Section 2
Theory of Operation

2-1. INTRODUCTION

This section provides theory of operation in a top-down format. The calibrator is first broadly defined in terms of digital functions (relating to the Digital Motherboard assembly) and analog functions (relating to the Analog Motherboard assembly). The interrelationship of these two areas is then explored in discussions of each output function. Finally, this overall picture is rounded out with a discussion of system interconnections.

Most of this section is devoted to detailed circuit descriptions, first of in the digital (unguarded) section, then in the analog (guarded) section.

2-2. CALIBRATOR OVERVIEW

Figures 2-1, 2-2, and 2-3 comprise the block diagram of the 5700A. These figures are presented further on in the Analog Section Overview and the Digital Section Overview.

The 5700A is configured internally as an automated calibration system with process controls and consistent procedures. Internal microprocessors control all functions and monitor performance, using a switching matrix to route signals between modules. Complete automatic internal diagnostics, both analog and digital, confirm operational integrity.

The heart of the measurement system is a 5-1/2 digit adc (analog-to-digital converter), which is used in a differential mode with the 5700A dac. (The dac is described next under "Internal References.")

2-3. Internal References

The major references that form the basis of the 5700A's accuracy are the hybrid reference amplifiers, patented Fluke solid-state thermal rms sensors, an extremely linear dac, and two internal precision resistors.

2-4. HYBRID REFERENCE AMPLIFIERS

A precision source can only be as accurate as its internal references, so the dc voltage reference for the 5700A was chosen with extreme care. Years of data collection have proven the ovenized reference amplifier to be the best reference device available for modern, ultra-stable voltage standards.

In a microprocessor-controlled precision instrument such as the 5700A, the important characteristics of its dc voltage references are not the accuracy of the value of the references, but rather their freedom from drift and hysteresis. (Hysteresis is the condition of stabilizing at a different value after being turned off then on again.) The 5700A hybrid reference amplifiers excel in both freedom from drift and absence of hysteresis.

2-5. FLUKE THERMAL SENSOR (FTS)

Thermal rms sensors, or ac converters, convert ac voltage to dc voltage with great accuracy. These devices sense true rms voltage by measuring the heat generated by a voltage through a known resistance.

Conventional thermal voltage converters suffer from two main sources of error. First, they exhibit frequency response errors caused by component reactance. Second, they have a poor signal-to-noise ratio because they operate at the millivolt level. The FTS has a full-scale input and output of 2V and a flat frequency response.

After initial functional verification of the Fluke Thermal Sensors, their characteristics only change by less than 1/10th of the allowed ac/dc error per year. External calibration of the ac voltage function of the 5700A consists of verifying that the 5700A meets its specifications.

2-6. DIGITAL-TO-ANALOG CONVERTER (DAC)

A patented 26-bit dac is used in the calibrator as a programmable voltage divider. The dac is a pulse-width modulated (pwm) type with linearity better than 1 ppm (part-per-million) from 1/10th scale to full scale.

2-7. DIGITAL SECTION OVERVIEW

The unguarded Digital Section contains the CPU assembly (A20), Digital Power Supply assembly (A19), Front Panel assembly (A2), Keyboard assembly (A1), and the unguarded portion of the Rear Panel assembly (A21). Figure 2-1 is a block diagram of the digital section of the 5700A.

Power for the digital assemblies and the cooling fans is supplied by the Digital Power Supply assembly.

