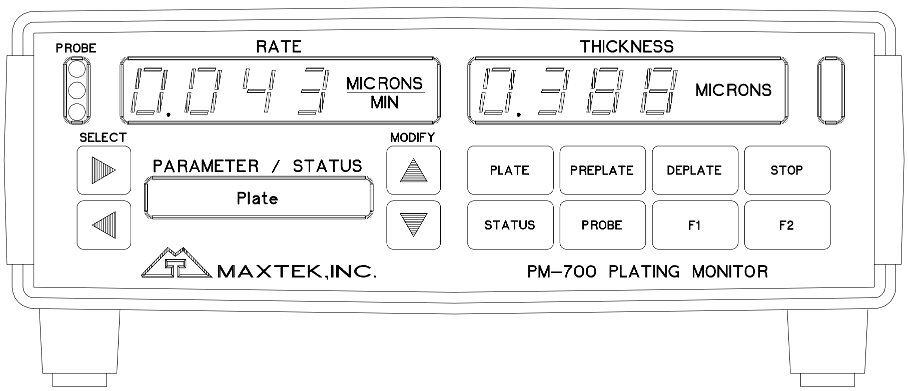
OPERATION AND SERVICE MANUAL

PM-700 SERIES
PLATING MONITOR



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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 for a period of (twenty-four) 24 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 the 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.

DISCLOSURE

SAFETY

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

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1. GENERAL DESCRIPTION

The PM-700 Series of Plating Monitors act like intelligent electronic coupon systems. The monitor continuously displays the thickness of the film on the coupon and the rate of change of that thickness. It does this rapidly, in fractions of a second, and with very high resolution.

The heart of the intelligent coupon is the quartz crystal mounted in the end of the probe. It is the film on this crystal whose thickness and rate of change of thickness is displayed on the monitor.

Use of this technique allows instantaneous measurement and display of the plating rate of any liquid plating or etching process.

The basic monitoring system consists of the monitor itself, a probe with the crystal installed and a cable connecting the probe to the monitor.

Various configurations of monitor, probe and crystal are available to meet different requirements and the monitors incorporate numerous user modifiable parameters so that they can be tailored to specific processes.

1.1 SPECIFICATIONS

PM-700 Series Common Specifications

Monitor accuracy: 0.5 %

Basic measurement resolution:
Thickness: 0.01 µg/cm^2
Frequency: 0.5 Hz @ 5 MHz

Display Resolution:
Weight: 0.01 µg/cm^2
Efficiency: 0.1%
Frequency: 0.1 Hz

Discrete Outputs:
Preplate achieved.
Thickness achieved.
Low rate alarm.
High rate alarm.
Crystal failed.
Spare.
Spare.

Level: 0 to 5 Vdc CMOS logic level.
Source impedance: 100 ohm.

Discrete Inputs:
Start Preplate.
Start Plate.
Start Deplate
Stop or Reset.
Spare.

Logic level: Ground true.
Internal 4.7 kς pull-up to 5 Volt.

DAC Interface:
Outputs: Two independent analog outputs
Range: 0 to 5.0 Vdc
Accuracy: ± 3% of range + 1% of full scale.
Linearity: 0.5% of full scale
Output impedance: 10 kς ± 2%
Control inputs: Zero, Full Scale
Logic level: Ground true.
Internal 4.7 kς pull-up to 5 volt.

Plate/Deplate Current Supply:

Range: 0 to ± 22.12 ma.
0 to ± 1.615 ASD (amp per sq. decimeter)*
0 to ± 15 ASF (amp per sq. foot)*

* For standard crystal electrode area of 1.37 cm^2

Resolution: 0.05%
Linearity: 0.1%
Accuracy: ± (0.5% of value + 0.1% full scale)
Compliance: ± 4 Vdc

RS-232 Interface:

Connector: 9 Pin, Male, D shell (IBM AT type)
Baud Rate: 9600, Full Duplex
Format: 8 bits, No parity, 1 Stop bit

Environmental:

Operating Temperature: 0 to 50^o C.
Storage Temperature: -40^o to $+70^o$ C.
Humidity: Up to 95% relative humidity at or below $+40^o$ C;
to 75% relative humidity from $+41^o$ to $+50^o$ C.

Power requirement: 90 VRMS to 140 VRMS or
200 VRMS to 260 VRMS
at 47 to 63 Hz, 25W.

Physical

Dimensions:
Height: 89 mm (3.5 in.)
Width: 216 mm (8.5 in.)
Depth: 235 mm (9.25 in.)
Net Weight: 8.3 kg (3.75 lbs.)
Shipping Weight: 11.3 kg (5.1 lbs.)

2. UNPACKING, INSPECTION AND BENCH CHECKOUT

2.1 UNPACKING, INSPECTION

Carefully inspect your plating monitor and its shipping container for evidence of possible shipping damage. If such evidence is present, notify the carrier and Maxtek as soon as possible. Keep the shipping container as evidence if shipping damage is present or for possible future return of the monitor. Check the material received against the packing list to ensure that all materials are accounted for. Items included with your plating monitor are:

1	Plating Monitor
1	Operation and Service Manual
1	Power cord

In addition, you may have ordered one or more of the accessories. If there is no evidence of damage, the monitor can now be bench checked.

2.2 BENCH CHECKOUT

Before connecting ac power to your Plating Monitor, make sure input voltage requirement is correct for your installation. The selected line voltage can be seen through the plastic window on the monitor rear panel. If it does not correspond to the power line voltage to be used, follow the steps below to select the correct line voltage.

1. Slide plastic cover to the left, exposing fuse and voltage selector p.c. board.
2. Remove fuse by pulling "FUSE PULL" lever to the left.
3. Remove voltage selector p.c. board by pulling it with a suitable tool on the small hole in the center of the board.
4. Select the voltage by positioning the p.c. board so the desired voltage is indicated on upper left corner. Insert board into place in this position.
5. Install fuse and slide cover to the right. The selected voltage will be visible through the plastic window.

Connect the ac power cord to the monitor rear panel line connector. Turn on the monitor via the rear panel rocker switch. When power is applied to the monitor it goes through an internal test routine during which all displays and indicators are lit up. This condition lasts approximately six seconds. The Rate and Thickness displays will begin to flash a P FAIL message indicating that power has been interrupted. This is normal and it will happen every time the monitor is turned off.

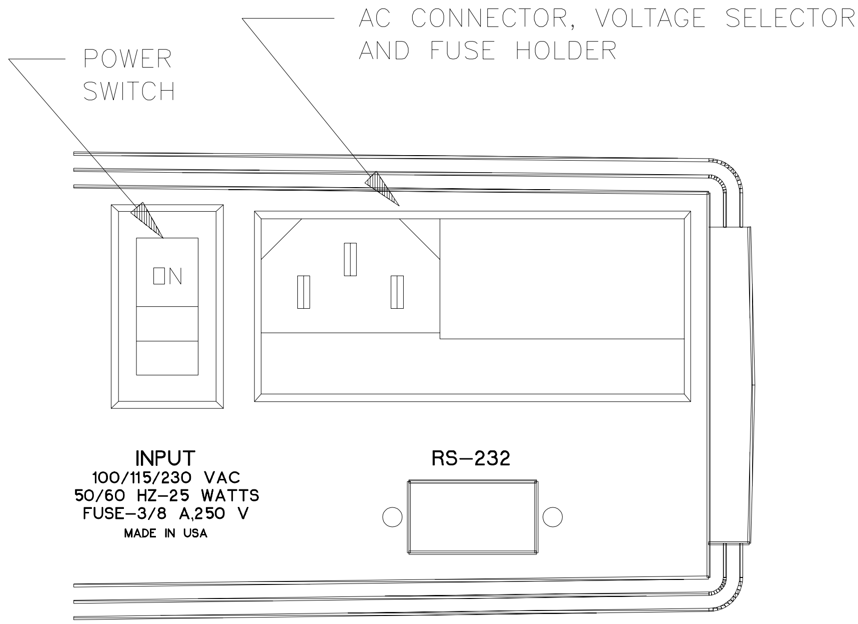

Figure 1 Power Switch and AC Connector

You may see an E FAIL or I FAIL message for a short time, this is normal. However, if the display stops on either of those messages, an internal fault has been detected and the monitor will remain inoperative until the fault has been corrected. Further details of error messages can be found in the Troubleshooting Section on page 63.

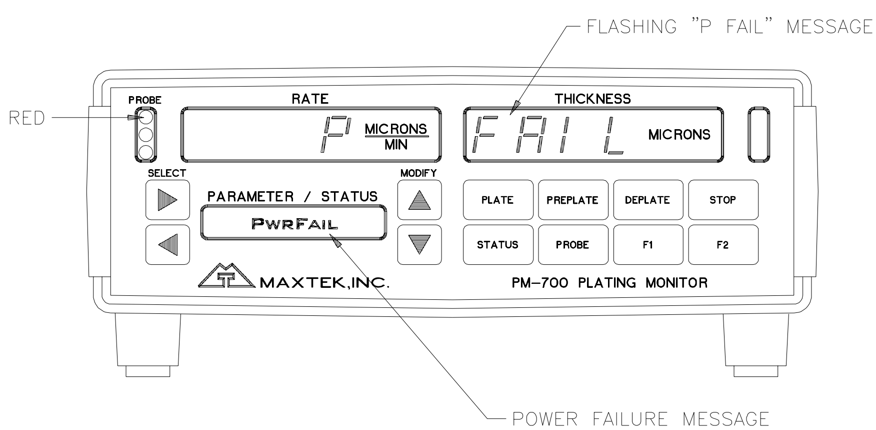

Figure 2 Front Panel Indication, First Power-On

Press the Stop button to clear the P FAIL message. Now, an O FAIL will be flashing. The red light in the Probe Status window will be on indicating a probe failure, because there is no probe with crystal has been connected to the monitor. Note that during actual operation, a P FAIL message indicates the line power to the monitor has been interrupted. The red light in the Probe Status window and the O FAIL message indicates a problem with the probe or the sensor crystal.

The Parameter/Status display will show the last display mode selected prior to removing power from the monitor. See Parameter/Status Display Modes Section on page 26 for detail description of the Parameter/Status display.

Using the standard 3 meter triaxial cable and connect the Sensor Probe to the Plating Monitor rear panel connector labeled PROBE A. Be careful not to touch the surface of the sensor crystal installed in the crystal holder. After the Sensor Probe has been connected, pressing the STOP button should step Probe Status Indicator from red to green indicating a good Sensor Probe is connected and is in active. The O FAIL message then should be clear.

Pressing PLATE or PREPLATE will reset thickness display to zero. Breathe lightly onto the sensor crystal surface. The displayed thickness should increase due to condensed water vapor on the crystal. The thickness then will decrease as additional water vapor evaporates from the crystal surface.

If your monitor is a dual probe model, you may also want to connect a second Sensor Probe to the monitor connector labeled PROBE B. You will need to make Probe B the active probe by pressing PROBE B button follow by PLATE button (Note that Probe A is now in standby). An O FAIL message should flash in the main display indicating Probe B has been failing. Press STOP key, the O FAIL message should be clear and the Probe B Status Indicator should change from red to green. Probe B is now the active probe. Test Probe B the same way you have tested Probe A.

If everything responds as described above, the total system is OK. The monitor can now be programmed to suit your application.

