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L&SP 4475

AIRCO

Temescal

Model FDC 8000–1

(Part No. 0506-1010-0)

and

Model FDC 8000–2

(Part No. 0506-1010-1)

Film Deposition Controller

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Terms and Conditions

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THERE ARE NO EXPRESS OR IMPLIED WARRANTIES THAT EXTEND BEYOND THE WARRANTY HEREINABOVE SET FORTH. THERE IS NO WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE WITH RESPECT TO THE APPARATUS OR ANY PART OR COMPONENT THEREOF AND NO WARRANTY SHALL BE IMPLIED BY LAW.

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Any obligations on Airco's part under this Performance Warranty are subject to the following requirements: (x) the nature of the failure of the apparatus to comply with the specifications must be promptly reported to Airco in writing; (y) if the apparatus has been delivered and field tested, the Purchaser must return the apparatus or any part or component to Airco upon its request, not later than sixty-seven (67) days after initial shipment to Purchaser, to the address designated by Airco, during normal business hours, transportation charges prepaid; and (z) upon examination and testing by Airco, the apparatus must be found not to comply with the specifications. Return trip transportation charges for the apparatus or any part or component shall be paid by the Purchaser. This Performance Warranty shall be void and the apparatus shall be deemed to be purchased AS IS in the event that the entire purchase price has not been paid within thirty (30) days of original shipment of the apparatus.

THERE ARE NO EXPRESS OR IMPLIED WARRANTIES THAT EXTEND BEYOND THE WARRANTY HEREINABOVE SET FORTH. THERE IS NO WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE WITH RESPECT TO THE APPARATUS OR ANY PART OR COMPONENT THEREOF AND NO WARRANTY SHALL BE IMPLIED BY LAW.

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USER RESPONSIBILITY

This equipment will perform in accordance with the instructions and information contained in this manual, and its referenced documents, when such equipment is installed, operated, and maintained in compliance with such instructions. The equipment must be checked periodically. Defective equipment shall not be used. Parts that are broken, missing, plainly worn, distorted, or contaminated, shall be replaced immediately. Should such repair or replacement become necessary, Airco recommends that a telephonic or written request for service be made to Airco Temescal.

The equipment, or any of its parts, shall not be altered without the prior written approval of Airco Temescal. The user and/or purchaser of this equipment shall have the sole responsibility for any malfunction which results from improper use, faulty maintenance, damage, improper repair or alteration by any party other than Airco Temescal.

SAFETY

All standard safety procedures associated with the safe handling of electricity must be observed. Always disconnect power when working inside the FDC-8000. Only trained personnel should attempt to service the instrument.

HEALTH HAZARD

The condensates deposited on the tank walls of a vacuum system are generally in the form of extremely fine particles. The nature, as well as the form, of the materials poses the following potential health hazards:

a) Inhaling fine particles (powder) may cause damage to the lungs. Wear a protective respirator mask with a fine filter to help prevent this.

b) Some substances are toxic and inhaling them should be avoided. Take steps to ascertain whether or not the material being deposited is a known toxic substance.

c) Certain powders, titanium for instance, can cause flash fires when exposed to oxygen or other oxidizers. Therefore, when opening the chamber door after a deposition cycle, exercise extreme caution and allow time for the coating surface to oxidize. Breakage of some of the more reactive condensates may still be hazardous even with the above precautions. In this situation fire-protective clothing should be worn.

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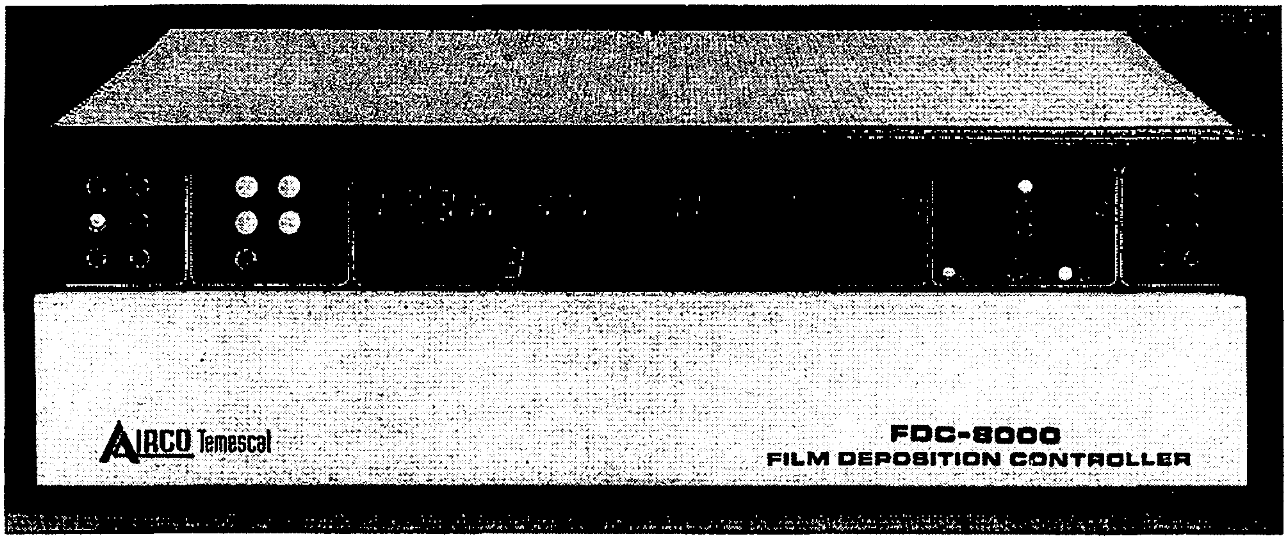
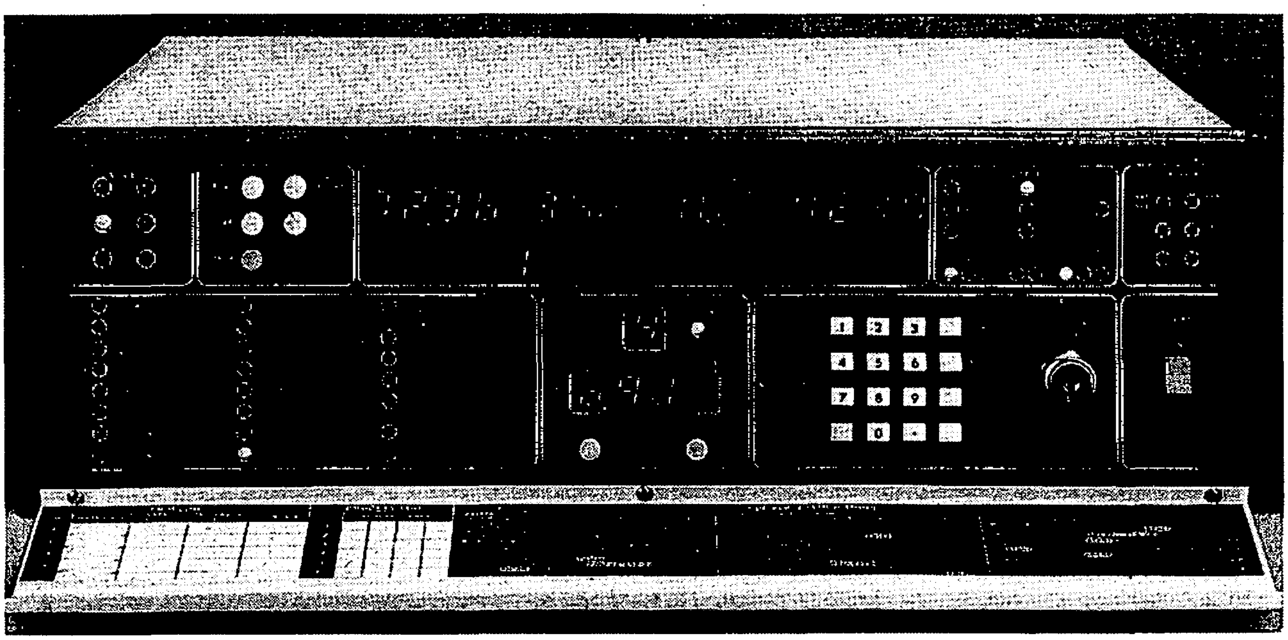




Front View, FDC-8000

SECTION 1

GENERAL DESCRIPTION

The Airco Temescal Model FDC-8000 Film Deposition Controller provides automatic control of single or multi-layer film deposition in either a production or development environment. Improved predictability and repeatability of deposited film characteristics is accomplished by dependable digital control of the deposition process. A number of previously unavailable features make the FDC-8000 particularly suited to run unattended in the fully automatic mode: run completion in the event of crystal failure, extensive internal checking and user-setable performance limits and abort enables.

NOTE

> The basic FDC-8000-1 controls evaporation-deposition from a single source and includes one programmable discrete input/output. The instrument comes equipped with hand-held control and 2.4-meter (8-foot) input power cable.
>
> The upgraded Model FDC-8000-2 will control evaporation-deposition from up to three sources and includes three programmable discrete input/outputs. The inclusion of Discrete Input/Output Board #2 and two additional Source/Sensor Boards provides these additional capabilities.

This publication covers the installation and operation of the FDC-8000. Identify the particular capabilities of your instrument by determining the number of Discrete I/O and Source/Sensor boards in the machine before applying these instructions.

1.1 FEATURES

The FDC-8000 incorporates numerous features which have only recently become economically justifiable as a result of rapid advances in semiconductor technology and in particular the advent of low-cost microprocessors.

1.1.1 Extensive Film Program Storage
The FDC-8000 is capable of storing all the parameters required to deposit up to six independent and totally unrelated films. All parameters specific to the film are included in the individual film program; special interlock or discrete output conditions, source definition, sensor definition, error limits, and all the normal film deposition parameters.

1.1.2 Multiple Process Capability
In addition to the individual film programs, the FDC-8000 will store up to eight independent processes. Each process defines an automatic sequence of up to four film layers. Each layer can be any one of the previously defined films.

1.1.3 Long-Term Program Storage
The ability of the FDC-8000 to store this much information would be of questionable value if the information were easily lost. Rechargeable nickel cadmium batteries, coupled with ultra low power CMOS memory circuits, assure that the FDC-8000 will maintain its memory for a minimum of 60 days without external power.

1.1.4 Key-Lockable Programs
To assure the integrity of stored programs, the FDC-8000 incorporates a key lock to guard against unauthorized program changes.

1.1.5 Process Log and Condensed Instructions
A process log area and condensed instructions are included inside the front panel door of the FDC-8000 to present pertinent information and to list programmed films and processes.

1.1.6 Improved Update Rate
The use of high speed Schottky circuits and the 8080 microprocessor allow the FDC-8000 to completely update film thickness, deposition rate, and source power four times per second while still maintaining a resolution of one angstrom of material with density one.

1.1.7 Acoustic Impedance Correction to 0.1%
Each thickness reading is corrected for acoustic impedance mismatch to an accuracy of better than 0.1%.

1.1.8 Superior Display Resolution
Time is controlled and displayed to a resolution of one second while rate and power are controlled and

displayed to a resolution of 0.1%. Internal calculations are performed to a significantly greater resolution than displayed.

1.1.9 Designed for Unattended Operation

The FDC-8000 has been designed for truly automatic operation and toward this end incorporates extensive internal monitoring and overriding abort circuitry to minimize the possibility of damage in the event of a failure or other problem in the total deposition system.

1.1.10 Controller Fail Abort

In the event of an FDC-8000 failure as evidenced by unsatisfactory internal checks, the FDC-8000 will attempt to abort the process and shut off all outputs.

1.1.11 User-Enabled Aborts

In addition to the internal checks, the FDC-8000 also provides user-enabled aborts on excessive rate control error, maximum power limit, or crystal failure. The level of error or power deemed to be excessive is user-defined and included as a film parameter.

1.1.12 Abort Status Retention

In the event that the FDC-8000 does abort the deposition, the reason for the abort, in addition to the total machine status, is stored at the time of abort. This storage is independent of external power and is maintained a minimum of 60 days.

1.1.13 Run Completion on Crystal Failures

The extensive monitoring and abort functions of the FDC-8000 are designed to protect the system and/or process from serious and hopefully infrequent malfunctions of the deposition system. A condition which need not cause an abort is the condition of crystal failure. Unless the user considers crystal failure during deposition serious enough to require an abort, the crystal fail abort can be left disabled. In this event, the FDC-8000 will attempt to successfully complete a deposition during which a crystal failure has occurred.

The FDC-8000 accomplishes this by continuing to output a power level equal to the average power during the last few seconds prior to crystal failure, and assumes that the deposition rate subsequent to crystal failure is equal to the average rate prior to the failure. The instrument then simulates a thickness buildup based on this assumed rate and terminates the deposition when the simulated thickness achieves the desired film thickness.

1.1.14 Powerful Programmable Interlock and Discrete Output Functions

Powerful programmable interlock and discrete output functions permit the FDC-8000 to be easily interfaced into deposition systems controlling the most complex processes. Programmable interlock inputs allow the FDC-8000 to be stepped from state to state, held in a state, or locked in a state under external control. Programmable discrete outputs provide signals to external equipment that can be complex functions of the deposition state and/or process set-points.

1.1.15 Time and Thickness Process Set-Points

The FDC-8000 incorporates independent time and thickness process set-points for each film which can be used to enable or disable external interlocking inputs or activate external outputs.

1.1.16 Auxiliary Time and Power Set-Points

The FDC-8000 incorporates a feed-state which immediately follows the deposit state. The duration of and the output power level during this state are film parameters. Although nominally designed to enable automatic source material replenishment, it is not specific to this function.

1.1.17 Independently Isolated Inputs and Outputs

To further ease integration problems, the FDC-8000 incorporates independently isolated outputs. System ground loops are thus avoided and ac line identity is not required.

1.1.18 Correlated Shutter Outputs

Each control voltage output of the FDC-8000 has its own dedicated shutter output which allows the source for any particular film to be reprogrammed without re-wiring the system.

1.1.19 Improved Power Supply Noise Tolerance

Integral RFI filter and large energy storage capacitors allow the FDC-8000 to tolerate high levels of power supply noise and power interruptions of 100 ms or less without effect. Power interruptions of greater than 100 ms will cause a power-fail abort which will be displayed on return of power.

1.1.20 International Standard Power Connector

The power connector on the FDC-8000 is internationally approved and meets International Electrotechnical Commission (IEC) standards. It allows selection of input power voltages ranging from 100 to 240 volts at a frequency of 50 or 60 Hz, and includes an integral RFI filter.

1.1.21 Solid State Indicators

All solid state indicators eliminate the need for incandescent lamp replacement.

1.1.22 Field-Upgradable

Rear panel plug-in interface cards and option cards allow the basic FDC-8000-1 to be upgraded in the field to the maximum system level.

1.1.23 Digital to Analog Converter Option

A D-to-A converter option card provides two independent analog outputs which can be individually selected to display any one of the following five parameters: time, rate, power, thickness, or error. The parameters can be displayed with two or three digit resolution.

1.1.24 Expandable to Meet Future Needs

Additional rear panel option card slots are provided to allow future communication between the FDC-8000 and other equipment such as tape readers, digital data recorders, and other computers.

1.2 SPECIFICATIONS

1) Thickness measurement range - three automatic ranges	0 to 999.9 kÅ
2) Rate measurement range - two automatic ranges	0 to 999 Å/sec
3) Thickness limit	0 to 999.9 kÅ
4) Two independent set-points -	
Thickness set-point	0 to 999.9 kÅ
Time set-point	0 sec to 99 min, 59 sec
5) Measurement update rate	4 times per second
6) Rate control range	1.0 to 999 Å/sec
7) Rate control resolution	0.1 Å/sec up to 99.9 Å/sec; 1.0 Å/sec from 100 to 999 Å/sec
8) Measurement accuracy -	
Thickness and rate readout	0.5% ±1 count

9)	Rate control accuracy	Accuracy of rate control is displayed
	Resolution of display	0.1%
10)	Thickness display resolution	1Å from 0 to 9.999 kÅ 10Å from 10 to 99.99 kÅ 100Å from 100 to 999.9 kÅ
11)	Rate display resolution	0.1Å/sec from 0 to 99.9 Å/sec; 1Å/sec from 100 to 999 Å/sec
12)	Rise time	0 to 99 min, 59 sec
13)	Soak time	0 to 99 min, 59 sec
14)	Predeposit time	0 to 99 min, 59 sec
15)	Tooling	10 to 499%
16)	Soak power	0 to 99%
17)	Predeposit power	0 to 99%
18)	Maximum power	0 to 99%
19)	Idle power	0 to 99%
20)	Response (gain)	0 to 99
21)	Density	0.8 to 99.99 gm/cc
22)	Acoustic impedance	5.00 to 59.9 x 10^5 $gm/cm^2 sec$
23)	Feed power	0 to 99%
24)	Feed time	0 to 99 min, 59 sec
25)	Control voltage	
	Range	0 to ±9.90V dc at 20 mA
	Isolation	Three independently isolated outputs with optical digital coupling (FDC-8000-2)
26)	Layer completion	Control signal automatically converted to time/power control on crystal failure to complete layer
27)	Program storage	Program and status memory is maintained for a minimum of 60 days without external power.
28)	External control inputs	a) Reset & Start b) Abort c) Format d) Programmable interlock no. 1 e) Programmable interlock no. 2 (FDC-8000-2) f) Programmable interlock no. 3 (FDC-8000-2)
29)	Input signal requirements	60 to 135V ac

30)	Remote power switch	Remote power switch allows remote control of output power level and remote abort
31)	Abort enables	Internal switches allow independently-enabled aborts on crystal failure, excessive power requirement, or excessive rate control error. Power limit and control error limit are user-programmed film parameters.
32)	External control outputs	a) Programmable output no. 1 b) Programmable output no. 2 (FDC-8000-2) c) Programmable output no. 3 (FDC-8000-2) d) Abort e) In process or layer start f) Process complete or layer complete g) Shutter no. 1 h) Shutter no. 2 (FDC-8000-2) i) Shutter no. 3 (FDC-8000-2)
33)	Output relay ratings (resistive load)	1mA to 2A at 26V dc 1mA to 1A at 115V ac
34)	Front panel controls	a) Reset b) Start c) Abort d) Zero e) Diagnostic self-test f) Manual mode for remote power control g) Program key lock h) Power Switch
35)	Input power requirements Selectable voltage input	100, 120, 200, 240V; 50/60 Hz; 60 Watts
36)	Operating temperature range Instrument Sensor head	 0 to 50°C -20 to + 185°C

37) Physical Data

Weight	19 pounds
Size	5-1/4 inches high, 19 inches wide, 13 inches deep
Oscillator	
Weight	2 ounces
Size	7/8 inch high, 1-1/8 inches wide, 3 inches long
Sensor	
Weight	4 ounces
Size	1.08 inches high, 1.44 inches wide, 1.22 inches deep

1.3 ACCESSORIES

1) Sensor Head/Oscillator: Includes quartz crystal sensor head, oscillator, internal (vacuum) and external cables, and five spare crystals (part number 0506-7150-0).
2) Source/Sensor Circuit Board: For upgrading the FDC-8000-1 to two- or three-source control (part number 0506-7190-0).
3) Discrete Input/Output Circuit Board: For upgrading FDC-8000-1 to three programmable input/outputs (part number 0506-7200-0).
4) Digital to Analog Converter Board: Permits simultaneous analog display of any two digitally displayed functions (rate, thickness, power, time, or error) (part number 0506-7210-0).
5) Sensor Head and Internal Cable: Includes 760-mm (30-inch) internal coaxial cable, 150-mm (6-inch) stainless steel water lines, and five spare crystals (part number 0506-7140-0).
6) Oscillator and External Cable: Includes 3-meter (10-foot) coaxial cable for connecting controller and vacuum feedthrough (part number 0506-7130-0).
7) Dual Water/Electric Feedthrough: For 1-inch-diameter bolt-hole (part number 0303-6772-0).
8) Dual Water/Electric Feedthrough: For 2-3/4-inch Conflat flange (part number 0303-6782-0).
9) Sensor Crystals, package of 5 (part number 0506-7160-0)

SECTION 2

FRONT PANEL DISPLAYS AND CONTROLS

The FDC-8000 front panel is divided into two sections, the operating section and the programming section. The programming section of the display is normally covered by a hinged panel when not in use.

A detail of the front panel is presented in Figure 2.1.

2.1 OPERATING DISPLAYS AND CONTROLS

The upper half of the panel is devoted to the four groups of operating displays and one group of operating controls.

2.1.1 Operating Displays

2.1.1.1 Numeric Displays

a) PROCESS TIME: Process time, displayed in minutes and seconds, represents the elapsed time from the beginning of the current film layer. The process clock starts at the beginning of Rise and stops at Layer Complete. It also stops if the FDC-8000 is being held in the Hold state by an external signal.

b) RATE: A three-digit display with a floating decimal point displays deposition rate in angstroms per second. The resolution is 0.1Å per second from 0 to 99.9Å per second, and 1.0Å per second for rates from 100 to 999Å per second.

c) POWER: A three-digit display with a fixed decimal point displays percent of maximum power with a resolution of 0.1% from 0 to 99.0%. This corresponds to the control voltage range of 0 to 9.90 volts.

d) THICKNESS: Four digits with a movable decimal point display measured thickness in kiloangstroms. Resolution is 1Å from 0 to 9.999 kÅ, 10Å from 10.00 kÅ to 99.99 kÅ, and 100Å from 100.0 kÅ to 999.9 kÅ.

e) PROCESS NUMBER: A single digit displays the number of the process which will be run if in Ready, which is being run if in Process, or which was run if in Process Complete.

f) LAYER NUMBER: A single digit displays the number of the layer to be run if in Ready, being run if in Process, or was last run if in Process Complete or Layer Complete.

2.1.1.2 Mode Display

The operating mode of the FDC-8000 is displayed by six LEDs in the upper left-hand corner.

a) READY: The Ready mode indicates that the FDC-8000 has been Reset and is awaiting a Start command. Process selection is only allowed while the FDC-8000 is in the Ready mode.

b) IN PROCESS: A Start command steps the FDC-8000 into the In Process mode.

c) PROCESS COMPLETE: Upon completion of all the layers of the selected process, the FDC-8000 will step to the Process Complete mode and remain there awaiting a Reset signal to step it back to the Ready mode.

d) MANUAL: The Manual mode is activated by the Auto/ Manual switch on the programming panel. This mode may be selected any time when the program is unlocked. The Manual mode indicates that the FDC-8000 control voltage output is being controlled through the remote power switch. In the Manual mode, the control voltage remains constant unless incremented up or down by means of the remote power switch. At entry into the Manual mode the power remains at the last value prior to entry and is thereafter modified only through the remote switch. Exit from the Manual mode is accomplished by pushing either the Auto/Manual switch or Reset.

   The FDC-8000 can also be aborted through the remote power switch. This abort feature is active whether or not the FDC-8000 is in the Manual mode (see paragraph 4.5).

e) SELF-TEST: The Self-Test mode differs from the normal mode only to the extent that the Thickness and Rate displays are derived from a simulated sensor input rather than the actual sensor. While in this mode the simulated thickness build-up is directly proportional to the displayed power level and independent of actual thickness on the sensor. The Self-Test mode allows the total deposit process to be simulated. It also allows the tooling factor, density, and acoustic impedance calculations to be conveniently checked and altered if necessary.

f) ABORT: In the Abort mode all status displays and all operating controls are frozen, with the exception of Reset. In addition, all discrete outputs are disabled and all control voltage outputs are forced to zero. Programming controls remain active to allow verification of programmed parameters. Exit from the Abort mode requires a Reset signal.

2.1.1.3 State Display

The State display is on the upper right-hand side of the front panel. This display indicates the status of the deposition process.

a) RISE: The first state of a typical deposition cycle is Rise. During the Rise state the source power control voltage output is linearly ramped from zero to the programmed Soak power level. The duration of the Rise state is determined by the programmed Rise Time parameter.

b) SOAK: At the completion of the Rise state, the FDC-8000 steps to the Soak state. During this state the output power remains constant at the Soak power level. The duration of this state is determined by the Soak Time parameter.

c) PREDEPOSIT: Upon completion of the Soak state, the FDC-8000 steps to the Predeposit state. The total Predeposit time is determined by the Predeposit Time parameter. The predeposit time itself is divided into two equal times. During the first half of the Predeposit state, the output power is linearly ramped from the Soak power level to the Predeposit power level. During the second half of the state, the output power level remains constant at the Predeposit level. If crystal failure occurs during the Predeposit state, the FDC-8000 will automatically abort.

d) DEPOSIT: Upon completion of the Predeposit state, the FDC-8000 steps to the Deposit state. For the duration of the Deposit state the measured deposition rate is compared with the programmed deposition rate and output power is increased or decreased as necessary to keep the two rates equal. The Deposit state is terminated when the measured thickness equals or exceeds the programmed thickness.

e) FEED: The Feed state follows the Deposit state and its duration is determined by the Feed Time parameter. The output power level during the Feed state is defined by the Feed Power parameter. If the Feed state is not used, the Feed Time can be set to zero and the FDC-8000 will step directly from the Deposit state to the Layer Complete State.

f) LAYER COMPLETE: Upon entry to the Layer Complete state the output power level is determined by the Idle Power parameter. If the layer being deposited is the last layer in the process, the FDC-8000 will enter the Process Complete mode at this time. If the deposited layer was not the last layer of the process, the FDC-8000 will remain in the Layer Complete state awaiting a front panel Start signal or an external Reset & Start signal before stepping to the Rise state of the next layer. If an external Reset & Start signal exists prior to the entry of the FDC-8000 into the Layer Complete state, the FDC-8000 steps immediately to the Rise state of the next layer.

g) HOLD: Illumination of the Hold LED indicates that an external interlock is preventing the FDC-8000 from entering the next state. When the external interlock is removed, the Hold light will extinguish and the FDC-8000 will step to the next state.

h) SOURCE ACTIVE: Three LEDs in the lower left-hand corner of the State Display indicate the status of the three source voltage outputs. The LEDs are labeled 1 through 3 to indicate the number of the source whose status is being displayed. A lighted LED indicates that the source output is active, i.e., that the source is being controlled or is being held at idle power level.

i) SET-POINT INDICATORS: The set-point indicators, Set-Point Time and Set-Point Thickness, are related to the two programmed independent process set-points, Set-Point Time and Set-Point Thickness. An illuminated Set-Point Time LED indicates that the Process time equals or exceeds the Set-Point Time parameter. An illuminated Set-Point Thickness LED indicates that the displayed thickness equals or exceeds the Set-Point Thickness parameter.

j) DISCRETE OUTPUTS: The status of the three programmable discrete outputs are indicated by three LEDs in the lower right-hand corner of the State display. The LEDs are labeled with the numbers of the discrete output whose status is being displayed. An illuminated LED indicates that the output is active and that the common contact on the output relay is tied to the yes contact.

