feedthru, the coaxial cable is already attached. Merely pull the coils apart to desired length. Maximum expansion is 30 inches.

4.4 Sensor Oscillator Installation

Use the 6 inch coaxial cable with BNC connectors to connect the "Transducer" end of the oscillator to the feedthrough.

Use the 10 foot cable to connect the other end of the oscillator to the Monitor. Be careful to route the cable away from any high voltage or RF lines and away from hot or moving surfaces.

For a complete description of the oscillator see Appendix A.4.

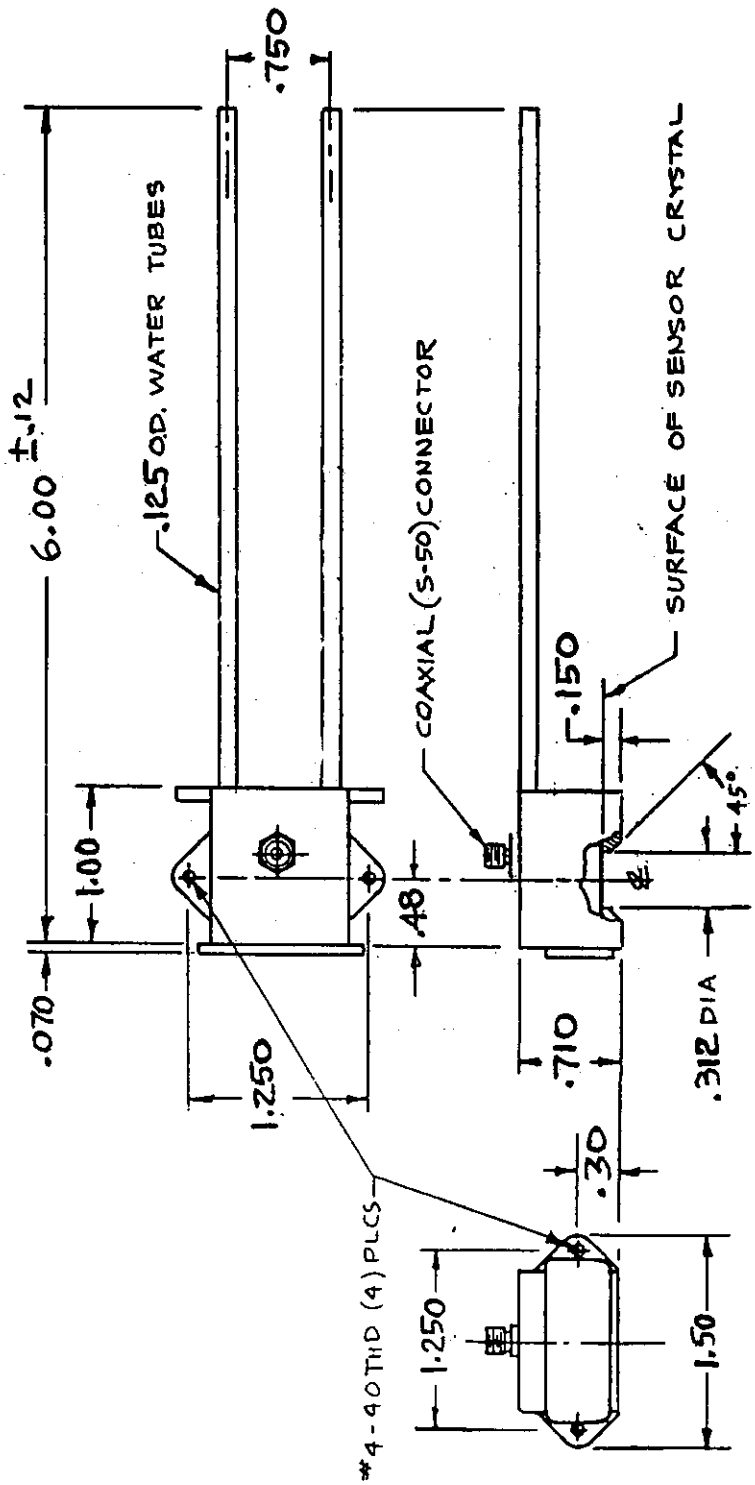


FIGURE 4.1 SENSOR HEAD OUTLINE

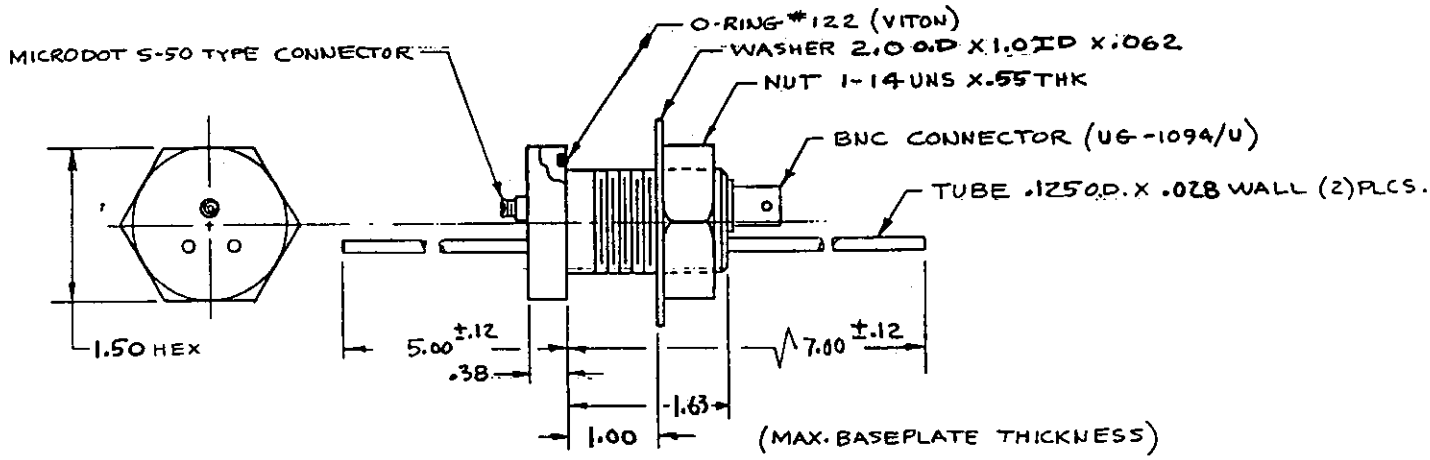


FIGURE 4.2 INSTRUMENTATION FEEDTHROUGH OUTLINE

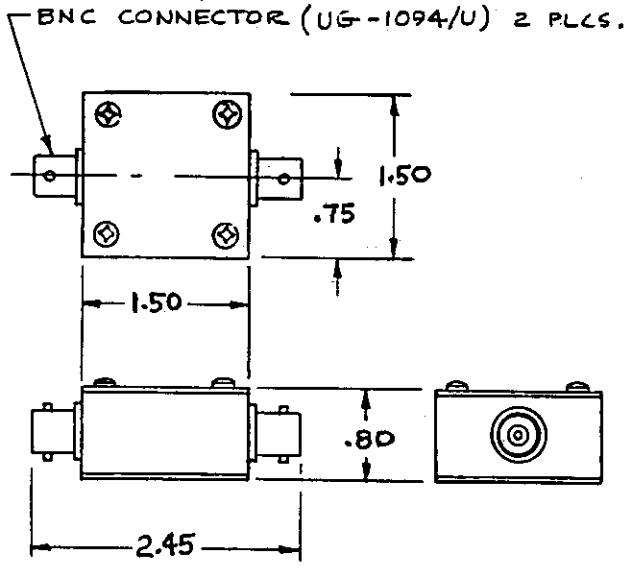
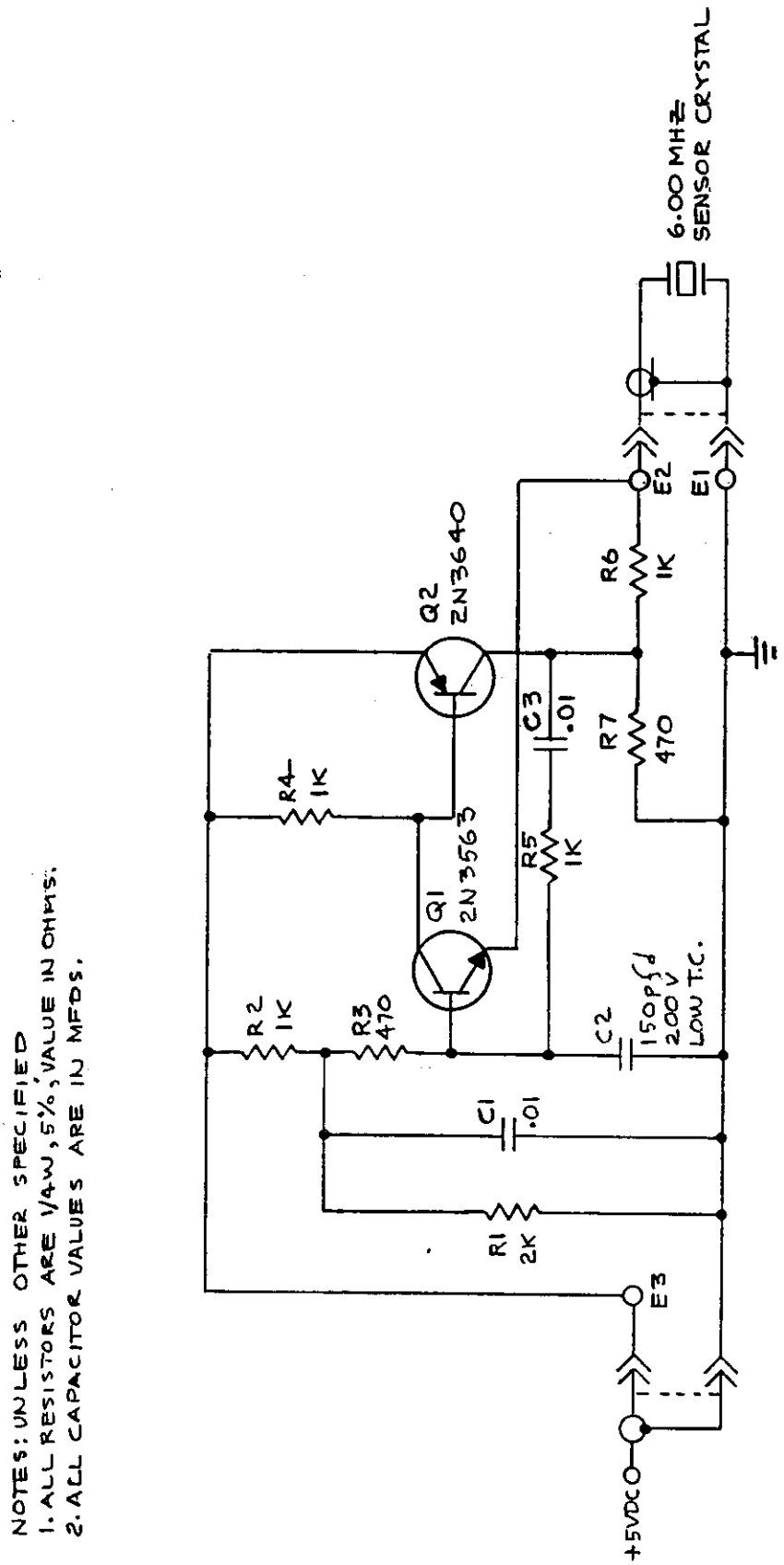


FIGURE 4.3 SENSOR OSCILLATOR OUTLINE



NOTES: UNLESS OTHER SPECIFIED
1. ALL RESISTORS ARE 1/4W, 5%, VALUE IN OHMS.
2. ALL CAPACITOR VALUES ARE IN MFDS.

FIGURE 4.4 SENSOR OSCILLATOR SCHEMATIC

5 Sensor Crystal Replacement

The 123200 Sensor Head is especially designed for easy sensor crystal replacement and reliable operation. The crystal lies in a drawer that slides into the sensor housing. Pull the drawer straight out of the sensor housing by gripping the drawer's edges between thumb and forefinger. With the drawer removed pull straight up on the retainer spring clip and shake out the spent crystal. Drop a new crystal into the drawer with the full electrode side down and the pattern electrode side up. Make sure the crystal is properly seated in the bottom of the drawer. Install the retainer clip by gently pressing it onto the drawer. The retainer clip should snap into the drawer. All three retaining legs must be fully engaged onto the drawer housing. Replace the drawer into the sensor housing. The drawer should slide in easily and snap into place.

Removal and replacement of sensor crystals should be performed in a clean environment. An isolated clean work bench is recommended for crystal replacement. To prevent crystal contamination use clean lab gloves or plastic tweezers when handling the crystal and keep the new crystals in a closed plastic case. When handling the drawer always hold it by the edges to avoid touching the crystal surface.