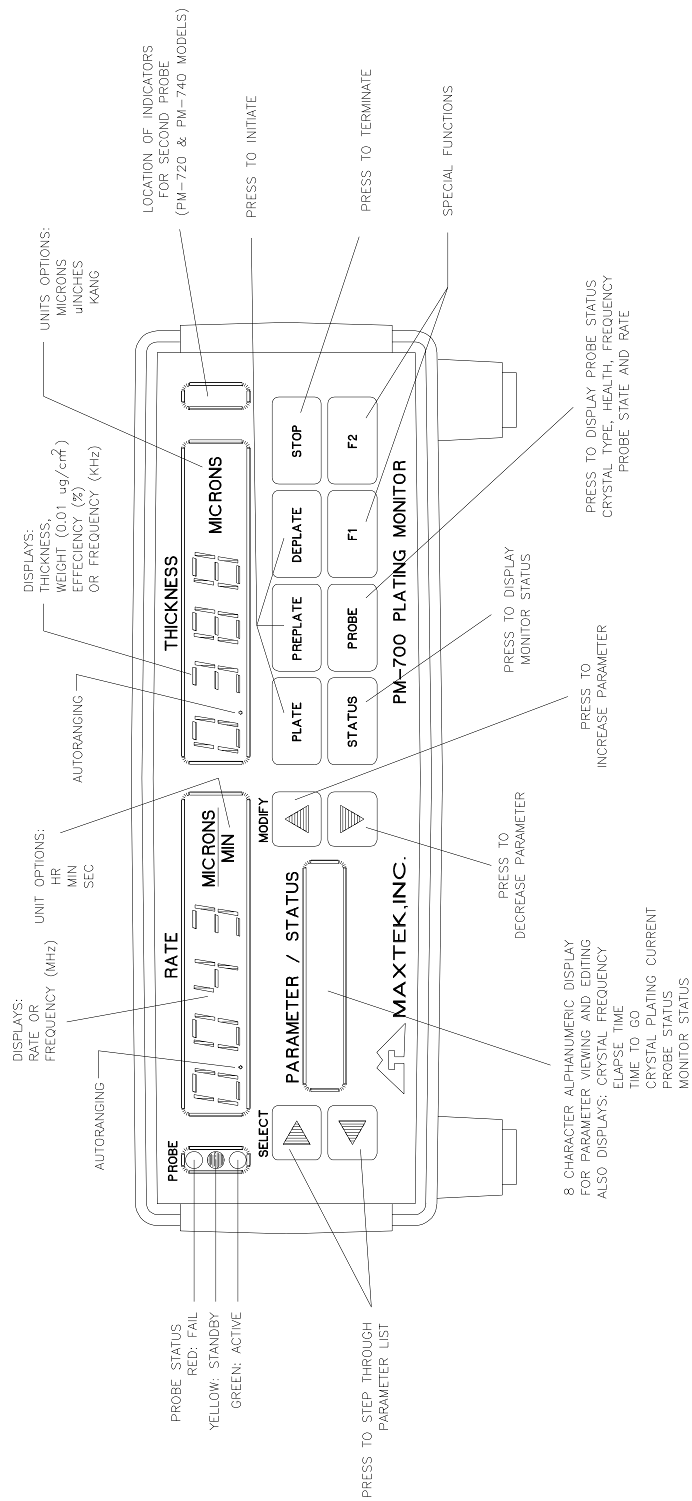

Figure 3 PM-700 Front Panel Outline

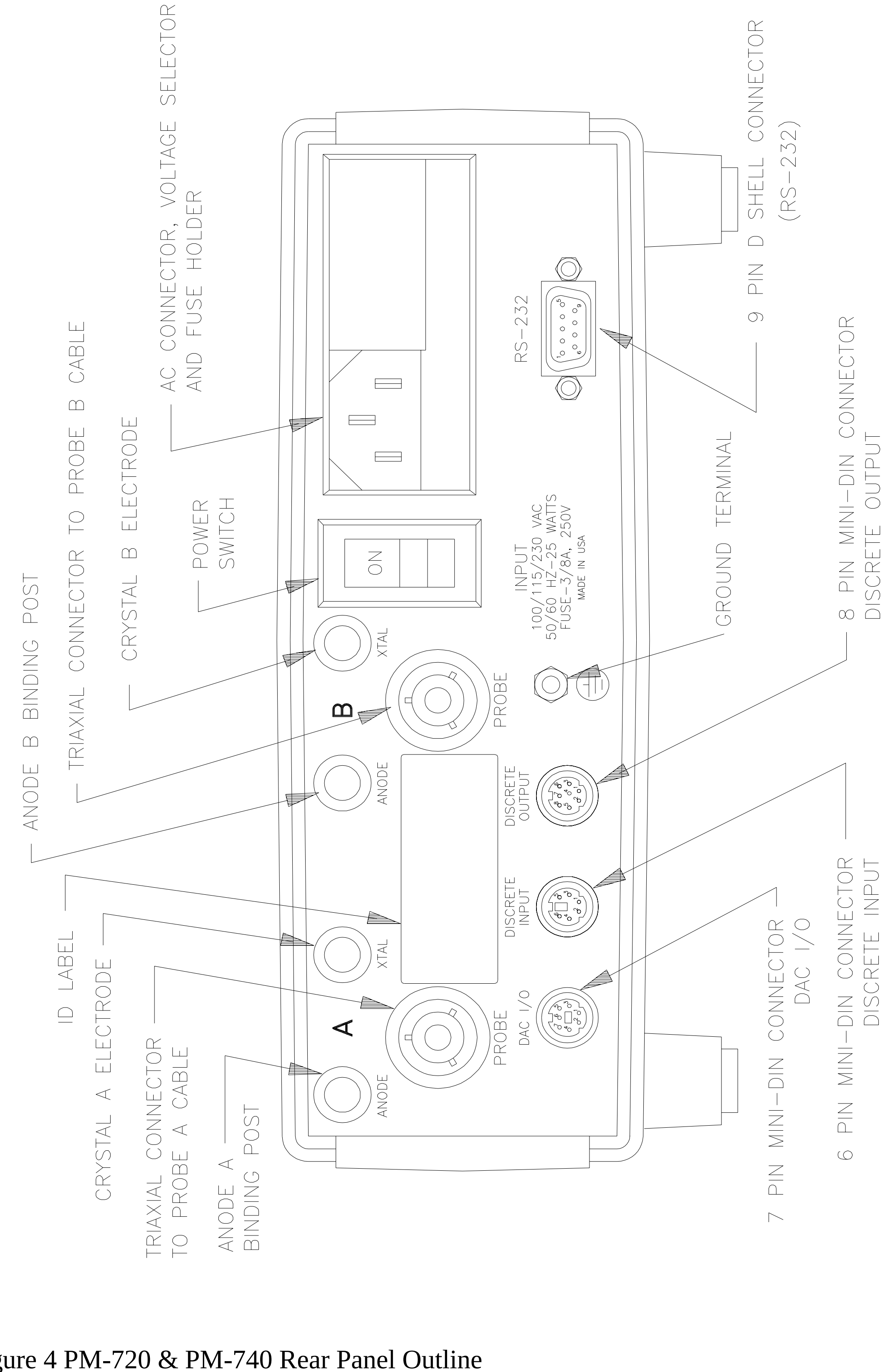

Figure 4 PM-720 & PM-740 Rear Panel Outline

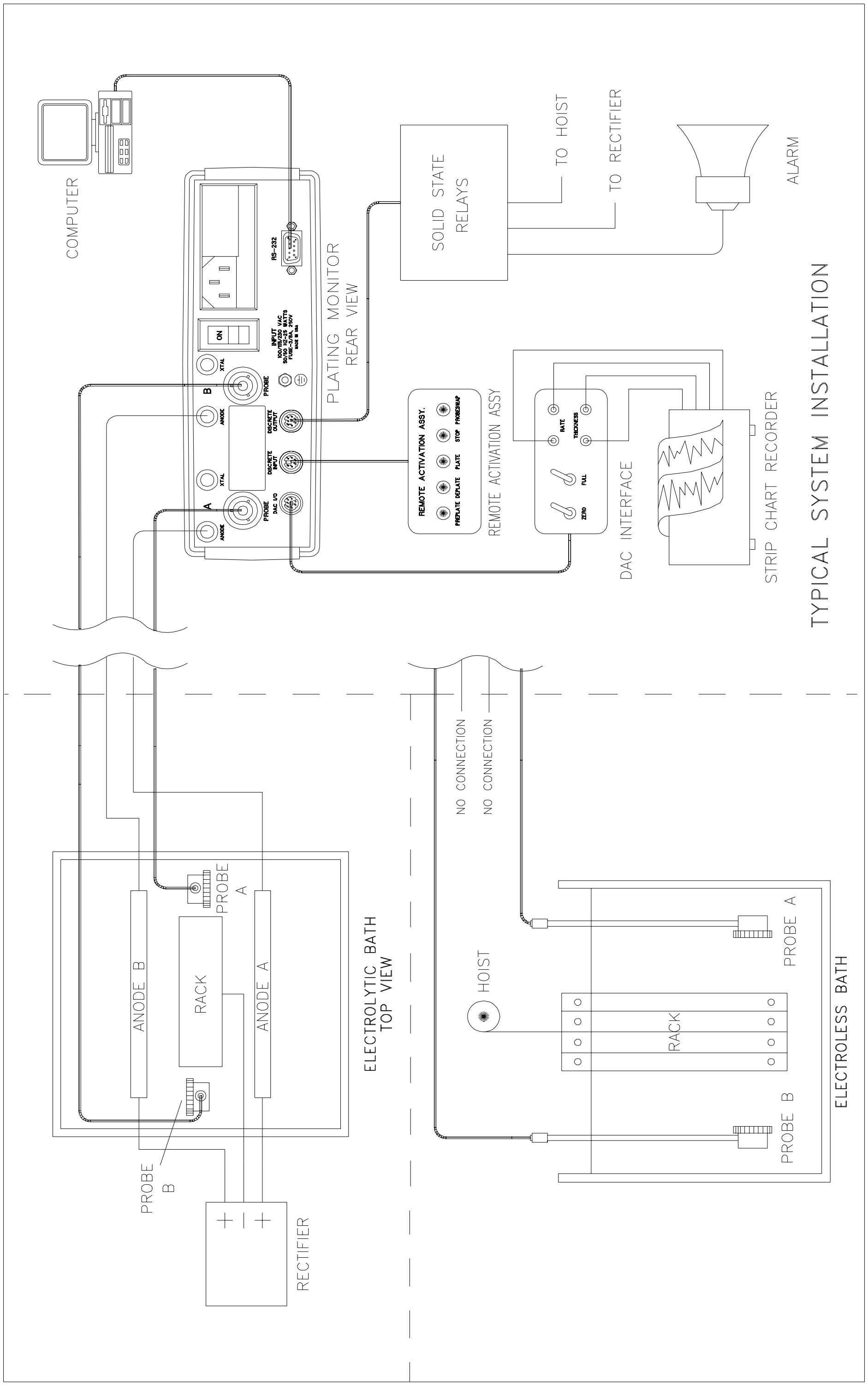

Figure 5 Typical System Setup

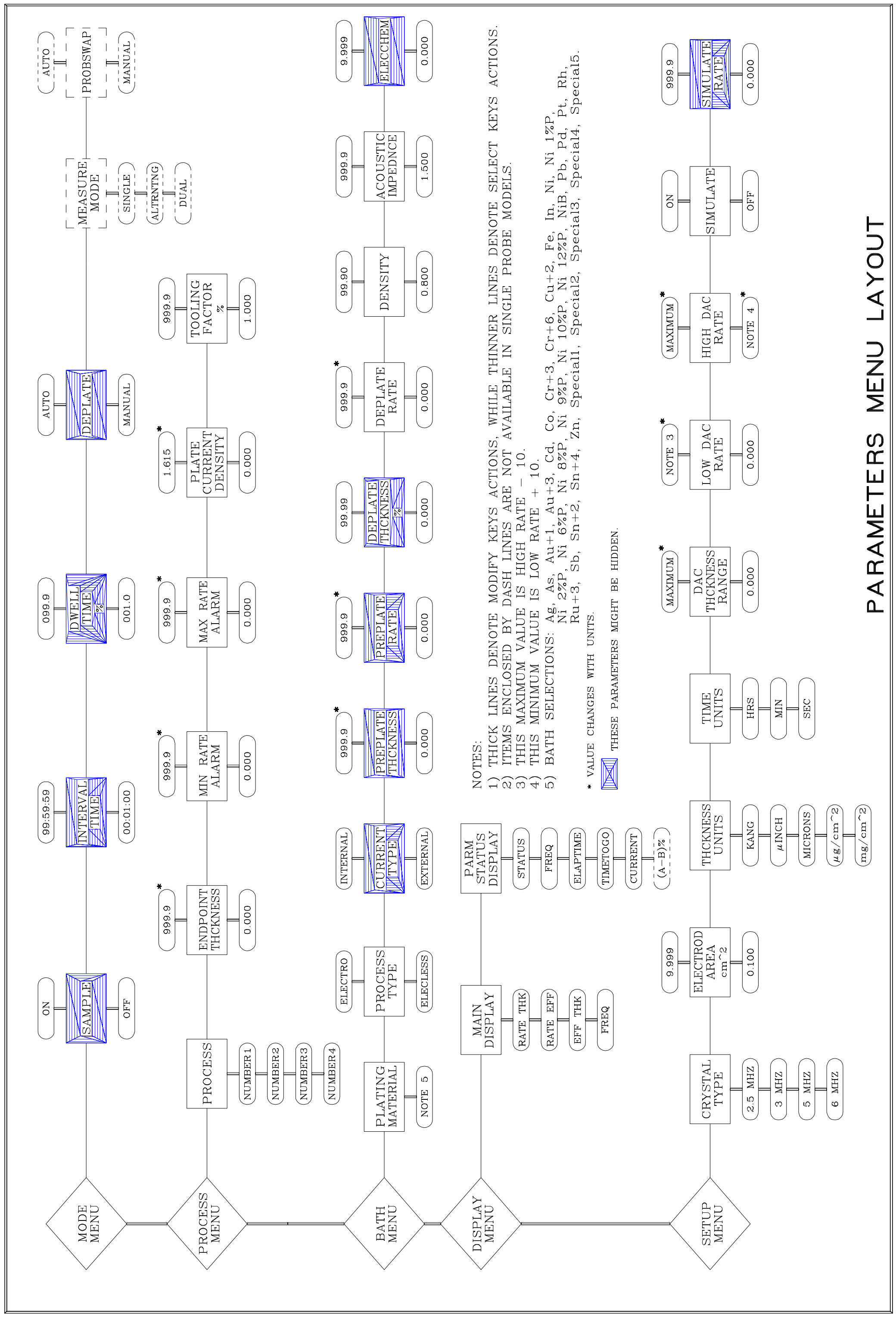

Figure 6 Parameter Menu Layout

3. SIMPLIFIED OPERATION

This section is designed to help first time user of the PM-700 Series Plating Monitor to become familiar with viewing, programming and editing of the monitor parameters.