2.1.1.4 Trouble Display

Six LEDs in the upper right-hand corner of the front panel display conditions which in most cases are indicative of a problem. On the right, three displays indicate problems which create an automatic abort. The other three displays normally will not cause an abort unless enabled by switches inside the FDC-8000. The purpose of the Trouble display is to advise the operator of possible problems, or in the case of an abort, to display the cause of the abort.

a) POWER FAIL: This LED indicates that power to the FDC-8000 was interrupted for a period of more than 100 ms, and therefore caused an abort.
b) EXTERNAL ABORT: This LED indicates that the abort was caused by an external signal from the front panel, rear panel, or remote power switch.
c) CONTROLLER FAIL: This LED indicates failure of the FDC-8000 to pass a number of internal checks, i.e., a failure within the FDC-8000 itself. Since the nature and extent of such a failure cannot be established, a Controller Fail condition creates an automatic abort.
d) POWER MAX: This LED signals that the output power of the FDC-8000 is being limited by the programmed Maximum Power parameter.
e) CRYSTAL FAIL: This LED indicates lack of a valid signal from the sensor. Generally, signal failure results from a failed crystal, but it may also indicate problems in the crystal mounting or interconnection between the sensor and the FDC-8000.
f) EXCESS ERROR: This LED signals that the Rate Control Error is equal to or exceeds the Maximum Error parameter.

2.1.2 Operating Controls

Five pushbutton switches on the operating panel control the normal operation of the FDC-8000.

a) RESET: Pressing the Reset button steps the FDC-8000 from the Process Complete or Abort modes to the Ready mode. The Reset switch is inactive during the In Process mode and cannot be used to abort a deposition. The Reset switch automatically resets the Manual and Self-Test modes back to normal and automatic.
b) START: The Start switch is pressed to begin the process by stepping the FDC-8000 from the Ready mode to the In Process mode.
c) ABORT: The Abort switch illuminates the external abort trouble light and drives the FDC-8000 to the Abort mode.
d) SET PROCESS NUMBER: The Set Process Number switch is used to establish the process number, and is active only during the Ready mode. Press the Set Process Number switch and then key the desired process number on the keyboard in the Programming section.
e) ZERO: Pressing the Zero button causes the thickness display to go to zero. This button is active at all times and if pressed during the Deposit state will result in a film thicker than that desired by an amount equal to the thickness displayed at the time the display was zeroed.

2.2 PROGRAMMING DISPLAYS AND CONTROLS

The lower half of the FDC-8000 front panel is dedicated to the programming displays and controls. Programming is independent of control and previously entered film parameters and process sequences can be displayed at any time. The program, however, must be unlocked in order to modify a parameter or process.

Although film parameters can be changed at any time, changing certain parameters during deposition could adversely affect the process. Therefore, parameter modifications should not be made on a film being deposited. For the same reason, a process cannot be modified during the process run.

The FDC-8000 stores process programs and film programs independently of each other. A process is a sequence of up to four film numbers. A film program consists of the parameters required to deposit a single film.

For example, to deposit a single film layer, the film is assigned one of the six available film numbers, and the necessary parameters are entered under the assigned film number. Then, one of the eight available processes is programmed as a one-film sequence incorporating the previously selected film number. Deposition of the film is initiated by pushing the Set Process # button, keying in the appropriate number on the keyboard (the number will appear on the Process # display), and pushing the Start button.

To program a specific parameter of a film, the program memory for the film is brought forward by pressing the orange Film key on the keyboard and then the appropriate number key. The single digit will be displayed on the Process #/Film # display in the center of the programming panel. The parameter to be altered is called forward by pressing the orange Parameter key and keying in the two-digit parameter number.

The indicator LED for the selected parameter will illuminate and the central numerical readout will show the parameter value currently stored in the program memory. Key in the new value on the programming keyboard, and enter it in the program memory by pressing the Enter key. The new value is now displayed.

A new process is programmed by pressing the orange Process key on the keyboard (which will recall to the display the present process program), keying in the single digit film numbers for the new sequence, and pressing the Enter key. The new process sequence of film numbers is now displayed and in the program memory.

2.2.1 Programming Displays

a) FILM/PROCESS NUMBER DISPLAY: Two LEDs are used to indicate whether a process sequence or film parameter is being displayed. A single digit indicates the number of the process or film being displayed.

b) SEQUENCE/PARAMETER DISPLAY: A four-digit display shows the value of the parameter being displayed or the sequence of film numbers which define the process.

c) PARAMETER INDICATORS: A list of the parameters which constitute a single film deposition program is located on the left half of the Programming section. The parameter whose value appears in the Sequence/Parameter display is indicated by an illuminated LED adjacent to the parameter name. Each parameter is assigned a number, which must be keyed in order to recall or change a parameter value.

2.2.2 Programming Controls

The FDC-8000 Programming Controls consist of a 16-key keyboard, a program keylock switch, and two push-button switches labeled Auto/Manual and Normal/Self Test. Programming of the FDC-8000 is accomplished through the keyboard which, in addition to the numeric and decimal point keys, includes five control keys.

a) POWER ON/OFF: Although located on the programming panel, the POWER ON switch activates power to the entire instrument and should remain on at all times.

b) PROGRAM KEYLOCK: The program is unlocked by means of the keylock switch and its unlocked condition is indicated by an illuminated Program Unlocked LED. The Auto/Manual and the Normal/Self Test switches are disabled unless the program is unlocked. Previously entered parameters and processes can be displayed at any time whether or not the program is locked, but the program must be unlocked to modify or enter a new parameter or process.

c) AUTO/MANUAL SWITCH: The Auto/Manual switch is a momentary switch and toggles the FDC-8000 from the normal, automatic mode to the manual mode and back.

d) NORMAL/SELF TEST SWITCH: The Normal/Self Test switch is also momentary and toggles the FDC-8000 from the normal, automatic mode to the self test mode and back.

e) FILM KEY: The Film key is used to select the film to be displayed or programmed. Depression of the Film key followed by the desired number key will light the Film # LED and the selected film number will appear in the Film #/Process # indicator. In addition, the Parameter display will show the parameter last displayed. Invalid film numbers (over 6) are ignored.

f) PARAMETER KEY: The Parameter key is used to display a parameter. Press the Parameter key, key in the two-digit parameter number, and the display will show the value of the selected parameter and the appropriate parameter indicator LED will light. Invalid parameter numbers are ignored.

g) PROCESS KEY: The Process key is used to display a process. Press the Process key, key in the process number and the display will show the film numbers and then sequence in the process. Invalid process numbers are ignored.

h) ENTER KEY: The primary function of the Enter key is to enter the contents of the Sequence/Parameter display into program memory. Digits keyed into the Sequence/Parameter display are not entered into the program memory until entered by means of the Enter key. This function is disabled if the program is locked or the parameter being entered would seriously disrupt the deposition in process.

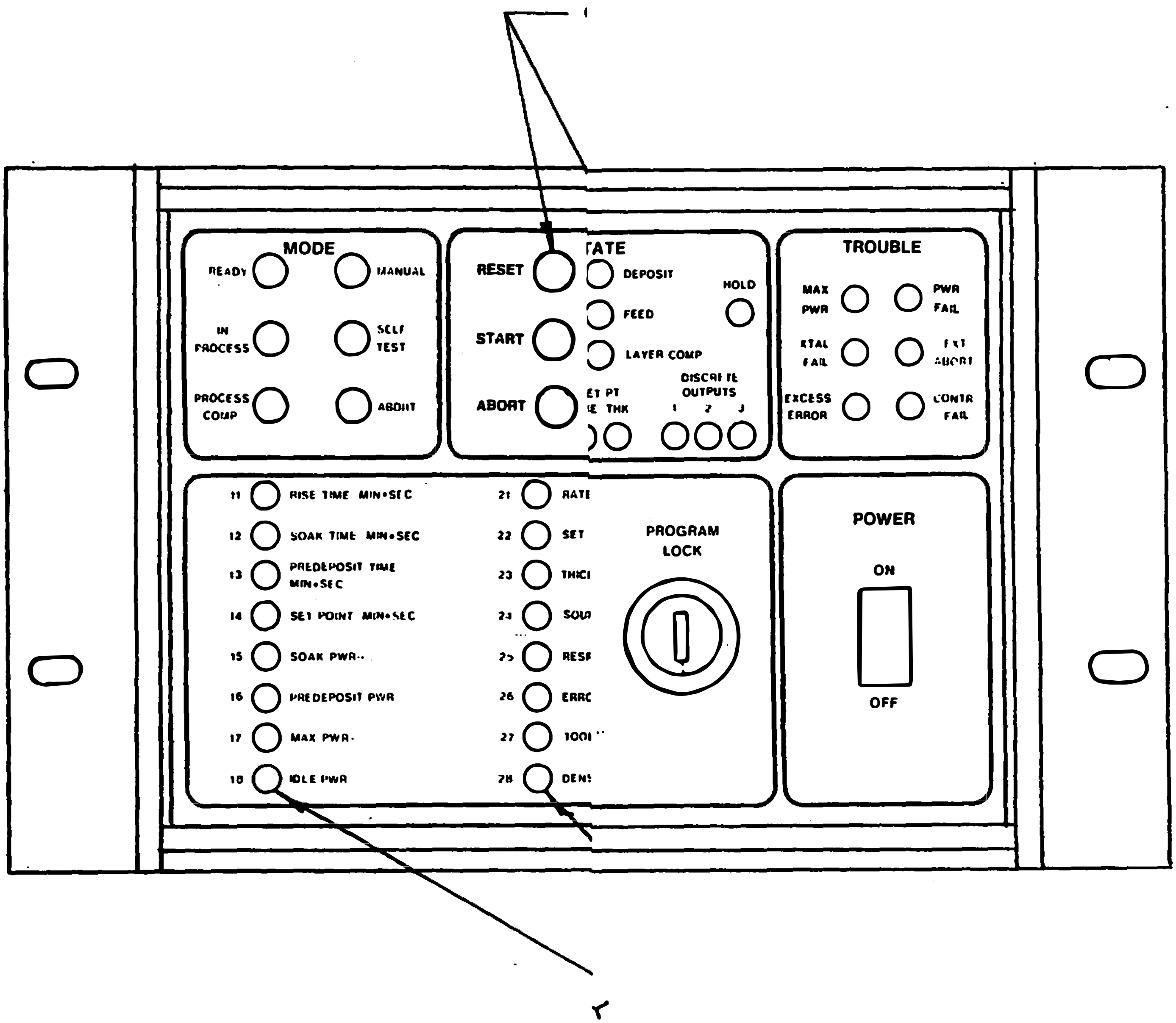
Out of range or otherwise invalid parameters are not entered. The stored value of the parameter continues to display following an invalid entry attempt.

The second function of the Enter key is to increment the Sequence/Parameter display to call up the next parameter in sequence (or the Process display to the next Process in sequence). If no change in the program is made, pressing the Enter key will increment the display to the next parameter or process. When a new value has been entered, the Enter key must be pressed twice — once to enter the new value, and a second time to increment the display.

i) CLEAR KEY: The Clear key, labeled "C" and located in the lower left-hand corner of the keyboard, clears previously keyed digits from the Sequence/Parameter display and recalls to the display the value currently in memory.

j) NUMERIC KEYS: The numeric keys are used to define a process, film, or parameter, and also to key new values into the Sequence/Parameter display. Digits are entered in the display from left to right as they would be written. Leading and trailing zeroes are not required. For example, to enter 0.100 kÅ, press Decimal Point, One, Enter. Prior to entry the Sequence/Parameter display will show 0.1. After entry the parameter will be recalled to the display as 0.100.

irco Temescal FDC-8000



SECTION 3

PROGRAMMING

3.1 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.

a) RISE TIME (11): All other things being equal, the Rise Time should be established at the minimum time necessary to provide an orderly increase in source material temperature to the Soak level. It should be long enough to allow the material to achieve an equilibrium temperature without spitting or, in the case of evaporation from a boat or filament source, to protect the evaporation source from unnecessary thermal shock.

b) SOAK TIME (12): The Soak Time should allow the material to reach equilibrium and fully outgas.

c) PREDEPOSIT TIME (13): The Predeposit Time should allow the source material to be brought to the deposit temperature level and stabilized in an orderly manner. The predeposit power level will generally cause evaporation; therefore, excessive predeposit time will result in unnecessary build-up of material on the shutter and unnecessary material loss.

d) SET-POINT TIME (14): The Set-Point Time is used in conjunction with the programmable Discrete Output, parameter 35, to provide an external signal at any pre-determined time during the deposition cycle. However, if it is set at a value greater than the time required to reach the Layer Complete state, the set-point time will not be reached and no output will occur.

e) SOAK POWER (15): The Soak Power value should assure that the source material is properly outgassed and prepared for subsequent deposition.

f) PREDEPOSIT POWER (16): In order to minimize any transient on entry to the closed loop deposit state, the Predeposit Power should be established as close as is practical to the power level required to reach the desired deposition rate. Use the Manual mode to externally control power in determining the Soak and Predeposit power levels.

g) MAXIMUM POWER (17): The Maximum Power value can be established two ways: 1) slightly above the maximum power level which would be reached in a normal deposition or, 2) at a level slightly below that which would result in undesirable source behavior or damage to the source. The FDC-8000 can be set up to abort when the maximum power level is reached. Therefore, the Maximum Power parameter can be used as a performance limit on an untended system by enabling the relay inside the FDC-8000 to abort deposition when the maximum power level is reached. In either case, the excess power trouble indicator on the control panel should light.

h) IDLE POWER (18): The Idle Power parameter is intended for load-lock systems where the source can be kept under power continuously. On entry to the Layer Complete state, the source power will decrease to Idle Power level and remain there until the next deposition cycle utilizing the same source or until the FDC-8000 is aborted. If the active source is at idle power when entering a new deposition cycle, the FDC-8000 will skip the Rise and Soak states and step directly into the Predeposit state. All source power outputs are always driven to zero on entry to the Abort mode. A deposition cycle which follows an Abort will always contain the Rise and Soak states.

i) RATE (21): The deposition rate is entered in angstroms per second and, although the allowed resolution is 0.1Å, the minimum rate which the FDC-8000 will accept is 1.0Å. In order to assure satisfactory rate control, the programmed rate should be slightly below the maximum rate which can be achieved with the source configuration and maximum power level utilized.

j) SET-POINT THICKNESS (22): The Set-Point Thickness parameter is used in conjunction with the programmable Discrete Output, parameter 35, to provide an external signal on deposition arriving at any predetermined thickness. If the thickness is not achieved, the output will not be activated.

k) THICKNESS (23): This parameter establishes the deposit thickness in kiloangstroms (800Å would be entered as 0.800kÅ).

l) SOURCE-SENSOR (24): This parameter establishes the source and the sensor to be used for the film deposition cycle being programmed. The first digit entered specifies the source and the second digit, the sensor. The FDC-8000 will accept this parameter only if it consists of two digits and each digit falls between 1 and 3.

m) RESPONSE (25): This parameter establishes the characteristics of the closed loop deposition response and is necessary to compensate for variation in power gain and response from system to system. It is best established by trial and error. Too large a value for response will result in an over active and possibly oscillatory behavior of the deposit power. Too low a response value will allow significant rate errors to persist for significant lengths of time. The response is best set by incrementing by factors of 10% and 20% during the deposit state until the optimum compromise between rate error and source activity is reached.

n) ERROR LIMIT (26): The error limit parameter is a performance limit on the FDC-8000. During untended operation it may be used in conjunction with the Excess Error Abort Enable to produce an automatic abort at the prescribed error limit.

o) TOOLING FACTOR (27): 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 paramter 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:

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

where: $dcry$ = distance from source to crystal,

$dsub$ = distance from source to substrate.

Empirical calibration of the tooling factor is described in paragraph 7.5.

p) DENSITY (28): The density parameter provides the FDC-8000 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 3-1. As a first approximation, bulk material density can be used in programming this parameter. Empirical calibration of this parameter is described in paragraph 7.5.

TABLE 3-1

DENSITY AND ACOUSTIC IMPEDANCE VALUES OF A NUMBER OF MATERIALS

Material	Symbol	Density (g/cm^3)	Impedance
Aluminum	Al	2.70	8.17
Antimony	Sb	6.62	11.49
Arsenic	As	5.73	8.53
Beryllium	Be	1.85	16.26
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
Chromium	Cr	7.20	28.95
Cobalt	Co	8.71	25.74
Copper	Cu	8.93	20.21
Gallium	Ga	5.93	14.89
Gallium arsenide	GaAs	5.31	5.55
Germanium	Ge	5.35	17.11
Gold	Au	19.3	23.18
Indium	In	7.30	10.50
Indium antimonide	InSb	5.76	11.48
Iron	Fe	7.86	25.30
Lead	Pb	11.3	7.81
Lead sulfide	PbS	7.50	15.6
Lithium fluoride	LiF	2.64	11.41
Magnesium	Mg	1.74	5.48
Magnesium oxide	MgO	3.58	21.48
Manganese	Mn	7.20	23.42
Molybdenum	Mo	10.2	34.36
Nickel	Ni	8.91	26.68
Niobium	Nb	8.57	17.91

Table 3-1 Continued

Material	Symbol	Density (g/cm^3)	Impedance
Palladium	Pd	12.0	24.73
Platinum	Pt	21.4	36.04
Selenium	Se	4.82	10.22
Silicon	Si	2.32	12.4
Silicon dioxide (fused quartz)	SiO_2	2.20	8.25
Silver	Ag	10.5	16.69
Silver bromide	AgBr	6.47	7.48
Silver chloride	AgCl	5.56	6.69
Sodium chloride	NaCl	2.17	5.62
Tantalum	Ta	16.6	33.70
Tellurium	Te	6.25	9.81
Tin	Sn	7.30	12.20
Titanium	Ti	4.50	14.06
Tungsten	W	19.3	54.17
Tungsten carbide	WC	15.6	58.48
Uranium	U	18.7	37.10
Vanadium	V	5.96	16.66
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

q) ACOUSTIC IMPEDANCE (31): The acoustic impedance of the deposited film is required by the FDC-8000 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 10^5 g/cm^{2}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 impedance should be used. 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:

$$\text{Acoustic impedance} = PC = \sqrt{PG}$$

where: P = density in g/cm^3,

C = transverse (shear) wave velocity in cm/sec,

G = shear modulus in dynes/cm^2.

A list of the acoustic impedance and density of the more commonly deposited materials is presented in Table 3-1, and a technique for empirically determining this parameter is presented in paragraph 7.5.

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: 8.83×10^5g/cm^{2}sec.

r) FEED POWER (32): This parameter establishes the source power level during the Feed state. It is normally used in conjunction with some type of material replenishment system, such as a wire, rod or vibratory feeder.

s) FEED TIME (33): The Feed Time is established in conjunction with the feed power to provide replenishment of the source material following deposition.

The Feed state does not have to be used for material feeding alone. It may also be used as a delay between Deposit and Layer Complete or as an intermediate power let-down state.

t) INTERLOCK INPUT (34): This parameter is used to define the conditions under which the FDC-8000 will be affected by external signals on the programmable discrete inputs and to define the effect that the external signals will have. The programming of this parameter is discussed in detail in paragraph 3.3.4.

u) DISCRETE OUTPUT (35): The discrete output parameter is used to specify the conditions under which one of the three programmable discrete outputs will be activated and to define which of the three will be activated.

v) CRYSTAL HEALTH AND RATE ERROR (36 & 37): The Crystal Health and Rate Error parameters are display-only parameters and cannot be programmed. At any time during deposition, either one may be called up by pressing the orange Parameter key and the digits 36 or 37, and crystal health or rate error will be displayed in the Film Sequence/Parameter readout display on the programming panel.

3.2 PROGRAMMING A PROCESS

After the individual films have been programmed, the process or processes should be programmed. Processes are programmed by selecting the desired process number for display, keying in the film numbers in the sequence in which they are to be deposited, and entering the resulting film sequence. The left-most film number will be deposited first, followed in sequence by the remainder of the programmed film numbers.

Unless more than two multiple layer processes are required, it is recommended that the first six processes be programmed as single-film processes so that Process #1 is film #1, Process #2 is film #2, and so forth. This will allow each of the films to be deposited independently. The desired multiple film processes can then be programmed into process numbers 7 and 8.

3.3 SYSTEM INTEGRATION

The FDC-8000 is designed for ease of integration into the total deposition system and for this purpose the instrument is equipped with a number of discrete (on, off) inputs and outputs which allow interaction with other components of the vacuum system. This interaction is of significant importance to systems engineers who must consolidate and integrate a variety of subsystems in order to accommodate a particular deposition process.

The FDC-8000 provides two types of inputs and outputs: dedicated and programmable. The dedicated inputs and outputs are fixed, that is, their function is predefined and cannot be changed. In most cases, these inputs and outputs will provide sufficient interaction with the deposition system. The programmable discrete inputs and outputs are extremely flexible and are provided through the Discrete Input/Output circuit board(s). The number available will depend on the particular instrument's configuration.

The function and use of the various discrete inputs and outputs are described below. Input signal requirements and output signal characteristics are described in Section 5.

3.3.1 Dedicated Outputs

a) Discrete I/O board #1 provides a choice of two groups of four dedicated outputs. The desired output group is selected by means of the Format input. If no voltage is applied to the Format input, the outputs available are Abort, In Process, Process Complete and Shutter #1. If a voltage is applied to the Format input pins (see Figure 6.5), the following alternate outputs become available: Abort, Layer Start, Layer Complete and Shutter #1.

1. Normal Outputs (Format=0V)

Abort: The Abort relay is activated whenever the FDC-8000 is in the Abort mode and also when the FDC-8000 is not being supplied power. It would typically be used to shut down other equipment and/or to activate an audio alarm.

In Process: The In Process output is active when the FDC-8000 is in the In Process mode. This output may be used to enable external equipment whose operation is only desired during the deposition process.

Process Complete: This relay is active when the FDC-8000 is in the Process Complete mode and, therefore, signals the completion of the Deposition Process. It may be used to activate an operator call and/or to initiate system cool-down and venting.

Shutter #1: This output is associated with Source #1 and is activated whenever the FDC-8000 is in the Deposit state depositing a film from the #1 source, and as such is intended to control the #1 source shutter.

2) Alternate Outputs (Format-115V)

Abort: The Abort output is unchanged from the description above.

Layer Start: The Layer Start output provides a 3-second pulse at the beginning of each layer deposition.

Layer Complete: The Layer Complete output provides a 3-second pulse at the completion of each layer deposition.

Shutter #1: The Shutter #1 output is unchanged from the description above.

A voltage applied to the Format input also converts the programmable #1 output, described in section 3.3.3, to a 3-second pulse.

b) Discrete I/O board #2 provides three dedicated outputs: Shutter #2, Shutter #3 and Feed.

1) Shutter #2: The Shutter #2 output is the same as the Shutter #1 output, except that it is active only when source #2 is being controlled.

2) Shutter #3: Shutter #3 signal is similar to the first two shutter signals, except that it is related to source #3.

3) Feed: The Feed output is active during the period that the FDC-8000 is in the Feed state. It would normally be used as a control signal to a wire, rod or other type of material feeding system.

3.3.2 Dedicated Inputs

The Discrete I/O board #1 provides three dedicated inputs: Abort, Reset and Start and Format.

1) Abort: A signal on this input will drive the FDC-8000 to the abort mode and light the external Abort trouble light. This signal would normally be tied in with a master system abort or other critical process parameter.

2) Reset & Start: A signal on this input will reset the FDC-8000 if it is in the Process Complete or Abort mode and will supply the Start signal to increment the unit to the In Process mode. It will also supply the necessary Start signal to increment the FDC-8000 from the Layer Complete state to the Rise state of the next layer.

3) Format: A signal applied to this input will select the alternate group of discrete output signals described in section 3.3.1.

3.3.3 Programmable Outputs (Parameter 35)

The programmable discrete output enables the systems engineer to generate an external signal at a specified point or during a specified period of the deposition cycle. The signal is created by a relay closure on the Input/Output circuit board. Depending on the FDC-8000 configuration, the controller has either one or three programmable outputs. However, regardless of configuration, only one output can be programmed per film layer.

NOTE

> Use of alternate Format input (section 3.3.1) modifies the programmable discrete output #1 to a 3-second pulse at the beginning of the period. Output #2 and #3 are not affected.

The permanent FDC-8000 software is organized to allow the systems engineer to specify which relay is to be closed and to describe the point or period during which it should be closed in terms of the film state, the time set-point parameter (14), the thickness set-point parameter (22), or combinations of film states and set-points. Signal points or periods can be described in five ways:

a) WHEN: This description specifies that the selected relay should be closed when certain film states, or time, or thickness conditions are in progress or have been reached.

   Example: Relay #1 should be closed when the film state is either in soak OR predeposit OR deposit. This instruction would maintain relay closure from the beginning of soak to the end of deposit.

   Example: Relay #1 should be closed when the time set-point is reached.

b) DURING: This description specifies that the selected relay will close and remain closed during the period when two or more mutually inclusive conditions exist simultaneously. The instruction must be programmed with a logical "and" rather than a logical "or".

Example: Relay #2 should be closed during the period when the time set-point has not yet been reached and the film is simultaneously in the deposition state.

Example: Relay #2 should be closed during the period after the thickness set-point has been reached and when the film is simultaneously in the deposition state.

Film states alone cannot describe "during" instructions since they are mutually exclusive and cannot occur simultaneously. Hence, an instruction that relay #1 should be closed when the film is in Rise and simultaneously in Soak is meaningless. If the desired result is to generate a signal from the beginning of Rise to the end of Soak, the description should take the form of a "when" instruction (for example, that Relay #1 should be closed either when the film state is in Rise or Soak).

c) ALWAYS (Inverted NEVER): This description specifies that the selected relay will close at the beginning of Rise and remain closed until a subsequent film layer is started.

d) ALWAYS EXCEPT WHEN (Inverted condition): This description specifies that the selected relay will close and remain closed at all times except when the conditions of a "when" instruction are satisfied.