6 Operation

6.1 Front Panel displays

The Monitor display consists of a 4 digit Thickness display, a three digit Rate display and a single LED on the TM-100, two LEDS on the TM-200, and three LEDS on the TM-300 to indicate a Shutter open condition. Both the 4 digit thickness display the the 3 digit rate display are sometimes used for other functions. These functions are described in later sections.

The Shutter Open LED's indicate that the shutter relay is activated.

6.2 Front Panel Controls

Momentary push button switches comprise the front panel controls. The buttons are arranged in three groups.

There are nine buttons on the TM-100 and TM-300 and eleven on the TM-200. The two buttons on the left and the four or six on the TM-200 in the middle are used for display and modification or parameters. Their use is described under "Display and Modification of Parameters"

The three buttons on the right form the normal operating controls. Depressing one of these buttons causes the following action:

START
Set the thickness display to zero and opens the shutter.

STOP
Closes the shutter. Also used to clear certain error conditions such as Power FAIL and Oscillator FAIL.

FILM NUMBER
For TM-200 Models. Selects a film from 1 to 100. When depressed, displays the current film in the rate display and can be incremented or depressing the increase or decrease buttons. Each film can be individually programmed by setting the film number and programming as per paragraph 6.3. A film parameter log is provided in Appendix A.9. Note: Failure mode must be cleared in order to advance to the next film.

TEST
Used to determine crystal health. While depressed, causes crystal data to be displayed in both the Rate and Thickness displays. Causes no other action. Display returns to normal upon release of button.

6.3 Display and Modification of Parameters.

Display of the parameter values stored in the Monitor is accomplished by depressing one of the appropriate buttons within the group of (4 on TM-100/TM-300, 6 on TM-200) parameter buttons. The value of the parameter is displayed in the Thickness display area for as long as the button is depressed and for a display hold period of approximately 3 seconds after it is released. On the TM-200, the layer NO. is displayed in the Rate Display area. At any time during the display of the parameter it can be increased or decreased by depressing one of the INCREASE or DECREASE buttons.

The parameter button need not be simultaneously pressed as pressing the increase or decrease buttons will hold the current parameter display for the normal parameter display hold period. If the increase or decrease button is kept depressed the rate at which the parameter varies gradually increases. Thus the longer the button is kept depressed the faster the parameter changes. When the button is released and then depressed again the rate returns to its initial slow value. With a little practice this allows parameters to be set to the necessary accuracy while keeping the time to go from one extreme value to another within reasonable limits.

The Increase and Decrease buttons are only active when a parameter is being displayed. The Rate display continues to display deposition rate independent of parameter displays. The parameters may be changed before, during, and after a deposition. Only during a failure condition will the parameters be viewable but unchangeable.

6.4 Thickness Set Point Shutter Control.

The TM-100 and the TM-300 provide a single shutter set point and the TM-200 provides two set points. The Thickness Set Point establishes the film thickness at which the shutter closes. As described above, depressing the START button zeros the Thickness Display and opens the shutter. The shutter is then automatically closed when the Thickness Display equals or exceeds the Thickness Set Point. The shutter can also be closed manually by depressing the STOP button. In this way complete manual control of the shutter, as may be required for servicing the source, is available through use of the START and STOP button. This eliminates the need for a separate OPEN, CLOSE, AUTO switch and eliminates the possibility of leaving such a switch in the open or close position when it should be in the auto position. If auto control of the shutter is not desired the Thickness Set Point parameter can be programmed at a value much greater than can reasonably be achieved. The "Thickness Set Point-2" may be used to activate a second shutter relay to allow two materials to be sequencially

deposited to two preset thicknesses or to operate other electrical or electrical-mechanical devices.

6.5 Crystal Test.

When the TEST button is depressed the normal displays are replaced with crystal test information.

The normal Rate Display is replaced with a three digit number the leftmost digit of which is a 5 or 6 indicating the type of sensor crystal the Monitor is set up for. The Monitor is compatible with both 5 and 6 Mhz sensor crystals. See Section 3.2.5, Crystal Type Selection.

The rightmost 2 digits display the crystal health. Crystal health is indicated as a percentage of crystal life remaining. See Appendix A.7.

A new crystal will have a health of 98 to 99%. The health decreases as material is deposited on the crystal sensing surface. The normal Thickness display is replaced with a display of the current operating frequency in megahertz of the sensor crystal.

The Crystal Test displays revert to normal after the TEST button is released. The crystal test function does not affect the normal operation of the Monitor. In particular, both Thickness and Rate continue to be calculated and the normal operation of the Thickness Set Point is not affected.

6.6 Crystal Fail Indication.

As material builds up on the sensor crystal, a point will be reached at which the crystal will no longer be able to support oscillation. At this point the crystal has failed. The Monitor indicates crystal failures by alternately flashing an O FAIL message and the last valid thickness reading prior to the failure. The Shutter closes and the Shutter Indicator LED is turned off.

There are two possible types of a crystal failure; a 'short term' failure and a 'permanent' failure. If the crystal recovers within 2 seconds the Monitor will regard it as a 'short term' failure, in which case the display returns to normal, the Shutter is reopened, and Shutter Indicator is turned back on. If the crystal is failed for more than 2 seconds the Monitor regards the failure as a 'permanent' failure. In this case the Shutter and Shutter Indicator LED are turned off and WILL NOT be turned back on if the crystal recovers at a later time. A permanent O FAIL condition must be cleared by pressing the STOP button.

A crystal which has failed at any time should be replaced. For obvious reasons crystals should normally be replaced well before

they are likely to fail. See Section 5 for the procedure on replacing spent crystals.

6.7 Power Fail Indication.

The Monitor is designed to tolerate short duration power failures of less than 250 milliseconds. During a deposition, if the power is disrupted for less than 250 milliseconds the Shutter closes and reopens when power returns. However, because the Monitor is designed for possible unattended operation it does not reopen the Shutter if the power failure lasts for more than 250 milliseconds as a process disruption of this duration could seriously affect the deposition. Instead the Monitor retains the value of the film thickness at the time of power failure and flashes the P FAIL message to indicate to the operator that power was down during his absence. The operator then has the option of continuing the deposition if desired by restarting the Monitor.

6.8 DAC Operation

The DAC provides for the conversion of either Rate or Thickness to an analog voltage suitable for recording with a strip chart recorder or other recording device. The DAC converts the last two or three digits of the selected quantity to a zero to 5 volt analog voltage. If a three digit conversion is selected, the last three digits of the quantity are converted. Thus a thickness of 0.999 KAng would correspond to the maximum analog output of 999/1000 times the full scale value. Since the full scale value is nominally 5.0 volts, a thickness value 0.999 KAng would correspond to a nominal output of 4.995 volts. At a thickness of 1.000 KAng the output would be zero corresponding to a value of zero for the last three digits. Since full scale corresponds to 1000 "counts" the DAC scale factor is 5.0 millivolt per Angstrom. A thickness of 1.020 would convert to a value of 0.1 volts.

If a two digit conversion is selected, the last two digits of the quantity are converted. Thus a thickness of 0.099 KAng would correspond to the maximum analog output of 99/100 times the full scale value of 5.0 volts for a nominal output of 4.95 volts. During two digit conversion the DAC scale factor is 50.0 millivolt per Angstrom.

When converting Rate, the basic resolution is 0.1 Angstrom/sec. Thus a rate of 55.0 Ang/sec would be converted to 550/1000 times 5.0 volts or 2.75 volts if three digit conversion were selected and 55/100 times 5.0 volts or 2.50 volts if two digit conversion were selected.

A rate of 150. Ang/sec would be converted to 500/1000 times 5.0 using 3 digit conversion and 00/100 times 5.0 using 2 digit conversion. The use of 2 digit conversion of rate at a deposi-

tion rate of 150 Ang/sec. would be unusual but would allow the recorded rate to be easily resolved to a resolution of 0.1 Ang/sec. If the rate increased to 151. Ang/sec the DAC output would increase to 10/100 x 5.0 or 0.5 volts.

6.9 TM-300 Operation

The TM-300 will monitor negative thickness (mass which is removed from the sensor crystal during the etching process) and negative rate (the speed at at which the material is removed from the sensor crystal).

When the monitor is used in an etching environment the negative sign will indicate negative rate and negative thickness.

DAC

The DAC output converts either rate or thickness to an analog voltage suitable for recording with a strip chart recorder or other recording devices. The DAC converts the rightmost two or three digits (which are selected by the operator) of the selected quantity to a zero to 5VDC analog voltage.

When converting thickness the DAC scale factor is 2.5 MV/Angstrom for three digit conversions and 25 MV/Angstrom for two digit conversions. The zero reference level is 2.5VDC. For positive values the output increases toward +5VDC. For negative values the output decreases toward zero volts. When converting rate, the DAC scale factor is 2.5 MV/0.1 Angstrom/sec for three digit conversion and 25.MV/0.1 Angstrom/sec for two digit conversion.

To calibrate, ground the appropriate pin on J4 (see Fig. 3.3). To monitor thickness, pin 5 is open, to monitor rate, pin 5 is grounded, for 2 decade selection pin 6 is open, for 3 decade selection pin 6 is grounded, for full scale positive calibration pin 8 is grounded, for full scale negative calibration pin 7 is grounded, for zero calibration pin 7 and 8 are grounded simultaineously. The output is monitored through pin 1.

7 Establishing the Deposition Parameters

The following is a guide to establishing the deposition parameters. Valid reasons may occur to deviate from the recommendations and these reasons of course would take precedence.

7.1 Tooling Factor

The Tooling Factor parameter compensates for geometric factors in the deposition system which result in a difference between the deposition rate on the substrates and the rate on the sensing crystal. This parameter is entered in percent units and 100% corresponds to equal rates at the substrate and at the sensing crystal. For initial approximation the tooling factor can be calculated using the following equation:

$$\text{Tooling \%} = (\text{dcry}/\text{dsub})^2 \times 100\%$$

where: dcry = Distance from the source to the crystal.
dsub = Distance from the source to the substrate.

Empirical calibration of the tooling factor is described in Section 7.4.

7.2 Density

The Density parameter provides the Monitor with the density of the material being deposited so that it can calculate and display the physical film thickness. If the film density is known, it should be used. A list of the more commonly used film densities is presented in Table 7.1. As a first approximation, bulk material density can be used in programming this parameter. Empirical calibration of this parameter is described in Section 7.4.

7.3 Acoustic Impedance

The shear wave acoustic impedance of the deposited film is required by the monitor in order to accurately establish the sensor scale factor when the sensor crystal is heavily loaded. If the acoustic impedance of the film material is known, it can be entered directly in units of 100,000 gm/sq. cm sec. In most cases the acoustic impedance of the bulk material can be used and can be obtained from the Handbook of Physics or other source of acoustic data. The shear wave acoustic impedance can be calculated from the shear modulus or the shear wave velocity and the density by using the following equations:

$$\text{Acoustic Impedance} = PC = PG$$

where: P = Density (gm/cubic cm).
C = Transverse (shear) wave velocity (cm/sec).
G = Shear modulus (dynes/sq. cm).

A list of the acoustic impedance and density of the more commonly deposited materials is presented in Table 7.1, and a technique for empirically determining this parameter is presented in Section 7.4.

In many cases, and particularly if the sensor crystal is not heavily loaded, sufficient accuracy can be achieved by using the acoustic impedance of quartz: 8.83 X 100,000 gm/sq. cm sec.

7.4 Empirical Calibration

If the density and acoustic impedance of the film material is known, the values should be entered into the monitor and a trial deposition should be made. If the displayed thickness does not agree with an independently measured thickness, the monitor should be calibrated as described below.

To calibrate the monitor; material density, tooling factor and acoustic impedance must be established in that order. Approximate values should be used initially. Table 7.1 in the manual provides density of some materials which should provide guidance as to the approximate density. If the acoustic impedance is unknown, use the value for quartz 8.83.

MATERIAL DENSITY

1. Use a fresh sensor crystal.
2. Plate test substrates as close as possible to the sensor crystal.
3. Make a trial deposition of sufficient thickness to permit adequate precision of measurement by an independent measuring device.
4. Determine the average thickness on test substrates.
5. If the displayed thickness is lower than the actual measured thickness, push the MATL DENSITY button and then push the DECREASE button. If the displayed thickness is higher than the actual thickness, push the INCREASE button. See table 1.
6. The thickness will be displayed three seconds after the INCREASE/DECREASE button is released. Check to see if the thickness displayed now equals the actual thickness. If it does not, repeat the procedure in 5 above until the displayed thickness agrees with the actual thickness.