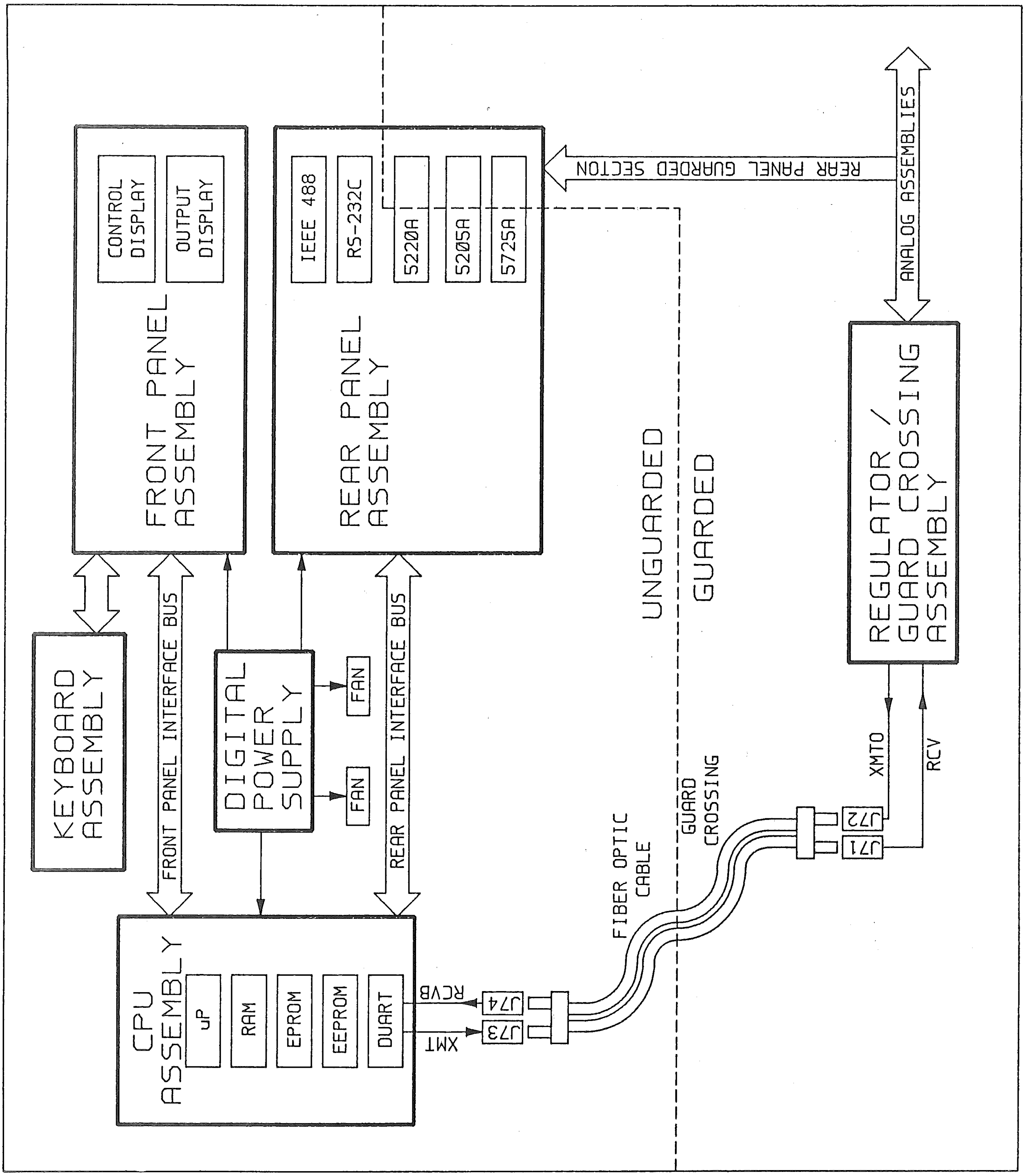


Figure 2-1. Digital Section Block Diagram

The CPU (central processing unit) assembly is a single-board computer based on the 68HC000 microprocessor. It controls local and remote interfaces, as well as serial communications over a fiber-optic link to the crossing portion of the Regulator/Guard Crossing assembly (A17). The guard crossing controls the guarded analog circuitry.

A Keyboard assembly provides the user with front-panel control of the 5700A. It contains four LED's, a rotary edit knob, and a forty-five key keypad. It connects to the Front Panel assembly via a cable.

The Front Panel assembly provides information to the user on an Output Display and a Control Display. The Front Panel also contains circuitry that scans the the keyboard and encodes key data for the CPU.

The Rear Panel assembly includes digital interfaces for the following:

- o IEEE-488 bus connection
- o RS-232-C DTE serial port
- o Four auxiliary amplifiers: the 5725A, 5205A, 5215A, and 5220A

2-8. ANALOG SECTION OVERVIEW

The guarded analog section of the 5700A contains the following assemblies:

- o Wideband Output (A5) (Part of Option -03)
- o Wideband Oscillator (A6) (Part of Option -03)
- o Current/Hi-Res (A7)
- o Switch Matrix (A8)
- o Ohms Cal (A9)
- o Ohms (A10)
- o DAC (A11)
- o Oscillator Control (A12)
- o Oscillator Output (A13)
- o High Voltage Control (A14)
- o High Voltage/High Current (A15)
- o Power Amplifier (A16)
- o Regulator/Guard Crossing (A17)
- o Filter/PA Supply (A18)