Example: Relay #1 should always be closed except when the film is either in the predeposit OR deposit state.

e) ALWAYS EXCEPT DURING: This description specifies that the selected relay will close and remain closed at all times except during the period when the conditions of a "during" instruction are satisfied.

Example: Relay #1 will always close and remain closed except during the period when the time set-point has not yet been reached and the film is simultaneously in ~~the~~ predeposit state. It should be noted that if the time set-point is reached before the film reaches the predeposit state, the relay will never open, since the "during" instruction has not been satisfied.

3.3.3.1 Programming the Discrete Outputs

Programming of the programmable discretes is constrained by the film parameter front panel input format. This constraint requires that the function of the discrete output be entirely specified by a four-digit code. For this reason, all actions and all conditions must be assigned a numeric code which can be thought of as a simple language. Like all computer languages, the FDC-8000 language is logical but arbitrary, and simply must be learned and followed.

The first digit of the possible four is used to define the action and, in the case of the programmable output, defines the effected output relay. The next three digits and one or more decimal points are used to specify the condition. The deposition states and the programmable time and thickness set-points are assigned arbitrary code numbers. These code numbers are combined with one or more decimal points to allow the specification of a condition which can be a logical combination of up to three states and/or set-point conditions, as previously described.

The Output Codes, State, and Set-Point Codes and Decimal Point Code are described below.

a) OUTPUT CODE:

Code	Selected Output
1	Discrete Output #1
2	Discrete Output #2
3	Discrete Output #3

b) STATE and SET-POINT CODES:

Code	Selected Output
1	Rise state
2	Soak state
3	Predeposit state
4	Deposit state

Code	Selected Output
5	Feed state
6	Layer Complete state
7	Elapsed time greater than or equal to time set-point
8	Elapsed time less than time set-point
9	Deposited thickness greater than or equal to thickness set-point
0	Deposited thickness less than thickness set-point
Blank(b)	No condition or never

c) DECIMAL POINT CODES:

- A decimal point (.) following a relay designation means "always except under the following conditions."

  Example: "2." means relay #2 will remain closed except under the condition following.
- A decimal point (.) between condition codes means "and" and forms a "during" instruction.

  Example: Condition code "9.4" means during the period after the thickness set-point has been reached and when the film is simultaneously in the deposit state.
- No decimal point ( ) following a relay designation means "without exception or only under the following conditions."
- No decimal point ( ) between condition codes means "or" and forms a "when" instruction.

  Example: Condition code "812" means when either the elapsed time is less than the time set-point OR the film is in the Rise state OR the film is in the Soak state.

d) PROGRAMMING RULES:

1) An instruction cannot consist of more than FOUR numerics.
2) The first numeric ALWAYS designates which relay (discrete output) is to be closed.
3) "Always" is programmed with a numerical relay designation followed by a decimal point.

   Example: "2." means relay #2 is always closed. Literally, it translates to "relay #2 is always closed except, no exceptions."
4) When programming the discrete outputs, remember:
   - To unlock the program
   - To recall the desired film.

- To recall Parameter #35
- To adhere to the programming codes and rules
- To view the programmed value in the parameter/sequence display
- To enter the program
- To lock the program

3.3.3.2 Programming Examples

a) WHEN Programs: 2123 means close relay #2 when the film is either in Rise or Soak or Predeposit. Relay will close at start of Rise and open at end of Predeposit.

b) DURING Programs: 14.8 means close relay #1 when the film is in the Deposit state and when, simultaneously, the elapsed time is less than the time set-point. Relay will close on entry to the Deposit state and open when the time set-point is reached.

29.8 means close relay #2 during the period when the actual thickness equals or exceeds the thickness set-point and the elapsed time is simultaneously less than the time set-point. Relay will close when the thickness set-point is reached and open when the time set-point is reached.

c) ALWAYS Programs: 2. means close relay #2 for the duration of the film deposition cycle. Relay will close and remain closed until subsequent layer is started.

CAUTION

Do not program ALWAYS as 2.0. This means close relay #2 always except when the actual thickness is less than the thickness set-point. Relay would open at the beginning of Rise and close then the thickness set-point was reached.

d) ALWAYS EXCEPT WHEN Programs: 3.123 means relay #3 will always be closed except when the film is either in Rise or Soak or Predeposit. Relay will close at the end of Predeposit and remain closed until the next film layer is started.

2.46 means relay #2 will always be closed except when the film is either in Deposit or Layer Complete. Relay will close at the start of Rise, open at the start of Deposit, close at the end of Deposit, and open at Layer Complete.

e) ALWAYS EXCEPT DURING Programs: 1.7.4 means relay #1 will always be closed except during the period when the elapsed time equals or exceeds the time set-point and the film is simultaneously in the Deposit state. Relay will close at the start of Rise, open at the time set-point, and close at the end of Deposit.

3.8.0 means relay #3 will always be closed except during the period when the elapsed time is less than the time set-point and the deposited thickness is simultaneously less than the thickness set-point. Relay will open at the start of Rise and will close when both the time and thickness set-points have been reached.

3.3.4 Programmable Inputs (Parameter 34)

Discrete I/O board #1 provides one programmable input and Discrete I/O board #2 provides two programmable inputs. The function of these input signals is programmable, as their name implies, and the function is determined by film deposition parameter 34.

The controller, therefore, has either one or three programmable inputs. However, regardless of configuration, only ONE input can be programmed per film layer. The programmable interlock input is parameter #34. If the programmable input is not to be used in the film layer, it should be programmed 0 (zero).

a) PHILOSOPHY OF THE PROGRAMMABLE INTERLOCK INPUT: The programmable interlock input (parameter 34) allows the systems engineer to alter or maintain the deposition cycle state upon receipt of an externally generated 115V ac signal. The incoming signal is optically converted to a logic signal and surveyed every 250 milliseconds (see Section 5) by the microprocessor. Programmable inputs enable the FDC-8000 to interact with other elements of the vacuum system such as heat sensors, pressure sensors, or residual gas analyzers.

The permanent FDC-8000 software is organized to allow the systems engineer to specify which of three effects will occur when the externally generated signal is received. The three effects are as follows:

b) HOLD: This description specifies that when the signal is received, the controller will hold in a specified state until the signal is removed. The programmable "hold" effect is similar to the *programmable* outputs inasmuch as it can be specified in terms of when, during, always, always except when, and always except during.

Example: The input can be specified to ALWAYS "hold" whatever state the deposition cycle is in when the signal is received. Likewise, it can be specified as ALWAYS "hold" whatever state the cycle is in EXCEPT if it is in the Deposition state.

c) STEP: This description specifies that when the signal is received, the controller will step from a specified deposition cycle state. Again, the programmable output specifications apply.

Example: The input can be programmed to "step" from either Rise OR Soak upon receipt of the signal. Also, it can be programmed to ALWAYS step from whatever state it happens to be in upon receipt of the signal.

d) LOCK: This description specifies that when the signal is received the controller will step to a specified state and remain in that state until the signal is removed. After the signal is removed, the controller will step to the next deposition cycle state. This effect is particularly useful in co-evaporation. A typical example involves the simultaneous evaporation of aluminum and silicon. The "master" controller would output a signal for the duration of its Deposit state. At that point, the "slave" controller would be stepped to the Deposit state and held until the "master" stepped out of Deposit, at which time the "slave" would also step out of Deposit.

3.3.4.1 Programming the Interlock Inputs

With one exception, the interlock inputs are programmed using the same rules, numerical codes, and decimal point codes as the discrete outputs. The exception is that in programming the interlock inputs, the first numeric designates not only the input which is being sampled, but also which of the three possible actions is desired.

a) INTERLOCK INPUT CODES:

Code	Input Monitored	Action
1	#1	HOLD
2	#1	STEP
3	#1	LOCK
4	#2	HOLD
5	#2	STEP

Code	Input Monitored	Action
6	#2	LOCK
7	#3	HOLD
8	#3	STEP
9	#3	LOCK

b) When programming the interlock inputs, remember:
- To unlock the program
- To recall the desired film
- To recall parameter 34
- To remember that the first numeric designates both the input number and the desired effect
- To adhere to the programming codes and rules prescribed for the discrete output
- To view the programmed value in the parameter/ sequence display
- To enter the program
- To lock the program

3.3.4.2 Examples of Programmed Interlock Inputs

a) 2123 means that upon receipt of an externally generated signal on input #1, the controller will step from Rise OR from Soak OR from Predeposit to the next state. If the deposition cycle state is in Rise, the controller will continue to step until it reaches Deposit (state #4). If the cycle is not in Rise, Soak, or Predeposit, the controller will ignore the signal.

b) 4.4bb means that upon receipt of an externally generated signal on input #2, the controller will hold in whatever state it is in except if it is in Deposit. If the deposition cycle is in the Deposit state, the controller will ignore the signal.

c) 94bb means that upon receipt of an externally generated signal on input #3, the controller will step to the Deposit state and remain there until the signal is removed, at which time it will exit the Deposit state. Regardless of whether the cycle is in Rise, Soak, or Predeposit, the controller will step to Deposit. After the signal is removed, the controller will step to the next state.

3.3.5 Two Process Examples Utilizing the Programmable Discrete Outputs and Interlock Inputs

a) CO-EVAPORATION AT A TEMPERATURE SET-POINT: The process requirement is to deposit an aluminum/ silicon alloy film on silicon wafers. However, the deposition cannot be started until the wafer temperature reaches 350°C. A sensor capable of generating a signal when temperature is reached is available.

Solution:

- Master Controller - Program all film parameters normally except Predeposit time (parameter 13). Program Predeposit time at 99:59 to negate variations from run to run in the time it takes for the substrates to reach 350°C. Program Interlock Input #1 to step from Predeposit when an external signal is received (parameter 34 - 22bb). Program discrete output #1 for relay closure during Deposit (parameter 35 - 14bb).
- Slave Controller - Program all film parameters normally except Predeposit time (parameter 13). Program this parameter at 99:59. Program Interlock Input #1 to LOCK in Deposit when an external signal is received (parameter 34 - 34bb).

In this process example, when temperature is reached, the master controller will step to Deposit and simultaneously generate a signal which will cause the slave controller to step to Deposit and remain there until the deposition being controlled by the master controller is completed. After thickness is reached, both controllers will step to the next state.

b) A THREE-LAYER BLENDED FILM: This is a three-layer process consisting of 1.0 kÅ chromium, 7.5 kÅ titanium, and 2.0 kÅ gold. However, in this process example all films must be blended at the interface. Therefore, the titanium deposition must start when the chromium thickness has reached .800 kÅ, and the gold deposition must start when the titanium thickness reaches 7.0 kÅ.

Solution:

- Master Controller - Program process #1 as a two-layer film consisting of chromium and gold. Program the chromium film normally. Program thickness set-point (parameter 22) at .800 kÅ. Program discrete output #1 (parameter 35) for relay closure at the thickness set-point (19bb). Program the gold film normally, except for Predeposit time (parameter 13) which should be programmed at 99:59. Program Interlock Input #1 (parameter 34) to step from Predeposit on receipt of an externally generated signal (23bb).
- Ancillary Controller - Program process #1 as a one-layer film consisting of titanium. Program

the film normally except Predeposit time (parameter 13) which will be at 99:59. Program Interlock Input #1 (parameter 34) to step from Predeposit upon receipt of a signal (23bb). Program thickness set-point (parameter 22) at 7.0 kÅ. Program discrete output #1 (parameter 35) for relay closure at the thickness set-point (19bb).

The master controller and the ancillary controller will begin their deposition cycles simultaneously. However, the ancillary controller (titanium) will hold in Predeposit. When the chromium thickness reaches .800 kÅ, the master controller will transmit a signal to the ancillary controller to release to the deposition state. The chrome film will continue to 1.000 kÅ, the last .200 kÅ of which are being co-evaporated with titanium. When the chrome layer is complete, the master controller will advance to layer #2 of process #1 (gold) when activated by an external signal. This layer will step to Predeposit where it will hold. When the titanium thickness reaches 7.000 kÅ, the ancillary controller will transmit a signal to the master controller to release to the deposition state. The titanium film will continue to 7.500 kÅ, the last .500 kÅ of which are being co-evaporated with gold. Both controllers will continue to Process Complete.

NOTE

This programming solution to the blended film is only one of the many possibilities. The best method depends on the overall system integration situation.

SECTION 4

BENCH CHECKOUT & SELF-TEST

4.1 INSPECTION

Your FDC-8000 was released to the carrier in good condition and properly packed. It is essential to all concerned that the contents of the shipment be carefully examined when unpacked to assure that no damage occurred in transit. Check the material received against the packing list to be certain that all elements are accounted for. Next, check for damage. If loss or damage is claimed:

a) Notify the carrier or his agent to request inspection of the loss or damage claimed.
b) Keep shipping containers until it is determined whether or not they are needed to return the equipment to Airco Temescal.

4.2 INITIAL TURN-ON

When turned on the FDC-8000 will normally display the status of the instrument at the time it was turned off. It will normally come up in the Abort mode with the trouble lights indicating an External Abort or a Power Fail. The FDC-8000 does not know the difference between power loss due to power source failure and power loss due to the unit being switched off; it only knows that if it was not already in the Abort mode, it had to abort due to loss of power.

Because all of the memory of the FDC-8000 is maintained without external power, the instrument cannot tell whether it has been off for 600 ms or 60 days.

The FDC-8000 can lose its memory if it has been off for more than 60 days and the storage environment has been difficult. Under these circumstances it will come up in a very confused state when power is applied. This confusion is normal and should not be disconcerting.

To re-establish a normal display, press Reset, select a Process Number, and put the unit in Self Test. This should restore the operating displays to meaningful values. The stored program, however, will probably be lost and will have to be re-entered. Recalled parameter values may appear very unusual since the machine will have forgotten what is reasonable. It is suggested that the sample program presented in the following section be entered into the FDC-8000 for checkout and that the unit be left on for a minimum of 24 hours to fully re-charge its batteries.

4.3 SAMPLE PROGRAM

The following film program may be used in checking out the FDC-8000 through the Self Test mode. Program entry is described below.

a) FILM #1:
   1) Rise time: 10 seconds
   2) Soak time: 10 seconds
   3) Predeposit time: 10 seconds
   4) Set-point time: 1 minute
   5) Soak power: 5%
   6) Predeposit power: 10%
   7) Maximum power: 20%
   8) Idle power: 5%
   9) Rate: 100 Å/second
   10) Set-point thickness: 8.0 kÅ
   11) Thickness: 10.0 kÅ
   12) Source-Sensor: 1-1
   13) Response: 20
   14) Error limit: 5%
   15) Tooling: 100%
   16) Density: 1.00
   17) Acoustic impedance: 8.83
   18) Feed power: 7%
   19) Feed time: 10 seconds
   20) Interlock input: 0
   21) Discrete output: 15. (one, five, point)

b) FILM #2:
   1) Rise time: 5 seconds
   2) Soak time: 5 seconds
   3) Predeposit time: 10 seconds
   4) Set-point time: 1 minute
   5) Soak power: 15%
   6) Predeposit power: 27%
   7) Maximum power: 50%
   8) Idle power: 10%
   9) Rate: 50 Å/second
   10) Set-point thickness: 4.8 kÅ
   11) Thickness: 5.0 kÅ
   12) Source-Sensor: 2-1
   13) Response: 50
   14) Error limit: 5%
   15) Tooling: 50%
   16) Density: 2.69
   17) Acoustic impedance: 8.20
   18) Feed power: 0%

19) Feed time: 0
20) Interlock input: 1. (one, point, no zero)
21) Discrete output: 27. (two, seven, point)

c) Enter the above program as follows:
1) Unlock program. Press SET PROCESS button.
2) Select Process #1 by pressing PROCESS, ONE.
3) Program Process #1 as a two layer process consisting of film #1 and #2 in sequence. Press ONE, TWO, and ENTER. Press C (clear). Clear always recalls the value stored in memory and should be used if there is any doubt that a parameter has been entered. If pressing C does not result in a display of 12bb (b = blank), the process was not entered. Is the program unlocked? Is the FDC-8000 in process on Process #1? Under either of these conditions Process #1 cannot be changed.
4) After Process #1 has been programmed, select Film #1 by pressing FILM, ONE.
5) Select Rise time (parameter 11) by pressing PARAMETER, ONE, ONE.
6) Enter 10 seconds by pressing POINT, ONE, and ENTER. Remember that seconds follow the decimal point and minutes precede it. The decimal point simulates a colon.
7) Step to the next parameter by pressing ENTER again.
8) Enter the rest of the time parameters, the power parameters, and the rate.
9) Thickness parameters are entered in kiloangstroms. To enter 8.0 kÅ, press EIGHT, ENTER. To enter 4.8 kÅ, press FOUR, POINT, EIGHT, ENTER. Four hundred angstroms would be entered as .400 kÅ by pressing POINT, FOUR, ENTER.
10) Select source #1 and sensor #1 by entering 11 for parameter 24.
11) Enter the remainder of the parameters.
12) After parameter 35 is entered, push the Enter key a second time to return the parameter display to parameter 11. The stored program can be scanned by using the Enter key to step through the program.
13) Parameters 36 and 37 are display-only parameters and cannot be programmed. These parameters are displayed by pressing PARAMETER, THREE, SIX or PARAMETER, THREE, SEVEN.
14) Next, program Film #2 in the same manner.

4.4 SELF TEST OPERATION

The FDC-8000 is best checked by operating it first in the Self Test mode. To enter the Self Test mode the program must be unlocked.

The Self Test mode is identical to the normal mode except that the sensor input is simulated. For this reason, entry to the Self Test mode will extinguish the Crystal Fail light if it is on. No other differences between the Self Test mode and the Normal mode occur until entry to the Deposit State.

The following description assumes the FDC-8000 has been programmed with the sample programs provided above.

a) Reset the FDC-8000 and select Process #1 by pressing SET PROCESS # button and key ONE. Enter the Self Test mode, and press Start. The State display will show Rise, the Power display will increase toward 5%, and the Process Time display will increment.

b) When Process Time shows about 10 seconds, the unit steps to the Soak state and the power is maintained at the Soak level of approximately 5%.

c) At Process Time of about 20 seconds, the unit steps to the Predeposit state and during the next 5 seconds or so the power increases to approximately 10%, where it remains until the process Time equals about 30 seconds.

d) At 30 seconds or so the unit steps to the Deposit state. Upon entry to the Deposit state, the FDC-8000 simulates thickness build-up at a rate proportional to the output power. The constant of proportionality is 0.01-micrograms per centimeter squared per second per 0.1% power, which corresponds to a rate of approximately 1Å per second of material with density 1 per 0.1% power. Thus, the programmed rate of 100Å per second for Film #1 should require a power level of about 10%, since Film #1 is also programmed for a tooling factor of 100%, a density of 1.00, and an acoustic impedance of 8.83 (quartz). Because the simulated mass rate is directly proportional to power, the tooling factor, density, and acoustic impedance calculations can easily be verified by comparing the Self Test power required with the predicted value.

e) Simulated mass rate equals power, in percent times ten, and mass rate is equal to the thickness rate divided by the tooling factor and multiplied by the density and the acoustic impedance correction factor. The acoustic impedance correction factor is one for acoustic impedance equal to that of quartz (8.83). See Section 7 for a description of these factors.

f) When the Process clock reaches about 1 minute, the Set-Point Time LED will light.

g) At a thickness of 8.0 kÅ, the Set-Point Thickness LED should light.

h) At a thickness of 10.00 kÅ, the FDC-8000 will step to the Feed state and the power will go to about 7%. In addition, Discrete Output #1 will be activated since it was programmed to be active during the Feed state.

i) After 10 or so seconds in the Feed state, the unit will step to the Layer Complete state, Discrete Output #1 will go out, and the power will go to the idle power level of about 5%.

j) The FDC-8000 will then remain in the Layer Complete state until given a Start signal.

k) Following a Start signal, the FDC-8000 will step into the Rise state and the layer # will increment to 2.

l) If an external signal is applied to the programmable Interlock Input #1, the FDC-8000 will be held from stepping to the next state and the Hold LED will light. Removing the external signal will allow the FDC-8000 to continue.

m) Source-active LEDs #1 and #2 will both be lit as source #1 is in Idle and source #2 is being controlled.

n) Discrete Output #2 will come on at the Set-Point Time as programmed.

o) During Deposit the power should stabilize at approximately 26.9% if the crystal health is 99%. This is because the mass rate is equal to the thickness rate, divided by the tooling factor (.5), and multiplied by the density (2.69) and the acoustic impedance correction factor (approximately 1 for a new crystal).

p) Following the Deposit state there will be no Feed state and the unit will step directly from the Deposit state to the Layer Complete state.

q) Upon completion of layer #2, the FDC-8000 will step to the Process Complete mode awaiting a Reset signal.

r) At this time it is possible to observe the effect of the Tooling, Density, and Acoustic Impedance parameters. If prior to Reset, the Tooling Factor parameter for Film #2 is increased, the displayed thickness should increase proportionately.

If the Density is increased, the thickness should decrease proportionately. If the Acoustic Impedance is increased, the thickness should increase. The amount of increase will depend on the crystal health. If the crystal health is close to 99% the thickness may increase very little or not at all. If the crystal health is low the increase will be greater. See Section 7 for a description of the effect of acoustic impedance on displayed thickness.

s) Crystal health decrease can be simulated on the FDC-8000 by disconnecting the sensor, or by selecting a non-existent sensor in the film program, thereby simulating a crystal failure, and then simulating a very high deposition rate. Under these conditions the crystal health will slowly decrease. Allowing the crystal health to go below zero will produce meaningless results as this condition is beyond the range of the instrument. The crystal health will be restored to a normal value by reconnecting an operating sensor.

4.5 MANUAL OPERATION

To enter the Manual mode the program must be unlocked and the Auto/Manual switch depressed. A second depression of the switch will cause the FDC-8000 to exit the Manual mode, as will a Reset.

The Manual mode is identical to the Normal mode in all respects, except that output power is controlled only through the remote power switch.

The remote power switch has four positions (see Figure 4-1). In the neutral position, output power is maintained at its last value. Moving the plunger sideways in the direction of the "+" arrow will increase the power, moving the plunger sideways in the direction of the "-" arrow will decrease the power. Pushing the plunger straight down will create an External Abort.

The External Abort feature is present whether or not the FDC-8000 is in the Manual mode, and therefore can be used as a remote "panic button."

In order to assure adequate resolution, the minimum increment by which the power is increased or decreased is 0.1% and the rate at which the power is increased is one increment per quarter second. If the increments were constant, this would require 250 seconds to go from zero power to full power. For this reason, the size of the increment is allowed to increase if the power switch is held in a constant position. The size of the increment is increased by .1% every quarter second, allowing the FDC-8000 to go from zero to 99% in 12 seconds, while maintaining a set-point resolution of 0.1%. With a little practice, precise manual power setting becomes fast and easy.

4.6 SETTING ABORT ENABLES

The FDC-8000 is shipped with the Power Limit, Crystal Fail, and Excess Error Abort Enable switches turned off; i.e., as shipped, the FDC-8000 will not abort under these conditions. The Abort Enable switches are accessible through the rear of the FDC-8000 and can be changed at any time, but they are most easily changed before installation by removing the top cover to gain access to the switches. The Abort Enable switches are located on the left side of the I/O Interface board as viewed from the rear. Figure 6-1 shows the location of the switches. Putting the switch lever in the "+" position enables the Automatic Abort on that function.

4.7 INSTALLING OPTION BOARDS

Option boards are also most easily installed while the FDC-8000 is on the bench. Figure 6-2 is a view of the FDC-8000 rear panel and shows the location of the various option boards.

All Source-Sensor boards are identical as are all Discrete I/O boards. The input-output configuration of these boards is defined by the slot into which they are inserted. For this reason these boards have a notch in the upper left-hand corner of their mounting plates. When mounted, a number appears in this notch which then becomes the number of the I/O board; thus any Source-Sensor board plugged into the number 3 Source-Sensor slot will provide sensor input number 3 and source output number 3. The Digital to Analog Converter board has a dedicated slot. The two optional card slots are both identical. Each type of I/O card is keyed so that it can not be plugged into the wrong slot.

4.8 DIGITAL TO ANALOG CONVERTER (DAC) CHECKOUT

The optional DAC board contains two converters which allow simultaneous recording of any two of the following five functions: Time, Rate, Power, Thickness and Error. The full scale output of the DAC is 5 volts and the output impedance is 1 kohm. The analog outputs are single-ended outputs referenced to ground. Parameter selection for each of the independent channels is accomplished by connecting appropriate control pins to ground. Figure 6-7 lists the control pins and the affect of tying them to ground. In addition to the individual channel control pins there are two control pins which are common to both channels and are intended to simplify the process of setting up analog recorders. Connecting the zero control line to ground will drive both channel outputs to zero, allowing the recorder zero to be easily set. Releasing the zero line and connecting the full scale line to ground will drive both channel outputs to full scale for establishing the recorder full scale calibration.

The individual channels will normally convert the three least significant digits of the display to analog, thus a thickness of 0.500 kÅ would result in a half scale analog output of 2.50 volts or a scale factor of 5 millivolts per angstrom. If more resolution is desired, each individual channel can be configured to convert only the last two digits of the display, thus the analog output would achieve full scale at 100. Actually, the maximum analog output is reached at 99Å, corresponding to an output voltage of 5.95. The output scale factor in this configuration is 50 millivolts per angstrom. The above scale factors are based on the assumption that the thickness display is in the zero to 9.999 kÅ range. Because the thickness and rate displays are autoranging, the analog output of these variables will also autorange so that, in the above example, if the thickness is in the range of 10 kÅ to 99.9 kÅ, the analog scale factor would be 50 millivolts per 10Å.

The Error parameter must be handled differently than the other parameters because it can be negative. Maximum positive error is converted to 5 volts, maximum negative error is converted to 0 volts, and zero error is converted to a midscale, 2.5 volts output. Maximum corresponds to 99 or 999 plus 1.

The DAC can be checked by putting the FDC-8000 in the Self Test mode and checking for correspondence between the analog output and the selected front panel displays.