The programmed material density will now be correct for that particular material. Record this value for future use.

TOOLING FACTOR

1. Use a fresh sensor crystal.
2. Place test substrates in a location which is representative of where the production substrate will be located.
3. Make a trial deposition with the known material density as

determined above.

4. Determine the average thickness on the test substrates with an independent thickness measuring device.
5. Alternating between the TOOLING FACTOR and the INCREASE and DECREASE button, follow the procedure described in item 5 above except the DECREASE button is used to lower the displayed thickness to the actual thickness and the INCREASE button is used to raise the display thickness to actual thickness. Continue until the displayed thickness agrees with the actual measured thickness. See Table 1.

The Tooling factor should now be correct for the specific application measured.

ACOUSTIC IMPEDANCE

1. Use a heavily loaded sensor crystal with a crystal health of about 75%.
2. Deposit on the sensor crystal until the crystal health approaches 50%.
3. Measure the actual thickness of the deposition.
4. Alternating between ACOUSTIC IMPEDANCE and the INCREASE and DECREASE buttons, follow the procedure described in item 5 under Tooling Factor until the displayed thickness agrees with the actual measured thickness. See Calibration Adjustment below.

This calibrates the acoustic impedance for the material being deposited.

For future reference record the specific parameters, determined above, in Appendix A.9.

CALIBRATION ADJUSTMENT

THICKNESS	MATERIAL DENSITY	TOOLING FACTOR	ACOUSTIC IMPEDANCE
Display is greater than actual	INCREASE	DECREASE	DECREASE
Display is lower than actual	DECREASE	INCREASE	INCREASE

Table 7.1

Density and Acoustic Impedance Values for Selected Materials

Material	Symbol	Density	Impedance
Aluminum	Al	2.70	8.17
Antimony	Sb	6.62	11.49
Arsenic	As	5.73	9.14
Beryllium	Be	1.85	16.26
Bismuth	Bi	9.8	11.18
Boron	B	2.54	22.70
Cadmium	Cd	8.64	12.95
Cadmium Sulfide	CdS	4.83	8.66
Cadmium Telluride	CdTe	5.85	9.01
Calcium Fluoride	CaF_2	3.18	11.39
Carbon(Diamond)	C	3.52	40.14
Chromium	Cr	7.20	28.95
Cobalt	Co	8.71	25.74
Copper	Cu	8.93	20.21
Copper(I)Sulfide(alpha)	Cu_2S(alpha)	5.6	12.80
Copper(I)Sulfide(beta)	Cu_2S(beta)	5.8	13.18
Copper(II)Sulfide	CuS	4.6	10.77
Dysprosium	Dy	8.54	14.72
Erbium	Er	9.05	11.93
Europium	Eu	5.244	
Gadolinium	Gd	7.89	13.18
Gallium	Ga	5.93	14.89
Gallium Arsenide	GaAs	5.31	5.55
Germanium	Ge	5.35	17.11
Gold	Au	19.30	23.18
Hafnium	Hf	13.09	24.53
Holnium	Ho	8.8	15.22
Indium	In	7.30	10.50
Indium Antimonide	InSb	5.76	11.48
Iridium	Ir	22.40	68.45
Iron	Fe	7.86	25.30
Lanthanum	La	6.17	9.59
Lead	Pb	11.30	7.81
Lead Sulfide	PbS	7.50	15.60
Lithium	Li	0.53	1.50
Lithium Fluoride	LiF	2.64	11.41
Magnesium	Mg	1.74	5.48
Magnesium Floride	MgF_2	3.00	13.86
Magnesium Oxide	MgO	3.58	21.48
Manganese	Mn	7.20	23.42
Manganese(II)Sulfide	MnS	3.99	9.39
Mercury	Hg	13.46	11.93
Molybdenum	Mo	10.20	34.36
Nickel	Ni	8.91	26.68
Niobium	Nb	8.57	17.91

Table 7.1 continued

	Symbol	Density	Impedance
Palladium	Pd	12.00	24.73
Platinum	Pt	21.40	36.04
Potasium Chloride	KCl	1.98	4.31
Rhenium	Re	21.04	58.87
Rhodium	Rh	12.41	42.05
Rubidium	Rb	1.53	3.48
Samarium	Sm	7.54	9.92
Scandium	Sc	3.0	9.70
Selenium	Se	4.82	10.22
Silicon	Si	2.32	12.40
Silicon(II)Oxide	SiO	2.13	10.15
Silicon Dioxide(fud quartz)	SiO_2	2.20	8.25
Silver	Ag	10.50	16.69
Silver Bromide	AgBr	6.47	7.48
Silver Chloride	AgCl	5.56	6.69
Sodium	Na	0.97	1.84
Sodium Chloride	NaCl	2.17	5.62
Strontium	Sr	2.620	
Sulfur	S	2.07	3.86
Tantalum	Ta	16.60	33.70
Tantalum(IV)Oxide	Ta_2O_5	8.2	29.43
Tellurium	Te	6.25	9.81
Terbium	Tb	8.27	13.38
Thallium	Tl	11.85	5.70
Tin	Sn	7.30	12.20
Titanium	Ti	4.50	14.06
Titanium(IV)Oxide	TiO_2	4.26	22.07
Tungsten	W	19.30	54.17
Tungsten Carbide	WC	15.60	58.48
Uranium	U	18.70	37.10
Vanadium	V	5.96	16.66
Ytterbium	Yb	6.98	7.81
Yttrium	Y	4.34	10.57
Zinc	Zn	7.04	17.18
Zinc Oxide	ZnO	5.61	15.88
Zinc Selenide	ZnSe	5.26	12.23
Zinc Sulfide	ZnS	4.09	11.39
Zirconium	Zr	6.51	14.72

8 Troubleshooting

This section is included to help isolate, as rapidly as possible, any failures which may occur in the Thickness Monitor setup.

The Monitors' internal self test features allow for quick isolation of both system installation faults and failures internal to the Monitor unit itself. However, please note that in-field service of the Monitor unit is NOT recommended and may indeed void the warranty.

Section 8.1 "Self Test Failure Detection" describes the Monitor's failure messages, which are referred to in all subsequent sections.
Section 8.2 and 8.4 are troubleshooting guides which may be used to help in isolating both external and internal faults to the Monitor.

Section 8.5 gives the operator the necessary background to understand the Monitor circuitry when internal troubleshooting is necessary.

8.1 Self Test Failure Detection

The Monitor's self test features detect several system failures. The specific failures are described below. Upon detection of a failure the appropriate message is displayed. There are basically two types of system failures; failures which may not be reset by the operator and those that may. The E FAIL and I FAIL messages are NOT resetable. They may be cleared only by the replacement of the defective components. These failures are displayed continuously and ALL OTHER SYSTEM OPERATIONS ARE DISABLED. For these Internal failures, it is recommended that the unit be returned to the factory for repair. On failures that may be reset, the front panel display alternates the particular failure message and the Rate and Thickness values prior to the failure. The display continues to alternate the failure until the fault has been reset.

The following is a summary of detected failures, the displayed messages and the necessary actions to reset them.

Detected Failure	Failure Message	Reset by:
ROM Failure	E FAIL	Replacement of defective ROM(s)
RAM Failure	I FAIL	Replacement of defective RAM(s)
Invalid Parameters	C FAIL	Press STOP button, parameter values will be preset.

Power Failure	P	FAIL	Press STOP button
Oscillator Failure	O	FAIL	If less than 2 seconds: Self clearing If greater than 2 seconds: Press STOP button

Any long term failures will cause serious thickness errors if they occur during a run. To save any materials which may be in process the shutter is automatically closed. The process can be continued only after the fault has been corrected and the message has been reset as described above. If there is more than one failure, the other failure will then be displayed. When no failures exist, only current Rate and Thickness values will be displayed. A description of the conditions of the individual failures follows.

8.1.1 Power Failure

Since power interruptions may seriously effect your run, indication of any significant A.C. line disruptions is provided by the P FAIL message. The shutter is automatically closed if a run was in process. It may be continued, once all other equipment is functioning normally again, by depressing the STOP switch.

Note that it is normal for the power failure message to flash when the unit is first turned on. Press the STOP button to clear this message.

8.1.2 Oscillator Failure

An Oscillator Fail message indicates an improper or missing signal from the oscillator. The problem is most likely with the sensor crystal, however, failures in the oscillator, coaxial cables, feedthrough, or sensor head can also generate this failure message. The oscillator failure message will be cleared automatically when the Monitor receives a proper signal from the sensor oscillator if the failure lasts for less than 2 seconds. Failures of more than 2 seconds require the pressing of the STOP button to clear.

8.1.3 Invalid Parameters

The deposition parameters Tooling Factor, Acoustic Impedance, Material Density, and Thickness Set Point are numbers that must be stored in the Monitor through periods of up to 60 days without A.C. power connected. If the integrity of these numbers is lost then the C FAIL message will be flashed when the Monitor is turned on. This warns you of a possible internal failure of the TM-100/200/300. The C FAIL message can be cleared by pressing the STOP switch. The clearing of the failure message also results in the presetting of the parameters as defined in Section 2.1. If there are no other failure messages indicated then it

is possible that the Monitor Ni-Cad batteries simply require recharging. The batteries are automatically recharged when the Monitor is connected to A.C. power. If after an overnight charge your monitor still does not retain the parameters intact (flashes C FAIL after periods of power down) then your Monitor should be returned for service.

NOTE: EMERGENCY OPERATION - If your Monitor does not maintain the parameters for the rated 60 hours but does for several hours or more, (make sure no other failure messages, except the P FAIL, flash on power up) it may be possible to reprogram your monitor and continue depositing as long as the A.C. power is not removed. Return the Monitor for service as soon as possible.

8.1.4 RAM Failure

In the case of a failure in the Monitor's data memory, RAM, the I FAIL message will be displayed. The shutter is automatically closed since reliable operation of the Monitor is impossible until it is serviced. To confirm the RAM failure cycle the AC power to the unit. The monitor will recheck its memory and if failed, will again display the I FAIL message. If the I FAIL message is not displayed on power up the second time, the problem may be intermittent, it is recommended that your monitor be returned for service.

8.1.5 ROM Failure

In the case of a failure in the TM-100/200/300's program memory, ROM, the E Fail message is displayed. A ROM failure is treated in exactly the same manner as a RAM failure. Read the above section, 8.1.4, for details.

8.2 Troubleshooting Aids to Isolate Installation Faults

The following table describes possible problems that could occur when interfacing the Monitor with a vacuum system. With each symptom is a list of probable causes.

If you should decide to remove the Monitor cover read Section 3.3 and 8.3 carefully before doing so.

Table 8.1

Trouble-Shooting Aids for External Problems
Symptom with Probable Causes

1) Front Panel Displays never illuminate:
   Voltage selector p.c board is in the wrong position.
   See Section 3.2.4.
   Line fuse is blown, F3.
   Rear Panel fuse holder.

2) Random "P FAIL" occurrence:
   Low A.C. line voltages.
   Intermittent A.C. line connection.

3) Random "O FAIL" occurrence:
   Defective sensor crystal.
   See Section 5.
   Defective crystal holder.
   Defective sensor oscillator.
   See Section 3.2.1.
   Intermittent oscillator cable connections.
   Defective coaxial cables (in particular the vacuum chamber cable).
   Thickness Monitor not properly grounded to the vacuum system.
   Wrong crystal selection, J5.
   See Section 3.2.5.

4) Shutter never activated:
   Shutter fuse is blown, F1 or F2.
   Internally mounted on P.C. board.
   Defective shutter wiring.
   See Section 3.2.2.
   Defective shutter solenoid.
   No shutter solenoid power.
   Defective Shutter Relay.
   Thickness set point is 0.

5) Faulty DAC output including no response from control inputs:
   External recording equipment puts an excessive load on DAC outputs.
   Excessive resistance in DAC control input lines.
   Improper DAC wiring. See Section 3.2.3.

8.3 Handling Precautions

Please follow these guidelines any time it is necessary to open the Monitor package and handle internal circuitry or components.

CAUTION
Disconnect the A.C. line power before disassembling the thickness monitor.

CMOS integrated circuits can be damaged by static discharge to their inputs. This discharge is the same phenomenon that produces the unpleasant shock when one grabs a door knob after walking across a carpet. The likelihood of static buildup is proportional to the dryness of the air and can be particularly troublesome in cold, dry climates, or hot desert climates.

In order to minimize the chances of discharging body charge into

the IC inputs, always handle circuit boards by the edge. When moving a board from one surface to another, always touch the new surface or location before laying down or inserting the board, so that you, the board, and the surface or equipment are all at the same electrical potential. In dry climates, it is always wise to minimize the amount of movement when handling or replacing ICs in circuit boards. When handing a circuit board or IC to another person, always touch the person first.