These analog assemblies are interfaced to the Analog Motherboard assembly (A3). The guarded digital bus generated by the guard crossing portion of the Regulator/Guard Crossing assembly controls all analog assemblies except the Filter/PA Supply. The Guard Crossing interfaces with the unguarded CPU assembly via a fiber-optic link. The Transformer assembly, along with the filter portion of the Filter/PA Supply assembly and the regulator portion of the Regulator/Guard Crossing assembly, create the system power supply for all the analog assemblies. The Power Amplifier Supply portion of the Filter/PA Supply assembly provides the high voltage power supplies required by the Power Amplifier assembly. The amplitudes of these high voltage supplies are controlled by circuitry contained on the Power Amplifier assembly.

Figures 2-2 and 2-3 are block diagrams for the analog section of the 5700A.

2-9. FUNCTIONAL DESCRIPTION PRESENTED BY OUTPUT FUNCTION

This part of the theory section presents 5700A operation from the perspective of each output function. It describes which assemblies come into play, and how they interact. It does not provide a detailed circuit description. Refer to the individual assembly theories further on in this section for detailed circuit descriptions.

2-10. DC Voltage Functional Description

The DAC assembly (A11) provides a stable dc voltage and is the basic building block of the 5700A. DC voltages are generated in six ranges:

- 220 mV
- 2.2V
- 11V
- 22V
- 220V
- 1100V

The 11V and 22V ranges are generated by the DAC assembly, with its output, DAC OUT HI and DAC SENSE HI routed to the Switch Matrix assembly, where relays connect it to INT OUT HI and INT SENSE HI. Lines INT OUT HI and INT SENSE HI connect to the 5700A binding posts by relays on the Analog Motherboard assembly (A3).

The 2.2V range is created on the Switch Matrix assembly by resistively dividing by five the 11V range from the DAC assembly. Relays on the Switch Matrix and Analog Motherboard route the 2.2V range output to the 5700A binding posts.

The 220 mV range is an extension of the 2.2V range. The Switch Matrix assembly resistively divides by ten the 2.2V range to create the 220 mV range. Relays on the Switch Matrix and Analog Motherboard route the 220 mV range output to the front panel binding posts.

The 220V range is generated by the DAC and Power Amplifier assemblies. The the Power Amplifier amplifies the 11V range of the DAC assembly by a gain of -20 to create the 220V range. The output of the Power Amplifier is routed to the High Voltage Control assembly (A14), where a relay connects it to PA OUT DC. Line PA OUT DC is routed to the binding posts via relays on the Switch Matrix and Analog Motherboard.

The 1100V range is generated by the High Voltage/High Current assembly (A15) operating in conjunction with the Power Amplifier assembly and the High Voltage Control assembly. The 11V range of the DAC assembly is routed to the High Voltage/High Current assembly which amplifies by a gain of -100 to create the 1100V range. Basically the high voltage output is obtained by rectifying and filtering a high voltage ac signal generated by the High Voltage Control assembly operating in conjunction with the Power Amplifier assembly.

2-11. AC Voltage Functional Description

The Oscillator Output assembly (A13) is the ac signal source for the 5700A. The Oscillator Control assembly (A12), controls the amplitude of this ac signal by comparing it with the accurate dc voltage from the DAC assembly and making amplitude corrections via the OSC CONT line. The frequency of oscillation is phase locked to either the high resolution oscillator on the Current/Hi-Res (A7) assembly or an external signal connected to the PHASE LOCK IN connector on the rear panel. AC voltages are generated in the following ranges:

- 2.2 mV
- 22 mV
- 220 mV
- 2.2V
- 11V
- 22V
- 220V
- 1100V

The 2.2V and 22V ranges are generated by the Oscillator Output assembly and routed to the 5700A binding posts via relays on the Switch Matrix (A8) and Analog Motherboard assemblies.

The 220 mV range is generated on the Switch Matrix assembly, which resistively divides by ten the 2.2V range of the Oscillator Output assembly. Relays on the Switch Matrix and Analog Motherboard route the 220 mV range to the 5700A binding posts.

The 2.2 mV and 22 mV ranges are generated on the Switch Matrix assembly. In this mode, the Switch Matrix resistively divides the 2.2V range or the 22V range by 1000 to create the 2.2 mV and 22 mV ranges respectively. Relays on the Switch Matrix and Analog Motherboard route these ranges to the 5700A binding posts.