First, refer to Figure 7 Front Panel Buttons on page 19, locate the four arrow buttons and study their functions. Next, refer to Figure 6, Parameter Menu Layout, on page 6 and study the way the menus and parameters are laid out. Notice that the SELECT buttons (left and right arrows) are used to move horizontally through the parameters. The two MODIFY buttons (up and down arrows) are used to vertically step through the menus or to change a parameter value. Note that these arrow buttons have auto repeat functions. If one of them is pressed and held down it will scroll to the ultimate limit (i.e. if you are at a parameter with a numerical value, pressing and holding down the MODIFY UP arrow will ultimately increase that parameter value to its maximum limit).

PM-700 Series Plating Monitor are shipped with Process Number 2 as the default process. Process Number 1 may be programmed to your specific plating process if you requested Maxtek to do so at the time you purchased your monitor. The following table is a list of parameters default values for Process Number 2. Use the four arrow buttons you have just learned above to step through the parameters and check their default values against the list. Also, practice changing some of the parameter values to get a feel on how to modify them. There are four material parameters that could be reset to their factory set default values. If you wish to do so, simply press the STATUS button while both of the Up and Down arrow buttons are depressed.

Table 1 Process 2 Parameter Default Values

Menu	Parameter	Default Value
Mode Menu	Sample	Off
Mode Menu	Measure Mode *	Single
Mode Menu	ProbSwap *	Manual
Process Menu	Process	Number 2
Process Menu	Endpoint Setting	10.00
Process Menu	Min Rate Alarm	0.000
Process Menu	Max Rate Alarm	9.999
Process Menu	Plate Current Density	0.001
Bath Menu	Bath	Special1
Bath Menu	Type	Elecless
Bath Menu	Preplate Thckness	1.000
Bath Menu	Preplate Rate	0.200
Bath Menu	Deplate Rate	0.100
Bath Menu	Density	1. 000
Bath Menu	Acoustic Ratio	8.830
Display Menu	Main Display	Rate Thk
Display Menu	Parm Status Display	Status
Setup Menu	Crystal Type	5 MHz
Setup Menu	Crystal Area cm^2	1.370
Setup Menu	DAC Thckness Range	5.000
Setup Menu	DAC Low Rate	0.000
Setup Menu	DAC High Rate	9.999
Setup Menu	Simulate Mode	Off

* These parameters are only available in dual probe models.

The following example is a typical plating process. It is provide for you to practice parameter programming.

3.1 SAMPLE PROCESS

Suppose a PM-700 monitor is to be used to continuously measure the plating rate and thickness in an **electroless nickel** bath, giving a deposit with **6% phosphorus**. Since this bath will not initiate plating on a pure gold surface, the sensor crystal will have to be electrolytically preplated with, for example, **.5 microns** of nickel at a controlled rate in order to support subsequent autocatalytic electroless plating. Assume that the desired **plating thickness endpoint is 20 microns** and it is desired that the plating monitor warns the operator if the **plating rate falls outside the normal limits of .100 ±0.02 micron/min**. It is also desired that the total elapsed time since introduction of the work into the plating bath be displayed. These parameters will be established for **process number 3**.

Given the above example, the following list of parameters will need to be programmed into the monitor.

Table 2 Sample Process Parameter Values

Menu	Parameter	Value
Process Menu	Process	Number 3
Process Menu	Endpoint Setting	20.00
Process Menu	Min Rate Alarm	0.080
Process Menu	Max Rate Alarm	0.120
Mode Menu	Sample	Off
Bath Menu	Bath	Ni 6%P
Bath Menu	Type	Elecless
Bath Menu	Preplate Thckness	0.500
Bath Menu	Preplate Rate	0.050
Display Menu	Parm Status Display	Elaptime
Setup Menu	Simulate	Off

Since the above parameters will be established for process number 3, the first thing to do is select process number 3 as the current process. You can do this by going to the Process parameter in the Process Menu and use the SELECT arrow buttons to find Number 3. Then follow the above list to program the rest of the parameters.

4. DETAILED OPERATION

4.1 INTRODUCTION AND GENERAL CONCEPTS

Basic operation of the PM-700 monitors is straightforward but the many options and operating modes available through the programmable parameters may appear overwhelming on first glance. We believe, however, that once the basic operating concepts are understood, operation of the system will be experienced as straightforward and intuitive.

In order to facilitate a rapid understanding of the PM-700's basic operating concepts, we have seen fit to describe the operation in terms of modes and states.

The monitor has a number of operating states and modes, which are described below. In addition, the probes themselves have their own states and modes, which may be different than those of the monitor.

For example, the monitor may be operating in the electroless plating mode; the measurement mode might be single probe, with sampling. The monitor might then be in the Plate State (as opposed to the Ready, Preplate, or EndPoint states). Meanwhile the probe might also be in the Plate State or alternately in the Hold State if the monitor is between samples. If the monitor supports dual probes, then the second probe will likely be in the hold mode or it could be in the failed state if the crystal is being replaced.

The monitor is shipped from the factory with default settings for all parameters so that no more than a few parameters must be setup to begin operation.

4.2 DISPLAYS

There are five display windows in the plating monitor front panel. On the upper left most and upper right most are the Probe Status windows. Each contains three indicator LED's. Note that in the PM-700, only the left status window is utilized since PM- 700 supports single probe. Located in- between the two Probe Status windows is the Rate and Thickness displays. Each contains four large numerical LED's for easy readout of monitor measurements. Below the Rate display is the Parameter/Status display. This is an 8 character alphanumeric display used for parameter programming, viewing and editing. It is also used for displaying the monitor status or other functions. See Figure 3, page 6.

4.3 BUTTONS

There are twelve membrane push buttons on the plating monitor front panel. The four left most buttons are used for parameter viewing and editing, and the eight right most buttons are monitor operational buttons. Their uses are described below.

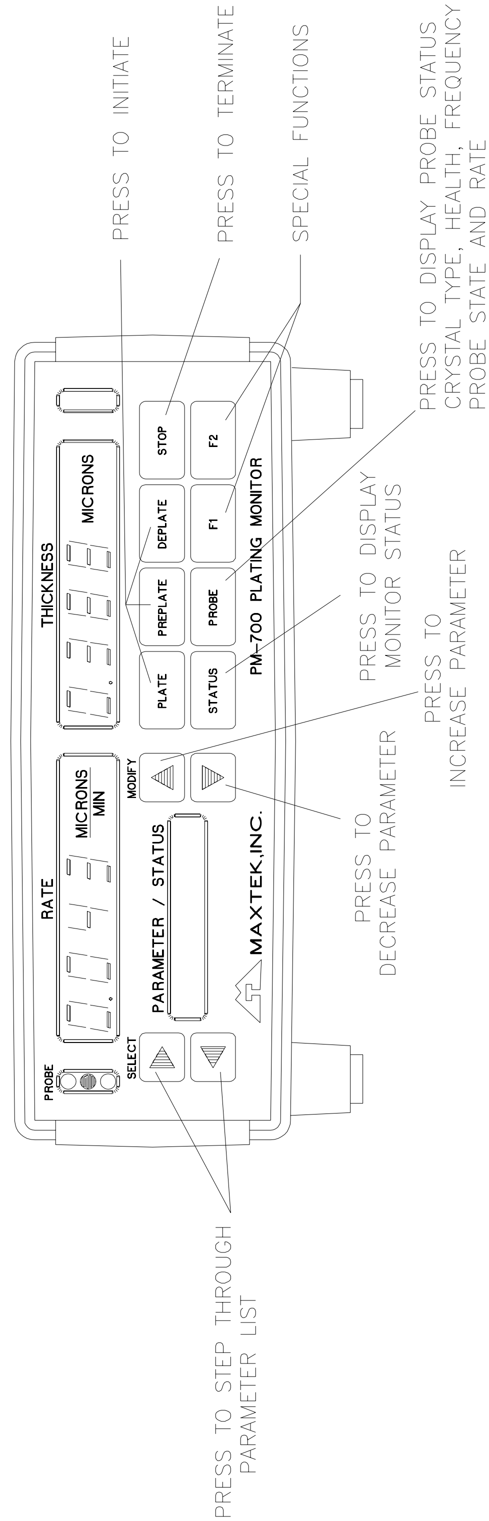

Figure 7 Front Panel Buttons

Select Buttons

Select Buttons are used to step between parameter items.

Modify Buttons

Modify Buttons are used to step up and down between menus, and to modify parameters values.

Plate Button

Plate Button is used to initiate the plating process.

Preplate Button

Preplate Button is used to initiate the preplate process.

Deplate Button

Deplate Button is used to initiate the deplate process.

Stop Button

Stop Button is used to terminate any active process. It is also used to clear failure messages.

Status Button

When Status Button is pressed down, the Parameter/Status Display will sequentially display important information involving the currently selected process, such as thickness endpoint, type of bath, etc. This will save the user of having to go to each menu to verify these parameters.

Probe Button

This button, when pressed, will display the Probe Sensor status in the Rate and Thickness windows. The two left most digits of the Rate display shows the crystal type. The next two digits show the crystal health and the Thickness display will show the crystal frequency in megahertz. In PM-720 and PM-740 models, this button is labeled Probe A.

Probe B Button

This button is used in the same way as Probe A button. Probe B status information will be displayed.

In PM-700 model, this button is labeled F1 and there is no function assigned to it.

Spare buttons

The lower right most button, either labeled F2 (PM-700) or F1 (PM-720 & PM-740), is spare. Its function is not implemented.

4.4 OPERATION

The operation of the PM-700 is described in terms of Monitor States and Measurement Modes and Probe Activity States and Operating States.

4.4.1 Monitor Operating States

The PM-700 can be in any one of a number of Operating States depending upon the type of bath being monitored, electrolytic or electroless.

4.4.1.1 Electroless plating

Five different states are defined for operation with electroless plating baths.

4.4.1.1.1 Ready State

In the Ready State plating rate and thickness are being monitored, but the Endpoint check is not being performed and the crystal electrode current is zero. The Ready State is entered on power ON and also by pressing the Stop button. Pressing the Preplate, Plate or Deplate buttons steps the monitor from the Ready State into the selected state.

4.4.1.1.2 Preplate State

The Preplate State is activated by pressing the Preplate button while in the Ready mode. If pressed in any state other than the Ready State, the Preplate button has no effect. Upon entry to the Preplate state the crystal electrode current is adjusted by the monitor to achieve the Preplate Rate parameter value and is maintained until the Preplate Thickness is achieved at which time the monitor steps to the Plate state.

4.4.1.1.3 Plate State

The Plate State can be entered from the Ready State, Preplate State or Deplate State by pressing the Plate button or automatically upon completion of the Preplate State. During the Plate State the indicated thickness is compared with the Endpoint parameter. When the indicated thickness equals or exceeds the Endpoint parameter, the monitor steps to the Endpoint State.

4.4.1.1.4 Deplate State

The Deplate State can be entered from the Ready State or the Endpoint State by pressing the Deplate button. (Remember that monitor states are not the same as probe states.) The Deplate State is exited to the Ready State by pressing the Stop button or to the Plate State by pressing the Plate button. The Deplate State is automatically terminated when the crystal health recovers to 95% at which time the monitor returns to the Ready State.

4.4.1.1.5 Endpoint State

The Endpoint State is automatically entered from the Plate State when the indicated thickness equals or exceeds the Endpoint parameter value. Pressing the Stop or Deplate buttons steps the monitor from the Endpoint State to the Ready or Deplate state. The Preplate and Plate buttons produce no action while in the Endpoint State.

4.4.1.2 Electrolytic plating

Because the Preplate State is not necessary in the Electrolytic plating mode, the Preplate button is ignored and only four different monitor states are defined for this operating mode.

4.4.1.2.1 Ready State

In the Ready state plating rate and thickness are being monitored but the crystal electrode current is zero so no plating will be occurring. The Ready State is entered on power ON and also by pressing the Stop button. Pressing the Plate or Deplate buttons steps the monitor from the Ready State into the selected state.

4.4.1.2.2 Plate State

The Plate State is entered from the Ready State by pressing the Plate button. During the Plate state the crystal electrode current is set at the value required to achieve a plating current density equal to that programmed in the Current Density parameter. In addition, the indicated thickness is compared with the Endpoint parameter. When the indicated thickness equals or exceeds the Endpoint parameter, the monitor steps to the Endpoint State.