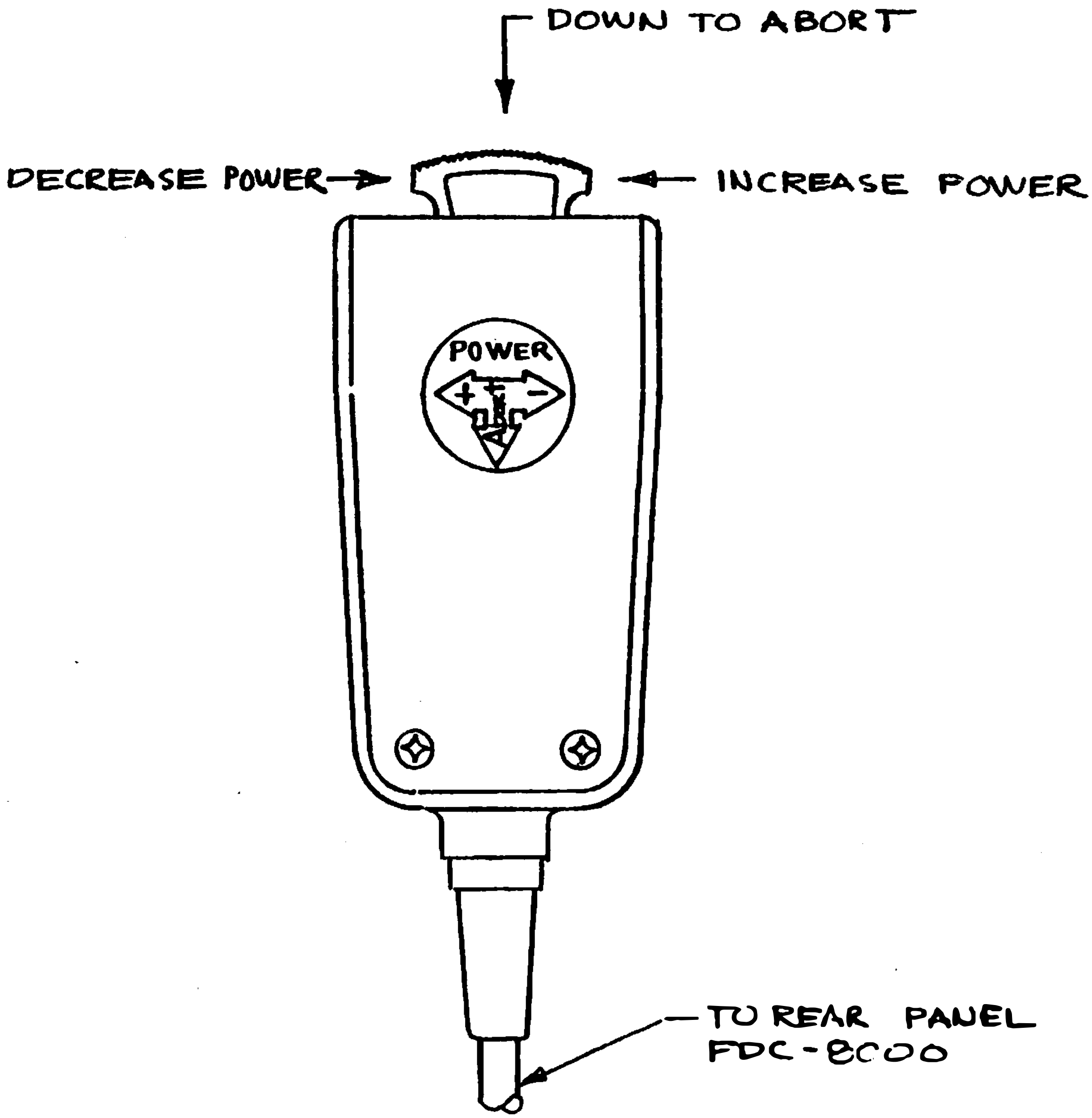


Figure 4-1 Remote Power Switch

SECTION 5

INPUT/OUTPUT CHARACTERISTICS

The following section describes the electrical characteristics of the FDC-8000 inputs and outputs. All outputs of the FDC-8000 are updated and all inputs are sampled every 250 milliseconds. In order to insure immunity to transients, inputs are not considered to have changed until the same input state is obtained on two successive samples.

Therefore, all input signals must have a minimum duration of at least 0.5 seconds. Input signals lasting less than 250 milliseconds may be ignored, while signals lasting between 250 and 500 milliseconds may or may not be recognized.

5.1 CONTROL VOLTAGE OUTPUT

Each control voltage output of the FDC-8000 is an independently isolated two-terminal output. The positive terminal or the negative terminal can be grounded. In the event that the receiving equipment has an isolated input, one of the input lines must be grounded to avoid build-up of excessive voltage potentials on the otherwise isolated circuitry.

The nominal voltage output is 9.9 volts plus or minus 5% at the maximum control voltage output of 99%. The output impedance is nominally 27 ohms. The outputs are short-circuit protected with short circuit current limited to between 20 and 40 milliamperes.

CAUTION

Long term shorting of all three Source-Sensor outputs may cause excessive temperature rise in the isolated supply windings on the power transformer and should be avoided.

A fuse is incorporated in the control voltage circuitry to protect the circuitry against inadvertent connection to high voltage. The fuse is rated at 1/16-ampere. A schematic of the control voltage output circuit is shown in Figure 5-1. The circuitry is located on the Source-Sensor card which is further described in Section 8.

5.2 SENSOR INPUT

The sensor oscillator is connected to the FDC-8000 through a single coaxial cable. Sensor ground is common with the FDC-8000 ground. Power to the sensor oscillator is carried on the center conductor of the coaxial cable. Power is supplied from the FDC-8000 internal 5-volt supply through a 50-ohm resistor which accomplishes the dual function of properly terminating the 50-ohm coaxial cable and providing short circuit protection. The sensor buffer circuit is shown schematically in Figure 5-2. The circuitry is located on the Source-Sensor card and is further described in Section 8.

5.3 DISCRETE OUTPUT

Each Discrete Output is an independent relay isolated output. The common, normally-closed, and normally-open terminals of the relays are available at the output connector. The output relays are socket mounted control relays equivalent to the American Zetler AZ420-C07-4L. The 41-type contact is a single gold-plated silver contact intended for light duty in the 1-milliampere to 2-ampere region. Resistive load contact ratings are 2 amperes at 26V dc, or 1 ampere at 115V ac.

5.4 DISCRETE INPUTS

Each Discrete Input is an independently isolated, optically coupled signal pair which requires an ac input voltage. The input voltage required is 60 to 135V ac at a frequency of 50 to 60 hertz. The input current required at an input of 115 volts at 60 hertz is 20 to 25 milliamperes. The input load is primarily capacitive and, therefore, the current decreases at an input of 115 volts at 50 hertz. The discrete input buffer circuit is shown in Figure 5-3.

5.5 DIGITAL-TO-ANALOG CONVERTER OUTPUT

The DAC analog outputs are single-ended and share the FDC-8000 common ground. The nominal output voltage range is 0 to 5.0 volts dc and the output impedance is 1.0 kohm nominal. The DAC analog output circuit is shown in Figure 5-4.

5.6 DAC CONTROL INPUTS

The DAC control inputs are single-ended and share a common ground with the FDC-8000. The inputs are activated by connecting them to ground through a jumper, mechanical switch, or transistor. In the open state, the inputs are pulled up to +12 volts through a 10-kohm resistor. The input circuit is described in Section 8 and a schematic of the circuit is shown in Figure 5-5. The circuitry is located on the DAC I/O card.

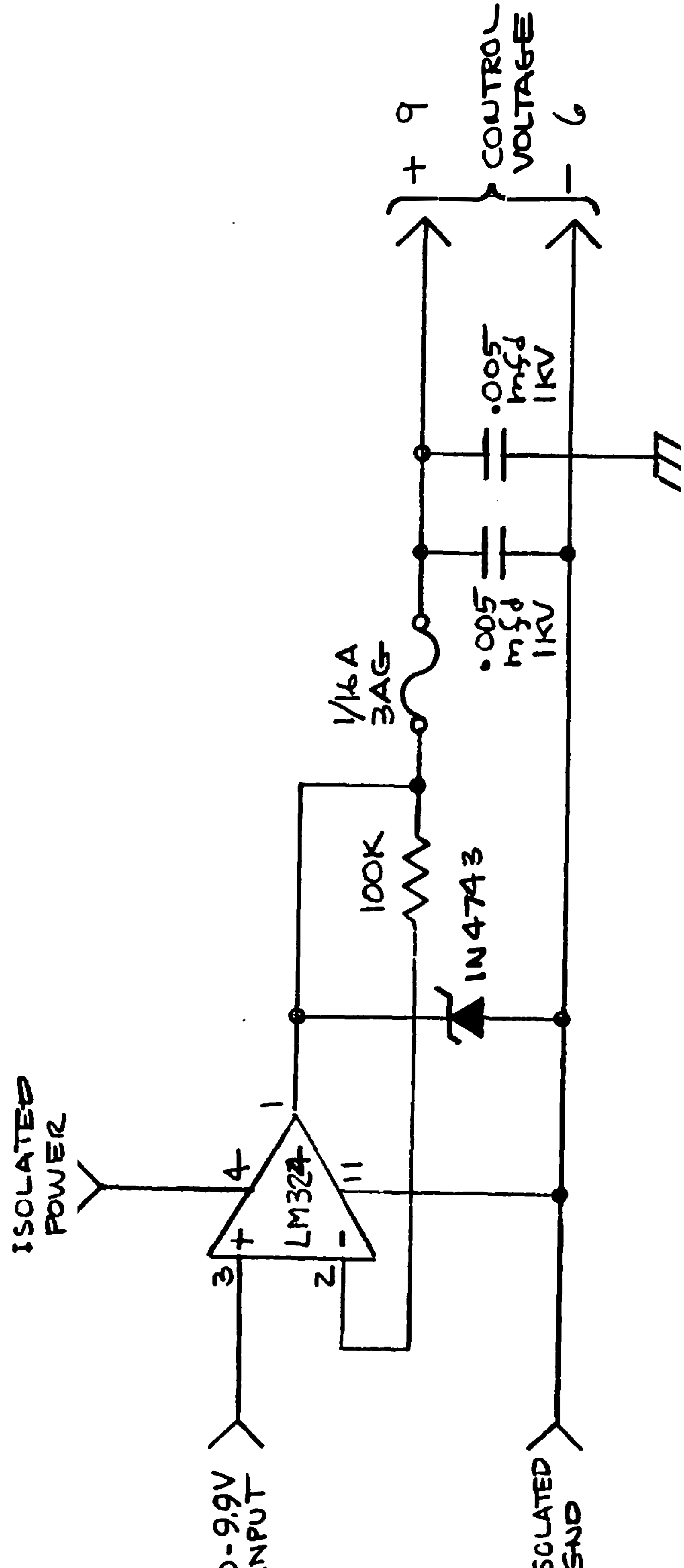


Figure 5-1 Control Voltage Output Circuit

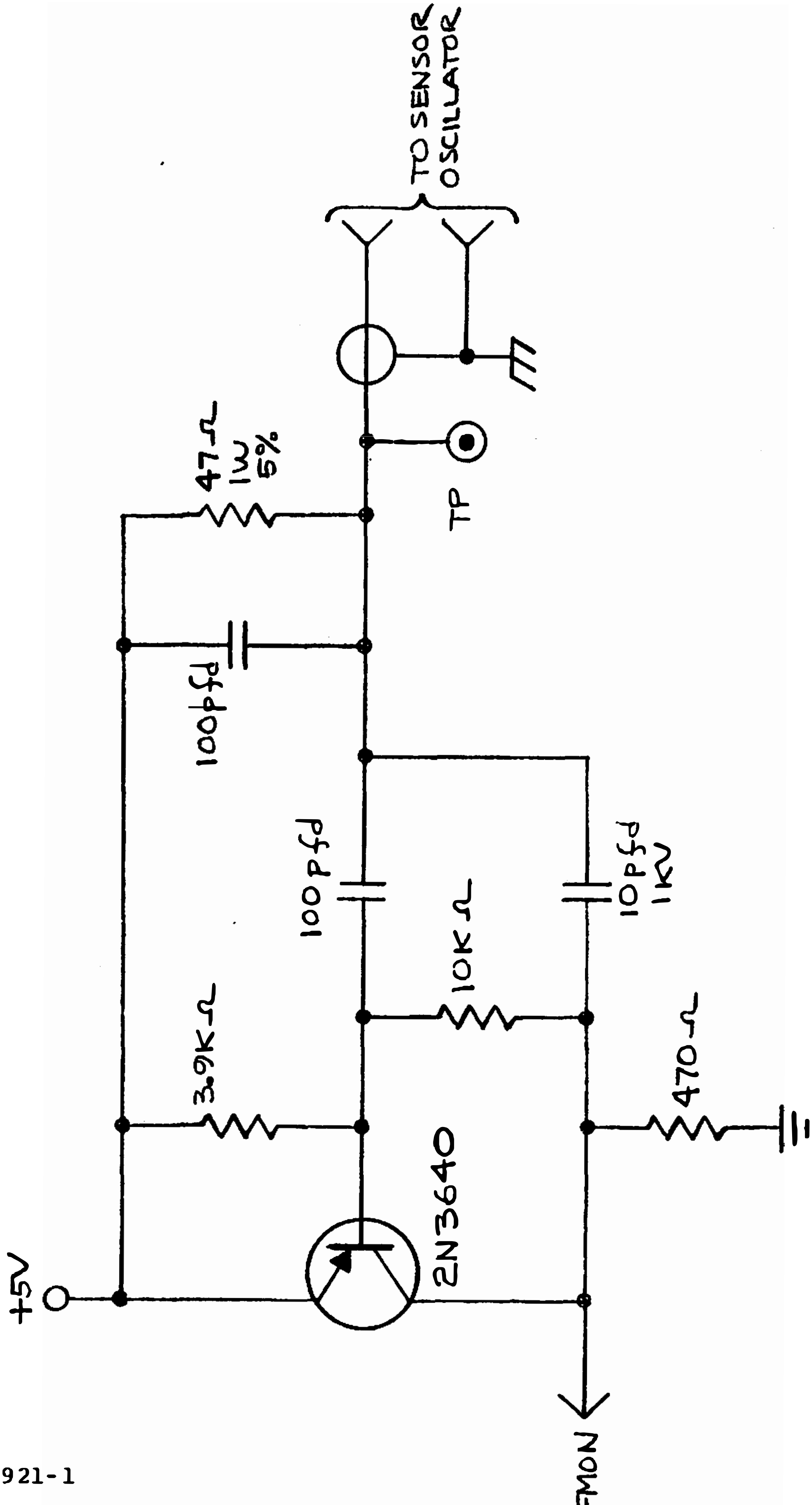


Figure 5-2 Sensor Input Buffer Circuit

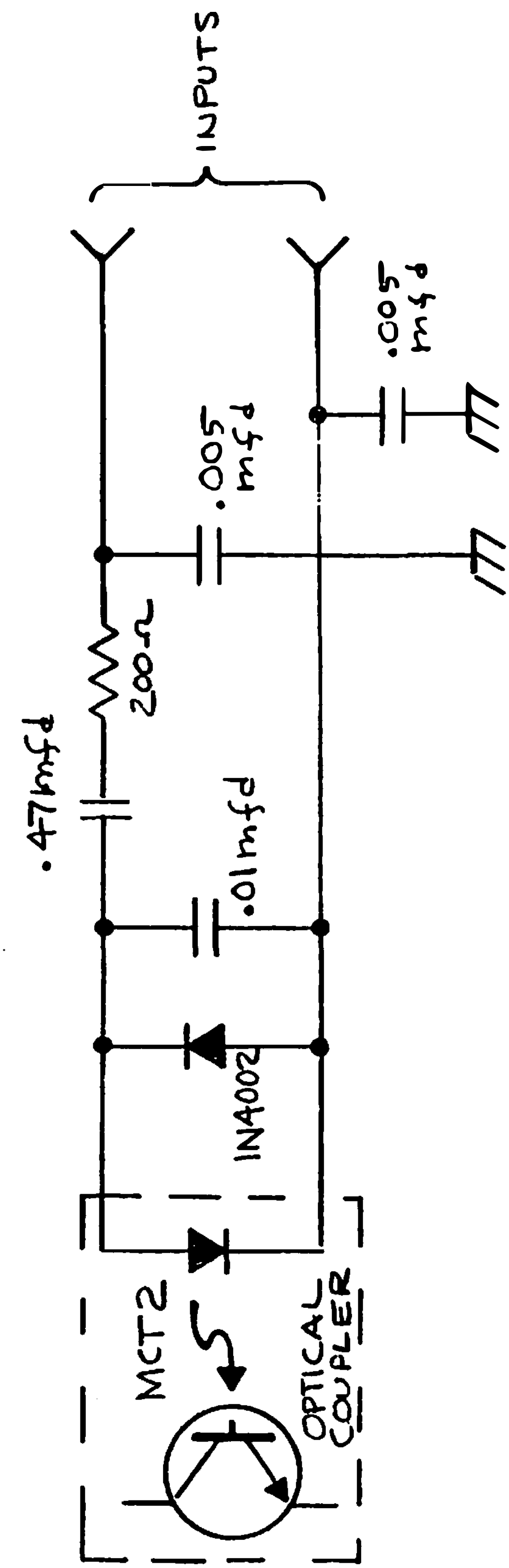


Figure 5-3 Discrete Input Buffer Circuit

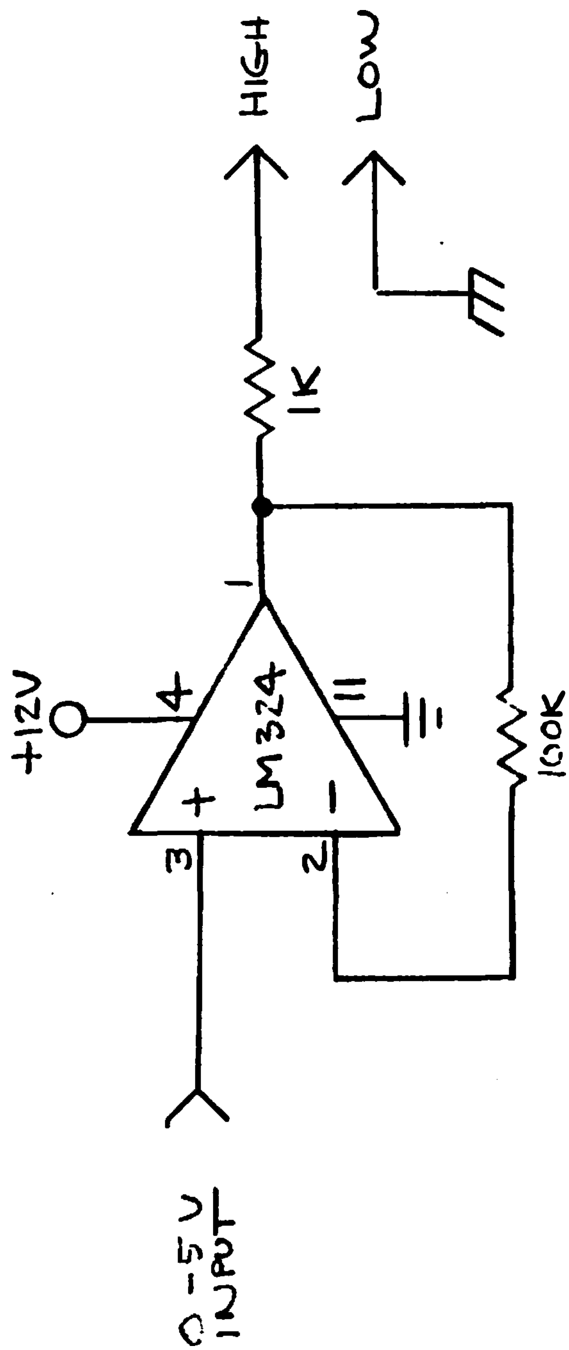


Figure 5-4 DAC Analog Output Circuit

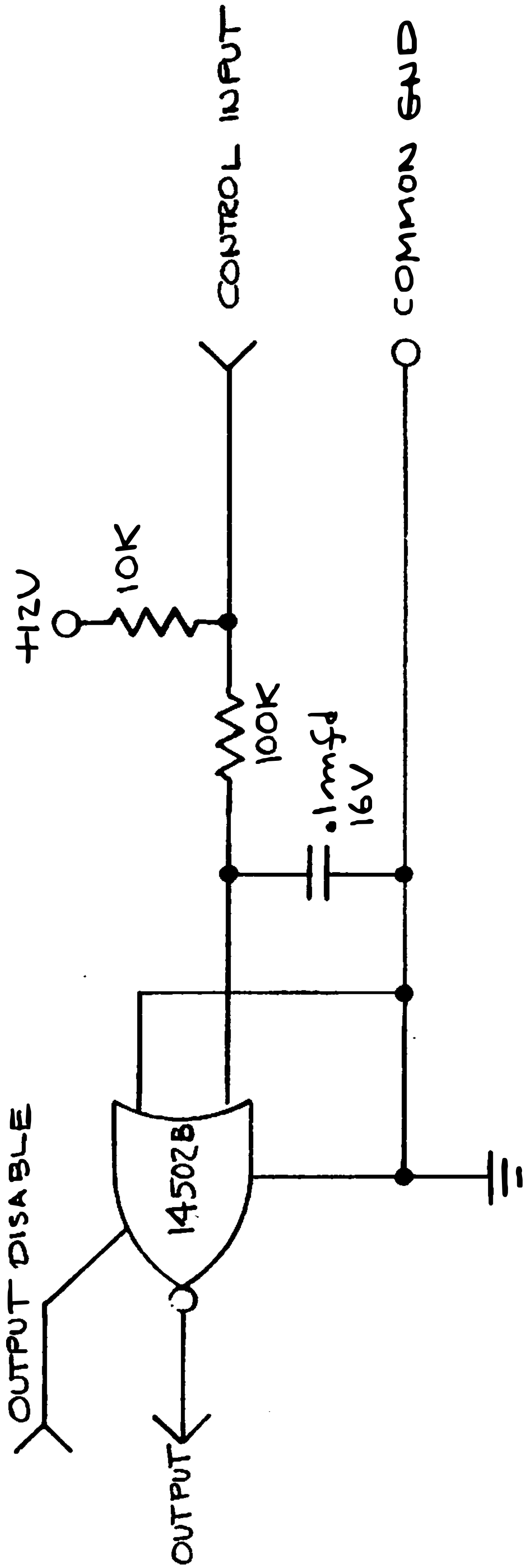


Figure 5-5 DAC Control Input Circuit

SECTION 6

INSTALLATION

6.1 ABORT ENABLES

The FDC-8000 is shipped with the optional abort conditions disabled. If the system application requires that any of these abort conditions be enabled, access to the Abort Enable switches is most easily achieved prior to installation by removing the top cover of the instrument (see paragraph 4.6). If the FDC-8000 has been installed, the Abort Enable switches can be reached by removing the left-most cover plate or accessory card at the rear of the instrument. (See Figure 6-1.)

6.2 MOUNTING

The FDC-8000 is intended for rack mounting. For maximum operating ease it should be mounted at approximately eye level. In its open position the hinged front panel cover hangs below the FDC-8000 and this should be taken into consideration when installing. If the FDC-8000 is mounted in a rack containing other heat generating equipment, care should be taken that there is adequate ventilation to keep the ambient temperature below the FDC-8000's ambient temperature rating.

6.3 PROPER GROUNDING

The FDC-8000 was designed for maximum noise immunity and in most cases will require no special grounding precautions. If noise sensitivity is noted in unusually noisy environments, more attention to proper grounding may be required. It is important that the rack in which the FDC-8000 is mounted is tightly grounded to the vacuum station. This grounding is best accomplished by a multipoint mechanical connection through the structure itself or through grounding straps. Grounding straps should be as wide as practical and may be foil or braid. Standard small diameter copper conductor does not create an effective ground. Although the dc resistance measured on such a system may be low, the inductance can be high, allowing rapidly changing fault currents to create large potential differences over the lengths of the ground wire. Multiple current paths significantly reduce the inductance, and since the inductance of a conductor is inversely proportional to its radius, wide straps will have the lowest inductance.

In particularly noisy environments it is desirable to ground the FDC-8000 to the rack frame, or other good ground, by means of a ground strap connected to the grounding lug provided on the rear panel beneath the power receptacle (see Figure 6-2).

6.4 EXTERNAL CONNECTION

All external connections to the FDC-8000 are made through the rear panel (see Figure 6-2).

6.4.1 Power (J1)

The power receptacle in the FDC-8000 is an internationally approved type. A fuse, voltage selection board, and RFI filter are part of the power receptacle assembly. The power plug must be removed to change the fuse or the voltage selection board.

6.4.2 Voltage Selection

The voltage selection is preset at the factory for a nominal input of 120 volts. However, the following nominal input voltages can be selected: 100, 120, 200, and 240. To change the desired nominal input voltage, remove and reorient the voltage selection board as shown in Figure 6-3.

6.4.3 Ground Lug (J2)

In particularly noisy environments the FDC-8000 should be grounded to the instrument rack or other good ground by means of the grounding lug immediately below the power receptacle (see Figure 6-2).

6.4.4 Remote Power Switch (J3)

Figure 6-2 shows the location of the receptacle into which the Remote Power switch is plugged.

6.4.5 Source-Sensor (J4)

The system interface between the FDC-8000 and the remote sensor oscillator is a 50-ohm coaxial cable terminated with BNC connectors similar to AMP 225395-1 (plug) and AMP 225396-1 (jack). The plug on the Source-Sensor board mates to a jack on the cable which is supplied with the transducer.

The control voltage output is interfaced through a 9-pin, D-shell connector equivalent to the AMP HD-20 series, P/N 205203-1. The pin layout is defined in Figure 6-4, and Figure 6-6 supplies information on the mating connector.

The Source-Sensor cards are all functionally identical. The particular source number and sensor number to which connection is being made is determined by the position of the card, and is indicated by the number which shows through the mounting plate notch (see Figure 6-2).

6.4.6 Discrete Input/Output

The Discrete I/O System interface is through a 25-pin D-shell connector. There are two Discrete I/O card slots in the chassis and, although the I/O boards are functionally equivalent, the signals on the pins change in relation to the slot into which the board is plugged. The system side of the interface is a receptacle with crimp on pins equivalent to the AMP HD-20 series, P/N 205207-1.

Figure 6-5 shows the pin configuration, and Figure 6-6 supplies pertinent information on the mating connector. When the output condition is true, the yes pin is connected to the common pin.

6.4.7 Digital to Analog Converter (DAC)

The Digital to Analog Converter is through a 15-pin, D-shell connector. The system side of the interface is a receptacle with crimp on pins equivalent to the AMP HD-20 205205-1. Figure 6-7 shows the pin layout.