The 220V range is generated on the Power Amplifier assembly. In this mode, the Power Amplifier is set for a nominal gain of -10 to amplify the 22V range from the Oscillator Output to the 220V range. The 220V ac range from the Power Amplifier is routed to the 5700A binding posts by relays on the High Voltage Control assembly and the Analog Motherboard.

The 1100V range is generated by the High Voltage Control assembly operating in conjunction with the Power Amplifier assembly. In this mode, the 22V range from the Oscillator Output is amplified by the Power Amplifier and High Voltage Control assemblies, which create an amplifier with a nominal gain of -100. Relays on the High Voltage Control and Analog Motherboard assemblies route the 1100V ac range to the 5700A binding posts.

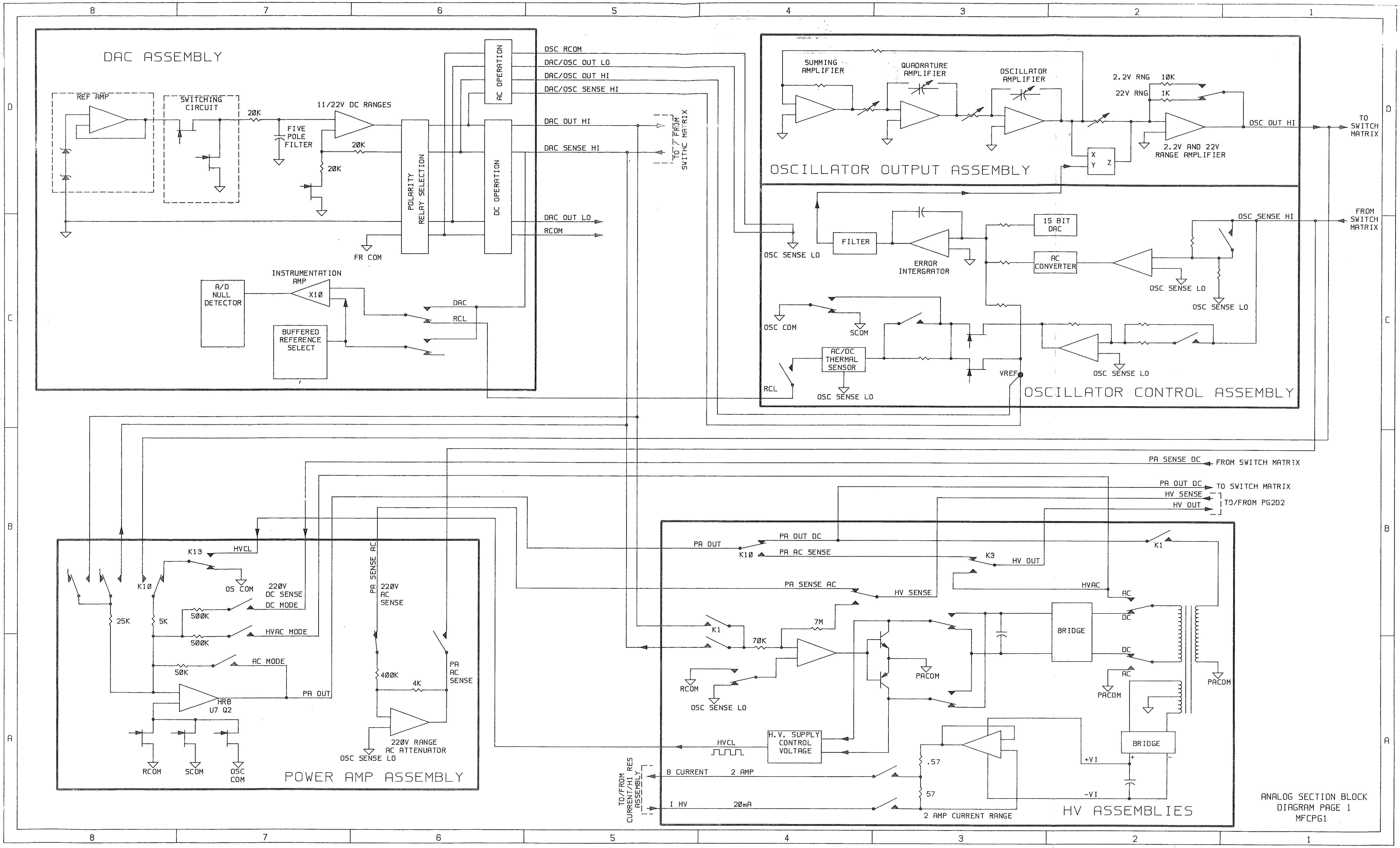