4.4.1.2.3 Deplate State

The Deplate State is entered from the Ready State or the Endpoint State by pressing the Deplate button. In this state the crystal electrode current is adjusted by the monitor as required to achieve the de-plating rate specified by the Deplate Rate parameter. The Deplate State can be exited to the Ready State by pressing the Stop button, or to the Plate State by pressing the Plate button. The Deplate State is automatically terminated to the Ready State if the crystal health increases to 95% or more.

4.4.1.2.4 Endpoint State

The Endpoint State is automatically entered from the Plate State when the indicated thickness equals or exceeds the Endpoint parameter value. Pressing the Stop or Deplate buttons steps the monitor from the Endpoint State to the Ready or Deplate state. The Plate button is ignored while in the Endpoint State.

4.4.2 Monitor Measurement Modes

4.4.2.1 Single Probe Measurement Modes

The following three measurement modes require only one probe and can be utilized on any of the PM-700 series of monitors.

4.4.2.1.1 Continuous

In this mode the bath is monitored continuously. Should the Probe fail during the Preplate, Plate or Deplate state, the failure is enunciated, the Rate Display is held at its most recent value, and the displayed Thickness is increased at the displayed rate to indicate the best guess for the substrate thickness buildup.

4.4.2.1.2 Sample

This mode is used to increase the crystal's range. In the Sample mode the plating rate is monitored on a sampled basis. Between samples the rate established during the last sample is displayed and the displayed thickness value is increased at the displayed rate to show the assumed substrate thickness buildup. Plating of the probe crystal is halted by applying enough deplating current to the crystal to hold the plating rate at zero. Should the Probe fail, the failure will be enunciated, but the displayed thickness will continue to increase on the basis of the last valid rate sample. Parameters are provided to allow the user to set the duration of the sample period and the interval between sample periods.

4.4.2.1.3 Sample with Deplate

This mode is identical to the Sample mode except that the Probe crystal will be electrolytically deplated between samples. The amount of deplating is established by the user as a percentage of the amount plated during the sample. The rate of deplating is set by the amount, which must be deplated, and the time between samples.

4.4.2.2 Dual Probe Measurement Modes

The following measurement modes require two probes and, therefore, require the use of a Dual Probe model.

4.4.2.2.1 Auto Probe Swap

The Auto Probe Swap mode can be applied to all three of the Single Probe measurement modes. In the Auto Probe Swap mode a second probe is installed in the bath. While the active probe monitors the bath, the second probe is held in standby. In the event of a failure of the active probe, the monitor will automatically switch to the second, or standby, probe. If the standby probe requires initializing, it will be initialized with a preplate cycle, prior to the swap. During the time it takes the unit to switch over to the second probe, the rate display is held at the last valid rate value and the displayed thickness continues to buildup at the displayed rate.

4.4.2.2.2 Alternating Measurement mode

In this mode two probes are used to provide continuous monitoring. Usage of the two probes is alternated. While one probe is monitoring the bath the second probe is being deplated. The percentage of deplate between plating cycles is established by the user. The rate at which the two probes are alternated is determined by the Sample Interval parameter. The alternate probe is changed back to the plate mode 10 seconds before the probes are switched. This is done so when the probes are switched, the plating rate is stabilized on the new probe. In the event that one of the probes fails, the monitor reverts to the single probe Sample with Deplate mode.

4.4.2.2.3 Dual Probe Measurement mode

In this mode both probes are actively monitoring the plating process. The monitor compares the two probes and computes the average and the percentage difference between the probes. A number of display modes are available.

4.4.3 Probe States and Modes

At any particular time a Probe can be in any one of three states and, independently, in any one of three modes. For instance a Probe could be in the Standby State and the Deplate mode or in the Standby State and the Hold mode. The possible states and modes are described below:

4.4.3.1 Probe States

A probe can be in any one of the following three states: Failed, Standby, or Active. The state of the probe is indicated by the three probe status LED's. (See Figure 3.)

4.4.3.1.1 Failed state.

A failed probe means that for some reason, the monitor is not receiving a valid frequency signal from the probe.

4.4.3.1.2 Standby state

The standby state indicates that the monitor is receiving a valid frequency from the probe but the displayed information is not based on the output of this probe.

4.4.3.1.3 Active state

The active state indicates that the probe is not failed and that it is the source of the display information and is being used to control any active process.

4.4.3.2 Probe modes

In addition to the above, a probe may be in any one of the following four modes: Hold, Deplate, Preplate, or Plate. The Hold and Preplate modes are applicable to the electroless plating process. The Probe Deplate and Probe Plate mode is applicable to both the electroless and the electrolytic plating processes.

4.4.3.2.1 Ready mode

In the Ready mode, the probe is not in preplate, deplate, plate or hold. The monitor does not supply current to the probe.

4.4.3.2.2 Hold mode

In the Probe Hold mode, the plating rate on the probe is held at zero. For electroplating processes, this is done by setting the electrode current to zero. For electroless processes, this is done by maintaining the electrode current at the negative value required to halt the electroless plating process. This current level is automatically determined by the monitor.

4.4.3.2.3 Deplate mode

In the Probe Deplate mode, enough negative electrode current is supplied by the monitor to create the desired deplating rate.

4.4.3.2.4 Preplate mode

In the Probe Preplate mode, enough positive electrode current is supplied by the monitor to create the desired preplating rate.

4.4.3.2.5 Plate mode

In the Probe Plate mode, the electrode current is zero for electroless processes and positive for electrolytic processes. In electrolytic processes the electrode current is established by the monitor at the value necessary to achieve the programmed current density.

The mode of the probe can be determined by pressing the Probe status button.

4.4.4 Main Display modes

The two four digit main displays are factory set to display plating rate and plating thickness, however, three alternate display formats can be selected by means of the Main Display parameter. All four possible Main Display modes are described below.

4.4.4.1 Rate and Thickness

This is the normal or default display mode as set at the factory. The measurement units will normally be displayed to the right of the digits unless the display units have been changed from those that were preset at the factory. If the Thickness Units parameter has been used to select and alternate set of units, then both units display areas will be dark. If the Time Units parameter has been modified, but the Thickness units are unchanged, then only the Rate display units will be dark.

4.4.4.2 Rate and Efficiency

In the Rate and Efficiency main display mode, the normal rate display is provided in the left hand display area while the right hand display is used to display the cathode efficiency in percent where 100% represents the theoretical maximum for the bath selected. Since cathode efficiency is only meaningful for electrolytic processes, a value of 00.00 is displayed if the monitor is in the Electroless plating mode.

4.4.4.3 Efficiency and Thickness

In this display mode, the left-hand display area is used to display the cathode efficiency in percent where 100% represents the theoretical maximum of the bath selected. Since cathode efficiency is only meaningful for electrolytic plating processes, a value of 00.0 is displayed if the monitor is in the Electroless plating mode. The right hand display area provides the normal plating thickness display.

4.4.4.4 Frequency

In this Main Display mode the left-hand display is used to display the crystal frequency in Megahertz while the right hand display is used to display the crystal frequency in Hertz. This allows for display of the total crystal frequency to a resolution of 0.1 hertz.

4.4.5 Parameter/Status Display modes

The Parameter/Status display serves a number of purposes. It is used to view and modify parameter values, or to display monitor status or to display a user selected variable. In the event of a warning condition or a failure condition, a descriptive message will be flash alternately with the selected display.

When any of the arrow buttons are pressed, the display is used to show the value of the previously selected parameter. Pressing one of the Probe buttons results in the display of that probe's status alternating with the plating rate on that probe. If the Status button is pressed, then the display cycles through a list of items, which describe the status of the monitor. When the Probe or Status buttons are released, or if the arrow buttons remain inactive for 30 seconds, then the display reverts to one of the six displays described below. The 30-second hold of the parameter display can be terminated early by pressing and releasing any of the Probe or Status buttons.

4.4.5.1 Status Display

In the Status Display mode, the monitor state is displayed.

4.4.5.2 Frequency Display

In the Frequency Display mode the frequency is displayed as an eight-digit number with a resolution of 0.1 hertz.

4.4.5.3 Elapsed Time Display

This display mode displays the time that has elapsed since the beginning of the current state. I.e., if the current state is the Plate State then the time displayed is the amount of time that has passed since the start of the Plate State. The time is displayed in hh:mm:ss format.

4.4.5.4 Time to Go Display

This display mode displays the estimated time required to complete the current state. In the case of the Plate State, the time to go is calculated by dividing the difference between the Endpoint thickness and the current thickness by the average rate.

4.4.5.5 Current Density Display

This display mode displays the current density at the probe electrode. The units are Ampere per square decimeter for monitors with metric unit display and Amperes per square foot for monitors with English unit display.

4.4.5.6 A-B)% Display

This display mode is only available on dual probe model monitors. In the Dual Probe measurement mode, this display shows the percentage difference between A and B probe measurements. The right four characters of the Parameter/Status display indicate the percentage difference between the measurements made by the A and B probes, the average of which is displayed in the right hand Main display. The quantity displayed is 100*(A- B)/(A+B) or the percentage that the measurement A is larger than the average of the two measurements. The format of the display is +XX.X or -XX.X. A positive sign indicates that the A measurement is larger than the B measurement. The left four characters of the Parameter/Status display indicate the percentage difference between the measurements made by the A and B probes, the average of which is displayed in the left hand Main display. The same format is used.

4.4.6 Simulation Mode

The PM-700 series of monitors include a simulation function that is useful for familiarization and demonstration of the monitor features and for trouble shooting. In the simulation mode the frequency signal from the Probe is replaced with a simulated frequency that reflects the change in frequency, which an ideal crystal would produce when plated at the rate, specified by the Simulate Rate parameter. The Simulation State is activated by the Simulation Mode parameter.

4.5 PARAMETERS

The PM-700 series of monitors incorporate a large number of parameters that allow fine-tuning of the monitor for a particular application. All parameters are provided with default factory set values so that the user need only be concerned with those parameters that he desires to change. There are two different types of parameters; they are the selection type and the value type. Selection type parameters are parameters that are limited to a small number of possible selections. Some have only two selections, On and Off. Value type parameters may have any numeric value between a maximum and a maximum value.

4.5.1 Viewing and modifying

Pressing any one of the arrow keys results in the display of the last viewed parameter. The parameters are arranged in five different menus according to their usage. See Figure 6. Once a parameter is displayed, the left and right arrow keys provide for horizontal movement as shown in Figure 7. The up and down keys allow for vertical movement which corresponds to selection of selection type parameters or for increasing or decreasing the value of value type parameters. Note that movement between menus is only available when menus are being displayed as indicated by the vertical lines between the menu selections. Holding the left arrow key down will rapidly take you to the menu parameter. The up and down keys can then be used to choose a particular menu. The rate at which value type parameters change value increases for as long as a direction key is held down. When the key is released, the rate of change returns to its minimum value.

This feature allows for very fine setting over a very broad range in a minimum amount of time.

4.5.2 Hidden parameters

Parameters, which are not applicable to the selected mode of operation, are not displayed. They are hidden. For example, Interval Time and Dwell Time are applicable only when the monitor is in the Sample measurement mode. Thus when the Sample mode is Off, these parameters are hidden. See Section 4.5 starting on page 27 to determine which parameters may be hidden and under what conditions.

4.5.3 Descriptions

The following is a list of the available parameters, organized according to menu, along with their type and their range.