6.5 SENSOR HEAD AND OSCILLATOR

6.5.1 Description

The SHC-8006 sensor head is constructed of gold plated stainless steel and features a brazed water cooling line for better thermal coupling and head temperature control. The crystal holding design makes for easy crystal changing and crystal contact with the socket or crystal retainer is limited to the outer-most edges of the crystal. The exposed surface of the crystal is grounded to eliminate electrostatic interference from stray RF fields and/or charged particles.

A collimation tube or heat shield may be mounted to the sensor head by using the tabs with #2-56 tapped holes provided on each side of the sensor face.

The sensor head, internal cable, and crystals may be ordered as a separate kit (Model SHC-8006). One oscillator and 10 feet of external cable are provided with the FDC-8000 unit.

6.5.2 Oscillator Installation

Connect one end of the 10-foot oscillator cable to the BNC connector (J4, Figure 6-2) on the appropriate source-sensor board at the rear of the FDC-8000. Connect the other end of the cable to the female plug on the oscillator. The male end of the oscillator connects directly to the feedthrough leading into the vacuum chamber (see Figure 6-8).

CAUTION

Do not connect the oscillator directly to the BNC connector on the source-sensor board. Always use the cable to make the connection. Failure to make this connection correctly will create a mismatch in the impedance of the oscillator circuit.

6.5.3 Sensor Installation

The sensor head can be installed in any appropriate location in the vacuum chamber, preferably more than 10 inches from the evaporation source. It can be supported by its integral mounting bracket furnished with two #4-40 tapped holes. The internal (vacuum) cable, supplied with the sensor kit, connects the sensor head to the dual water/electrical feedthrough, to which the oscillator is attached. The cable length from sensor head to feedthrough connection should not exceed 40 inches. Shield the sensor cable in the most expedient way possible to protect it from radiation heat released from the evaporation source or the substrate heater.

The water cooling tube connects to the feedthrough by brazing or vacuum couplings. If necessary, both cable and water lines may be wrapped in aluminum foil to extend their useful life. The mounting tabs may be used to install a radiation shield to specifically protect the microdot connector and cable at its attachment point to the head.

Water cooling of the sensor head should always be provided except during short depositions at low temperatures. In all cases, head temperature should not exceed 100°C. Sufficient cooling for thermal environment to 250°C can be provided by approximately 0.2-gpm water flow.

Use a shutter to shield the sensor 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.

6.5.4 Changing the Sensor Crystal (Figure 6-9)
The FDC-8000 sensor crystal lies in a drawer which is easily removed from the sensor housing. Grip the edges of the drawer between thumb and forefinger and pull straight out. Remove the round ceramic retainer by pulling it straight up. Shake out the spent crystal and drop in a new crystal with the plain (unmarked) side down. Always use clean lab gloves or plastic tweezers for handling the crystal. Replace the ceramic retainer over the crystal using gentle pressure until it is firmly seated.

CAUTION
Do not rotate ceramic retainer assembly after it is seated, since it will scratch the electrode on the crystal.

Replace drawer in housing; it will slide in easily. The drawer is keyed to the housing and cannot be installed upside down.

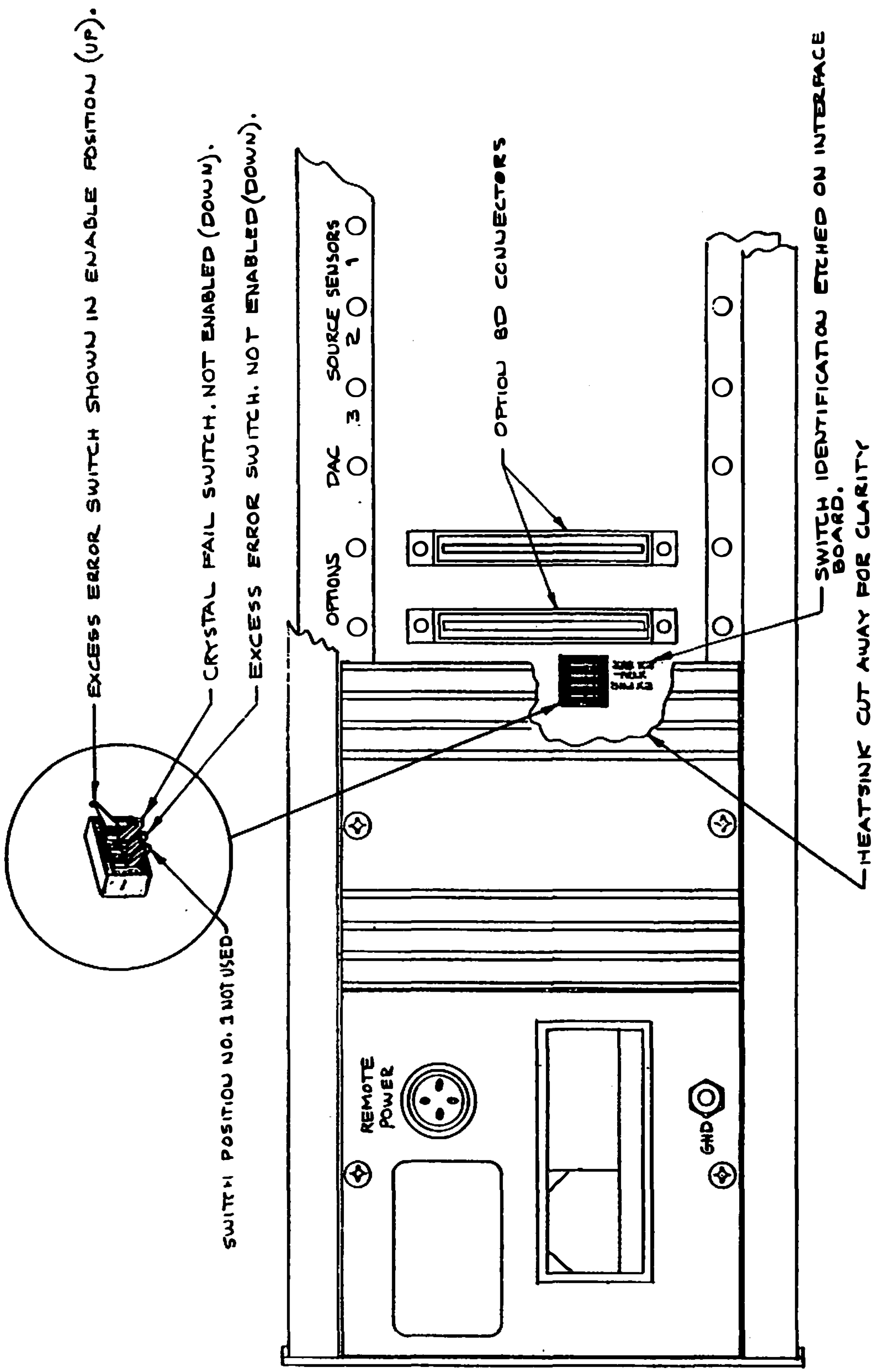


Figure 6-1 Remote Enable Switches

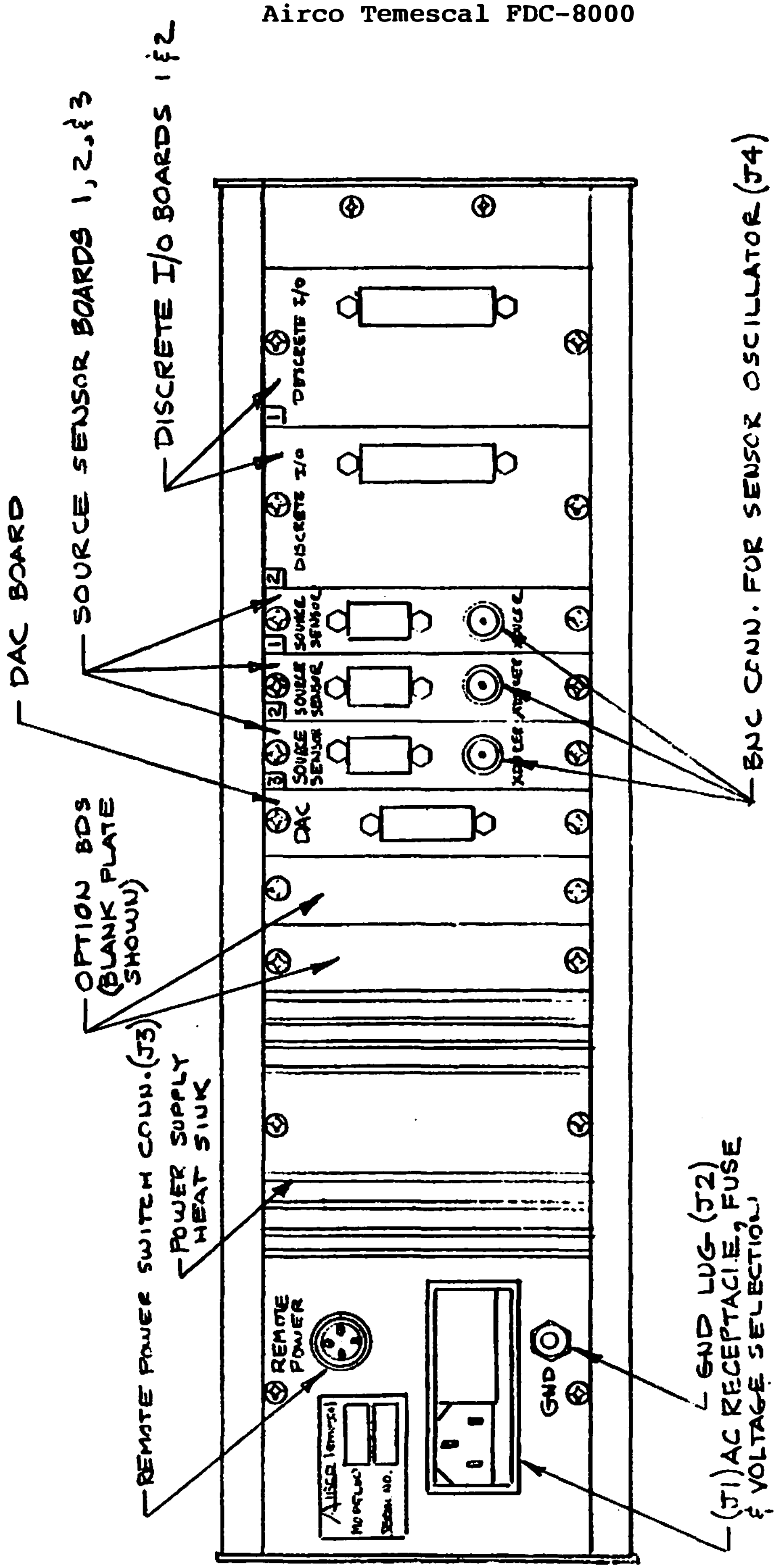
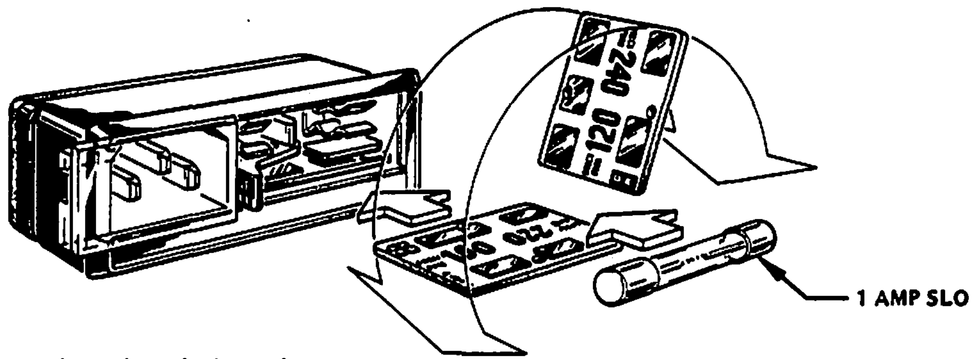
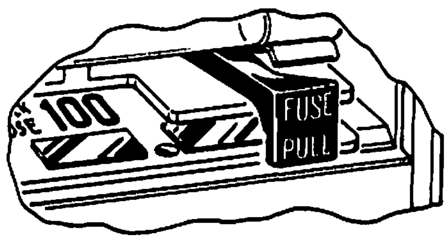


Figure 6-2 Rear Panel FDC-8000



Operating voltage is shown in VS&F Connector window.



HOW TO SELECT OPERATING VOLTAGE

1. Open cover door and rotate fuse-pull to left.
2. Select operating voltage by orienting PC Board to position desired voltage on top left side. Push board firmly into module slot.
3. Rotate fuse-pull back into normal position and re-insert fuse into holders, using caution to select correct fuse value.

Figure 6-3 Voltage Selection

P/N	FUNCTION
6	Control Voltage Negative
9	Control Voltage Positive

Figure 6-4 Source-Sensor System Interface Connector

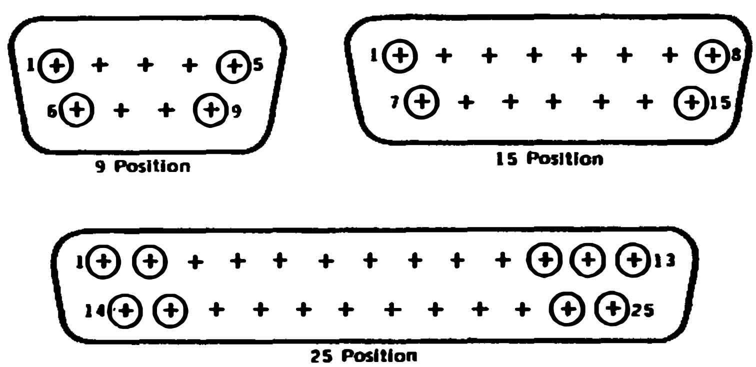
PIN NO.	DISCRETE I/O BOARD No. 1			DISCRETE I/O Board No. 2	
	SIGNAL	OUTPUT FUNCTIONS		SIGNAL	OUTPUT FUNCTIONS
		FORMAT INPUT OFF	FORMAT INPUT ON		
20	Yes			No	
21	No	Abort	Abort	Yes	Shutter No. 2 Output
22	Common			Common	
24	Yes			Yes	
25	No	Inprocess	Layer Start Pulse 3 sec. duration	No	Shutter No. 3 Output
23	Common			Common	
8	Yes			Yes	
9	No	Process Complete	Layer Complete Pulse 3 sec. duration	No	Programmable No. 2 Output
7	Common			Common	
18	Yes			Yes	
17	No	Shutter No. 1	Shutter No. 1	No	Programmable No. 3 Output
19	Common			Common	
11	Yes			Yes	
12	No	Programmable No. 1 Output	Programmable No. 1 Pulse 3 sec. duration	No	Feed Output
10	Common			Common	

	INPUT FUNCTIONS	INPUT FUNCTIONS
5,4	Abort Input Pair	Programmable Interlock No. 2 Input Pair
3, 2	Reset & Start Input Pair	Programmable Interlock No. 3 Input Pair
1, 14	Format Input Pair (110V on Pin 14, Neutral on Pin 1)	Not Used
15,16	Programmable Interlock No. 1 Input Pair	Not Used
13	Chassis Ground	Chassis Ground
6	No Connection	No Connection

Figure 6-5 Discrete I/O System Interface Connector

HDP-20 Connector		AMP Part Number
9 pin receptacle		205203-1
15 pin receptacle		205205-1
25 pin receptacle		205207-1
socket for above		205201-5
crimping tool		29004-1
pin insertion/extraction tool		91067-2
clamp and shield assy.	9 pin	205729-1
	15 pin	205730-1
	25 pin	205718-1

From: AMP Special Industries, San Mateo, (415) 573-7722



Electrical Characteristics

Contact Current Rating (with No. 20 AWG [0.5-0.6 mm²] wire): 7.5 A
Contact Resistance: 7.3 Milliohms (max.)
Dielectric Withstanding Voltage: 1000 V (min.)
Insulation Resistance: 5000 Megohms

Mechanical Characteristics

Contact Engagement Force: 12.0 Oz.* [3.4 N] (max.)
Contact Separation Force: 0.75 Oz. [0.2 N] (min.)
Contact Retention: 10 Lb. [44.4 N] (min.)
Tensile Strength (crimp):
- With No. 20 AWG [0.5 - 0.6 mm²] Wire–20 Lb. [88.96 N]
- With No. 22 AWG [0.3 - 0.6 mm²] Wire–12 Lb. [53.376 N]
- With No. 24 AWG [0.2 mm²] Wire–8 Lb. [38.584 N]
- With No. 26 AWG [0.12 - 0.15 mm²] Wire–4.5 Lb. [20.016 N]
- With No. 28 AWG [0.08 - 0.09 mm²] Wire–2.7 Lb. [12.0096 N]

Connector Mating Force (per contact): 8 Oz. [2.224 N] (max.)

Figure 6-6 Mating Connector

PIN NO.	SIGNAL		FUNCTION
8	Output		Channel #1 Outputs
15	Return		
12	2 Decade		Channel #1 Control Inputs
11	Error		
1	Rate	Time	
9	Power		
5	Full Scale		Control Inputs
7	Zero		
14	Control Input Return		
4	Output		Channel #2 Outputs
6	Return		
3	2 Decade		Channel #2 Control Inputs
13	Error		
10	Rate	Time	
2	Power		

Control inputs are activated by connecting them to ground.

If no parameter is selected thickness will be selected.

Time input is selected by simultaneously grounding both rate and power.

Figure 6-7 DAC System Interface Connector

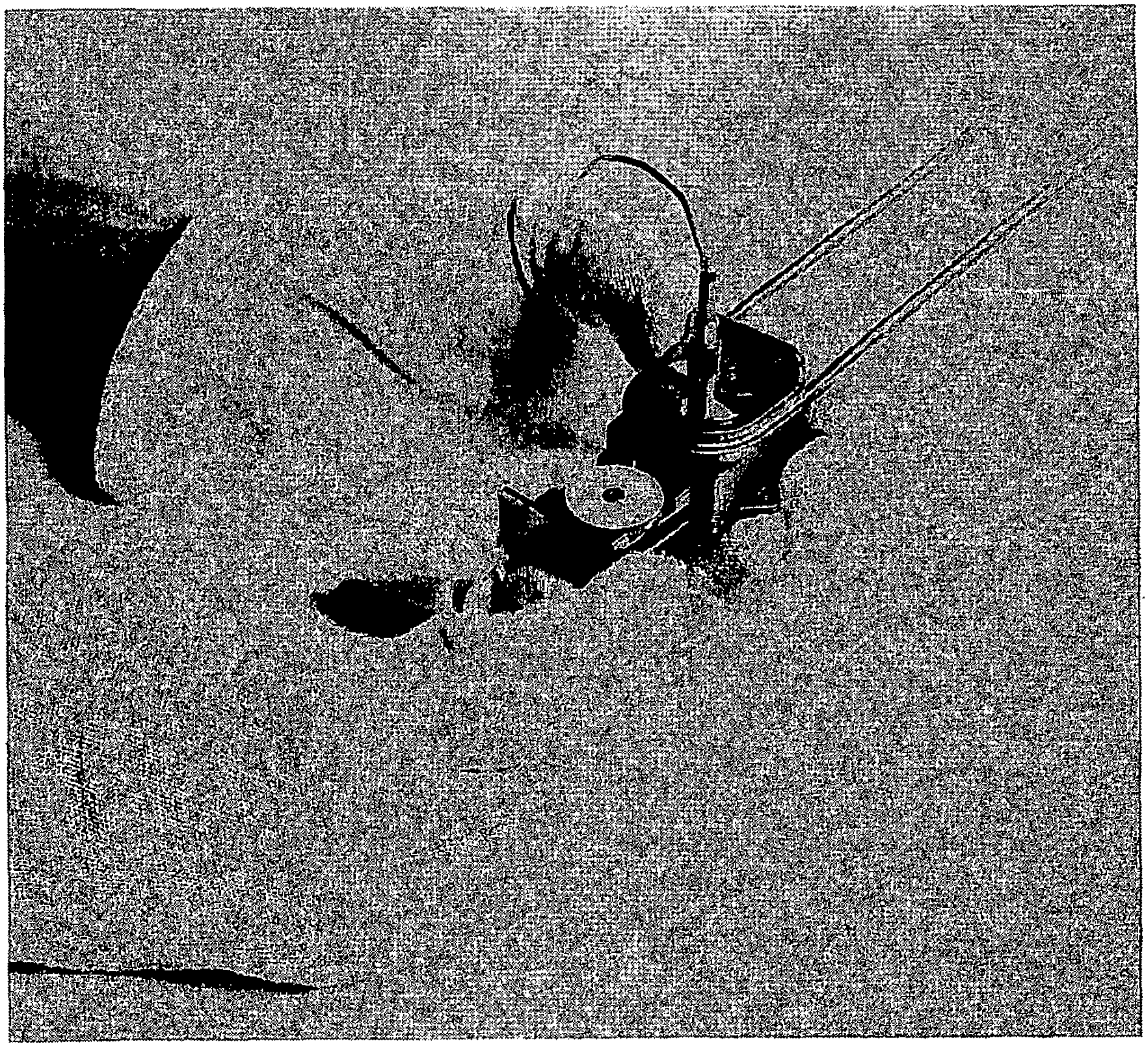


Figure 6-8 Airco Temescal Model SHC-8006 Crystal Sensor

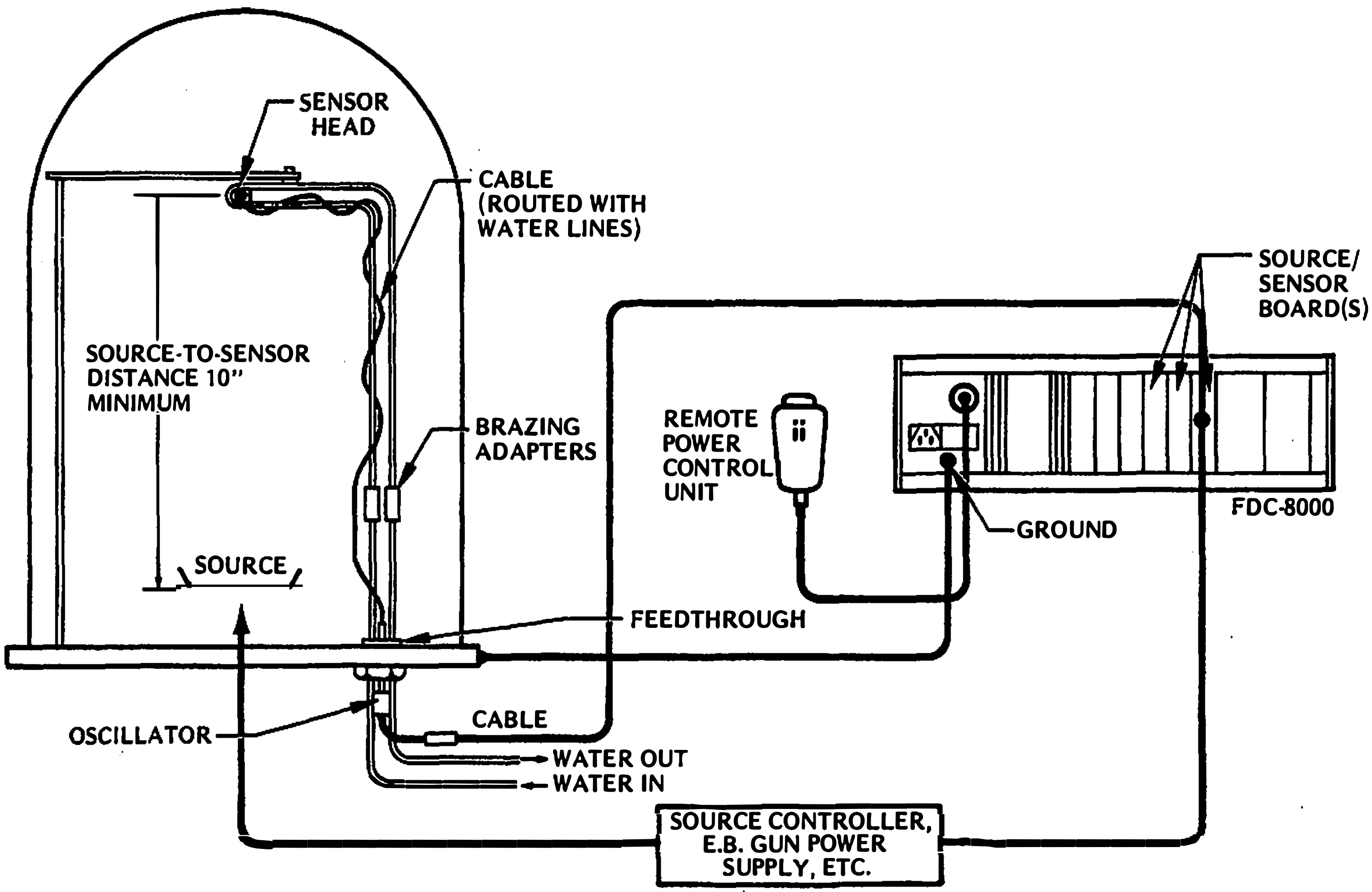


Figure 6-9 Typical System Installation

SECTION 7

THEORY OF OPERATION

7.1 BASIC MEASUREMENT

The FDC-8000 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 mm) 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.

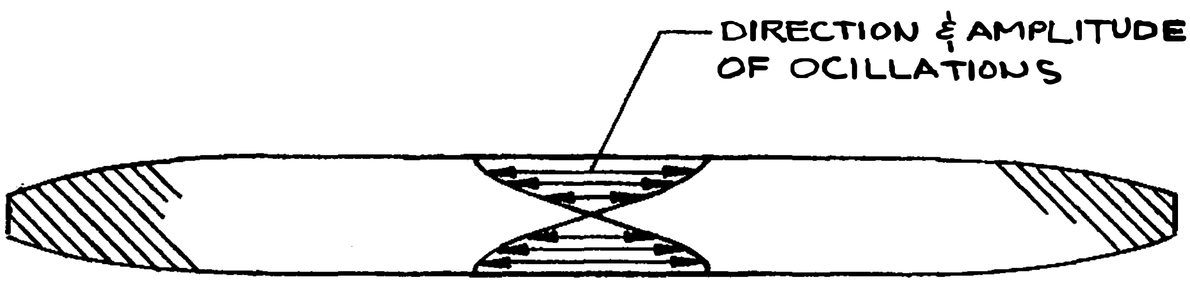


Figure 7-1 Cross-Section of Crystal Vibrating in Thickness Shear Mode

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

Early investigators noted that if one assumed that the addition of material to the 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.