Wood and paper are the most forgiving surfaces to work on. Plastic should be avoided. Metal is acceptable as long as the metal is always touched with the hands prior to laying down the ICs or circuit boards.

If the above precautions are observed, the chance of damage will be minimal.

CAUTION

The main P.C. board contains nickel-cadmium batteries. This board should never be placed on a metal surface or wrapped in metal foil. Fusing of the printed circuit etches may result from shorted batteries.

8.4 Troubleshooting Aids to Isolate Internal Monitor Faults

The following table describes possible problems that could occur with the Monitor due to internal component failures. In the event of a thickness monitor failure it is recommended that the unit be returned to the factory with a description of the problem for maintenance. In-field service may void the warranty.

If in-field service is deemed necessary and the facilities and expertise are available, then reference to the Block Diagram description of Section 8.5 will help in understanding the general circuitry areas referred to below.

If you should decide to open the Monitor read Section 8.3 on handling precautions carefully and Section 3.3 on cover removal.

Table 8.2

Trouble-Shooting Aids for Internal Problems
Symptom followed by Probable Causes

1) **Unit blows the line fuse (Rear Panel fuse holder):**
   Voltage selector p.c. board is in the wrong position.
   See Section 3.2.4.
   Defective power supply circuit.
   Short on p.c. board.

2) **Front Panel Displays never illuminate:**
   Voltage selector p.c. bd. is in the wrong position.
   See Section 3.2.4.
   Line fuse is blown, F3.
   Rear Panel fuse holder.
   CPU failure, see Symptom 14 below.
   Defective voltage regulator, VR1.
   Defective power monitor, U8.
   Defective Display Controller, U11.

3) **Meaningless Display Information:**
   Defective board connector on main p.c. board, J1.
   Defective 7 Segment Display, DS1-DS7.
   Defective Display Controller, U11.
   CPU failure, see Symptom 14 below.

4) **Random "P FAIL" occurrence:**
   Loose fuse holder connections, F3.
   Defective power monitor, U8.

5) **Random "O FAIL" occurrence:**
   Wrong crystal selection, J5.
   See Section 3.2.5.
   Defective monitor buffer, Q5.

6) **E FAIL message:**
Defective EPROMS, U4 and U7.

7) **I FAIL message:**
Defective RAM, U3.

8) **Shutter never activates but Indicator LED works:**
Shutter fuse is blown, F1, F2.
Internally mounted on P.C. board.
Defective relay circuitry, K1, K2.

9) **Indicator LED does not light but shutter operates:**
Defective LED, DS8.
Defective resistor, R32. R31
Defective board connector on main P.C. board, J1.

10) **Shutter and Indicator LED do not operate:**
Defective output latch, U9.
Defective transistor, Q4, Q3.

11) **Faulty DAC output including no response from control inputs:**
Defective input buffer circuitry, U16.
Defective output driver, U18.

12) **Loss of keyboard entered data, C FAIL:**
Aged or defective RAM batteries, BT1 and BT2.
Defective RAM battery charger, Q1 and Q2.
Defective power monitor, U8.

13) **No response from keyboard buttons:**
Defective front panel push buttons.
Defective board connector on main P.C. board, J1.
Defective input buffer, U5.
CPU failure, see Symptom 14 below.

14) **CPU failure:**
Defective Z-80, U12.
Improper clock signal, TP-20, U13, U14, and U15.
Defective memory, U3, U4, and U7.
Defective address decoders, U1 and U2.
Thickness Monitor not properly grounded to the vacuum system.

8.5 Block Diagram and Circuit Description

The Monitor hardware block diagram is shown in figure 8.1, the schematic is shown in Figure 8.2. Refer to figures 8.1 and 8.2 for the following circuit descriptions.

The Display Board may be disconnected from the main P.C. board to isolate faults between the two P.C. boards. The main board will

start up with all control signals operational should the Display Board be removed.

The integrated circuits with the highest failure rate are placed in sockets for easy removal.

The +5 volt regulator is mounted to the rear panel for heat dissipation. Normally the rear panel will exhibit a 20 deg. C rise above the ambient air temperature.

A functional description of the Block Diagram of Figure 8.1 is presented below. Active LOW signals are denoted on the Block Diagram with a Bar. Active LOW signals are followed by an asterisk in this text.

8.5.1 Z-80 CPU

The Z-80 Central Processor Unit (CPU, U12) performs all control functions. The Monitor incorporates an 8-bit data bus and a 16-bit address bus. Address decoders U1 and U2 allow the CPU to access individual I/O devices. Logic signal levels and control signal timing are diagrammed in Figure 8.4.

8.5.2 9513 System Timing Controller

The 9513 System Timing Controller (U13) performs all counter operations. A 4MHz crystal is resonanted by the 9513's internal oscillator. The oscillator frequency is divided by two (flip-flop U14) to provide the 2MHz CPU clock. A timing diagram of the 9513's control signals is presented in Figure 8.5.

8.5.3 7218 Display Controller

The 7218 Display Controller (U11) performs all 7-segment display functions. The CPU only loads data to the 7218. The 7218 multiplexes this data to the seven 7-segment LED displays. All multiplexing logic and LED drive circuitry are contained within the 7218. Figure 8.6 contains the timing diagram for loading data to the 7218.

8.5.4 Memory

Two 2716 EPROMS (U4 and U7) contain all program information (software). Do not remove the EPROM labels. If the EPROMS are exposed to bright light or sunlight (UV light) their contents will be erased.

One 6116 RAM (U3) provides temporary data storage including the deposition parameters. Because semiconductor RAMs lose their data when they lose power, the 6116 is supported by nickel-cadmi-

um batteries when power is removed from the Monitor. This assures data retention of the deposition parameters for at least sixty days.

See Section 8.5.7 for a description of the battery back-up circuit. Figure 8.5 contains the timing diagram of the Read and Write signals for accessing the EPROMs and RAM.

8.5.5 Front Panel

The Monitor incorporates 7-segment common anode LED displays. The LED brightness is controlled by the 7218 and is not adjustable.

The TM-100 and TM-300 have a single shutter output and the TM-200 has dual shutter outputs. The Shutter Open LED indicators are powered from the +VT supply voltage and R3 & 32. Transister Q3, Q4 switches the LED on and off depending on the status of the flip flop U9. The output of U9 is controlled by AB0 and DSCOUT*. The LED is lit when pin 2 or 5 of U9 is high.

Normally open push button switches are located on the front panel to handle most operator inputs. Other operator inputs include the DAC control inputs and the 5 or 6MHz crystal selector. All switch inputs are read by the CPU through U4 and U16 which are enabled by DSCIN1* and DSCIN2* respectively.

8.5.6 Rear Panel

The Oscillator Input provides +5 volt power to the Sensor Oscillator and receives current pulses from the oscillating sensor crystal. The sensor buffer input contains a 50 ohm current sense resistor. Transistor Q5 converts the current pulses to voltage pulses.

The TM-100 and TM-300 have a single shutter output and the TM-200 has dual shutter outputs. The shutter outputs are directly controlled by relay K1 or K2. The relay contacts are protected by the P.C. board mounted fuse F1 or 2. The fuse is a 3AG 5 Amp. The relay is powered from +VT and energized through transistor Q3 or Q4. As in the case of the shutter indicator, when pin 2 or 5 of U9 is high the relays are energized. The normally open/normally closed nomenclature above the shutter connector refers to the non-energized relay condition.

The Digital to Analog Converter (DAC) output consists of resistors R29 and R30 which provide the 20 Kohm output impedance. These resistors plus diodes CR11 and CR12 protect U18 from excessive voltages due to miswiring. U18 performs the function of a reference switch which produces 0 to +5 volt square waves. These square waves are pulse width modulated from the 9513. All four DAC control inputs are read from U2 upon a DSCIN2* signal.

8.5.7 Power Supply

The unregulated D.C. voltage, +VT, is approximately +10 to +15 volts D.C. +VT power drives the shutter relay, shutter indicator, RAM battery charger, power monitor, and +5 volt regulator (VR1). The voltage range on the +5V regulator is +4.75V to +5.25V. VR1 is mechanically secured to the rear panel for heat dissipation and typically operates 20 deg. C above the ambient temperature.

Transistors Q1 and Q2 monitor +VT and supply +5 volts for the RAM and charging current for the nickel-cadmium batteries. When +VT power ceases Q1 and Q2 isolate the batteries and the RAM from the rest of the unit. The batteries provide power to the RAM maintaining proper data storage under this condition. The nickel-cadmium batteries should maintain a minimum voltage of 1.2 volts apiece.

8.5.8 Power Monitor

The operational amplifiers of U8 continuously monitor +VT. C17 and R12 provide a 50 msec. power up delay to allow ample time for the 4MHz crystal to begin oscillating. R7 and R8 monitor +VT and activate RESET* through U8-Pin 14 should +VT drop below +8 volts. C15 and R18 provide a 250 msec. delay to monitor transient line voltage drop outs. If the power transient is less than 250 msec., the voltage in C15 does not drop below the reference established by R5 and R6. Hence U8-Pin 7 immediately goes high upon reapplication of power. See Figures 8.7 and 8.8 for timing diagrams of the power monitor outputs.

8.6 Major Monitor Parts

Table 8.3

Part Description	Part Number	Designator	Quantity
TM-100/200/300			
Power Fuse	3AG, 3/8A	F3	1
Relay Fuse	3AG, 5A	F2	1
Connector Pin Contact	SC16M-6TK6	-	12
Relay Connector, 3 Pin	SMS3P-3	J3	1
DAC Connector, 9 Pin	SMS9P-3	J4	1
Ni-Cad Battery	N-250AA	BT1,2	2
Push Button	D6-02-02	S1-S9	9
Relay	G2L113PVUADC12	K1	1
LED Indicator	LLT-203R	DS8	1
LED Display	MAN71A	DS1-DS7	7
I.C. CPU	Z-80PS	U12	1
I.C. Timing Controller	AM9513PC	U13	1
I.C. Display Controller	ICM7218AIJI	U11	1
I.C. RAM	CDM6116	U3	1

I.C. EPROM	102700	U4,7	2
5 Volt Regulator	LM7805-CT	VR1	1

ACCESSORIES

Monitor Oscillator			
Transistor	2N3563	Q1	1
Transistor	2N3640	Q2	1
30" Microdot Cable	506-723D	-	1