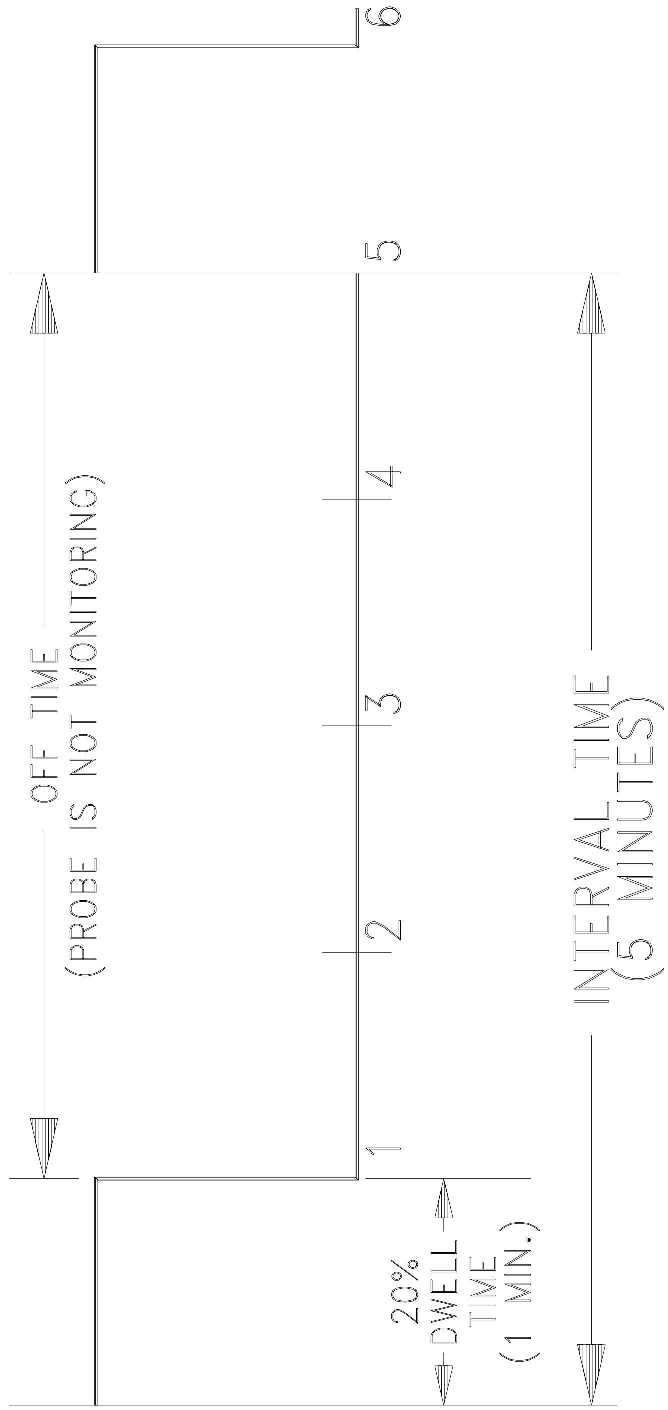

Figure 8 Graph of Interval Time and Dwell Time %

4.5.3.1 Mode Menu

Numonic	Name/Description	Minimum	Maximum	Default
Sample	Sample Allows the user to turn the monitor Sample Mode on or off. For a detail description of Sample Mode operation, refer to Sample section. Note this parameter will be hidden if the Measure Mode parameter is set to Altrntng.	Off	On	Off
Interval Time	Interval Time Defines the time of *one sampling cycle.* Refer to Figure 11 for an illustration of Interval Time. Note that this parameter will be hidden if the Sample Mode is off.	00:00:00 HH:MM:SS	99:59:59 HH:MM:SS	00:01:00
Dwell Time %	Dwell Time Percentage Defines the time, as a percentage of the Interval Time, during which the monitor is actually taking measurement from the Sensor Probe. Figure 11 illustrates Dwell Time % with respect to Interval Time. Note this parameter will be hidden from the Mode Menu if the Sample parameter is set to Off. It also is hidden if the Measure Mode is set to Altrntng.	000.0	099.9	050.0
Deplate	Deplate Sets the plating monitor to Automatic Deplate Mode or Manual Deplate Mode. This parameter will be hidden if the Sample Mode is set to Off. It is also hidden if the Measure Mode parameter is set to Altrntng.	Manual	Auto	Manual
Measure	Measure Mode	Single		Single

Mode	Allows for selection of one of the three measuring modes listed in the Minimum column. For detail description of these modes, refer to Monitor Measurement Modes section. Note that this parameter is only available in the dual probe models.	Altrntng Dual		
ProbSwap	Probe Swap Sets the monitor to perform probes swapping automatically or manually. Swapping Probes section offers a detail description of the Probe Swap feature. This parameter is available only in the dual probe models. Note this parameter will be hidden if the Measure Mode parameter is set to Altrntng or Dual.	Manual	Auto	Manual

4.5.3.2 Process Menu

Numonic	Name/Description	Minimum	Maximum	Default
Process	Process The plating monitor is capable of holding up to four different processes. This parameter allows selection of one of the four processes.	Number 1	Number 4	Number 1
EndPoint Setting	Endpoint Setting Allows setting of the plating endpoint thickness. This is the desired thickness to be plated on the substrate. When the monitor displayed thickness reaches this thickness setting, the monitor displayed thickness will begin flashing rapidly, informing the user that the plating process is done. Also, the Thickness Achieved Output will goes high (true). This output could be used to turn on other remote of alarming device.	0.000	999.9	10.00
Min Rate Alarm	Minimum Rate Alarm Allows the user to set the minimum allowable plating rate. When the plating rate drops below this set value, the displayed rate will flash rapidly. Also there is a Low Rate Alarm Output that will come on at this time. It could be used to turn on other remote alarming device.	0.000	999.9	0.000
Max Rate Alarm	Maximum Rate Alarm Similar to the Minimum Rate Alarm parameter, this	0.000	999.9	9.999

	parameter allows the user to set the maximum allowable plating rate. The displayed rate will flash rapidly, and the High Rate Alarm Output will come on.			
Plate Current Density	Plate Current Density Establishes the current density for the Sensor Crystal electrode.	0.000	1.615	0.001
Tooling Factor %	Tooling Factor Percentage Use to calibrate for the different in thicknesses, if any, between the Sensor Crystal and the plating substrate.	1.000	999.9	100.0

4.5.3.3 Bath Menu

Numonic	Name/Description	Minimum	Maximum	Default
Bath	Bath This parameter contains a list of readily programmed baths. The user can simply select a bath material that the plating monitor will be used with. See Figure___ for a list of selectable bath.			Special1
Type	Type Defines the type of plating bath that the monitor will be used in, either electrode plating or electroless plating.	Elecless	Electro	Elecless
PrePlate Thckness	PrePlate Thickness Defines the thickness to be PrePlated on the crystal, as an adhesion layer, in electroless plating bath. Note if the monitor is set to work in electrode plating bath, this parameter will be turned off.	0.000	999.9	1.000
PrePlate Rate	PrePlate Rate Defines the rate at which the monitor will use in the Sensor Crystal PrePlate process. This parameter will be off if Type parameter is set for Electro.	0.000	999.9	0.200
DePlate Thckness %	DePlate Thickness Percentage Defines a percentage of thickness to be deplated off the Sensor Crystal.	0.000	999.9	50.00
DePlate Rate	DePlate Rate Allows setting of the DePlate rate at which the monitor will use in DePlating the plated material off the Sensor Crystal.	0.000	999.9	0.100

Density	Material Density Allows setting of the density of the material being plated so that the monitor can calculate and display the correct physical film thickness. A list of the commonly used material density is presented in Table 21.	0.800	99.90	1.000
Acoustic Ratio	Acoustic Ratio Allows setting of the acoustic impedance of the plated material. This value is necessary for the monitor to accurately establish the sensor scale factor when the sensor crystal is heavily plated. A list of the commonly used material acoustic impedance is presented in Table 21.	1.500	999.9	8.830
ElecChem	ElectroChemical Equivalent Allows setting of the electro chemical equivalent of the plated material. A list of the commonly used electro chemical equivalent value is presented in Table 21. Note this value is only needed for the electrolytic plating bath. Therefore, this parameter is hidden if the Type parameter is set to Elecless (electroless).	0.000	9.999	1.000

4.5.3.4 Display Menu

Numonic	Name/Description	Minimum	Maximum	Default
Main Display	Main Display Mode This parameter allows a selection of four different Main Display Modes listed in the Minimum column. For a description of each of these modes, refer to Main Display Modes section.	Rate Thk Rate Eff Eff Thk Freq		Rate Thk
Parm Status Display	Parameter/Status Display Allows selection of one of the six Display Modes available to be display in the Parameter/Status Display window. These six Display Modes are listed in the Minimum and Maximum columns. For further detail of these modes, refer to Parameter/Status Display Modes section.	Status Freq ElapTime	TimeToGo Current (a - b)%	Status

4.5.3.5 Setup Menu

Numonic	Name/Description	Minimum	Maximum	Default
Crystal Type	Crystal Type Allows the user to set the monitor to work with different types of crystal frequency. Selectable crystal frequency are listed in the Minimum column.	2.5 MHz 3 MHz 5 MHz 6 MHz		5 MHz
Electro Area	Crystal Electrode Area Allows for Sensor Crystals that have different electrode area. Enter the electrode area in cm^2 if the crystal in use is not the monitor default area.	9.999	0.100	1.370
Thckness Units	Thickness Units Allows the user to change the monitor default thickness measurement unit to a different measurement unit. Warning if selected thickness measurement is not the default unit, the Thickness Unit Display will be off. Selectable units are listed in the Minimum column. For other possible plating measurement units, contact manufacturer.	kX µInch Micron $\mu g/cm^2$ mg/cm^2		Micron
Time Units	Time Units Similar to the Thickness Units parameter, this parameter allows the user the change the manufacturer default setting. The Rate Units Display will be off when the default is changed. Minimum column listed three selectable Rate Measurement Units. Call Maxtek for other possible rate measurement units.	Hrs Min Sec		Min

DAC Thckness Range	Digital to Analog Converter Thickness Range Establishes the full scale value of the DAC. See Digital to Analog Converters section for a detail description.	0.000	Maximum	5.000
Low DAC Rate	Low DAC Rate Establishes the lower limit of the DAC rate scale factor. See Digital to Analog Converters section for further details.	0.000	High rate minus 10	0.000
High DAC Rate	High DAC Rate Establishes the higher limit of the DAC rate scale factor. See Digital to Analog Converters section for further details.	Low rate plus 10	Maximum	9.999
Simulate	Simulate Mode Allows user to turn the monitor Simulate Mode on or off. For detail description of the Simulate Mode operation, refer to Simulation Mode section.	On	Off	Off
Simulate Rate	Simulate Rate Defines the rate at which the monitor will use in Simulate Mode. Refer to Simulation Mode section for a detail description. Note this parameter is hidden if Simulate parameter is set to Off.	0.000	999.9	0.200

4.5.4 Restoring to Default Values

The four material parameters, Tooling Factor, Density, Acoustic Impedance and ElecChem can be reset to their factory set default values by pressing the Status button while both the Up and Down arrow buttons are depressed.

4.6 STATUS ASSESSMENT

4.6.1 Monitor Status

The monitor status can be assessed any time by pressing the Status button. When the Status button is pressed, the following list of status parameters are displayed in the Parameter/Status display:

Simulate mode

Monitor state

Process Number

Top Left display quantity

Top Right display quantity

PRM/STATUS display quantity

Sample mode (ON/OFF)

Deplate mode (Manual/Auto)

Probe Swap mode (Manual/Auto)

Bath Type (Electro/Elecless)

Material (Bath Material)

Time units (Hours/Minutes/Seconds)

Thickness units (KX/µinch/Micron/µg per cm^2/mg per cm^2)

Crystal type (6 Mhz/5 Mhz/3 Mhz/2.5 MHz)

4.6.2 Probe Status

Pressing the Probe status button results in the display of the following information: crystal frequency type and health, crystal frequency in Megahertz, the plating mode of the crystal, and the plating rate on the crystal.

The crystal frequency and type is displayed in the Rate display area.

The crystal frequency, in Megahertz, is displayed in the Thickness display area.

The Probe mode and the plating rate are displayed alternately in the Parameter/Status display area.

4.7 SWAPPING PROBES

Swapping from the current active probe to the Standby probe can be manually initiated at any time. If the Probe Swap parameter is set to Auto then automatic probe swapping can occur.

4.7.1 Manual probe swapping

Manual probe swapping is accomplished by means of the Probe A and Probe B buttons.

4.7.1.1 Assessing the probe status prior to initiating the swap.

Pressing the Probe button for the probe that you wish to switch over activates the probe status display. The probe status display provides you with the information you need to be sure that the alternate probe is working properly before you command the swap.

4.7.1.2 Preplating prior to swapping.

Preplating of the standby probe can be initiated at any time prior to swapping probes by pressing the Standby Probe's button and then pressing Preplate button while holding the Standby Probes button down. This will initiate the Preplate cycle on the Standby probe. How do we terminate? Care must be taken to insure that the Standby Probe's button is pressed and held prior to pressing the Preplate button or a Preplate cycle may be initiated on the Active probe.

4.7.1.3 Commanding the swap.

To command the swap, simply press the Plate button while continuing to hold the Probe button down. The monitor will switch over to the alternate probe and the Probe status display will indicate that the probes have been swapped. The thickness accumulated on the previously active probe prior to the swap will be added to that accumulated on the new probe after the swap so that the displayed thickness will continue to increase at the displayed rate.

4.7.1.4 Deplating the Standby Probe.

Deplating of the Standby probe can be initiated at any time by pressing the Standby Probe's button and then pressing the Deplate button while holding the Standby probe's button down. This will initiate the Deplate cycle on the Standby probe. Care must be taken to insure that the Standby probe's button is pressed and held, prior to pressing the Preplate button. Otherwise, Deplate cycle may be initiated on the Active probe.

4.7.1.5 Manual termination of Preplate or Deplate on the Standby probe.

Manual termination of a Preplate or Deplate cycle on the Standby probe can be accomplished by pressing the Standby probe's button and then pressing the Stop button while continuing to hold the Standby probe's button down. Again, care must be taken to insure that the Standby probe's button is pressed and held prior to pressing the Stop button or the ongoing active process may be inadvertently terminated.