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

where:

N_q = Frequency constant for an "AT" cut quartz crystal vibrating in thickness shear (H_z/cm).

P_q = Density of quartz g/cm^3.

f_q = Resonant frequency of uncoated crystal.

f = Resonant frequency of loaded crystal.

TKf = Film thickness.

P_f = Density of film g/cm^3.

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

$$\frac{N_q \; P_q}{P_f \; f^2}$$

contains the crystal frequency which of course changes as the significant problem because the achievable frequency change was small enough that 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.

At this time it was noted that if the period of oscillation was measured rather than the frequency, 1/period could be substituted for frequency resulting in the following equation:

$$TKf = \frac{N_q\ P_q}{P_f} (\tau - \tau_q) \qquad (2)$$

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

τ_q = Period of uncoated crystal (sec).

Note: Units of N_q is $sec^{-1}cm^{-1}$.

Note that the constant of proportionality in this equation is constant. This approach was demonstrated to be a significant improvement over frequency measurement and was widely adopted.

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 composit resonator of quartz and the deposited film led to the equation below.

$$TKf = \left(\frac{P_q}{P_f}\right) N_q \frac{1}{\pi R_z f} TAN^{-1}\left[R_z\ TAN\ \pi \left(\frac{\tau_q - \tau}{\tau_q}\right)\right] \qquad (3)$$

where: R_z = The acoustic impedance ratio and 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 FDC-8000.

The basic measurement of the FDC-8000 is period, which can be thought of as a measurement of equivalent quartz mass.

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

At the start of 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.

7.2 CRYSTAL HEALTH

Crystal health decreases from a value of 100% for an uncoated crystal blank to 0 at a total deposited areal mass of 2.5 milligrams per square centimeter. The above value corresponds to a crystal frequency shift of approximately 1.5 MHz, or an aluminum thickness of 925 kÅ.

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 (Xtal Fail LED lights on Trouble panel), 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.

7.3 RATE CALCULATION

The deposition 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. The above filter has an effective time constant of about 2 seconds. Following a step the displayed rate will settle to 95% of the final value in 5 seconds.

7.4 RATE CONTROL

Deposition rate control is achieved in the FDC-8000 by comparing the measured thickness rate with the desired thickness rate. The rate error and the rate of change of rate error are then used to determine how much to increment the power up or down.

The amount the power is incremented is also affected by the front panel response parameter. The response parameter is divided by 50, and then used as a multiplier in the determination of delta power.

The rate error is divided by the programmed rate and multiplied by 100 to obtain the percent rate error which can be displayed during deposition as parameter 37.

7.5 EMPIRICAL CALIBRATION

The known film density and acoustic impedance of many film materials is sufficiently accurate to be used directly without empirical calibration. A list of the Density and Acoustic Impedance of the more commonly deposited materials is presented in Table 3-1.

If the values of the density and acoustic impedance are not known, the FDC-8000 can be calibrated empirically as described below.

The FDC-8000 is designed so that the density, tooling, and acoustic impedance parameters can be modified after the film is deposited and the effect of the new parameter value on the indicated thickness will be immediately displayed.

Using this feature, a trial deposition can be made. If the displayed thickness does not agree with the independently measured thickness on the test substrates because of an error in one of the parameters, the parameter can be corrected by modifying its value until the displayed thickness agrees with the measured thickness. Since the displayed thickness is affected by all three of the above parameters, it is important that the effects of the individual parameters be properly isolated.

To calibrate the FDC-8000, film density, tooling factor, and acoustic impedance must be established. If the approximate values of the parameters are known they should be used initially. If the acoustic impedance is not known, use the value for quartz, 8.83.

The film density can be established by depositing a trial film on several test substrates placed around and in the same plane as close as possible to the sensor crystal. The trial deposition should be thick enough to allow the film on the test substrates to be measured with adequate precision using an optical interferometer or surface measuring device.

When making the trial deposition, use a fresh crystal and do not reset the final thickness reading obtained on the FDC-8000. If the acoustic impedance parameter has been accurately established previously, a fresh crystal will not be required.

Determine the average film thickness on the test substrates. If the average measured thickness differs from that displayed by the FDC-8000, increase or decrease the programmed film density until the displayed thickness agrees with the measured thickness. The programmed film density will now be correct for that particular film.

Next, the tooling factor should be established. Place several test substrates at representative locations in the deposition fixture. Again, deposit a trial film, as above, using the known film density. Use a fresh crystal if the programmed acoustic impedance is known to be correct. Do not reset the FDC-8000 after the deposition. Measure the average film thickness on the test substrates. If the average thickness differs from the displayed thickness, adjust the tooling factor until they agree.

To establish the acoustic impedance, the crystal must be heavily loaded. Deposit on the sensor crystal until the crystal health approaches 50% or until the crystal is approaching the end of its useful life. Deposit another trial run as above and this time use the acoustic impedance parameter to bring the displayed thickness into agreement with the measured thickness. This calibrates the acoustic impedance parameter.

The FDC-8000 is now fully calibrated for the particular film material and should produce consistent and accurate films.

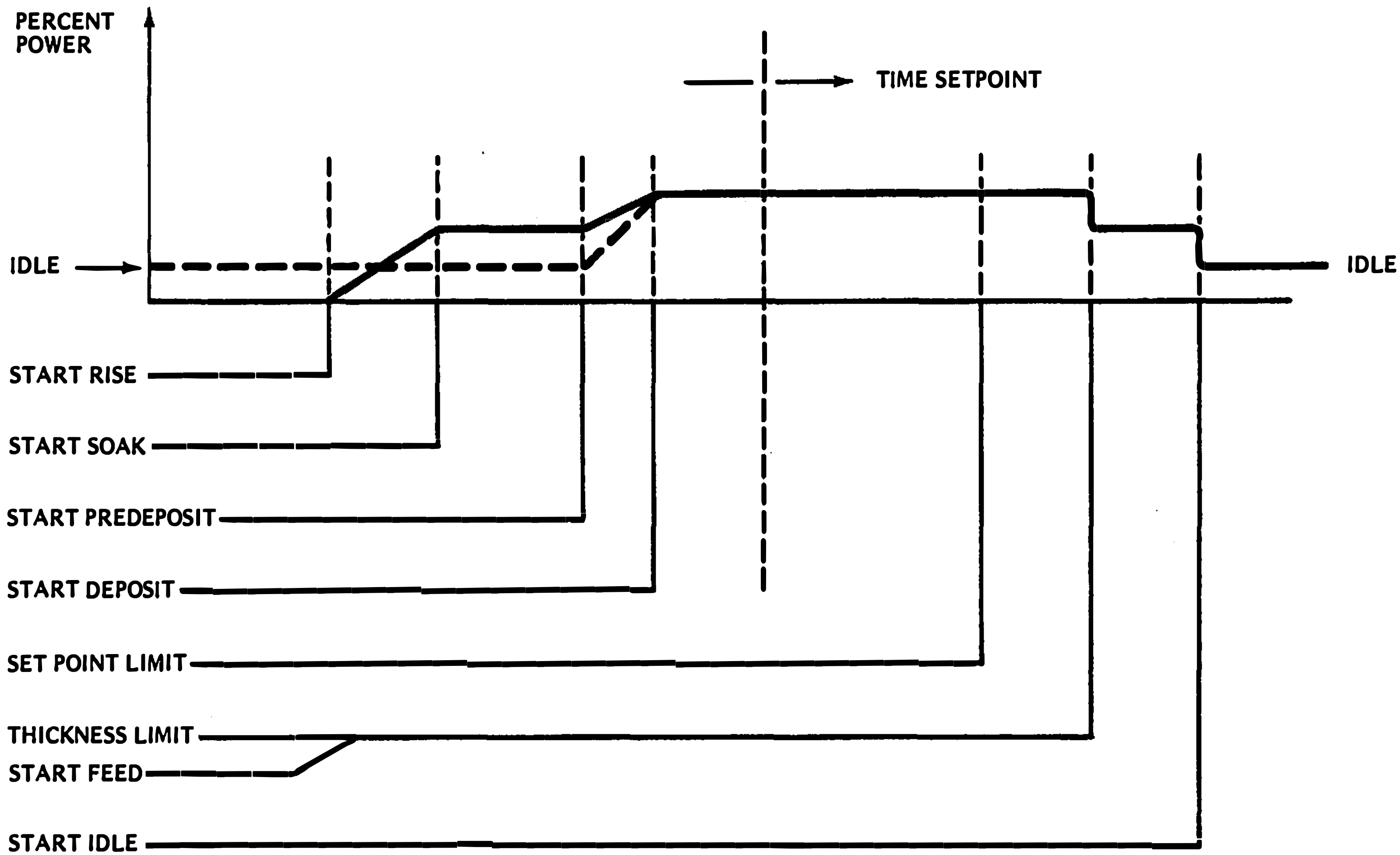


Figure 7-2 Typical Process Cycle

SECTION 8

REPAIR AND MAINTENANCE

8.1 HANDLING PRECAUTIONS

CMOS and Low Power Schottky integrated circuits can be damaged by static discharge into their inputs. This static 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 chance of discharging body charge into the IC inputs, always handle circuit boards by the edge, avoiding contact with the connector area. When moving a board from one surface or work area to another, first 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 potential. In dry climates, it is wise to minimize the amount of movement when handling or replacing IC's 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 all right as long as the metal is always touched with the hand prior to laying down the IC's or circuit boards.

CAUTION

The microprocessor board which contains the nickel-cadmium batteries should never be layed on a metal surface or wrapped in metal foil as the batteries may be shorted, invariably resulting in fusing of the printed circuit board etches.

PC boards or IC's should never be placed in plastic bags unless they are of the conductive plastic type intended for this use. These bags are typically black or pink and are normally labeled as conductive or anti-static. If no conductive plastic bags are available, boards or IC's can be wrapped in paper, and then placed in plastic bags or shipping bags.

If the above precautions are observed, the chance of damage will be minimal and no problems should be encountered.

8.2 MAINTENANCE PHILOSOPHY

The FDC-8000 design is based on a maintenance philosophy of board replacement. Field repair at the component level is not recommended and, indeed, will void the warranty. The following sections are intended primarily as an aid in understanding the operation of the FDC-8000 and to help in isolating problems to the board level.

All electronic components in the FDC-8000, with the exception of the power supply transformer and filter capacitors, are mounted on plug-in assemblies for ease of removal and replacement. The circuitry in the FDC-8000 is partitioned among plug-in modules on a functional basis to make fault isolation to the plug-in assembly level as straightforward as possible.

Most problems can be diagnosed to the board level without external test equipment and can be verified by simple board replacement.

8.3 TROUBLESHOOTING AIDS

Symptom	Possible Cause
1) Unit blows line fuse.	a) Line voltage selection card is not installed to agree with line voltage being used. b) Incorrect fuse size. c) Shorted rectifiers on power supply assembly. d) Shorted transformer or filter capacitor.
2) Front panel display fails to come "ON".	a) Blown fuse. b) Faulty clock generator or crystal (computer board). c) One or more power supply outputs missing.
3) "Xtal Fail" lamp stays on with selected sensor properly connected.	a) Unit in "Abort" mode not due to xtal fail (reset unit). b) Defective cable or cables. c) Defective or overloaded transducer crystal.

Symptom	Possible Cause
3) Continued	d) Bad oscillator unit. e) Q1 bad (Source-Sensor card). f) Bad I/O Interface board. g) Bad Measurement board. h) U3 or U4 bad (Front Panel Logic board).
4) No control voltage while monitoring output of selected source-sensor card.	a) Blown or loose fuse on Source-Sensor card under question. b) K1 faulty (Discrete I/O card). c) Cable/connector miswired or shorted (Source-Sensor card). d) Bad Source-Sensor card.
5) Front panel control buttons or keys non-functional.	a) Sticking button. b) Defective switch. c) Bad Front Panel Logic board.
6) "Control Fail" lamp on, unit in "Abort" mode.	a) Bad crystal on Measurement board. b) Bad Measurement board. c) Bad Computer board.
7) Unit does not retain keyboard-entered data.	a) "Power up" or "Power down" sequencing circuit malfunctioning. b) "RAM Power" switching circuit not functioning. c) Aged or defective batteries. d) Bad Computer board.
8) The unit fails to activate externally controlled devices (shutters, solenoids, etc.).	a) Faulty relay (Discrete I/O board). b) Bad Discrete I/O board.
9) Control voltage fails to drop to zero when unit is aborted.	a) K1 faulty (Discrete I/O board). b) Bad Discrete I/O board.
10) Unable to remotely control unit via Discrete I/O inputs.	a) Not using specified ac control voltage. b) Faulty photo coupler (Discrete I/O card). c) Improperly wired cable/connector. d) Bad Discrete I/O board.

8.4 BLOCK DIAGRAMS AND DESCRIPTIONS

The FDC-8000 can be thought of as having five major circuit functions, or areas. These are the Microcomputer, Front Panel, Rear Panel, Measurement, and Power Supply functions. A mother board is used to interconnect all the circuit areas except the Power Supply which plugs into a wiring harness that is a part of the mother board assembly. An overall block diagram of the FDC-8000 is shown in Figure 8-1.

The rear panel circuitry consists of the I/O Interface card which plugs into the mother board and individual input/output cards which plug into the I/O Interface card through slots in the rear panel. The I/O Interface provides a physical and electrical interface to the individual input/output cards.

The input/output cards contain the specific system interface and signal conditioning circuitry. They also include the external system interface connectors.

The rear-most slot of the mother board is reserved for the I/O Interface card and the connector is keyed so that other boards cannot be inadvertently inserted into this slot. All other slots in the mother board are identical so that the sequence of boards is inconsequential.

The Microcomputer, Power Supply, and Measurement boards are single board assemblies. The Microcomputer board and Measurement board plug into the mother board through an 86-pin edge card connector.

The Front Panel assembly is composed of the Display board, holding the mounted displays and very little other circuitry, and the Front Panel Logic board, containing almost all the circuitry necessary to drive the displays and monitor the switches.

A functional description of the individual boards is presented below and schematics are presented in section 8.6.

a) MICROCOMPUTER BOARD: All logic and calculations performed by the FDC-8000 are accomplished by the Microcomputer board. Input and output data to the microcomputer is transmitted via an 8-line data bus. The destination and/or source of data is transmitted on a 16-line address bus. Only a few of the 16 address lines are actually used external to the microcomputer board itself.

The microcomputer utilizes a number of control signals which form the control bus and provide I/O select signals on an 8-line I/O select bus.

For a thorough description of the microcomputer refer to the Intel MCS-80 user's manual. The following brief description is provided as an aid to understanding the various circuit functions. A block diagram of the microcomputer board is shown in Figure 8-2.

The Central Processor Unit (CPU) of the microcomputer is a single chip 8080 Microprocessor. This device outputs addresses to ROM and RAM memory, receives the instruction or data located at the transmitted address, performs the instruction or utilizes the data, and then transmits a new address, receives a new instruction and/or data, etc.

The basic instructions which tell the CPU in step-by-step fashion how to calculate thickness or display a number (i.e., the FDC-8000 internal software) are contained in six Read-Only Memories (ROMs) along the top of the microcomputer board.

Data, such as film parameters entered through the front panel, are stored in Random Access Memories (RAMs), also called read/write memories. Because semiconductor RAMs lose their memory when they lose power, the FDC-8000 incorporates CMOS RAMs, which dissipate very low power, and rechargeable nickel-cadmium batteries which will typically provide power to the RAMs for 180 days. Long term storage of programs is thereby assured.

In normal operation the RAM power switch connects the RAMs to the 5-volt logic supply. The RAM power switch and the RAM enable circuit monitor the 9.5-volt raw power signal; when it falls below a predetermined level, indicating that the FDC-8000 is losing its power source, the RAM enable circuit disables further writing or reading from the RAMs and the RAM power switch turns off, leaving the RAMs power by the battery.

An 18-MHz crystal provides the basic clock for the CPU and for the system. This frequency is divided by the clock generator and driver to provide two nonoverlapping signals to clock the CPU.

The 2-MHz phase 2 signal from the clock generator and driver is further divided in the Direct Memory Access and Interrupt Control Logic to provide a 1-MHz clock signal which is outputed to the system bus and is the basic clock signal for the FDC-8000.

The front panel of the FDC-8000 is serviced every millisecond. To accomplish this the 1-MHz system clock is divided by 1000 to provide a 1-kHz clock. This clock is used to interrupt the CPU in order to provide the front panel service function. Additional circuits on the microcomputer board are used to buffer data bus and address bus signals and to generate I/O and chip select signals by decoding the higher order address bus lines.

b) MEASUREMENT BOARD: A block diagram of the Measurement board is shown in Figure 8-3. The Measurement board contains all the circuitry necessary to convert the basic sensor signal to a 24-bit binary digital number proportional to crystal period and to multiplex this number and additional status signals onto the data bus when requested by the microcomputer.

A Missing Pulse and Oscillator Fail circuit monitors the incoming sensor signal in order to provide missing pulse and oscillator fail signals. The lack of a sensor signal is signalled by the oscillator fail output. The missing pulse detector provides a signal which warns that the incoming sensor signal was not continuous over the last sample period and therefore would possibly result in an erroneous measurement. These two signals together with the gate signal from the gate circuitry are multiplexed onto the data bus at the request of the CPU as status signals to be used by the CPU to determine the validity of the data and/or to spot internal malfunctions.

After being buffered by the missing pulse and oscillator fail circuitry, the sensor frequency is divided by a factor of 1,048,576, 2 to the 20th power, by the Scaler. The output of the Scaler is then a signal whose duration is between 200 and 250 milliseconds and is a linear function of the sensor period. This signal is used to gate a 42.2-MHz reference signal into the 24-bit period counter. As the sensor crystal period increases due to material buildup on its surface, the gate signal increases proportionately. The longer gate period allows additional reference pulses to be accumulated by the period counter. The Scaler count and the reference oscillator frequency are chosen so that each additional count in the period counter corresponds to an areal mass of 0.01-microgram per square centimeter which is equivalent to one angstrom of material with a density of one.

The control logic on the microcomputer board monitors five lines of the system bus and outputs the necessary reset signal and enable signals to the multiplexer and three-state data buffer as requested by the microcomputer.

c) I/O INTERFACE BOARD: The primary function of the I/O Interface board is to provide a physical interface to the individual input/output cards and, in order to provide improved noise immunity at the system interface, to convert the high speed 5-volt TTL logic levels on the mother board to slow 12-volt CMOS logic levels prior to routing them to the input/output cards. A block diagram of the I/O Interface board is shown in figure 8-4.

Data from the CPU bus is latched into a Programmable Peripheral Interface (PPI) IC and then converted in the TTL to CMOS buffer to 12-volt logic levels. After the output data is established on the High Level Output bus, a 4-bit enable address is transmitted to the PPI and translated to the CMOS logic levels where it is decoded by the Enable Generator. Each I/O board contains one or more enable inputs which are used to latch data appearing on the High Level Output bus into latches on the individual I/O cards. At the same time, external inputs from the I/O cards are enabled onto the High Level Input bus which is translated back down to TTL logic levels and multiplexed onto the data bus at the request of the CPU.

In addition to the above functions, the I/O Interface board contains the Abort Flip/Flop, the Abort Enable switches, the Remote Power Switch Buffer, and the Sensor Select Logic.

The Sensor Select Logic contains a latch which is periodically loaded with the 2-bit address of the current sensor. A multiplexer then gates the selected sensor input signal onto the system bus.

d) DISCRETE I/O BOARD: A block diagram of the Discrete I/O board is shown in Figure 8-5. The board provides five discrete relay outputs and four discrete inputs. A 5-bit latch is periodically updated from data appearing on the High Level Output bus. The five outputs drive relay drivers which in turn drive the output relays.

The #1 relay is of special significance as it is the Abort relay when the board is installed in the #1 Discrete I/O slot. The Abort Relay Control logic establishes whether or not it is in the #1 slot by means of the board #1 signal. The abort relay is off when the FDC-8000 is in Abort. Thus loss of power always results in an abort signal. Power to the other output relays in the system, which is also used as an enable signal on the Source-Sensor boards, is connected through the abort relay to automatically disable all relay and source outputs during Abort, independently of the processor.

The four discrete intput pairs are buffered for noise immunity and then coupled through optical couplers to a three-state bus driver which multiplexes the input onto the High Level Input bus when enabled. The output of the #1 input buffer is the abort input in the #1 slot and is tied directly to the abort condition line on the I/O Interface board.

e) SOURCE-SENSOR BOARD: A block diagram of the Source-Sensor board is shown in Figure 8-6.

The Source-Sensor board provides an isolated 0 to 10-volt dc output to control the source and a buffer to interface with the sensor oscillator. A 10-bit latch is used to latch the proper source power in digital form. This latch is updated every 250 milliseconds. A *modulo n* counter is used to convert the parallel digital signal to a single-line duty cycle signal which is transmitted via an optical coupler to an isolated switch, filter, and buffer amplifier.

The duty cycle signal consists of a pulse every millisecond. The duration of the pulse is directly proportional to the digital input coming to the modulo n counter and varies from zero to 1 millisecond. The switch, in conjunction with the 10-volt reference signal, is used to precisely control the height of the pulses downstream of the optical coupler so that when the pulse train is filtered by the filter it becomes an accurate dc signal proportional to the digital input.

A digital to analog converter of this type has a smooth continuous output which is very important in control applications where small incremental slope changes can cause control loop instability. In addition, the requirement for tight initial tolerances and the attendant performance degradation with time due to parameter drift are minimized with this type of converter. Since the optical coupler is coupling a digital signal, the analog output is not a function of coupler efficiency.

The sensor buffer on the source-sensor board supplies 5-volt power to the sensor oscillator through a 50-ohm resistor which also supplies the termination for the 50-ohm coaxial cable interface. The buffer also filters signals outside the sensor oscillation range to enhance noise immunity and converts the oscillator current signal to a 5-volt logic level.

f) DIGITAL TO ANALOG CONVERTER BOARD: Operation of the DACs on the DAC board is identical to those on the source-sensor board with three exceptions: no optical coupling is used so that the DAC output return is tied to the FDC-8000 ground, the reference voltage to the switch is 5 volts so that the full scale output is 5 volts, and the buffer amplifiers do not include the extensive protective circuitry included in the source buffer amplifiers.

Parameter and decade selection control inputs are buffered and multiplexed onto the High Level Input bus every 250 milliseconds when requested by the microcomputer. A block diagram of the DAC board is presented in Figure 8-7.

g) FRONT PANEL DISPLAY BOARD: The Display board is primarily a signal routing and mounting medium for the front panel displays. The display and front panel logic boards are combined on one block diagram, Figure 8-8.

h) FRONT PANEL LOGIC BOARD: The block diagram of the display and front panel logic board is shown in Figure 8-8. The FDC-8000 displays are multiplexed so that they appear to be on simultaneously and continuously, but actually only three digits are on at any one time and any individual display is on only one eighth of the total time. Each digit in a string of eight is lit in sequence at a fast enough rate that, to the human eye, all appear to be on simultaneously.

Data to be displayed is latched into a Programmable Peripheral Interface (PPI) by the microprocessor. The output of the PPI is organized into four 4-bit display busses. The top two display busses drive the operating displays. A BCD to seven segment decoder is used to provide a seven line segment driver bus. After the data to be displayed appears on the segment driver busses, the digit address is latched into the PPI by the processor. The digit address is decoded to one of eight lines by a BCD to decimal decoder which then lights the proper digits, The digit drive is then removed, the data updated to the next group of digits, and that group of digits light, and so forth.

The keyboard and control switches are also scanned. They are connected in a four-by-six cross point matrix with 4 bits of the 8-bit input port used to monitor the switch lines and 4 bits used to feed back the digit scan address.

An additional 4-bit input port is used to input the Abort signal, the Power Down signal, and the status of the Program Lock switch.

In addition to its primary display and input functions the front panel logic board contains the Power Down Detector and the Modulo 1000 counter which generates the 1-kHz system clock from the 1-MHz system clock. The schematic of the front panel logic and display boards is shown in section 8.6.

8.5 PARTS LIST

(This is not a complete parts list and is intended to be a guide to field replaceable or spare parts.)

Description	Part Number
Source-Sensor Board, Model SSB-8002	0506-7190-0
Discrete Input-Output Board, Model IOB-8003	0506-7200-0
Digital Analog Converter Board, Model DAC-8004	0506-7210-0
Measurement Board	0506-1080-0
Computer Board	0506-0790-0
Input Output Interface Board	0506-0950-0
Display Board	0506-0800-0
Front Panel Logic Board	0506-0810-0
Power Supply	0506-0820-0
Extender Board (for Computer, Measurement, and Input Output Interface Boards)	0506-1200-0
Connector Kit, 9-Pin (for Source Sensor Board)	0506-1490-0
Connector Kit, 15-Pin (for DAC Board)	0506-7080-0
Connector Kit, 25-Pin (for Discrete Input Output Board)	0506-7090-0
Transformer, Power Supply	0506-0753-0
Keyboard	0506-1042-0
Label, Process Log	0506-7312-0
Key (2) for Program Lock	89100-2
Fuse, 1-Ampere Slow-Blow	869916
Fuse, 1/16-Ampere Fast Blow	869801
Power Switch, Front Panel	892000
Relay	849000
7-Segment Display, Yellow	879000
7-Segment Display, Red	879001
Power Cord	803081
28-Pin Front Panel Cable	803082
Coaxial Cable, 3-meter (10 feet), BNC	0506-1330-0
Coaxial Cable, 760-mm (30 inches), Microdot	0506-7230-0
Remote Power Switch, Model PPS-8008	0506-1340-0
Oscillator, Model OEC-8007	0506-7130-0
Sensor Head, Model SHC-8006	0506-7140-0
Drawer, Crystal	0314-9843-0
Retainer, Crystal	9999-8092-0
Spring Clip	0314-9851-0
Bulkhead Connector Assembly	0314-0971-0
Crystals, Box of 5	0506-7160-0
Housing	0314-9862-0

Description	Part Number
Screw, Cap Socket-Head 2-56UNC-2A x 3/6 inches long gold plated (2)	1321-0451-1
Washer, Lock, Spring gold plated (2)	1373-0400-1
OEC-8007 Oscillator with External Cable 3-meter (10 feet)	0506-7130-0
Coaxial Cable, 1524-mm (60 inches)	0506-7230-1

8.6 SCHEMATICS

The schematics of the FDC-8000 are presented below. A detailed circuit description of the FDC-8000 is beyond the scope of this manual. However, functional circuit areas are blocked out in the schematics to correspond to the functional descriptions and block diagrams so that most of the circuits can be understood without a detailed circuit description. Most significant signals are named with their functional name. A bar is placed over the signal name if the function is true when the signal is low.