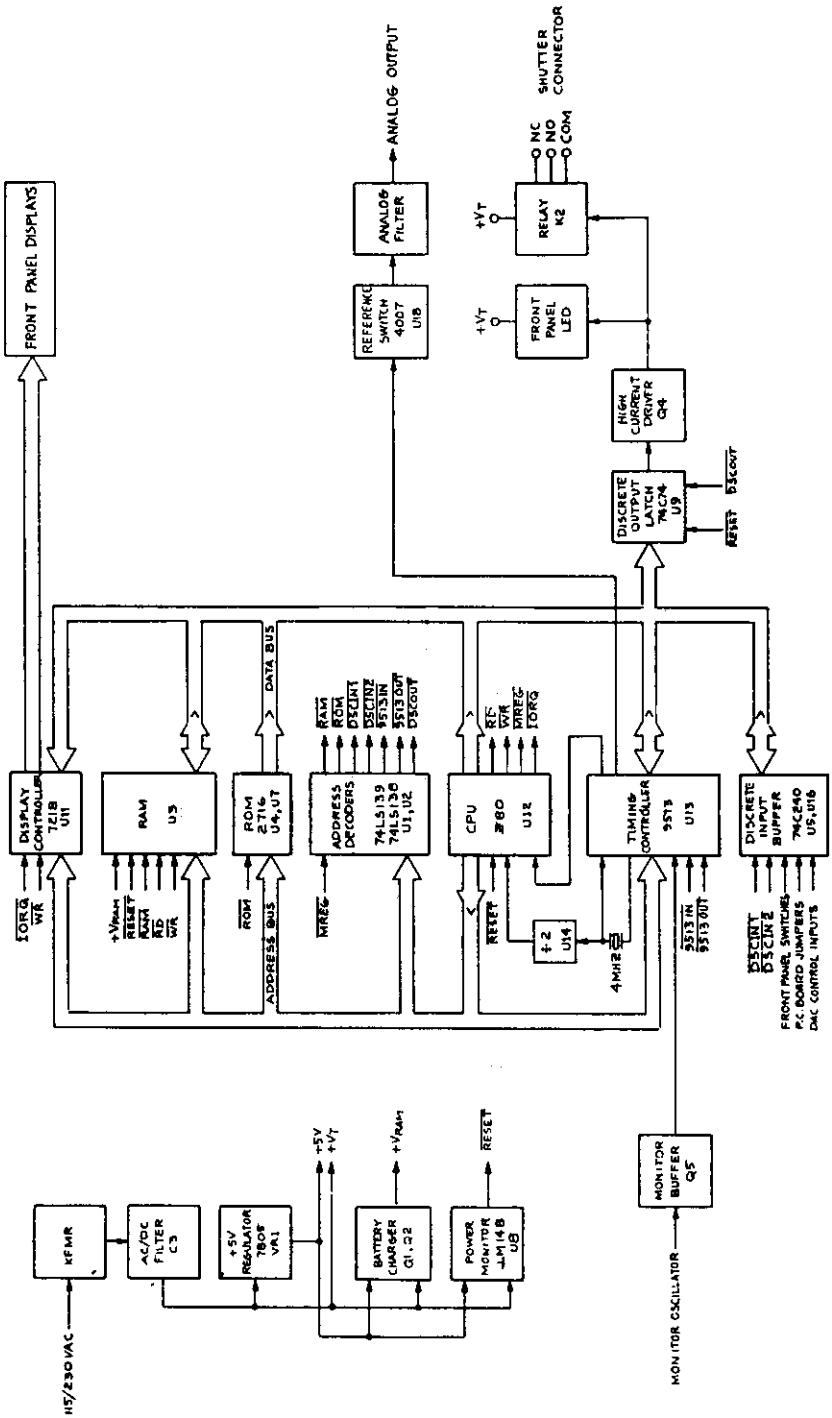


FIGURE 8.1 MONITOR BLOCK DIAGRAM

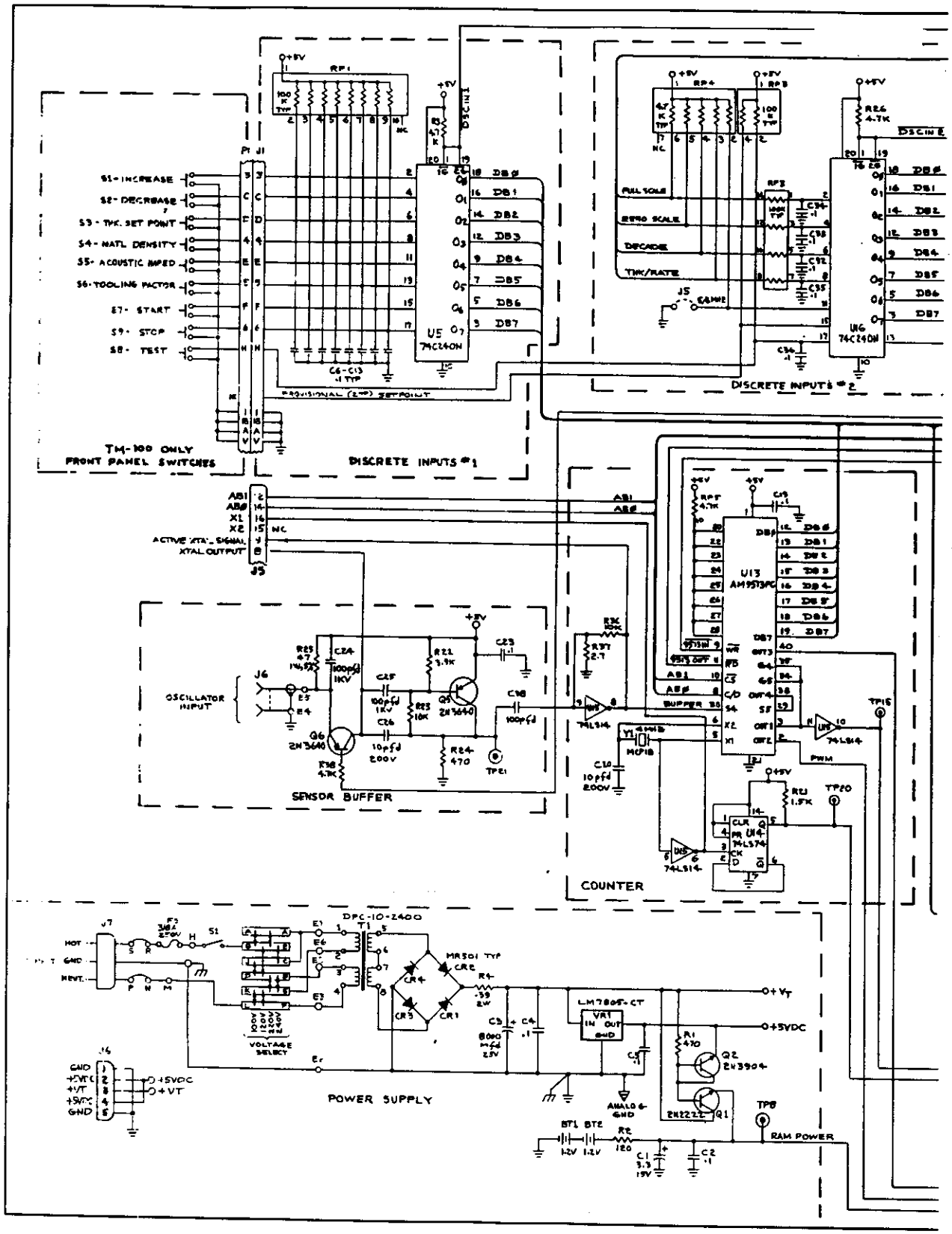


FIGURE 8.2 MONITOR HARDWARE SCHEMATIC (1 OF 3)

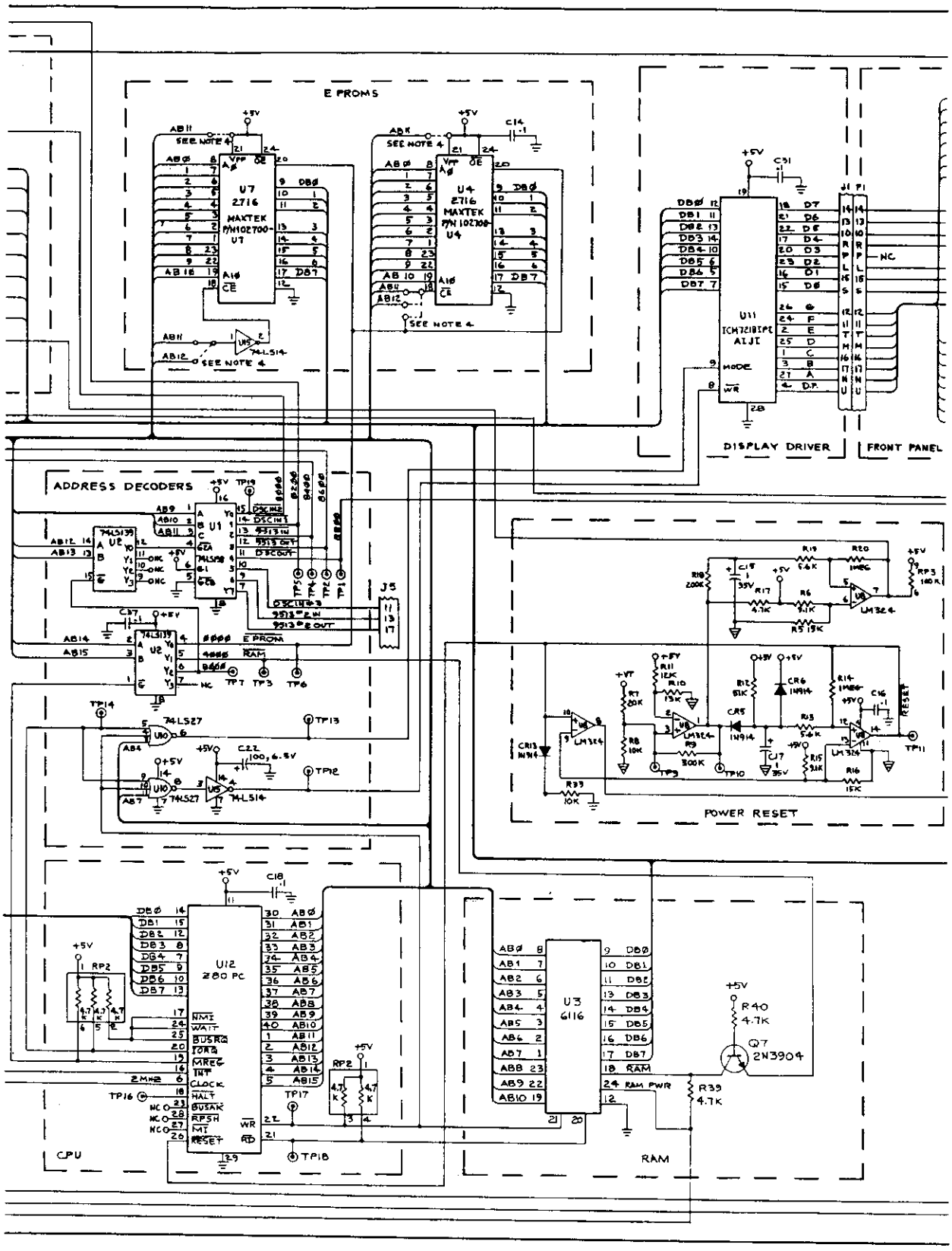


FIGURE 8.2 MONITOR HARDWARE SCHEMATIC (2 OF 3)

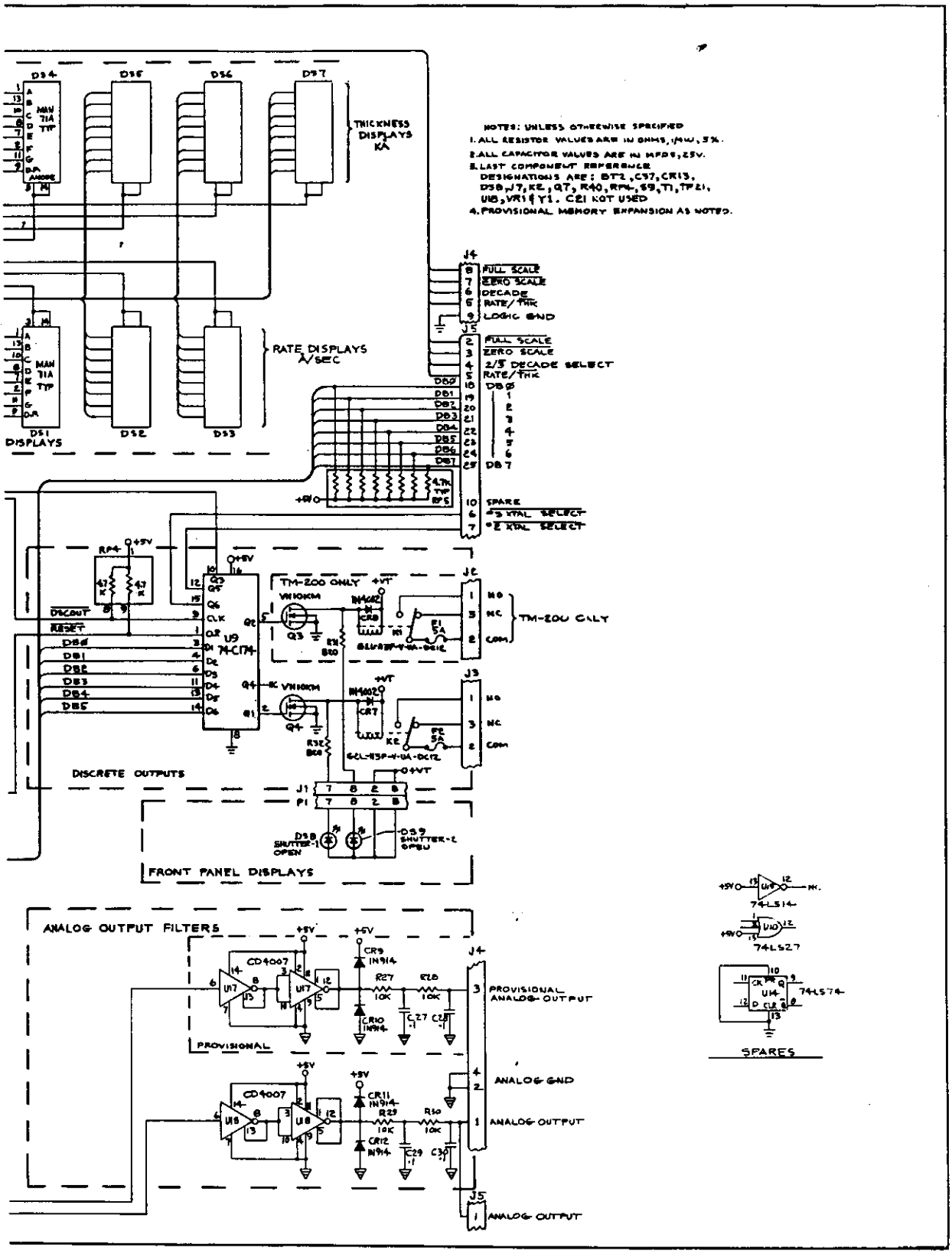


FIGURE 8.2 MONITOR HARDWARE SCHEMATIC (3 OF 3)