4.7.2 Automatic probe swapping

When the Probe Swap parameter is set to Auto, certain conditions will initiation an automatic probe swap. Conditions that will initiate an automatic probe swap are listed below:

4.7.2.1 Auto probe swap on active probe failure.

If the Probe Swap parameter is set to Auto, and the monitor is in the Plate State, then an automatic swap to the standby probe will be initiated if the active probe should fail.

4.7.2.2 Alternating Probe mode.

When the monitor is in the Alternating Probe mode the probe is automatically swapped at the end of each sample period.

4.7.2.3 Failed Standby Probe inhibits automatic swap.

The Standby probe is checked for a valid frequency signal prior to initiation of an automatic probe swap. If the Standby probe has failed, the swap is not initiated and the monitor automatically goes into the Auto Complete mode.

4.8 EXTERNAL INTERFACE

In addition to front panel controls, PM-700 Series Plating Monitors are equipped with I/O connectors allowing the monitor to interface with external devices. The I/O connectors are located on the rear panel of the monitor. The following sections provide descriptions of each connector.

4.8.1 Discrete Inputs

Discrete input signals can be used to remotely initiate any one of the five front panel functions. With exception of the Swap Probes Input, all other inputs act like a front panel key is pushed. Start PrePlate Input initiates preplate process, Start Plate initiates plating process, Start DePlate initiates deplating process, and Stop terminates any active process or clears failure messages. Swap Probes input will cause the monitor to swap from active probe to the standby one. This input is not available in the PM-700.

Each discrete input is independently pulled up to 5 volts through a 4.7 kς resistor. A ground signal is required to activate an input function. The ground signal on pin 6 of the Discrete Input connector is provided for this purpose. Discrete Input signals are provided through a six pin Mini-Din circular connector. Pin assignments are listed below and Figure 9 shows the connector outline.

Table 3 Discrete Input Connector Pin Assignments

Pin Number	**Signal Name**
1	Start Plate
2	Start PrePlate
3	Start DePlate
4	Stop
5	Swap Probes(PM-720 & PM-740)
6	Ground

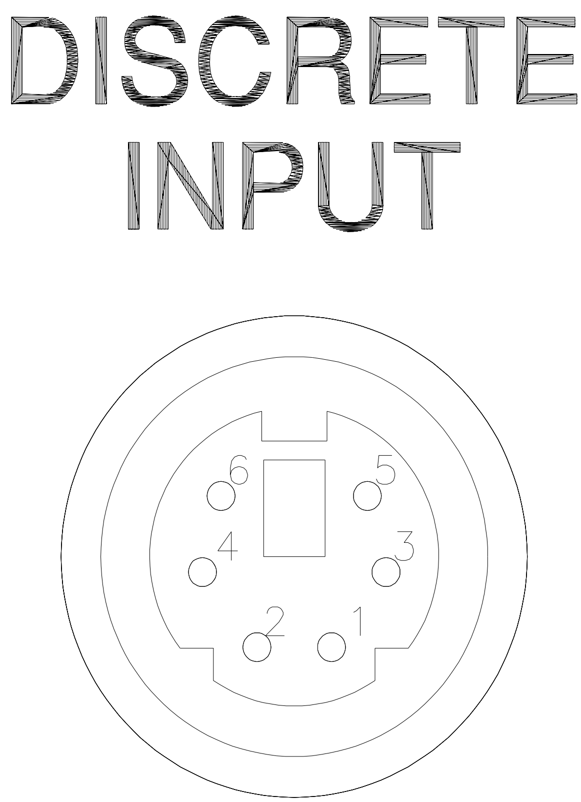

Figure 9 Discrete Input Connector, 6 pin Mini-Din

4.8.2 Discrete Outputs

There are six Discrete Outputs available. These outputs will become true when the monitor has reached a certain user programmed set points or when the monitor is at a certain state. PrePlate Achieved Output will become true when the displayed PrePlate thickness has reached the programmed PrePlate Thickness. In the same manner, the Thickness Achieved Output will come on when the displayed plating thickness has reached the programmed Thickness Endpoint. Either Low Rate Alarm Output or High Rate Alarm Output will become true should the displayed rate drops lower than Minimum Rate Alarm Setpoint or raise higher than Maximum Rate Alarm Setpoint. Crystal A Failed Output will become true when problems associate with Sensor Probe A is detected. Likewise, if problems associate with Sensor Probe B is detected, Crystal B Failed Output (*) will become true.

All discrete outputs are CMOS logic level signals, 0 to 5 VDC, and each has a source impedance of 100 ohms. These outputs are designed to drive solid state output modules, which then can be used to drive other external devices. Discrete Output signals are provided through an eight pin Mini-Din circular connector. Pin assignments are listed below and Figure 10 shows the connector layout drawing.

Table 4 Discrete Output Connector Pin Assignments

Pin Number	Signal Name
1	PrePlate achieved
2	Thickness achieved
3	Low rate alarm
4	High rate alarm
5	Crystal A failed
6	Crystal B failed *
7	Spare
8	Ground

* PM-720 and PM-740 Models only

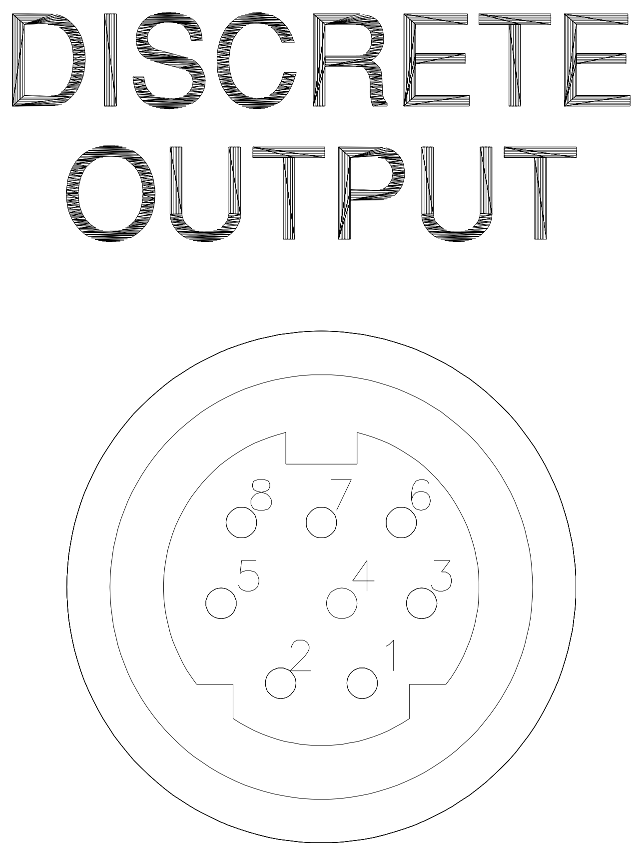

Figure 10 Discrete Output Connector, 8 Pin Mini-Din

4.8.3 Digital to Analog Converters

Two independent Digital to Analog Converters (DAC's) are provided, one for Rate and one for Thickness. The DAC outputs have a range of 0 to 5 volts dc. Refer to Figure 11 for the DAC connector outline and Table 5 below for the pin out assignments.

4.8.3.1 Thickness DAC

The scale factor of the thickness DAC is established by the Programmable Parameter DAC Thickness Range, which establishes the full scale value of the DAC. i.e. setting the DAC Thickness Range at 500 microns will result in a DAC output which varies linearly from 0 to 5 volts as the thickness varies from 0 to 500 microns. The measurement units for the DAC are the same as those for the Thickness display. The quantity that is converted is the magnitude of the Thickness; therefore, an increasingly negative Thickness going from 0 to -500 microns will also be converted to a 0 to 5 volt dc output.

4.8.3.2 Rate DAC

The scale factor of the Rate DAC is established by the two parameters, Low DAC Rate and High DAC Rate. The output of the DAC varies linearly from 0 to 5 volts dc as the magnitude of the Rate varies from the Low DAC Rate level to the High DAC Rate level. Negative rates are converted to the same output as positive rates of the same magnitude. Assuming that the nominal rate of the process is 1.5 microns per minute we might set the Low DAC Rate at 1 micron per minute and the High DAC Rate at 2 microns per minute. In this case the output will vary linearly from 0 to 5 volts dc as the Rate varies from 1.0 micron per minute to 2.0 microns per minute. A rate of 1.5 microns per minute would result in an output of 2.5 volts dc. For rates between 0 and the Low DAC Rate value, the DAC output is held at zero. At Rate magnitudes above the High DAC Rate value, the DAC output is held at 5 volts.

Table 5 DAC I/O Connector Pin Assignments

Pin Number	**Signal Name**
1	Thickness
2	Return (GND)
3	Rate
4	Return (GND)
5	Zero Scale
6	Full Scale
7	Ground

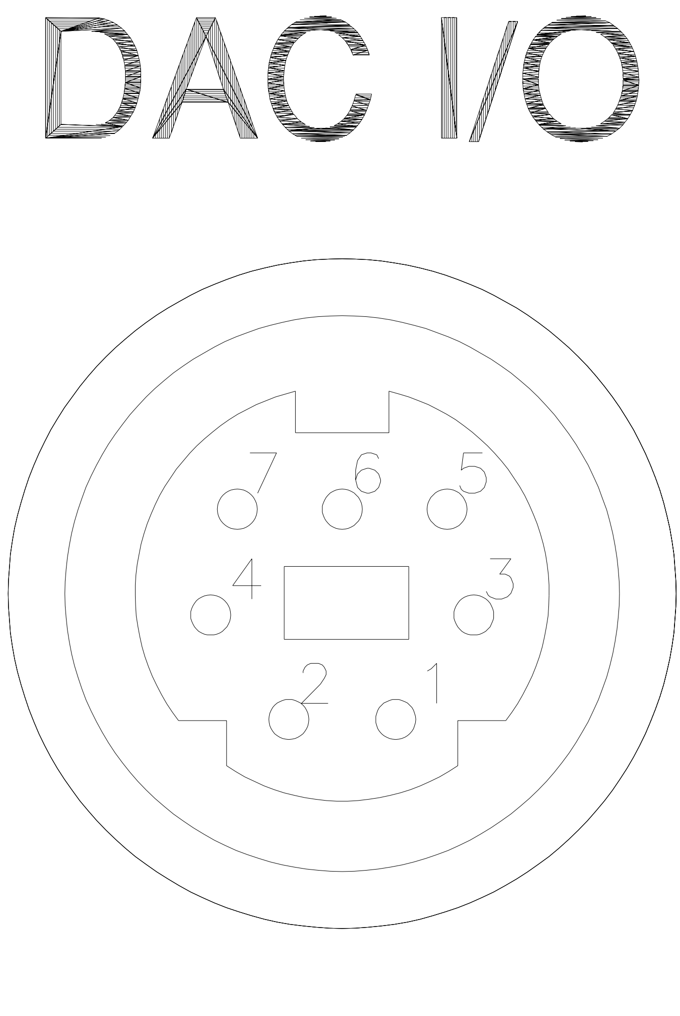

Figure 11 DAC I/O Connector, 7 Pin Mini-Din

4.8.4 Computer Connection

A 9 pin, D shell, male connector (IBM AT type) is provided as an RS-232 serial port. A standard 9 pin female to female RS- 232 cable is used to interface between the Plating Monitor and a host computer. To minimize Electromagnetic Interference, a shielded cable should be used. RS-232 connector pin assignments are listed below.

Table 6 RS-232 Connector Pin Assignments

Pin No.	Numonic	Input/Output	Description
1	Not used		No connection
2	TX	Output	Transmit data
3	RX	Input	Receive data
4	Not used		No connection
5	GND	Ground	Signal ground
6	Not used		No connection
7	CTS	Input	Clear to Send
8	RTS	Output	Request to Send
9	Not used		No connection

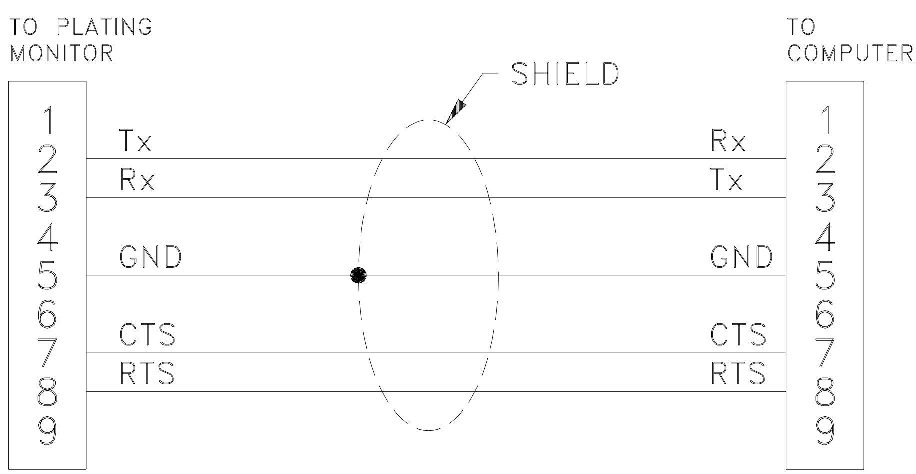

Figure 12 Typical RS-232 Interface Cable

4.8.4.1 RS-232 Interface

The PM-700 Series Plating Monitor will communicate through a standard RS-232 Serial I/O port. Through this port, the host computer will be able to initiate the following classes of operations:

1. Upload parameter store from the plating monitor to host computer.
2. Restore parameter store from host computer to the plating monitor.
3. Remotely activate the monitor.
4. Upload the monitor status from the plating monitor to host computer.
5. Start or stop automatic data transmission from the monitor to host computer.
6. Upload single data log from plating monitor to host computer.