Figure 2-2. Analog Section Block Diagram, Part 1

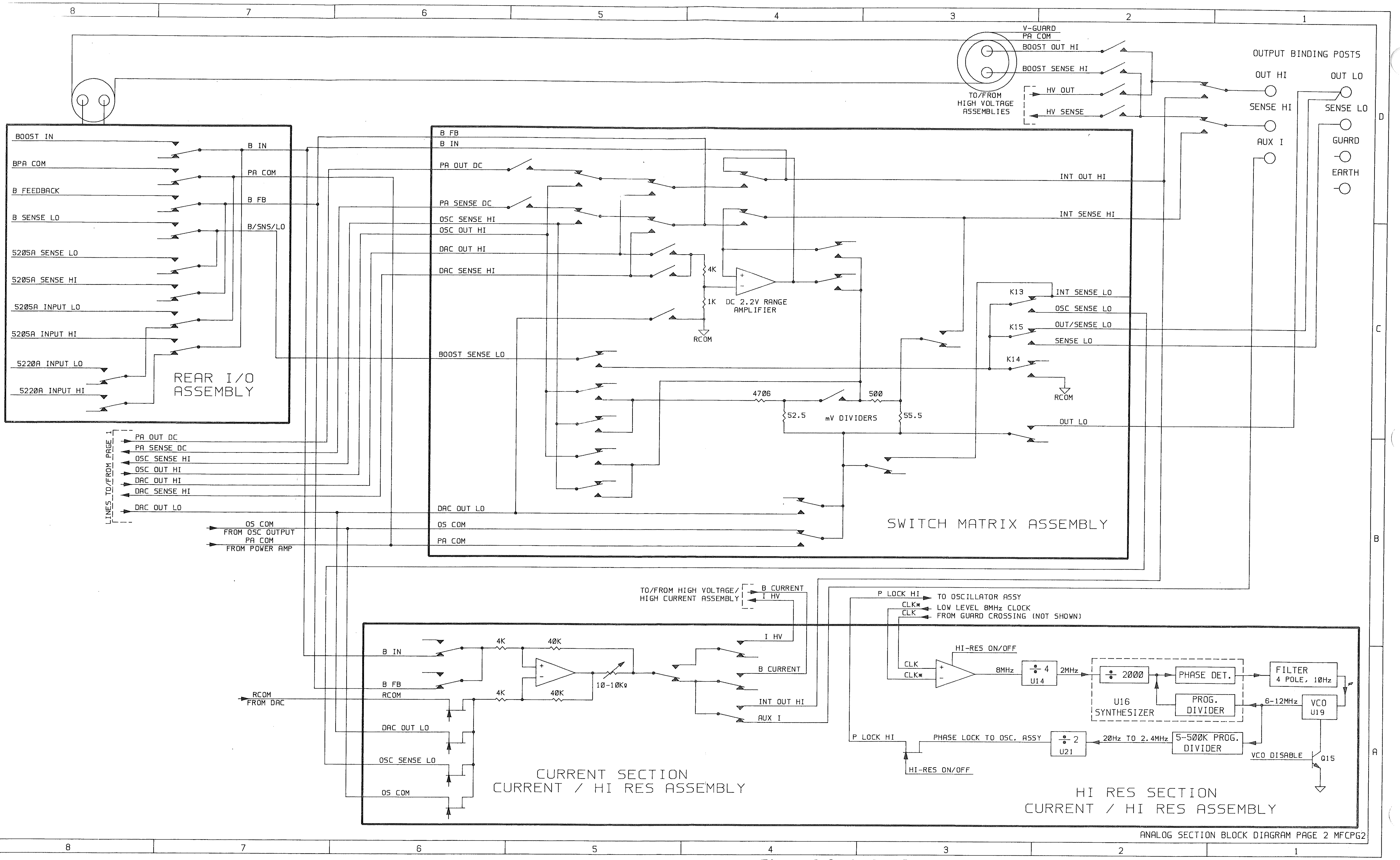


Figure 2-3. Analog Section Block Diagram, Part 2

2-12. Wideband AC V Functional Description (Option -03)

The Wideband AC Voltage module (Option -03) consists of the Wideband Oscillator assembly (A6) and the Wideband Output assembly (A5). There are two wideband frequency ranges:

- o 10 Hz to 1.1 MHz
- o 1.2 MHz to 30 MHz

During operation between 10 Hz and 1.1 MHz, output from the Oscillator Output assembly is routed to the Wideband Output assembly where it is amplified and attenuated to achieve the specified amplitude range. The output is connected to the 5700A front panel WIDEBAND connector. Operation between 1.2 MHz and 30 MHz works the same way, except the input to the Wideband Output assembly is the ac signal from the Wideband Oscillator assembly.