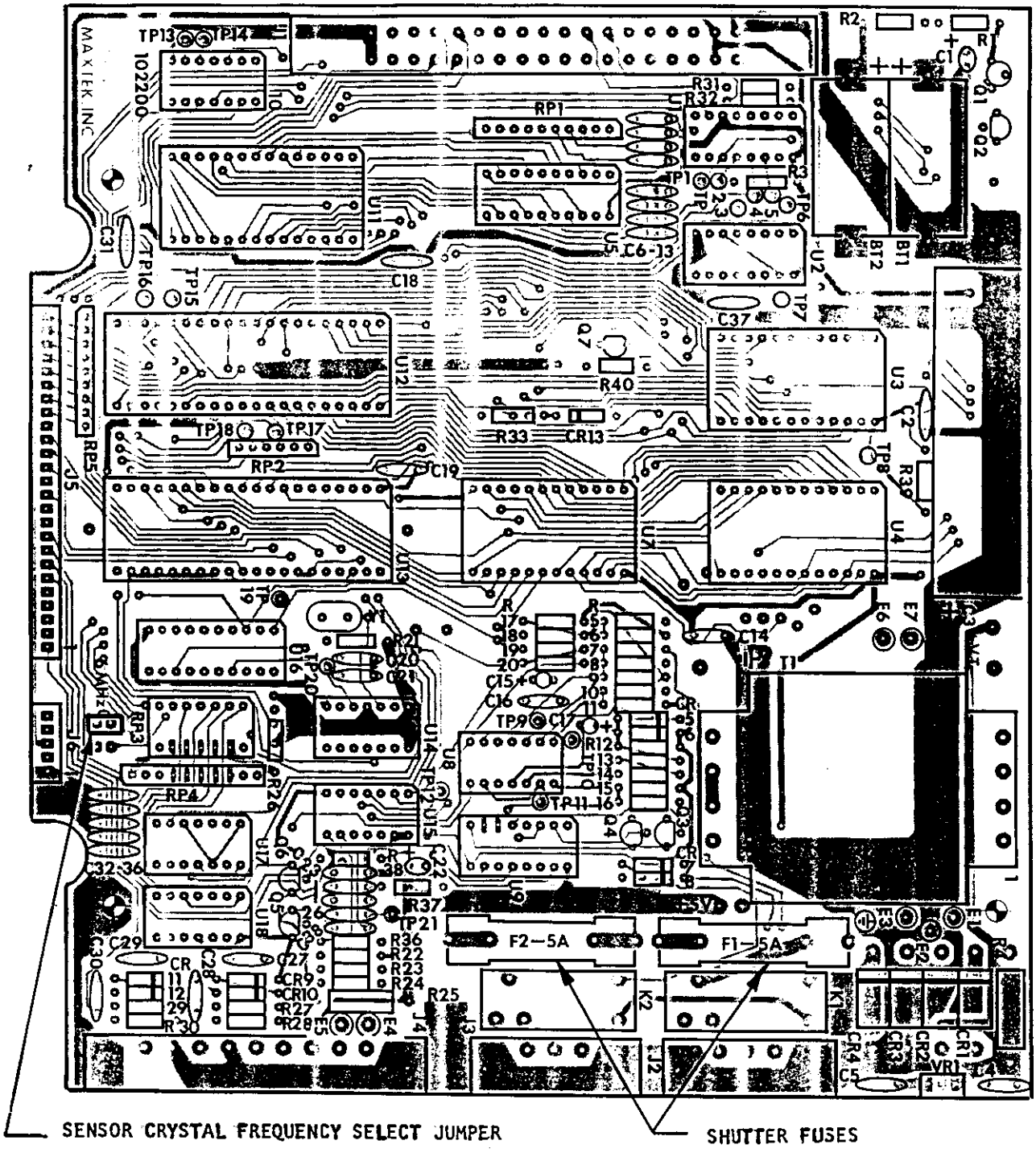


FIGURE 8.3 PRINTED WIRING BOARD ASSEMBLY DRAWING

REV J/FIJ

A LOGICAL "1" VOLTAGE SHOULD BE GREATER THAN 2.0V
EXCEPT FOR THE CLOCK INPUT WHICH IS 4.2V

A LOGICAL "0" VOLTAGE SHOULD BE LESS THAN 0.8V

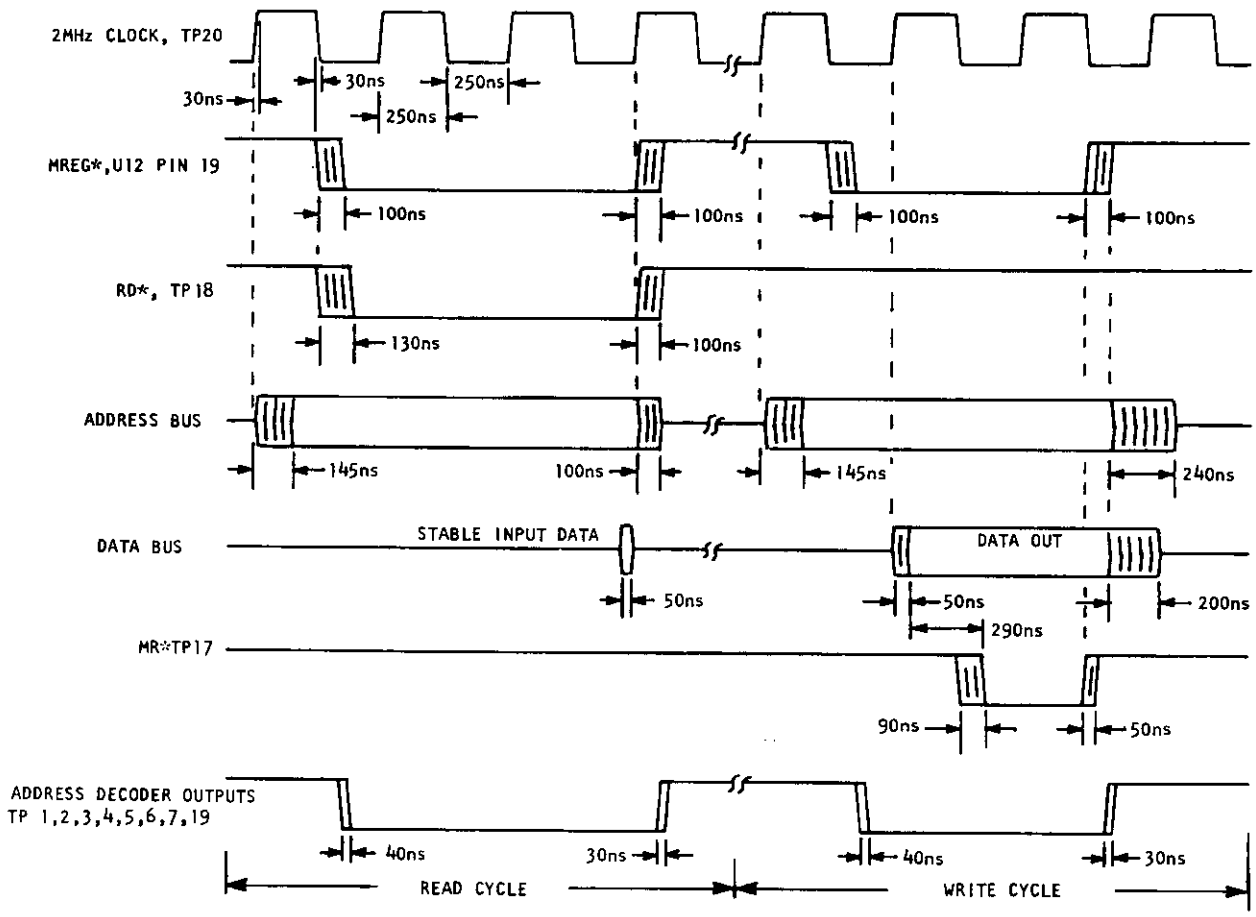


FIGURE 8.4 CPU TIMING DIAGRAM

A LOGICAL "1" VOLTAGE SHOULD BE GREATER THAN 2.0V

A LOGICAL "0" VOLTAGE SHOULD BE LESS THAN 0.8V

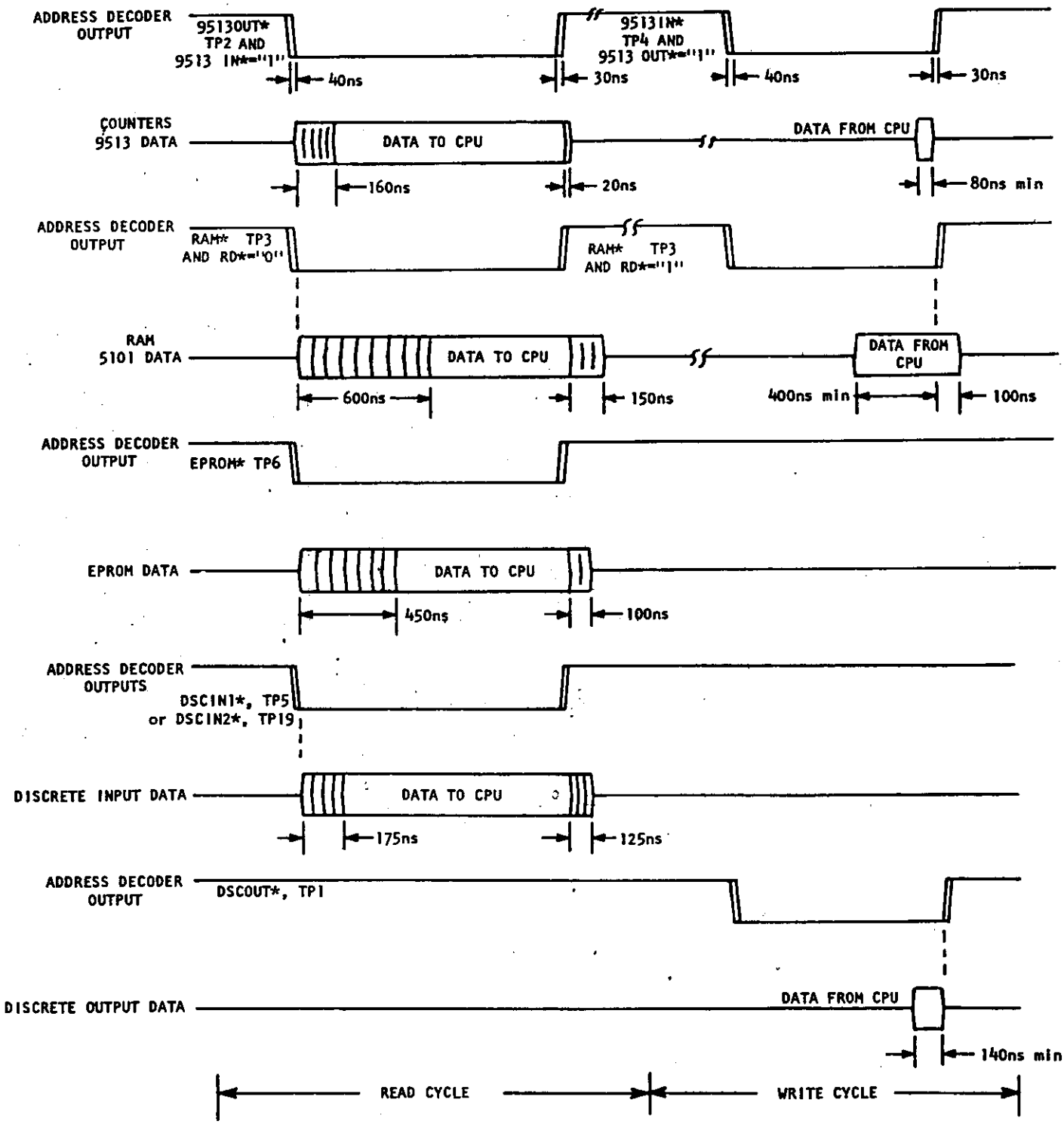


FIGURE 8.5 COUNTERS, MEMORY AND I/O TIMING DIAGRAM

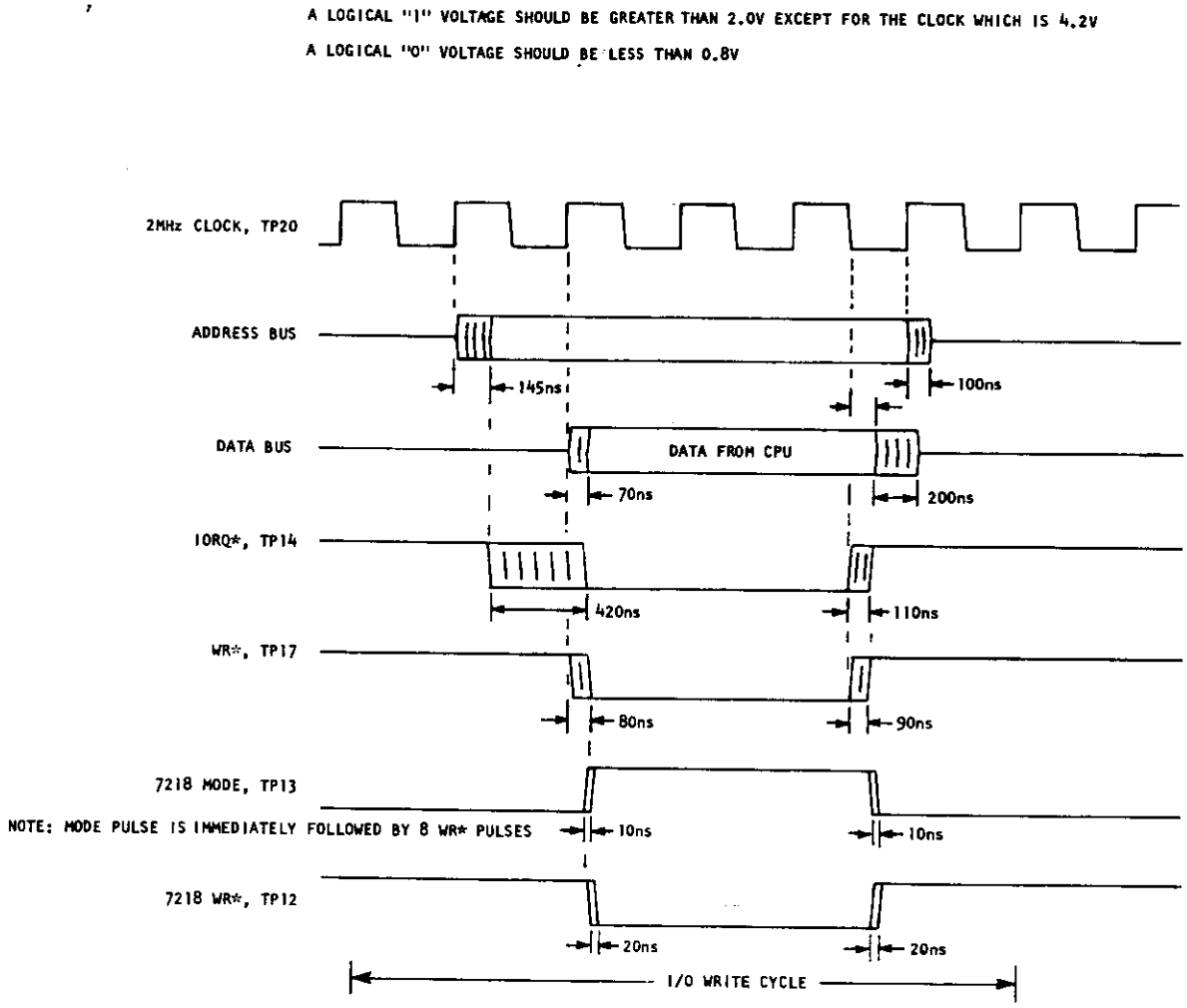


FIGURE 8.6 DISPLAY CONTROLLER TIMING DIAGRAM

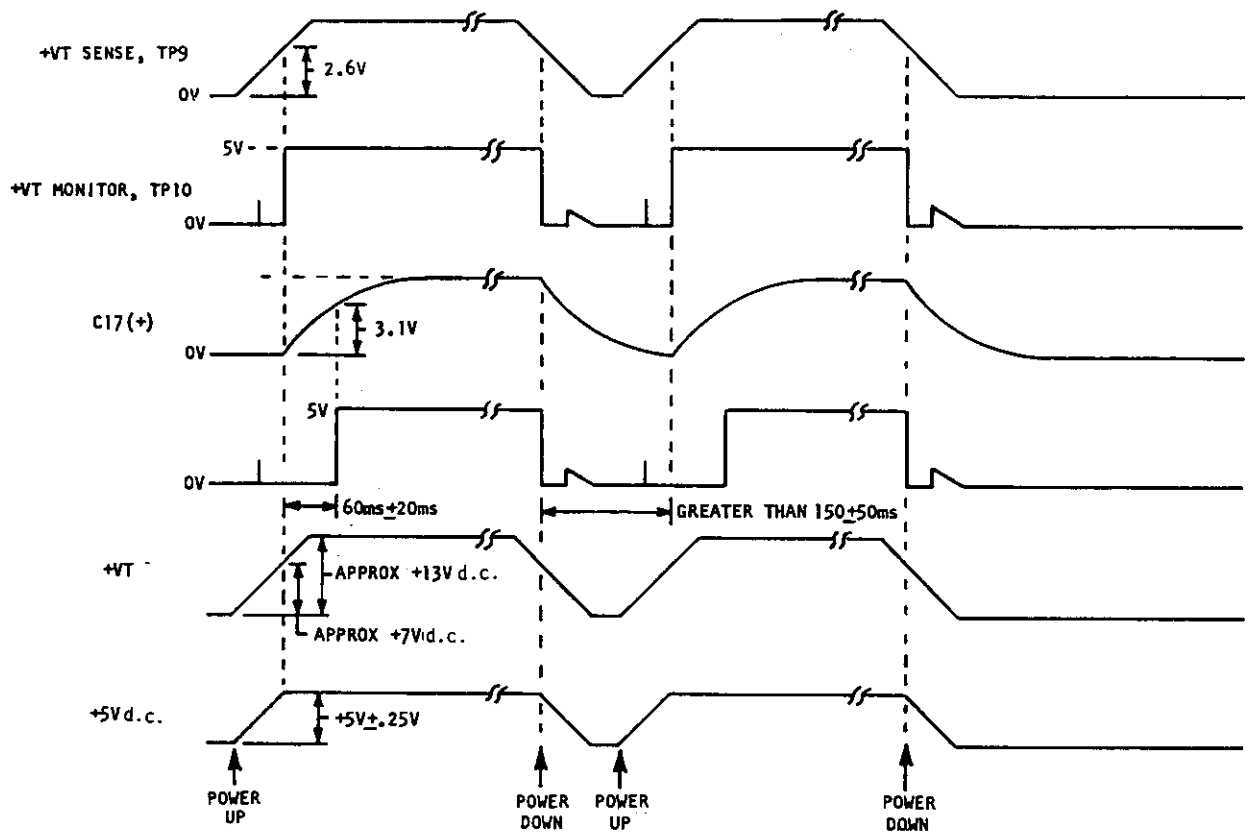