4.8.4.2 Protocol

These operations are initiated by the host computer by sending messages to the monitor. All messages sent and received by the plating monitor must be in the following format:

1. Two Byte header - FFh, FEh or Chr$(FFh)+Chr$(FEh)
2. One byte instruction code:
    a. 10h - Upload parameter store
    b. 20h - Restore parameter store
    c. 30h - Remotely activate
    d. 40h - Upload monitor status
    e. 50h - Establish automatic data logging
    f. 60h - Upload single data log

1. One byte message length.
2. Message or command code.
3. One byte checksum. (The checksum is the compliment of the one byte sum of all bytes from the instruction code to the end of the message or command.)

The plating monitor's RS232 port is set up to operate with the following specifications:

9600	-	Baud
8	-	Bit data
No	-	Parity
1	-	Stop bit

4.8.4.3 Remote Control

4.8.4.3.1 Upload Parameter Store (Instruction 10h)

This operation outputs the entire parameter store from the monitor to the host computer. All the parameters are output with the most significant byte first. The parameters are output in the following order:

Table 7 Upload Parameter Store

No.	Position	Description	Length (Bytes)	Decimal Point Pos.
1	1	Plate endpoint	3	*
2	4	Preplate endpoint	3	*
3	7	Minimum rate alarm	3	*
4	10	Maximum rate alarm	3	*
5	13	Preplate rate	3	*
6	16	Dwell time in %	3	3
7	19	Interval time (seconds)	3	N/A
8	22	Deplate rate	3	*
9	25	Tooling factor %	3	1
10	28	Material density (gm/cm^3)	3	1
11	31	Acoustic imp. [10^5 gm/(cm^{2}sec)]	3	1
12	34	Electrochemical eqv. (gm/Amphr)	3	1
13	37	DAC thickness range	3	*
14	40	DAC low rate	3	*
15	43	DAC high rate	3	*
16	46	Simulate rate (μg/cm^2/min)	3	1
17	49	Plate current density	3	*
18	52	Deplate thickness %	3	3
19	55	Electrode area in cm^2	3	1
20	58	Plating material	1	N/A
21	59	Sample (On|Off)	1	N/A
22	60	Bath type(Electro|Elecless)	1	N/A
23	61	Main display	1	N/A

No.	Position	Description	Length (Bytes)	Decimal Point Pos.
24	62	Parameter/Status display	1	N/A
25	63	Crystal type	1	N/A
26	64	Deplate (Auto|Manual)	1	N/A
27	65	Menu number	1	N/A
28	66	Thickness units	1	N/A
29	67	Time units	1	N/A
30	68	Simulate mode (On|Off)	1	N/A
31	69	Measurement mode **	1	N/A
32	70	Probe swap (Auto|Manual) **	1	N/A
33	71	Process number	1	N/A
34	72	Rate Filter (Fast|Medium|Slow)	1	N/A
Total			72	

** These parameters are only available in dual probe models.

The first 19 variables are parameter values. They contain the integer value of the parameter that they represent. Their true value can be determined by dividing their value by 10*decimal point position. For example, if the Electrode area parameter were set to 1.370 cm^2 then that parameter would contain the integer 1370. The true value = $1370/[10^{(4-1)}] = 1.370$. Where 1 represents the decimal point position for the electrode area parameter.

(*) The asterisks under some decimal point positions indicate that the decimal point position will change depending on the thickness and rate units. For the thickness parameters, such as Plate Endpoint and Preplate Endpoint, the decimal point position is held in the variable thickness decimal point position. And, for the rate parameters, such as preplate rate, the decimal point position is held in the variable rate decimal point position. The current decimal point position is held in the current decimal point variable. These variables are sent with the Upload machine status instruction, which is explained later in this section.

The last 14 variables are select parameters that contain a one byte integer that indicate that parameter's setting. The select parameter values are shown in the table below.

Plating material - This integer can range from 156 to 189.

Table 8 Select Parameter codes

Select Parameter	Number	Description
Ag	156	Silver
As	157	Arsenic
Au+1	158	Gold with valence 1
Au+3	159	Gold with valence 3
Cd	160	Cadium
Co	161	Cobalt
Cr+3	162	Chromium with valence 3
Cr+6	163	Chromium with valence 6
Cu+2	164	Copper with valence 2
Fe	165	Iron
In	166	Indium
Ni	167	Nickel
Ni 1% Phosphorus	168	Nickel with 1% phosphorus
Ni 2% Phosphorus	169	Nickel with 2% phosphorus
Ni 6% Phosphorus	170	Nickel with 6% phosphorus
Ni 8% Phosphorus	171	Nickel with 8% phosphorus
Ni 9% Phosphorus	172	Nickel with 9% phosphorus
Ni 10% Phosphorus	173	Nickel with 10% phosphorus
Ni 12% Phosphorus	174	Nickel with 12% phosphorus
NiB	175	Nickel Boron
Pb	176	Rubidium
Pd	177	Palladium
Pt	178	Platinum
Rh	179	Rhodium
Ru+3	180	Ruthenium with valence 3
Sb	181	Antimony
Sn+2	182	Tin with valence 2
Sn+4	183	Tin with valence 4

Select Parameter	Number	Description
Zn	184	Zinc
Special1	185	For material not listed
Special2	186	For material not listed
Special3	187	For material not listed
Special4	188	For material not listed
Special5	189	For material not listed
Sample	34	On
	35	Off
Bath Type	128	Electrolytic
	129	Electroless
Main Display	71	Rate and Thickness
	72	Rate and Efficiency
	73	Efficiency and Thickness
	74	Frequency
Parameter/Status Display	36	Status
	37	Frequency
	38	Elapsed Time
	39	Time To Go
	40	Current
	41	(A - B)% *
Crystal Type	56	2.5 MHz
	57	3 MHz
	58	5 MHz
	59	6 MHz
Deplate	78	Auto
	79	Manual
Menu number	61	Mode Menu
	62	Process Menu
	63	Bath Menu

Select Parameter	Number	Description
	64	Display Menu
	65	Setup Menu
Thickness Units	191	K⊕
	192	µinch
	193	Micron
	194	$\mu g/cm^2$
	195	mg/cm^2
Time Units	100	Hours
	101	Minutes
	102	Seconds
Simulate Mode	34	On
	35	Off
Measurement Mode *	109	Single
	110	Alternating
	111	Dual
Probe Swap *	78	Auto
	79	Manual
Process Number	45	Process 1
	46	Process 2
	47	Process 3
	48	Process 4

* This parameter is only available in the dual probe models.

To initiate an Upload parameter store output, the host computer would send the following data stream:

Header (2 bytes)		**Instruction Code (1 byte)**	**Message Length (1 byte)**	**Command Code or Message**	**Checksum (1 byte)**
FFh	FEh	10h	1h	0h	EEh

4.8.4.3.2 Restore Parameter Store (Instruction 20h)

This operation inputs the entire parameter store from the host computer to the plating monitor and then stores these values in their respective memory locations. To initiate this operation, the computer would output the following data stream:

Header (2 bytes)		**Instruction Code (1 byte)**	**Message Length (1 byte)**	**Command Code or Message**	**Checksum (1 byte)**
FFh	FEh	20h	47h	71 bytes	checksum

4.8.4.3.3 Remotely Activate (Instruction 30h)

This operation allows the computer to perform a remote key press of the plating monitor's front panel buttons through the RS232. The valid key codes are as follows:

Table 9 Remote Activation Command Codes

Remote Activation Command Code	**Description**
1h	Set DAC outputs to zero scale
2h	Set DAC outputs to full scale
4h	Manual probe swap *
8h	Stop button
10h	Deplate button
20h	Preplate button
40h	Plate button

* This parameter is only available in the dual probe models.

The data stream format to initiate a remote activation command is as follows:

Header (2 bytes)		**Instruction Code (1 byte)**	**Message Length (1 byte)**	**Command Code or Message**	**Checksum (1 byte)**
FFh	FEh	30h	1h	1 byte	checksum

For example, to initiate a remote plate start, the computer would send:

Header (2 bytes)		Instruction Code (1 byte)	Message Length (1 byte)	Command Code or Message	Checksum (1 byte)
FFh	FEh	30h	1h	40h	8Eh

4.8.4.4 Remote Monitoring

4.8.4.4.1 Upload Machine Status (Instruction 40h)

This operation outputs all relevant machine variables, flag registers, and I/O registers to the host computer. The variables are output in the following order:

Table 10 Upload Machine Status Codes

Number	Position	Description	Length (Bytes)
1	1	Rate scale factor x 256	3
2	4	Thickness scale factor x 256^2	3
3	7	Current scale factor x 256^2	3
4	10	Rate decimal position	1
5	11	Thickness decimal position	1
6	12	Current decimal position	1
7	13	Monitor status register	1
8	14	Failure register	1
9	15	Flag register	1
10	16	Mode register	1
11	17	RS-232 error register	1
12	18	Output #1 status register	1
13	19	Output #2 status register	1
Total			19

The following table presents bit map for all registers.

Table 11 Monitor Status Register

Bit Number	Description

0	Ready flag
1	Deplate flag
2	Internal
3	Preplate flag
4	Plate flag
5	Internal
6	Internal
7	Internal

Table 12 Failure Register

Bit Number	**Description**
0	Internal
1	Internal
2	Internal failure
3	EPROM failure
4	Parameter storage failure
5	Permanent oscillator failure
6	Oscillator failure
7	Power failure

Table 13 Flag Register

Bit Number	**Description**
0	Internal
1	Internal
2	Internal
3	Preplate set point
4	Plate set point
5	Internal
6	Internal
7	Internal

Table 14 Mode Register

Bit Number	**Description**
0	Internal

1	Internal
2	Internal
3	Internal
4	Auto complete flag
5	Excess current flag
6	Sample probe flag
7	Internal

Table 15 RS-232 Error Register

Bit Number	Description
0	Input buffer full error
1	Internal
2	Internal
3	Internal
4	Internal
5	Internal
6	Internal
7	Internal

Table 16 Output #1 Status Register

Bit Number	Description
0	Preplate endpoint
1	Plate endpoint
2	Low rate alarm
3	High rate alarm
4	Probe A failed
5	Probe B failed
6	Internal
7	Internal

Table 17 Output #2 Status Register

Bit Number	Description
0	Positive current A

1	Negative current A
2	Positive current B
3	Negative current B
4	Internal
5	Internal
6	Internal
7	Internal

To initiate a machine status output, the computer would send the following message:

Header (2 bytes)		**Instruction Code (1 byte)**	**Message Length (1 byte)**	**Command Code or Message**	**Checksum (1 byte)**
FFh	FEh	40h	1h	0h	BEh

4.8.4.5 Data Logging

4.8.4.5.1 Establish automatic data logging

This operation allows the computer to setup the plating monitor to automatically output a stream of variables to the RS232 every 100 milliseconds. The variable stream is determined by the bit values in the message.

Table 18 Data Logging Bit Map

Byte No.	Bit No.	Description	Units	Length (Bytes)	Decimal Point Pos.
1	0	Display thickness	Monitor	3	*
	1	Display rate	Monitor	3	*
	2	Display efficiency	0.1%	3	1
	3	Active probe current	counts	2	*
	4	Elapsed time	seconds	3	N/A
	5	Time to go	seconds	3	N/A
	6	Output #2 register	N/A	1	N/A
	7	Active probe flag register	N/A	1	N/A
2[1]	0	Display register	N/A	1	N/A
	1	Active probe freq or period[2]	Hertz	4	N/A
	2	Probe A freq or period[2]	Hertz	4	N/A
	3	Probe A thickness	Monitor	3	*
	4	Probe A rate	Monitor	3	*
	5	Probe A efficiency	0.1%	3	1
	6	Probe A current	counts	2	*
	7	Probe A flag register	N/A	1	N/A
3[1]	0	Internal	N/A	N/A	N/A
	1	Internal	N/A	N/A	N/A
	2	Probe B freq or period[2]	Hertz	4	N/A
	3	Probe B thickness	monitor	3	*
	4	Probe B rate	monitor	3	*
	5	Probe B efficiency	0.1%	3	1
	6	Probe B current	counts	2	*
	7	Probe B flag register	N/A	1	N/A

[1] Bit 2-7 of byte #2, and #3 are only available in dual probe models.
[2] Models PM-700 and PM-720 provide probe frequency × 25.6. Models PM-710 and 740 provide probe period, converted to frequency using $f = \frac{(98.3 * 10^6 * 500 * 256^2)}{Period}$

The displayed rate, thickness, and efficiency values are absolute. Their negative sign bits are stored in the probe flag register and are bit mapped as follows:

Table 19 Probe Flag Register

Bit No.	Description
5	Negative sign (display thickness)
6	Negative sign (display rate)
7	Negative sign (display efficiency)

The current value is in the units of counts and ranges from 1 to 2999. To convert this value to the displayed value, multiply by the current scale factor/256^2 and divide by 10*current decimal point position. This value is an absolute value for the probe current. Bits 0, 1, 2, and 3 of the Output2 register determine whether the current is positive or negative or none at all. The bit map for the Output2 register is shown in Table 17 on page 57.