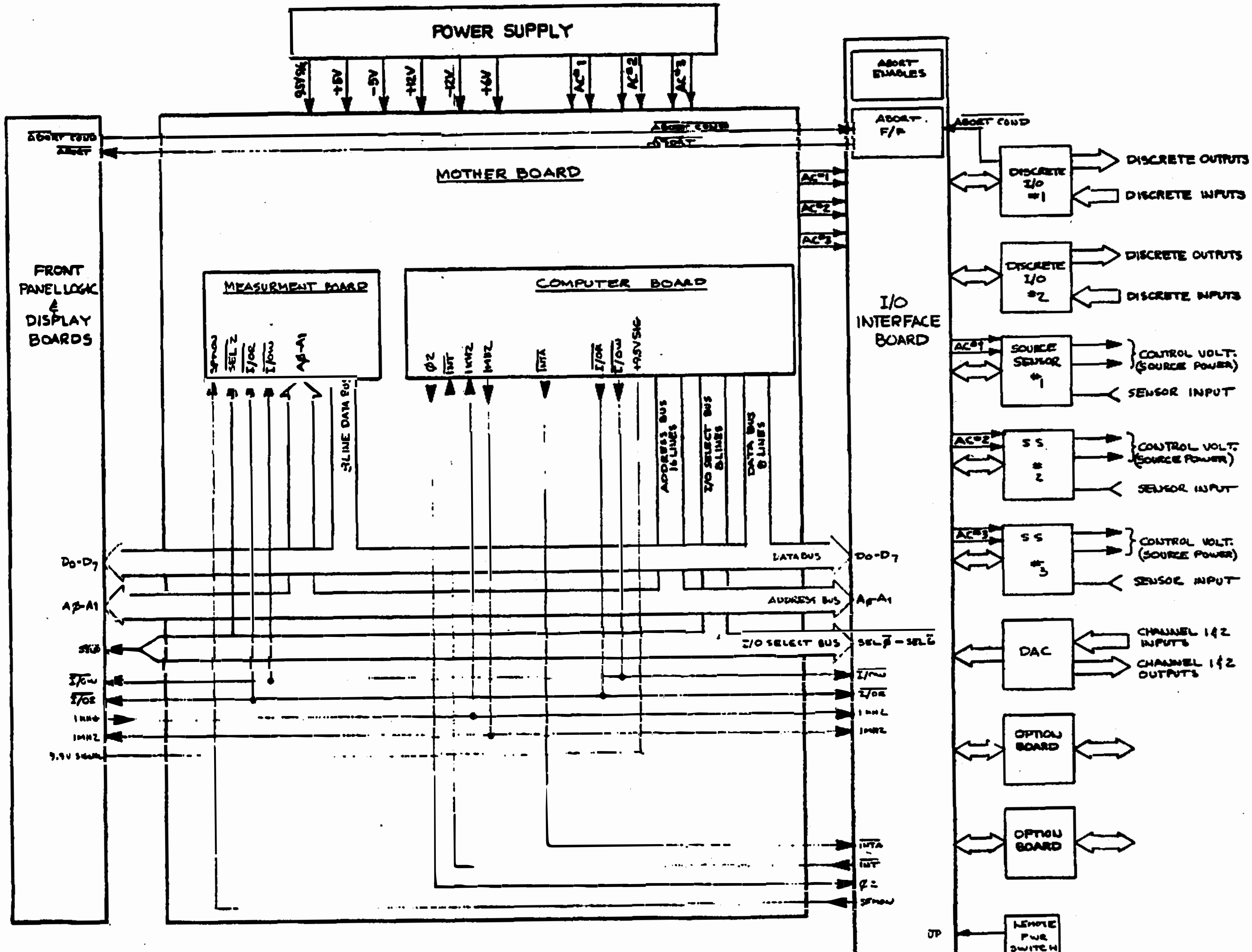


Figure 8-1 System Block Diagram

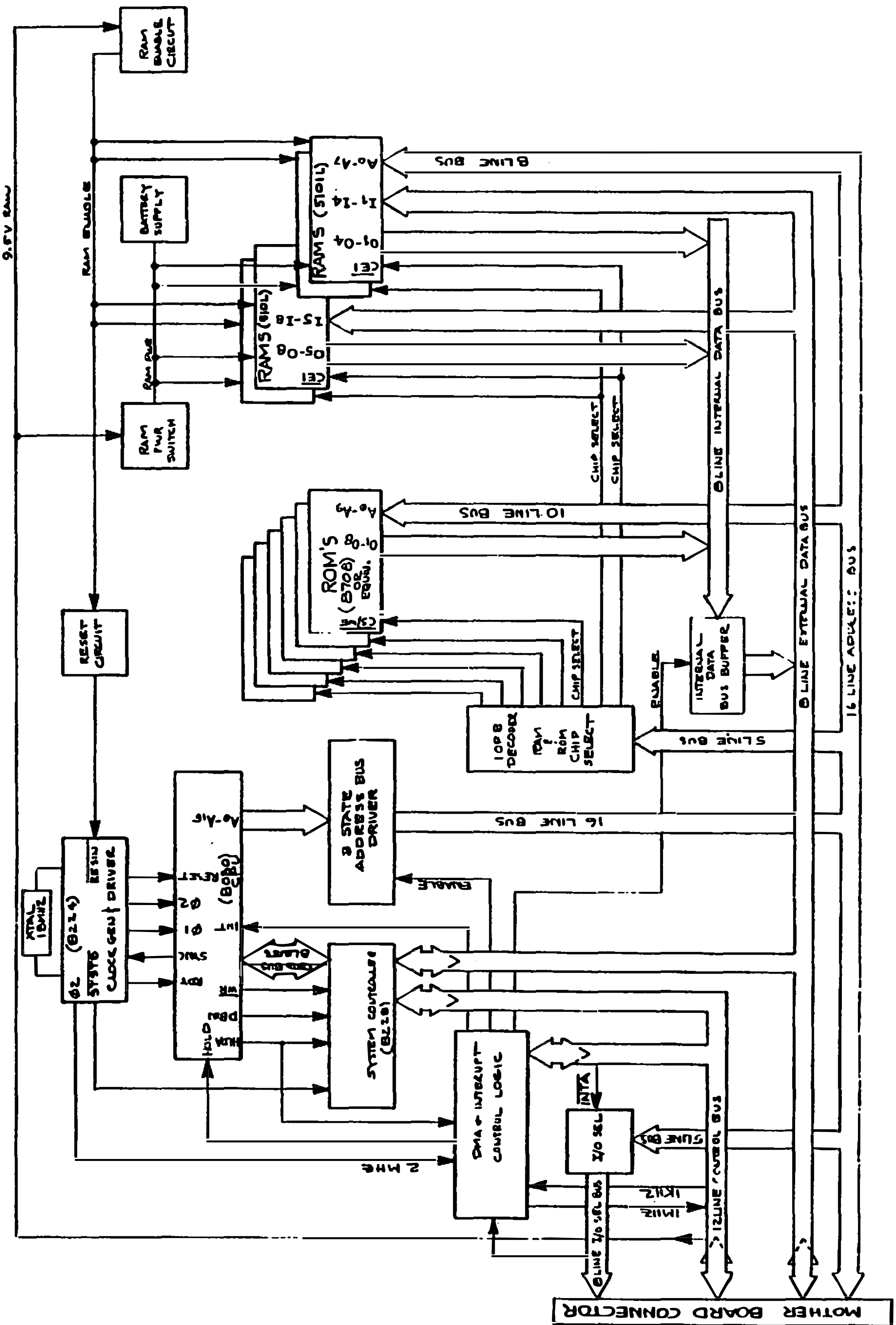


Figure 8-2 Micro-Computer Board, Block Diagram

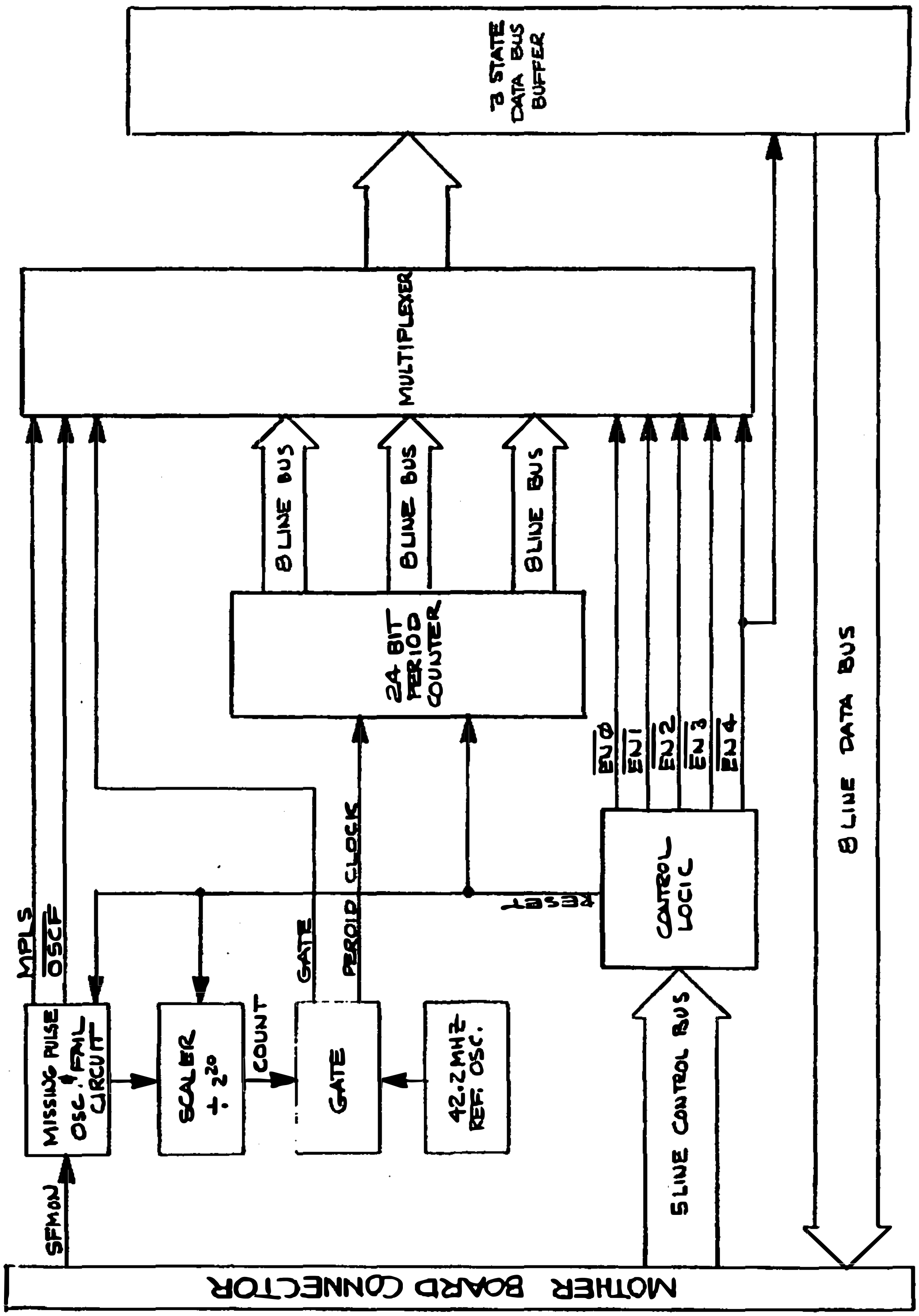


Figure 8-3 Measurement Board, Block Diagram

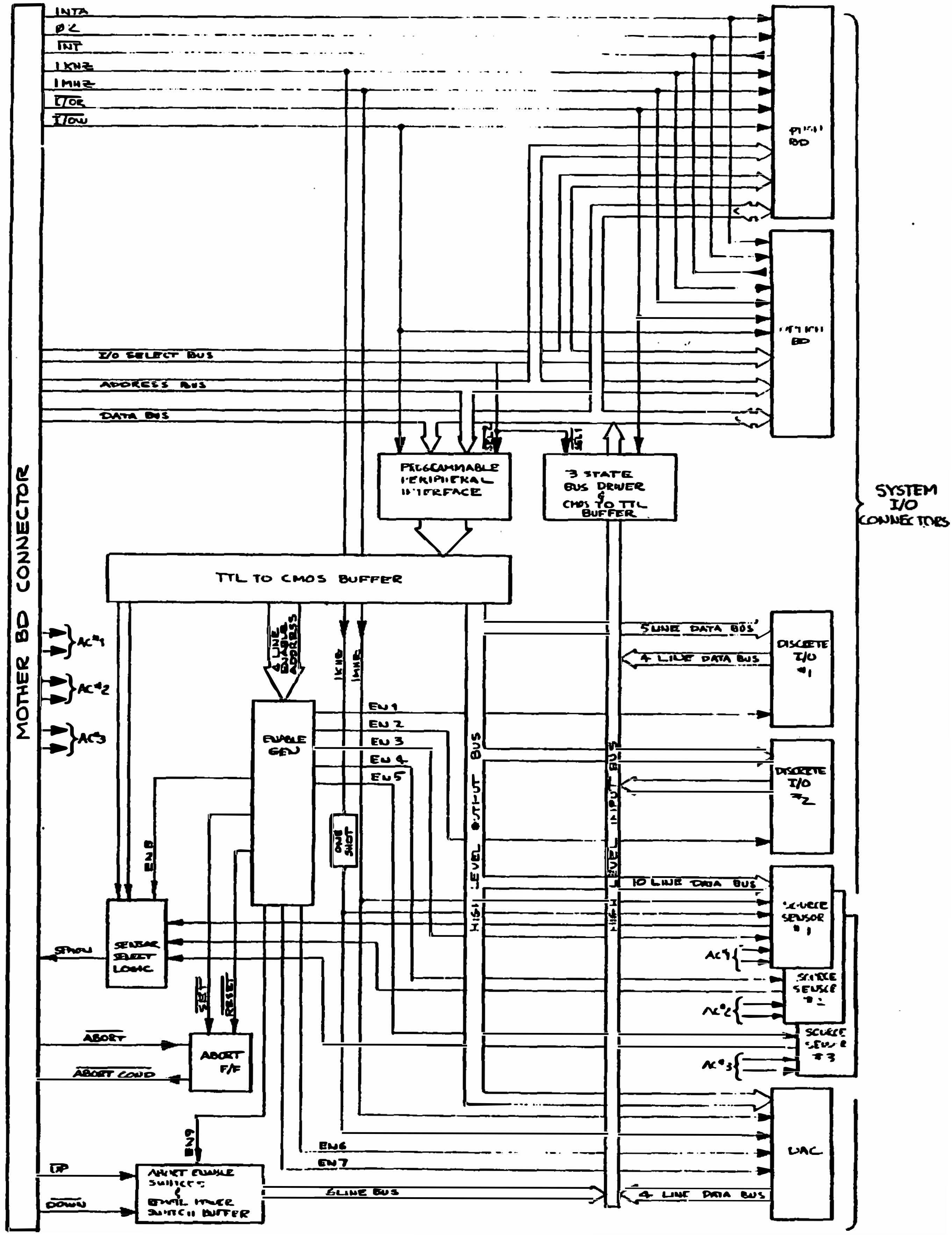


Figure 8-4 I/O Interface Board, Block Diagram

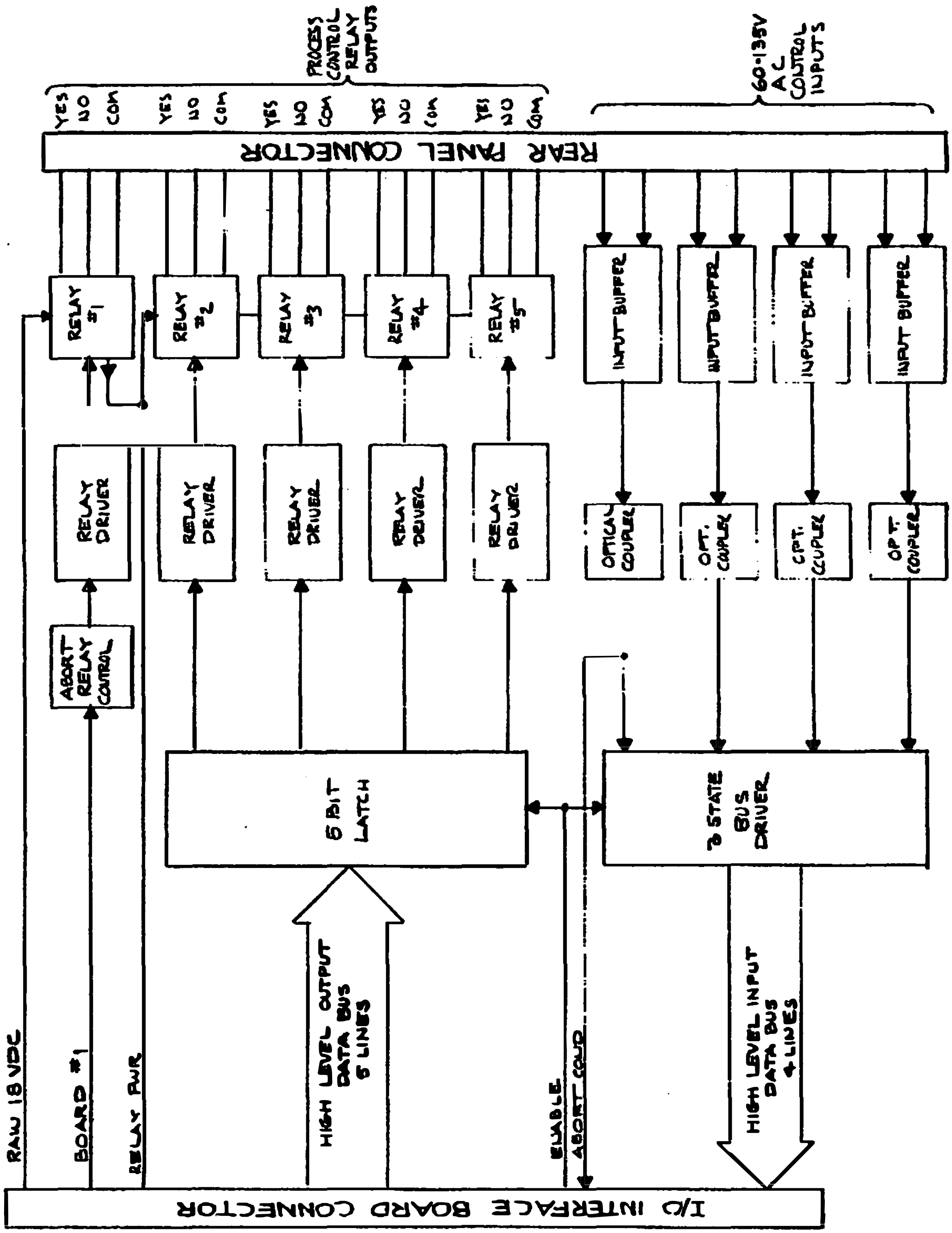


Figure 8-5 Discrete I/O Board, Block Diagram

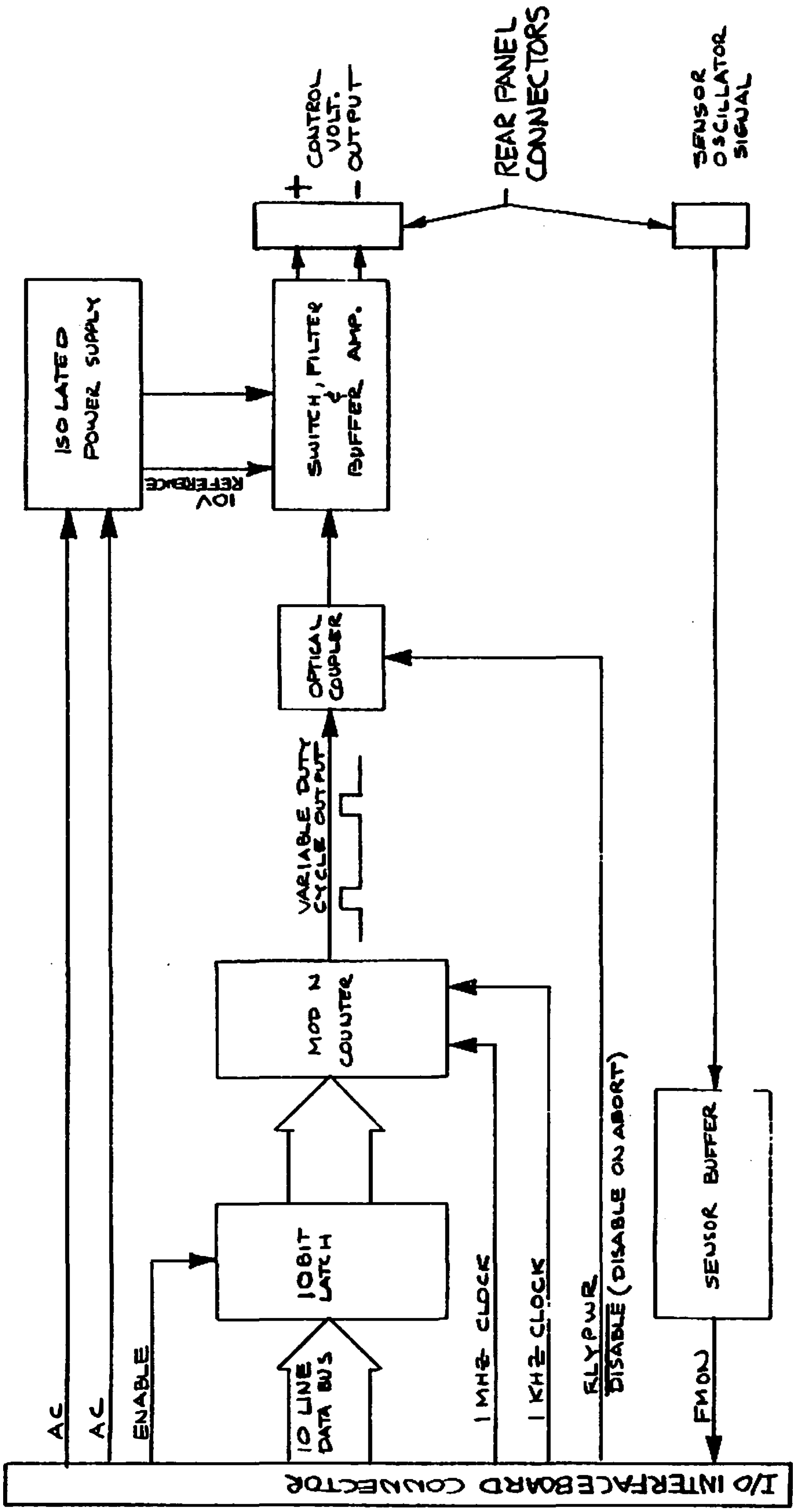


Figure 8-6 Source-Sensor Board, Block Diagram

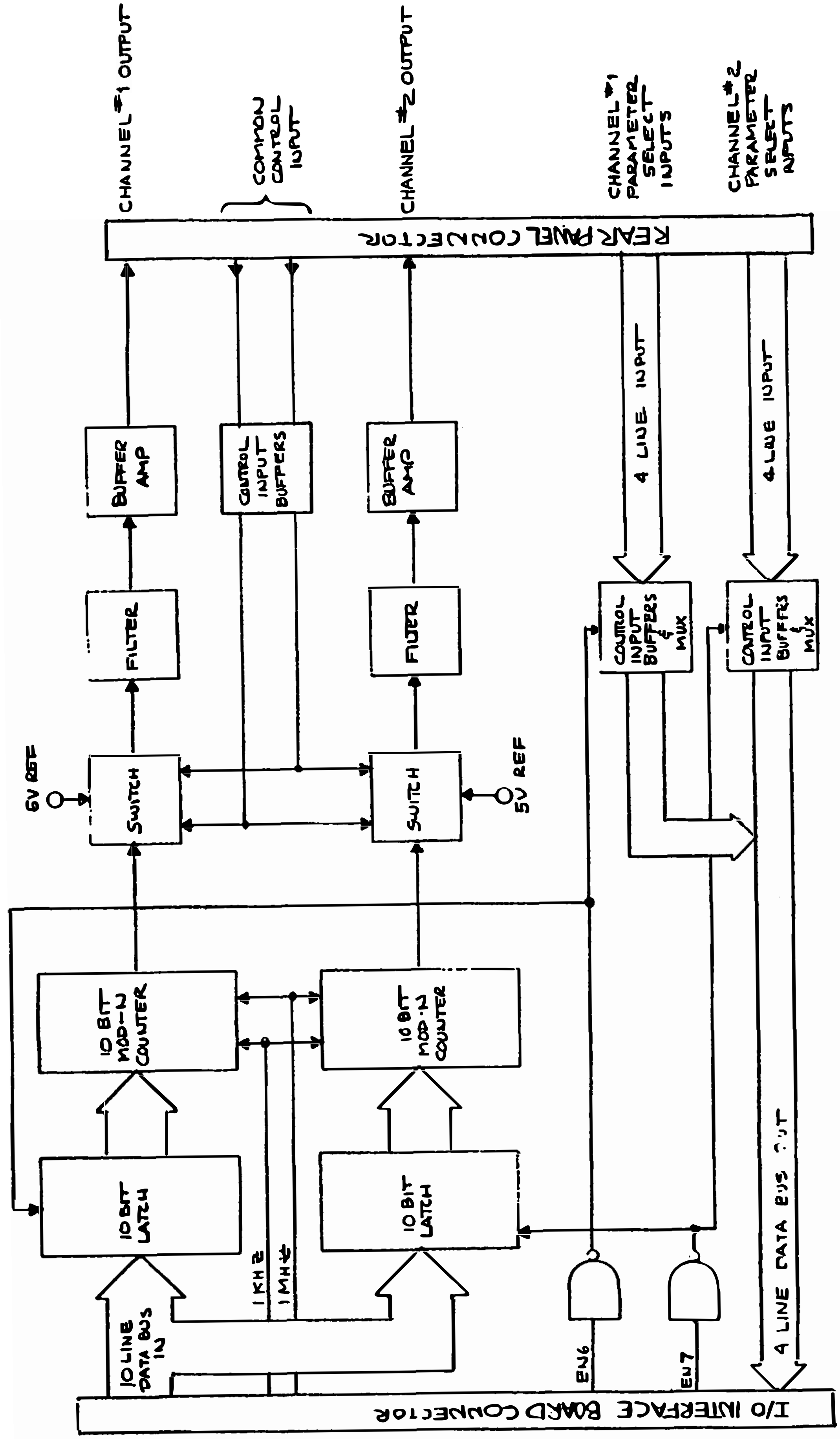


Figure 8-7 DAC Board, Block Diagram

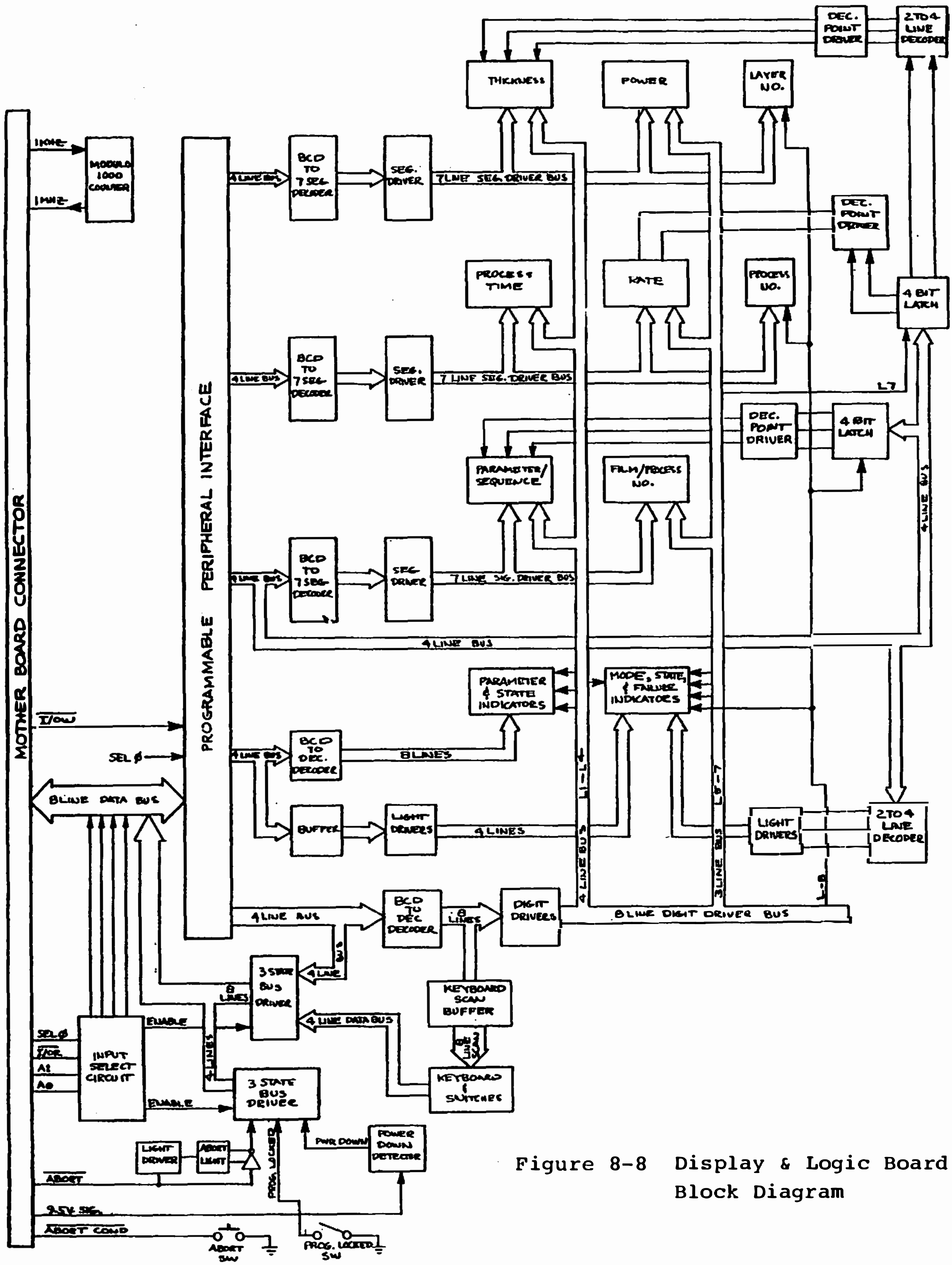


Figure 8-8 Display & Logic Board, Block Diagram

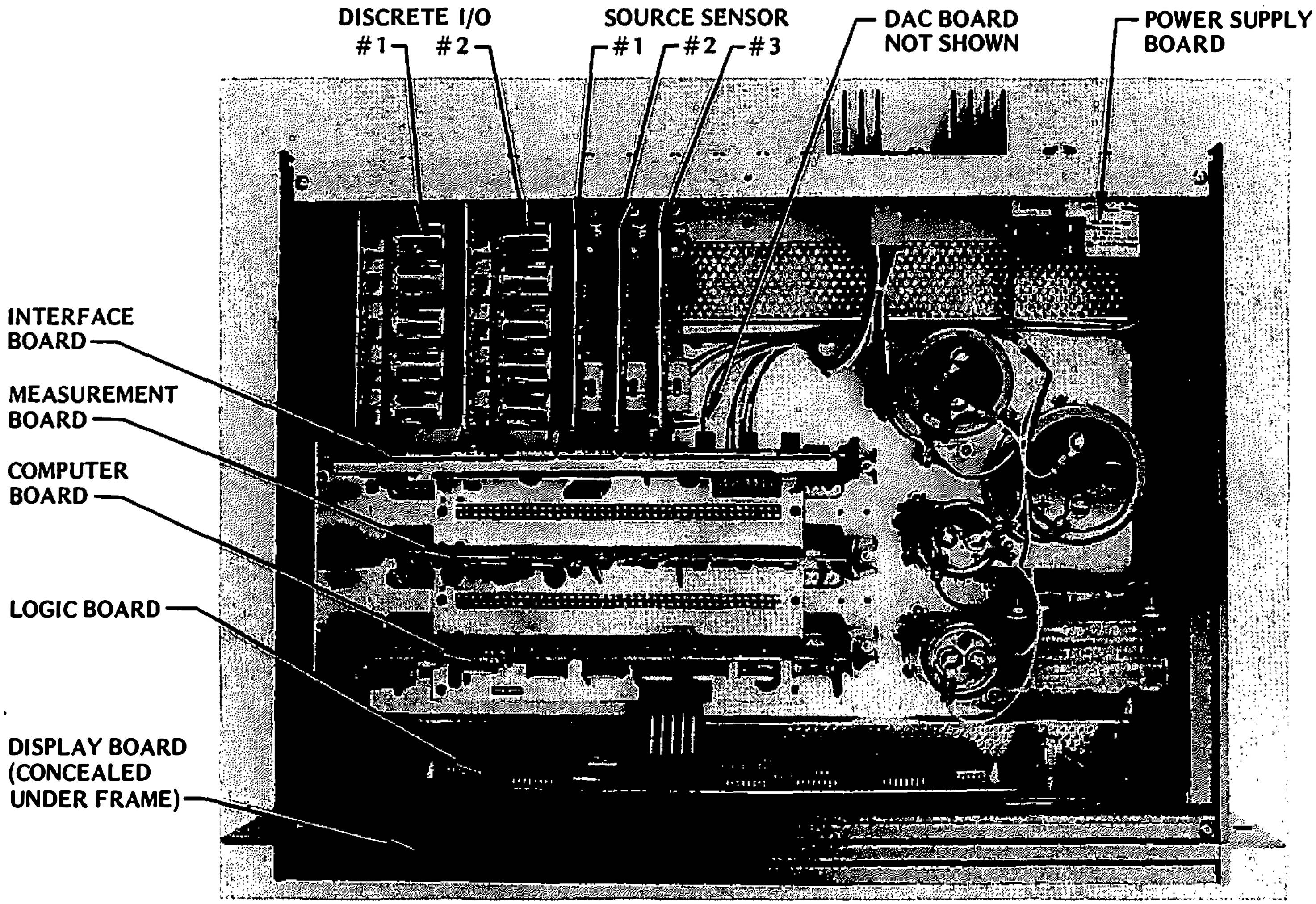
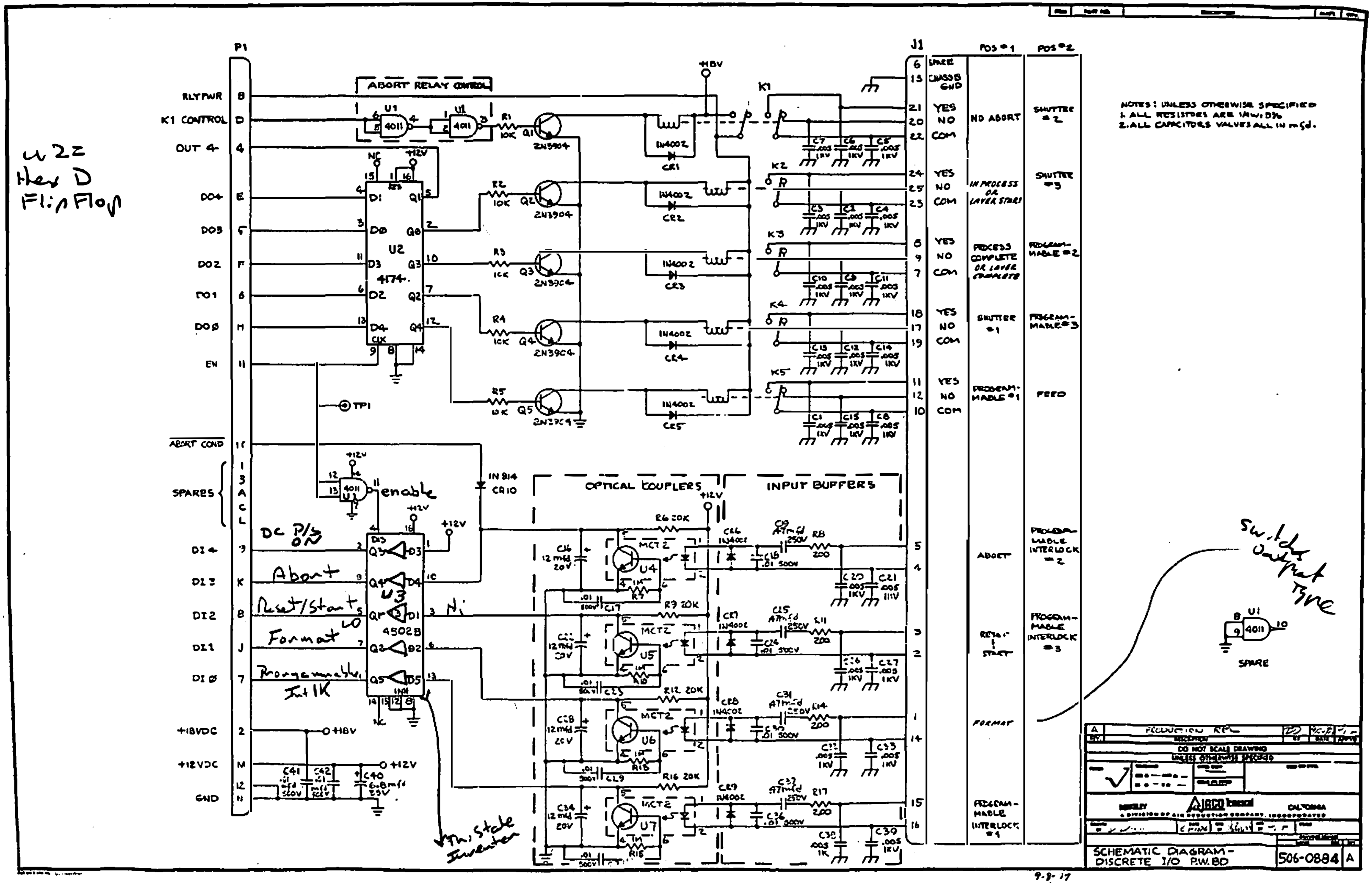
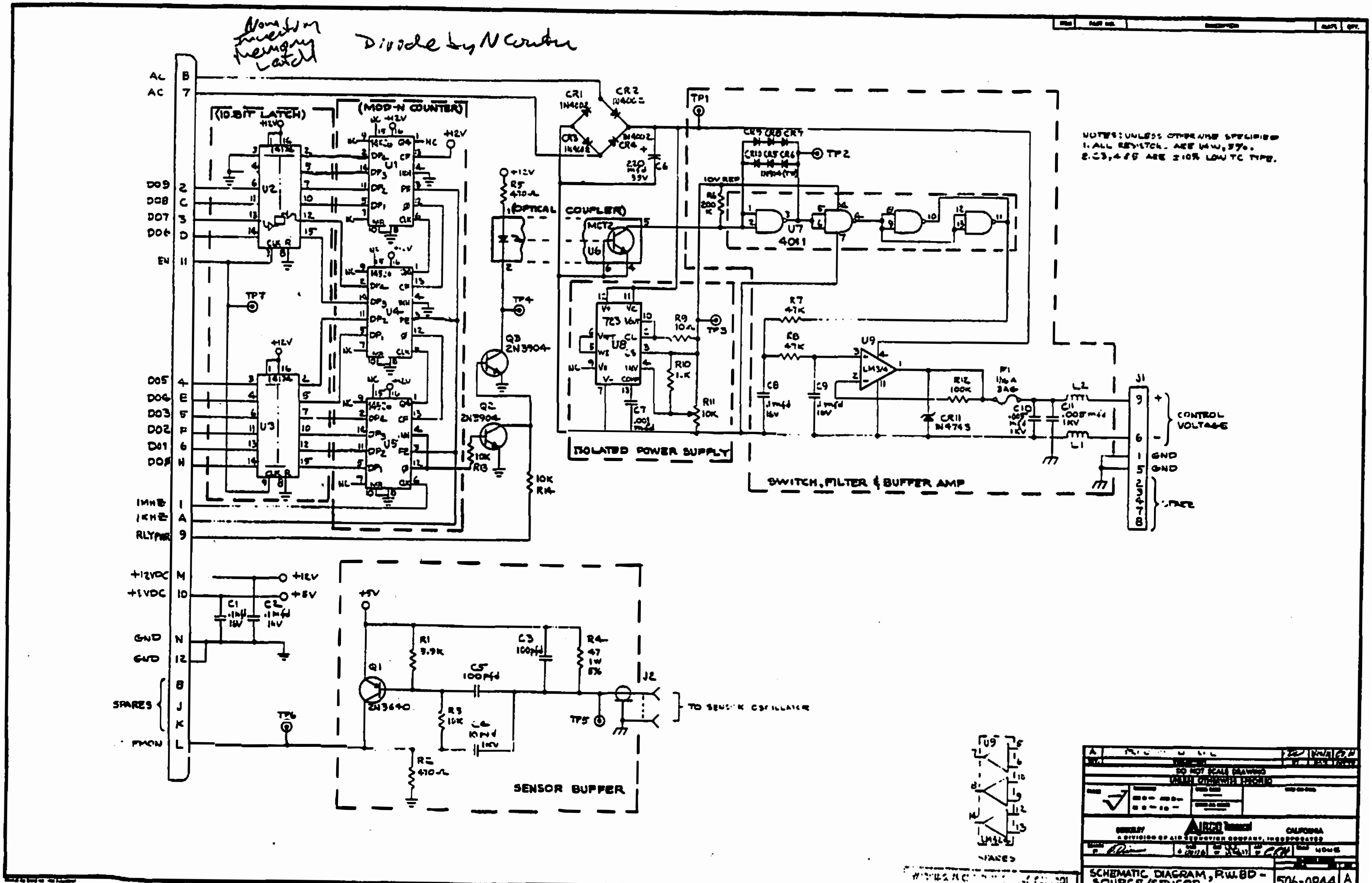


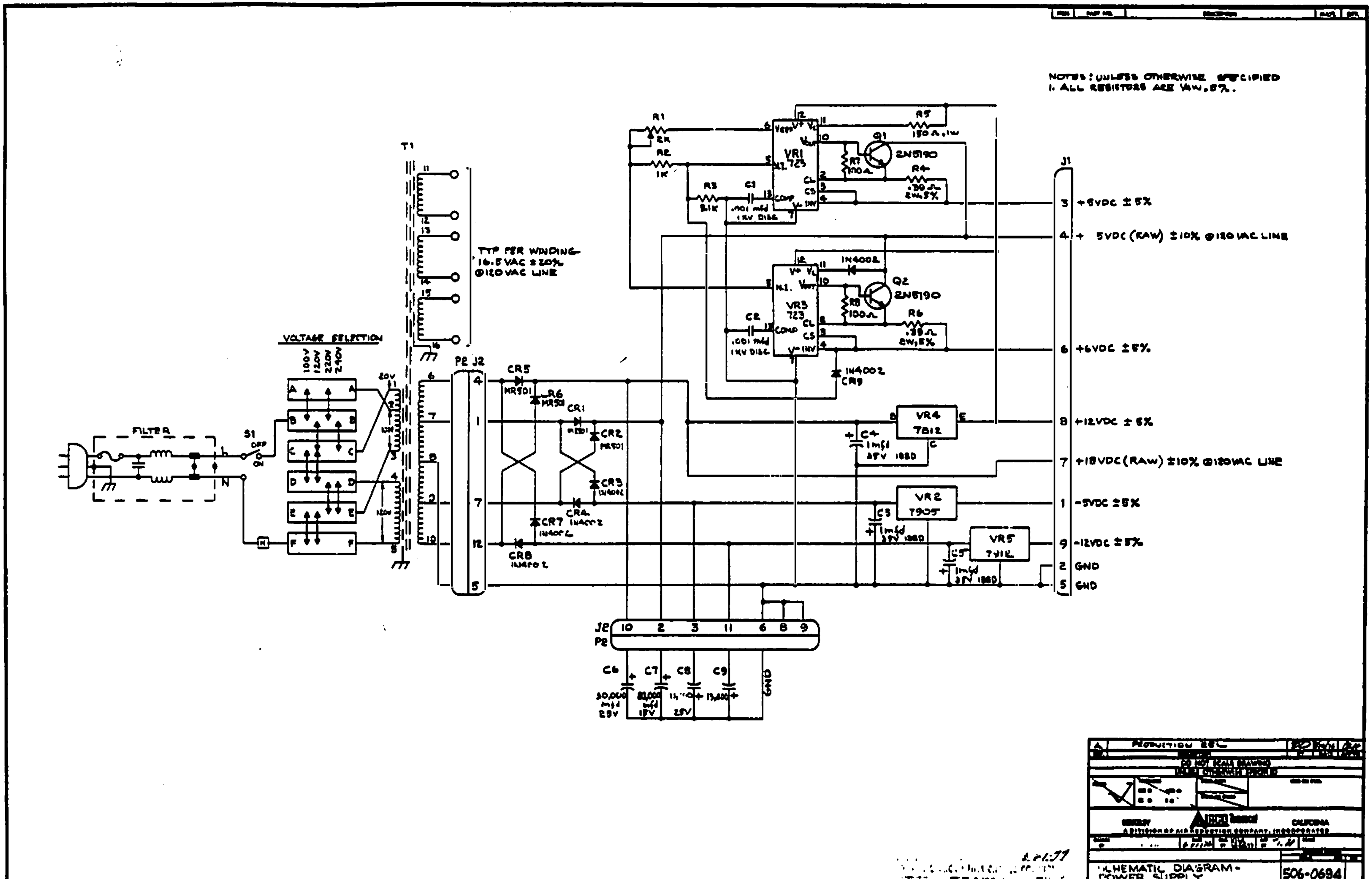
Figure 8-9 Top View, with cover removed, showing placement of circuit boards


u22 Hex D Flip Flop
P1
RLY PWR
K1 CONTROL
OUT 4
DO4
DO3
DO2
DO1
DOØ
EN
ABORT COND
SPARES
DI4
DI3
DI2
DI1
DIØ
+18VDC
+12VDC
GND
ABORT RELAY CONTROL
U1 4011
U2 4174
TP1
enable
DC P/S ON
Abort
Reset/Start
Format
Programmable Int 1K
U3 4502B
Tri-state Inverter
Q1 2N3904
Q2 2N3904
Q3 2N3904
Q4 2N3904
Q5 2N3904
1N4002
+18V
K1
K2
K3
K4
K5
1N914 CR10
OPTICAL COUPLERS
INPUT BUFFERS
MCT2
U4
U5
U6
U7
J1
POS #1
POS #2
SPARE
CHASSIS GND
YES
NO
COM
NO ABORT
SHUTTER #2
IN PROCESS OR LAYER START
SHUTTER #3
PROCESS COMPLETE OR LAYER COMPLETE
PROGRAMMABLE #2
SHUTTER #1
PROGRAMMABLE #3
PROGRAMMABLE #1
FEED
ABORT
PROGRAMMABLE INTERLOCK #2
RESET START
PROGRAMMABLE INTERLOCK #3
FORMAT
PROGRAMMABLE INTERLOCK #1
NOTES: UNLESS OTHERWISE SPECIFIED