2-13. DC Current Functional Description

DC current is generated in five ranges:

- o 20 uA - 220 uA
- o 220 uA - 2.2 mA
- o 2.2 mA - 22 mA
- o 22 mA - 220 mA
- o 2.2A

All current ranges except 2.2A are generated by the current portion of the Current/Hi-Res assembly. These currents are created by connecting the output of the DAC assembly, set to the 22V range, to the input of the Current assembly. The Current assembly uses this dc voltage to create the output current. The current output can be connected to the AUX CURRENT OUTPUT binding post by relays on the Current assembly, to the OUTPUT HI binding post by relays on the Current, Switch Matrix, and Analog Motherboard assemblies, or to the 5725A via the B-CUR line by relays on the Analog Motherboard assembly and Rear Panel assembly.

The 2.2A range is an extension of the 22 mA range. The 22 mA range output from the Current assembly is amplified by a gain of 100 by the High Voltage/High Current assembly operating in conjunction with the Power Amp assembly and the High Voltage Control assembly. The 2.2A current range is routed back to the Current assembly where it is connected to either the AUX CURRENT OUTPUT binding post, the OUTPUT HI binding post, or the 5725A in the same manner as the lower current ranges.

2-14. AC Current Functional Description

AC current is created in the same manner as dc current, except the input to the Current assembly is the ac voltage from the Oscillator Output assembly set to the 22V range. The switching between ac and dc is carried out on the Switch Matrix, Oscillator Control, Oscillator Output, and DAC assemblies.

2-15. Ohms Functional Description

Two assemblies function as one to supply the fixed values of resistance:

- o Ohms Main assembly (A10)
- o Ohms Cal assembly (A9)

All of the resistance values except the 1 ohm, 1.9 ohm, and short are physically located on the Ohms Main assembly. The 1 ohm, 1.9 ohm, and short are physically located on the Ohms Cal assembly. The desired resistance is selected by relays on these Ohms assemblies and is connected to the 5700A binding posts by relays on the Analog Motherboard. The Ohms Cal assembly also contains the appropriate circuitry to enable the 5700A to perform resistance calibration. Once calibrated, the 5700A output display shows the true value of the resistance selected, not the nominal (e.g., 10.00031 kilohm, not 10 kilohm).

Four ohms measurement modes are available:

- o For the two-wire configuration, measurement with or without lead-drop compensation sensed at the binding posts of the UUT (using the SENSE binding posts and another set of leads), or at the ends of its test leads is available for 19 kilohms and below.

- o Four-wire configuration is available for all but the 100 megohm value.