If bits 0 and 1 of the Output2 register are false (=0), then the output current to the probe-A is zero regardless of the probe current value. But, if bit 0 is true, then the output current is positive. Or, if bit 1 is true, then the output current is negative.

One important note is that the PM-710 and PM-740 output probe period instead of the probe frequency. To convert the period to frequency, use the following equation:

$$f = \frac{\left(98.3 * 10^6 * 500 * 256^2\right)}{Period}$$

To initiate automatic data logging, the computer would send a one byte message in the standard format. The variables will be sent in the order they are displayed in above. For example, to setup the monitor to automatically output the displayed rate and thickness, the following message would be sent to the monitor:

Header (2 bytes)		**Instruction Code (1 byte)**	**Message Length (1 byte)**	**Command Code or Message**	**Checksum (1 byte)**
FFh	FEh	50h	1h	3h	ABh

To terminate the automatic data logging, the host computer would send the following message:

Header **(2 bytes)**		**Instruction Code** **(1 byte)**	**Message Length** **(1 byte)**	**Command Code or Message**	**Checksum** **(1 byte)**
FFh	FEh	50h	1h	0h	AEh

4.8.4.5.2 Single data log

This operation allows the computer to initiate a single data log function.

To a single data log function, the computer would send a one byte message in the standard format. The variables will be sent in the order they are displayed in above. For example, to setup the monitor to automatically output the displayed rate and thickness, the following message would be sent to the monitor:

Header **(2 bytes)**		**Instruction Code** **(1 byte)**	**Message Length** **(1 byte)**	**Command Code or Message**	**Checksum** **(1 byte)**
FFh	FEh	60h	1h	3h	9Bh

5. TROUBLESHOOTING

This section is included to help isolate, as rapidly as possible, any failures that may occur in the monitor setup.

The monitor's 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.

The following table describes possible problems that could occur. With each symptom is a list of probable causes.

CAUTION

Remove AC line power before disassembling the monitor to avoid electrical shock.

5.1 TROUBLE-SHOOTING AIDS

Symptom	Probable Causes
1. Front panel displays never illuminate:	Voltage selector p.c. board is in the wrong position. Line fuse is blown, rear panel fuse holder.
2. Random "P FAIL" occurrence:	Low AC line voltage. Intermittent AC line connection.
3. Random probe failed indication:	Defective or overloaded sensor crystal. Defective crystal retainer ring. Defective sensor oscillator. Improper installation of sensor crystal. Wrong crystal frequency selection. Defective cables. Solution leakage - crystal retainer or O-ring not properly installed. Failure in probe buffer circuitry in the monitor.

4. Faulty DAC outputs:	External recording equipment puts an excessive load on the DAC. Improper DAC wiring. Programmable DAC ranges are improperly set in the monitor.
5. Monitor does not retain programmed data in memory:	Failure in RAM power circuitry. Aged or defective battery.

5.2 FAIL MESSAGES FOLLOWING POWER ON

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 can NOT be reset. 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. Following is a summary of detected failures, with displayed messages and the necessary actions to reset them.

Detected Failure	**Failure Message**	**Reset by**
Power Failure	P FAIL	Press STOP Button
Sensor Failure	O FAIL	If less than 2 seconds: Self clearing If greater than 2 seconds: Press STOP button
Invalid Parameters	C FAIL	Press STOP button, parameter values will be preset
RAM Failure	I FAIL	Replacement of defective RAM(s)
ROM Failure	E FAIL	Replacement of defective ROM(s)

5.2.1 Power Failure

Since power interruptions may seriously affect the run, indication of any significant A.C. line disruptions is provided by the P FAIL message.

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.

5.2.2 Sensor Probe Failure

An "O" Fail message indicates an improper or missing signal from the oscillator located in the Sensor Probe. The problem is most likely with the sensor crystal, however, failures in the oscillator, cable, or sensor head can also generate this failure message. The "O" 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.

5.2.3 Invalid Parameters

If the integrity of parameter values 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 monitor. **The C FAIL message can be cleared by pressing the STOP button. The clearing of the failure message also results in resetting of all parameters values to their defaults.** If there are no other failure messages indicated then it is possible that the monitor Lithium battery simply need to be replaced. If your monitor still does not retain the parameter values intact (C FAIL flashes after periods of power down) after replacement of the battery then your monitor should be returned for service.

5.2.4 RAM Failure

In the case of a failure in the monitor's data memory, RAM, the "I" FAIL message will be displayed. To confirm the RAM failure, cycle the AC power to the monitor. 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.

5.2.5 ROM Failure

In the case of a failure in the program memory, ROM, the "E" Fail message is displayed. A ROM failure is treated in exactly the same manner as a RAM failure. Please read the preceding section.

5.3 PROBE FAILED INDICATION

If a probe failure occurs, the red LED in the Probe Status window will be lit. If the failed probe is the active one then the "O FAIL" message, described in Sensor Probe Failure section on page 65, is also enunciated. Use Stop Button to clear the failure message once the problem has been corrected. To clear an inactive probe failed indication, after the problem has been corrected, press that probe button. For example, if Probe B is the inactive probe and it failed. The red LED in the Probe Status window will be lit (O FAIL message will not be enunciated). After

Probe B is repaired, press Probe B button will clear the red LED and the yellow LED should come on.

6. APPENDIX

6.1 THEORY OF THE QUARTZ CRYSTAL MICROBALANCE

6.1.1 Crystal Frequency

The monitor uses a quartz crystal as the basic transducing element. The quartz crystal itself is a flat circular plate approximately one inch (2.5 cm) in diameter and 0.011 to .0132 inches (.028-.033 CM) thick for 6 and 5 MHz. 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 5 or 6 Megahertz depending on crystal selected.

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

6.1.2 Crystal Health Calculation

Crystal health decreases from a value of 100% for an uncoated crystal blank to 0% at a total coated 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 92.5 Microns.

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, or stripped, several trial runs should be made to determine the point at which the crystal fails (O FAIL message flashes) and subsequent crystals should then be replaced or stripped well in advance of this point.

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

6.1.3 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.

$$TK_f = \frac{N_q \cdot \rho_q}{\rho_f \cdot f^2}\left(f_q - f\right) \qquad (1)$$

where: N_q = 1.668 X 10^5 cm/sec.

Frequency constant for an AT cut quartz

crystal vibrating in the thickness shear mode.

ρ_q = Density of quartz (gm/cm^3).

f_q = Resonant frequency of the uncoated crystal.

f = Resonant frequency of the loaded crystal.

TK_f = Thickness of plated material

ρ_f = Density of the material (gm/cm^3).

This equation proved to be adequate in most cases. However, the constant of proportionality is not actually constant because one of the terms 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:

$$TK_f = \frac{N_q \cdot \rho_q}{\rho_f}\left(\tau - \tau_q\right) \qquad (2)$$

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

τ_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 layer led to the equation below.

$$TK_f = \left(\frac{\rho_q}{\rho_f}\right) \cdot N_q \cdot \left(\frac{\tau}{\pi R_z}\right) \cdot \arctan\left[R_z \tan \pi\left(\frac{\tau - \tau_q}{\tau}\right)\right] \qquad (3)$$

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

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 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 material mass is stored. For each subsequent measurement the new corrected total mass is calculated and the mass deposited since the start of deposit is determined by subtracting the initial mass from the total mass.

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

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

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

6.1.4 Rate Calculation

The plating rate is calculated by dividing the change in thickness between measurements by the time between measurements. The rate is then filtered by a three-pole digital filter to minimize the quantizing and sampling noise introduced by the discrete time, digital nature of the measurement process. Following a step change, the displayed rate will settle to 95% of the final value in 7 seconds and to 99.5% of the final value in 8.5 seconds.

6.2 FINE TUNING WITH EMPIRICAL CALIBRATION

If the density and acoustic impedance of the material being plated is known, the values should be entered into the Plating Monitor, and a trial plating deposition should be made. If the displayed thickness does not agree with an independently measured thickness, the unit 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 21 on page 72 provides density of some materials which should provide guidance as to the approximate density. If the acoustic impedance is unknown, use the value of quartz 8.83.

6.2.1 Density

This Material Density is probably available from your chemical supplier. If not, follow the procedure below to establish the density.

1. Use a fresh sensor crystal.
2. Place 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 out-of-bath thickness measuring device.
4. Determine the average thickness on the test substrate.
5. If the displayed thickness is lower than the actual measured thickness, decrease the Density value. The displayed thickness will start increasing. Stop when the displayed thickness equals the actual measured thickness. Inversely, if the displayed thickness is higher than the measured thickness, increase the Density value until the displayed thickness agrees with the measured thickness.

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

6.2.2 Tooling Factor

1. Use a fresh sensor crystal.
2. Place a test substrate in a location which is representative of where the production substrate will be located.
3. Make a trial deposition with the material density as determined above.
4. Determine the average thickness on the test substrate with a thickness measuring device.
5. If the actual measured thickness is lower than the displayed thickness, increase the Tooling Factor value. This will bring the displayed thickness up. Stop when the displayed thickness equals the measured thickness. If the measured thickness is higher than the displayed thickness, decrease Tooling Factor until the displayed thickness agrees with the actual measured thickness.

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

6.2.3 Acoustic Impedance

1. Use a heavily loaded sensor crystal with a crystal health of about 75%.
2. Plate on the sensor crystal until the crystal health approaches 50%.

3. Measure the actual thickness of the plating.
4. If the displayed thickness is lower than the measured thickness, increase the Acoustic Impedance until they are matched. If the displayed thickness is higher than the measured thickness, decrease the Acoustic Impedance value. Stop when the displayed thickness agrees with the measured thickness.

This calibrates the acoustic impedance for the material being deposited.

Record these specific parameters determined above for future reference.

Table 20 Summary of Calibration Adjustment

SUMMARY OF 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

6.3 LIST OF MATERIAL CONSTANTS

Table 21 Material Constants

Material	Symbol	Density	Impedance	ElecChem*
Antimony	Sb	6.62	11.49	1.514
Arsenic	As	5.73	9.14	0.932
Cadmium	Cd	8.64	12.95	2.097
Chromium+3	Cr+3	7.20	28.95	0.323
Chromium+6	Cr+6	7.20	28.95	0.323
Cobalt	Co	8.71	25.74	1.099
Copper+2	Cu+2	8.96	20.21	1.186
Gold(ous)	Au+1	19.30	23.18	7.348
Gold(ic)	Au+3	19.30	23.18	2.449
Indium	In	7.30	10.50	1.428
Iron(ous)	Fe	7.86	25.30	1.042
Lead	Pb	11.30	7.81	3.865
Nickel	Ni	8.91	26.68	1.095
Nickel 1%Phosphorus	Ni 1%P	8.85	26.48	1.095
Nickel 2%Phosphorus	Ni 2%P	8.79	26.16	1.095
Nickel 6%Phosphorus	Ni 6%P	8.56	24.88	1.095
Nickel 8%Phosphorus	Ni 8%P	8.44	24.24	1.095
Nickel 9%Phosphorus	Ni 9%P	8.39	23.92	1.095
Nickel 10%Phosphorus	Ni 10%P	8.33	23.60	1.095
Nickel 12%Phosphorus	Ni 12%P	8.21	22.96	1.095
Nickel Boron	NiB	8.77	26.15	1.095
Palladium	Pd	12.00	24.73	1.985
Platinum	Pt	21.40	36.04	1.819
Rhodium	Rh	12.41	42.05	1.280
Ruthenium+3	Ru+3	12.41	----	1.259
Silver	Ag	10.50	16.69	4.024
Tin+2	Sn+2	7.30	12.20	2.214
Tin+4	Sn+4	7.30	12.20	1.106

Zinc	Zn	7.14	17.18	1.219
Special1		1.00	8.83	1.000
Special2		1.00	8.83	1.000
Special3		1.00	8.83	1.000
Special4		1.00	8.83	1.000
Special5		1.00	8.83	1.000

* ElecChem = Electro Chemical Equivalent

DATA LOG

Process/ Material	PrePlate Thickness	Plating Endpoint Thickness	Material Density	Acoustic Impedance	Tooling Factor