1. ALL RESISTORS ARE 1/4W, 5%
2. ALL CAPACITORS VALUES ALL IN mfd.
Switch Output Type
U1 4011
SPARE
DO NOT SCALE DRAWING
AIRCO Temescal
BERKELEY CALIFORNIA
SCHEMATIC DIAGRAM - DISCRETE I/O P.W. BD
506-0884 A



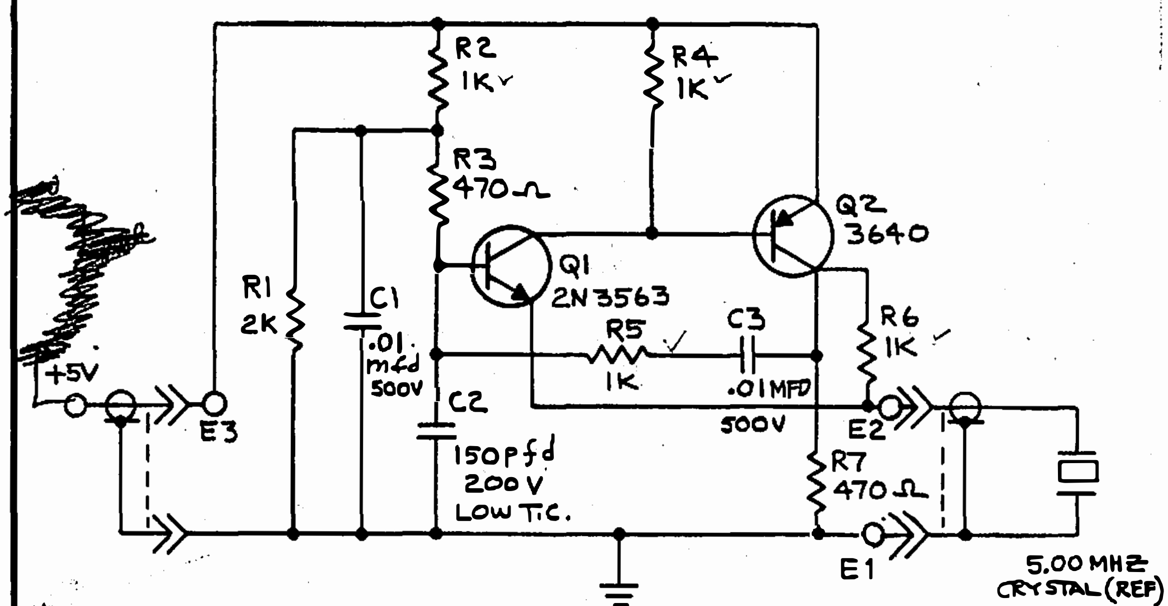
SCHEMATIC DIAGRAM, P.W. BD - SOURCE/SENSOR

506-0844 A


NOTES: UNLESS OTHERWISE SPECIFIED
1. ALL RESISTORS ARE 1/4W, 5%.
VOLTAGE SELECTION
100V
120V
220V
240V
FILTER
S1
OFF
ON
T1
TYP PER WINDING
16.5 VAC ± 20%
@120 VAC LINE
P2 J2
CR5
MR501
R6
MR501
CR1
CR2
CR3
1N4002
CR4
1N4002
CR7
1N4002
CR8
1N4002
R1
2K
R2
1K
R3
8.1K
C1
.001 mfd
1KV DISC
VR1
723
Q1
2N5190
R7
100Ω
R5
150Ω, 1W
R4
.30Ω
2W, 5%
VR3
723
Q2
2N5190
R8
100Ω
R6
.35Ω
2W, 5%
C2
.001 mfd
1KV DISC
1N4002
CR9
VR4
7812
C4
1mfd
35V
VR2
7905
C3
1mfd
35V
VR5
7912
C5
1mfd
35V
J1
3 +5VDC ± 5%
4 + 5VDC (RAW) ± 10% @120 VAC LINE
6 +6VDC ± 5%
8 +12VDC ± 5%
7 +18VDC (RAW) ± 10% @120 VAC LINE
1 -5VDC ± 5%
9 -12VDC ± 5%
2 GND
5 GND
J2
P2
C6
30,000 mfd 25V
C7
82,000 mfd 15V
C8
25V
C9
13,000
GND
PRODUCTION REL
DO NOT SCALE DRAWING
SCHEMATIC DIAGRAM - POWER SUPPLY
506-0694

NOTES:
1. ALL RESISTORS ARE 1/4W, 5%. VALUE IN OHMS

ITEM	PART NO.	DESCRIPTION	MAT'L	QTY.



REV.	DESCRIPTION	BY	DATE	APPVD
A	PRODUCTION REL		7/24/76	

DO NOT SCALE DRAWING

UNLESS OTHERWISE SPECIFIED

FINISH | TOLERANCE XXX ± ANG ± XX ± X ± | INTER. RADII BREAK ALL EDGES | USED ON DWG.

BERKELEY **AIRCO Temescal** CALIFORNIA

A DIVISION OF AIR REDUCTION COMPANY, INCORPORATED

DRAWN BY | DATE 5/28/76 | CHK BY | APP BY | SCALE NONE

3-21-77

SCHEMATIC DIAGRAM - TRANSDUCER OSCILLATOR

DRAWING NUMBER: 506-0722 | REV: A

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