FIGURE 8.7 POWER RESET TIMING DIAGRAM

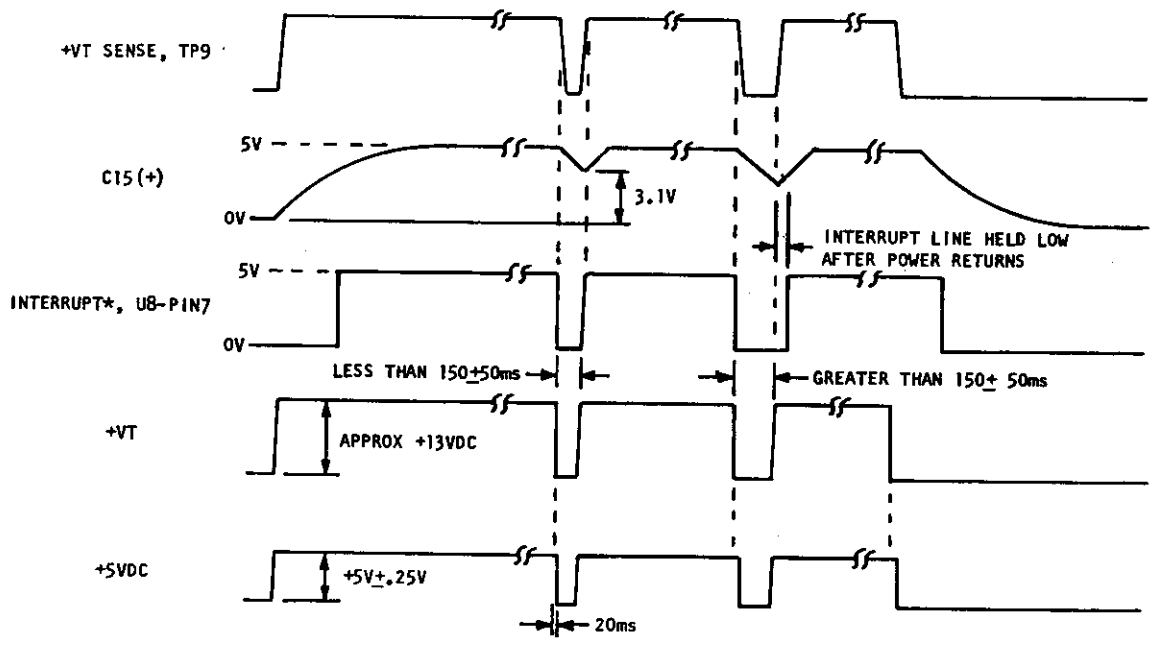


FIGURE 8.8 POWER INTERRUPT TIMING DIAGRAM

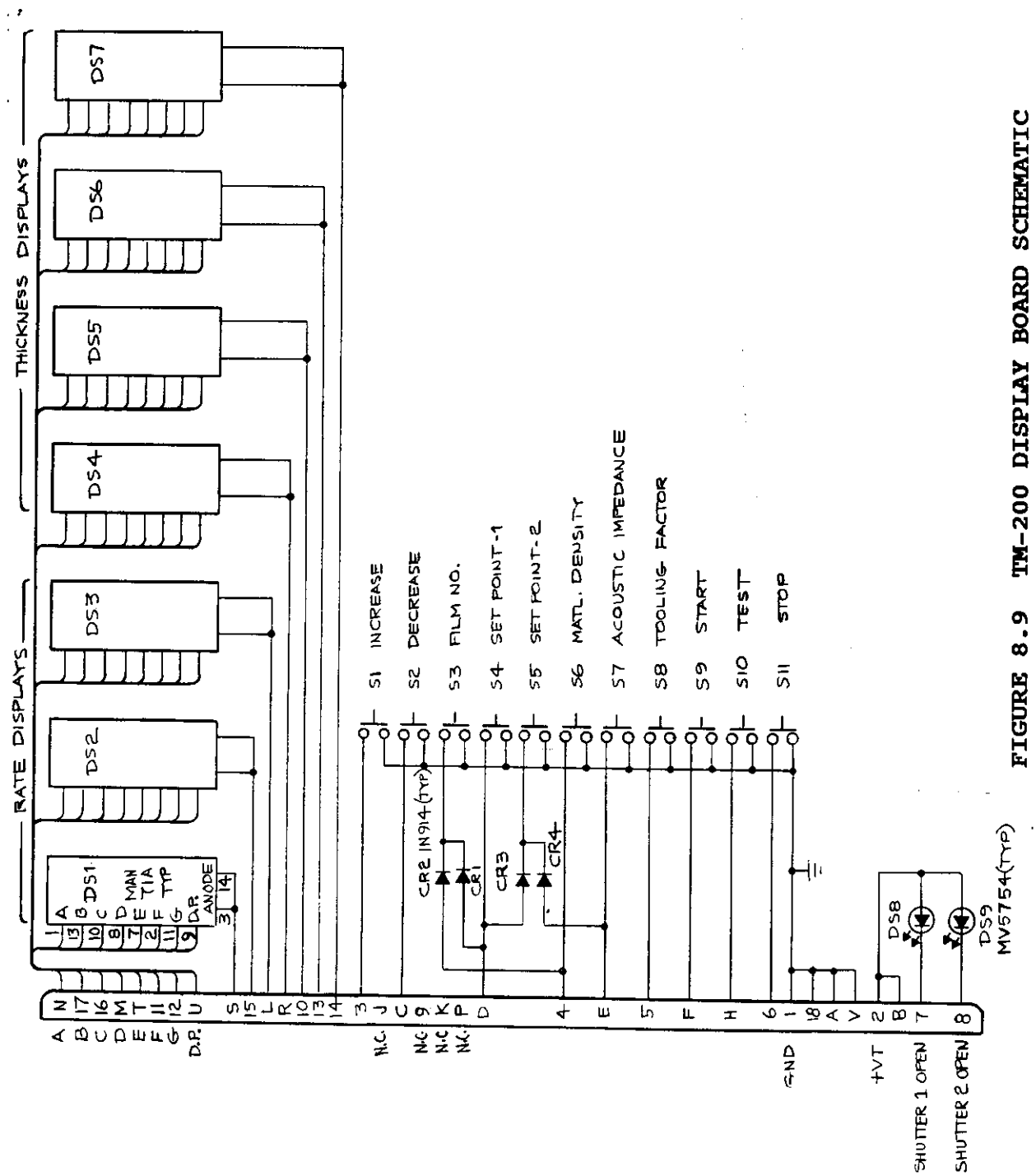


FIGURE 8.9 TM-200 DISPLAY BOARD SCHEMATIC

REV J/FIJ

Appendix A.1

Simplified Operating Procedure

Initial Set-Up

1) Install a 6 MHz crystal into the sensor head (see Section 5).
2) Connect the sensor head to the feedthrough (or Microdot to BNC adaptor) using the 30" Microdot cable.
3) Connect the feedthrough to the oscillator's TRANSDUCER input using the 6 inch coaxial cable.
4) Connect the Monitor to the oscillator using the 10 ft. coax cable.

Initial Power On

1) Apply proper A.C. power to the Monitor (see Section 3.2.4). Display will have all 8's and decimal points lit. "P FAIL" (power fail) will flash on the display.
2) Press the STOP button to clear the failure message.
3) If "O FAIL" (oscillator fail) should flash, check all cable connections, crystal installation, or crystal type selector (see Section 3.2.5).

Parameter Programming

1) Press the STOP button. There should be no failure messages.
2) Press the desired parameter button. Current value is viewed in the thickness display. On TM-200 the layer no. is displayed in the rate display.
3) Press the INCREASE or DECREASE button to vary the displayed parameter value up or down.

Start

1) Press the START button.
Opens the shutter, and zeros the thickness display.
2) Deposition mode continues until the displayed thickness value exceeds the Set Point value. At that time the shutter closes and the shutter indicator turns off.

Stop

1) Press the STOP button.
Closes the shutter.

Test

1) Press the TEST button.
Displays crystal type, crystal health, and the crystal frequency. Crystal type is the leftmost digit of the rate display. Crystal health is the rightmost 2 digits of the rate display. Crystal frequency is displayed in megahertz in the thickness display.

Appendix A.2

Sensor Head Description

P/N 123200 Sensor Head

The sensor head is designed for simple installation and easy crystal replacement. It consists of two basic units; a water cooled 304 stainless steel housing which is permanently positioned in the vacuum system and a quickly removable gold plated 304 stainless steel crystal holder which snaps into the housing. The crystal holder accomodates an industry standard .550" diameter (6MHz) crystal.

This design provides several features in performance and use. The crystal holder is thermally shielded by the water cooled housing insuring excellent crystal performance in temperature environments up to 300 degrees centigrade. The sensor may be baked out with no water cooling to temperatures up to 160 deg. C.

The exposed crystal electrode is fully grounded to effectively eliminate problems due to free electrons and RF interference.

The crystal holder is easily removed and installed even in awkward locations in the vacuum system. Once removed from the housing the crystal is still retained in the crystal holder by a snap-on retainer. The crystal can be easily replaced with no tools at a more convenient place such as a clean bench.

The housing is provided with: (4) tapped (4-40) holes for convenient mounting, 1/8" diameter X 5" long inlet and outlet water cooling tubes, and a coaxial connector. The electrical connection to an instrumentation feedthrough is made with a 30" coaxial cable. Both ends of the cable terminate with standard Microdot S-50 type connectors. Cable lengths up to 60" are available upon request.

The sensor head is supplied with 6 crystals (1 installed) and a 30" coaxial cable. Additional sensor crystals are available (5 crystals per box), P/N 103200.

Appendix A.3

Instrumentation Feedthrough Description

P/N 130200 Instrumentation Feedthrough (IF-110)

This feedthrough is 1" diameter, O-Ring sealed, with 1/8" source and return water cooling lines, and internal and external coaxial cable connectors. Baseplate thicknesses up to one inch can be accomodated.

RF interference and free electrons are effectively shielded from the signal connector through the use of fully closed coaxial cable connections. A standard coaxial cable with a Microdot S-50 connector mates the internal feedthrough connector to the sensor head. The external coaxial cable mates with the feedthrough with a standard BNC connector.

P/N 130204 Instrumentation Feedthrough (IF-275)

This feedthrough is the same as the above except it is mounted with a 2 3/4" Conflat* flange seal.

*Registered trademark of Varian Assoc., Inc.

Appendix A.4

Sensor Oscillator Description

P/N 124200 Sensor Oscillator

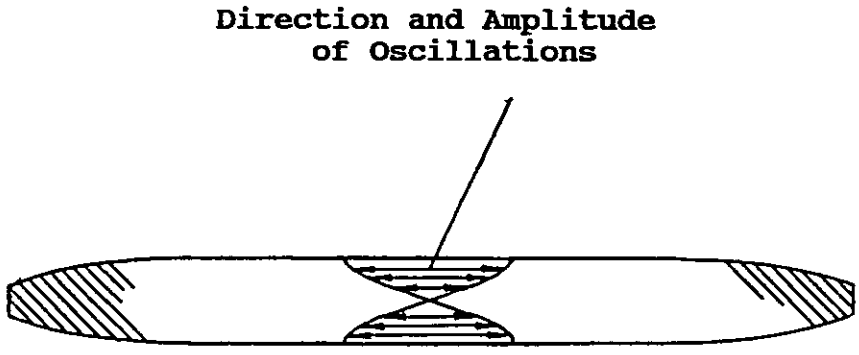
The sensor oscillator is designed to be used with industry standard 6 megahertz sensor crystals. The oscillator's characteristics enable it to obtain maximum life from the sensor crystal.

The oscillator is supplied with a 6" coaxial cable and a 10' coaxial cable. The 6" cable interconnects the oscillator and the feedthrough. The 10' cable interconnects the oscillator and the thickness monitor. This single coaxial cable provides both power for the oscillator and the signal output for the thickness monitor. Cable lengths up to 50' are available upon request for replacing the 10' cable.

Appendix A.5

Measurement Process

The Monitor uses a quartz crystal as the basic transducing element. The quartz crystal itself is a flat circular plate approximately 0.55-inch (1.40 cm) in diameter, and 0.011-inch (28 cm) thick. The crystal is excited into mechanical motion by an external oscillator. The unloaded crystal vibrates in the thickness shear mode at a frequency of approximately 6 megahertz.



Cross-Section of crystal vibrating in Thickness Shear Mode.

The frequency at which the quartz crystal oscillates is lowered by the addition of material to its surface.

Appendix A.6

Film Thickness Calculation

Early investigators noted that if one assumed that the addition of material to the crystal surface produced the same effect as the addition of an equal mass of quartz, the following equation could be used to relate the film thickness to the change in crystal frequency.

$$TK_f = \frac{N_q}{P_f} \frac{P_q}{f^2} (f_q - f) \qquad (1)$$

where: N = 1.668×10^5 m/sec. Frequency constant for an AT cut quartz crystal vibrating in the thickness shear mode.

P_q = Density of quartz (gm/cubic cm).

f_q = Resonant frequency of the uncoated crystal.

f = Resonant frequency of the loaded crystal.

TK = Film thickness.

P_f = Density of the film (gm/cubic cm).

This equation proved to be adequate in most cases. However, the constant of proportionality is not actually constant because the term contains the crystal frequency which of course changes. Because the achievable frequency change was small the change in scale factor fell within acceptable limits.

In the late 1960's improvements in sensor crystals and oscillator circuits resulted in a significant increase in achievable frequency shift. At the same time, low cost integrated digital circuits became available allowing a significant increase in basic instrument accuracy so that the frequency squared term in the scale factor became important.

Substituting 1/period for frequency results in the following equation:

$$TK_f = \frac{N_q \, P_q}{P_f}(t - t_q) \qquad (2)$$

where: t = Period of the loaded crystal (sec).

t_q = Period of the uncoated crystal (sec).

Note: Units of N_q is cm/sec.

Note that the constant of proportionality in this equation is constant.

The original assumption that the addition of a foreign material to the surface of the crystal produced the same effect as that of the addition of an equal mass of quartz was, of course, questionable. Crystals heavily loaded with certain materials showed significant and predictable deviation between the film thickness measured and that predicted by equation 2. Analysis of the loaded crystal as a one dimensional composite resonator of quartz and deposited film led to the equation below.

$$TK = \frac{P_q}{P_f} N_q \, \frac{T}{\pi R_z f} \arctan\left(R_z \tan \pi\left(\frac{T - T_q}{T}\right)\right) \qquad (3)$$

where: R = The acoustic impedance ratio which is obtained by dividing the acoustic impedance of quartz by the acoustic impedance of the deposited film.

This equation introduces another term into the relationship: the ratio of the acoustic impedance of quartz to the acoustic impedance of the deposited film. The acoustic impedance is that associated with the transmission of a shear wave in the material. Note that if the acoustic impedance ratio is equal to one, quartz on quartz, equation 3 reduces to equation 2.

Although the above equation still involves a number of simplifying assumptions, its ability to accurately predict the film thickness of most commonly deposited materials has been demonstrated.

The use of microprocessors allows an equation as complex as equation 3 to be solved economically and implemented in the Monitor.

The actual film mass on the crystal is then determined by applying the acoustic impedance correction factor.

At the start of the deposit or at zero the initial equivalent quartz mass and the initial corrected film mass is stored. For each subsequent measurement the new corrected total film mass is calculated and the film mass deposited since the start of deposit is determined by subtracting the initial film mass from the total film mass.

The film thickness on the crystal is calculated by dividing the film mass by the film density.

The film thickness on the substrates is then calculated by multiplying the film thickness on the crystal by a tooling factor.

If the acoustic impedance parameter is changed following a deposition, both the total and the initial film masses are recalculated. This allows the effect of the changed parameter value to be immediately displayed.

Appendix A.7

Crystal Health Calculation

Crystal health decreases from a value of 100% for an uncoated crystal blank to 0% at a total deposited areal mass of 25 milligrams per square centimeter. The above value corresponds to a crystal frequency shift of approximately 1.5MHz, or an aluminum thickness of 925 kA.

Since very few materials can be deposited to this thickness without producing a crystal failure, a crystal health of zero will not normally be achieved; indeed, for some materials the crystal health may never get below 90%.

In order to establish the point at which the crystal should be changed, several trial runs should be made to determine the point at which the crystal fails (0 FAIL message flashes) and subsequent crystals should then be replaced well in advance of this point.

Because the crystal health is determined from the calculated film mass, the Acoustic Impedance parameter will affect the displayed crystal health.

Appendix A.8

Rate Calculation

The deposition rate is calculated by dividing the change in thicknes between measurements by the time between measurements. The rate is filtered by a three-pole digital filter to minimize the quantizing a sampling noise introduced by the discrete time, digital nature of th measurement process. The above filter has an effective time constan about 4 seconds. Following a step change, the displayed rate will settle to 95% of the final value in 7 seconds and to 99.5% of the fi value in 10 seconds.

Appendix A.9

Film Parameter Log

FILM #	THICK SET PT-1	THICK SET PT-2	DENSITY	ACCOUSTIC IMPEDANCE	TOOLING FACTOR
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					

Appendix A.9

Film Parameter Log

FILM #	THICK SET PT-1	THICK SET PT-2	DENSITY	ACCOUSTIC IMPEDANCE	TOOLING FACTOR
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
31					
32					
33					
34					
35					
36					
37					
38					
39					
40					

Appendix A.9

Film Parameter Log

FILM #	THICK SET PT-1	THICK SET PT-2	DENSITY	ACCOUSTIC IMPEDANCE	TOOLING FACTOR
41					
42					
43					
44					
45					
46					
47					
48					
49					
50					
51					
52					
53					
54					
55					
56					
57					
58					
59					
60					

Appendix A.9

Film Parameter Log

FILM #	THICK SET PT-1	THICK SET PT-2	DENSITY	ACCOUSTIC IMPEDANCE	TOOLING FACTOR
61					
62					
63					
64					
65					
66					
67					
68					
69					
70					
71					
72					
73					
74					
75					
76					
77					
78					
79					
80					

Appendix A.9

Film Parameter Log

FILM #	THICK SET PT-1	THICK SET PT-2	DENSITY	ACCOUSTIC IMPEDANCE	TOOLING FACTOR
81					
82					
83					
84					
85					
86					
87					
88					
89					
90					
91					
92					
93					
94					
95					
96					
97					
98					
99					
100					