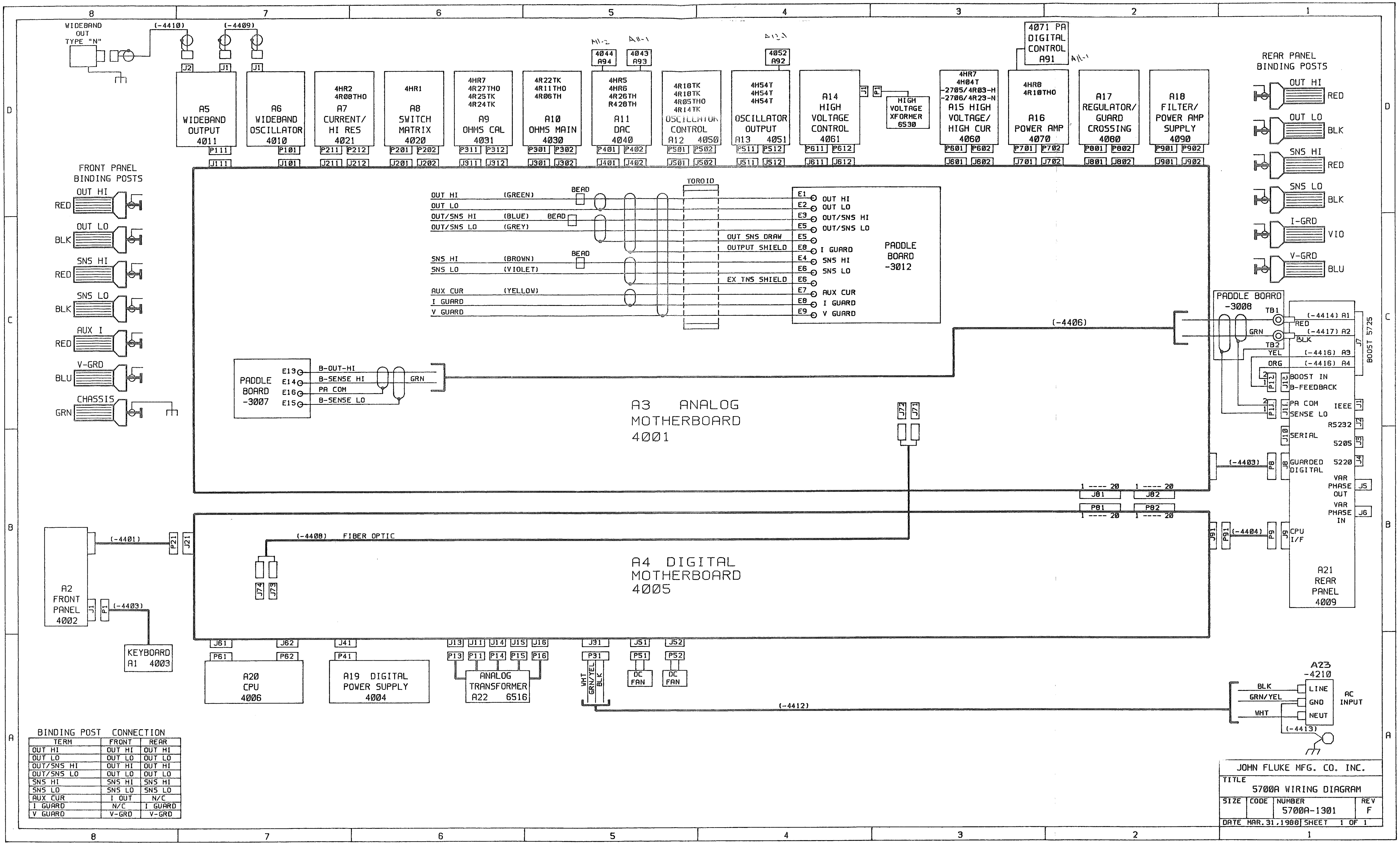
2-16. SYSTEM INTERCONNECT DETAILED CIRCUIT DESCRIPTION

The Motherboard assembly contains the Digital Motherboard assembly (A4), and the Analog Motherboard assembly (A3). These two Motherboards are mechanically fastened together with screws. They are electrically connected by connectors P81 and P82 on the Digital Motherboard and connectors J81 and J82 on the Analog Motherboard. AC voltage taps from the Transformer assembly (A22) are connected to the Analog Motherboard through these connectors. Refer to Figure 2-4 for an overview of system interconnections. Figure 2-4 continues on the reverse side, showing system grounds.

2-17. Digital Motherboard Assembly (A4)

The Digital Motherboard contains the line-select switches, line fuse, power switch, a fiber-optic transmitter (J73), and a fiber-optic receiver (J74). It also contains connectors for the Transformer assembly (A22), Digital Power Supply assembly (A19), CPU assembly (A20), Front Panel assembly (A2), Rear Panel assembly (A21), and the two 24V dc fans mounted in the chassis.

The fiber-optic receiver and transmitter provide the serial communication link between the CPU on the unguarded Digital Motherboard and the Regulator/Guard Crossing on the guarded Analog Motherboard.



BINDING POST CONNECTION

TERM	FRONT	REAR
OUT HI	OUT HI	OUT HI
OUT LO	OUT LO	OUT LO
OUT/SNS HI	OUT HI	OUT HI
OUT/SNS LO	OUT LO	OUT LO
SNS HI	SNS HI	SNS HI
SNS LO	SNS LO	SNS LO
AUX CUR	I OUT	N/C
I GUARD	N/C	I GUARD
V GUARD	V-GRD	V-GRD

Figure 2-4. System Interconnections

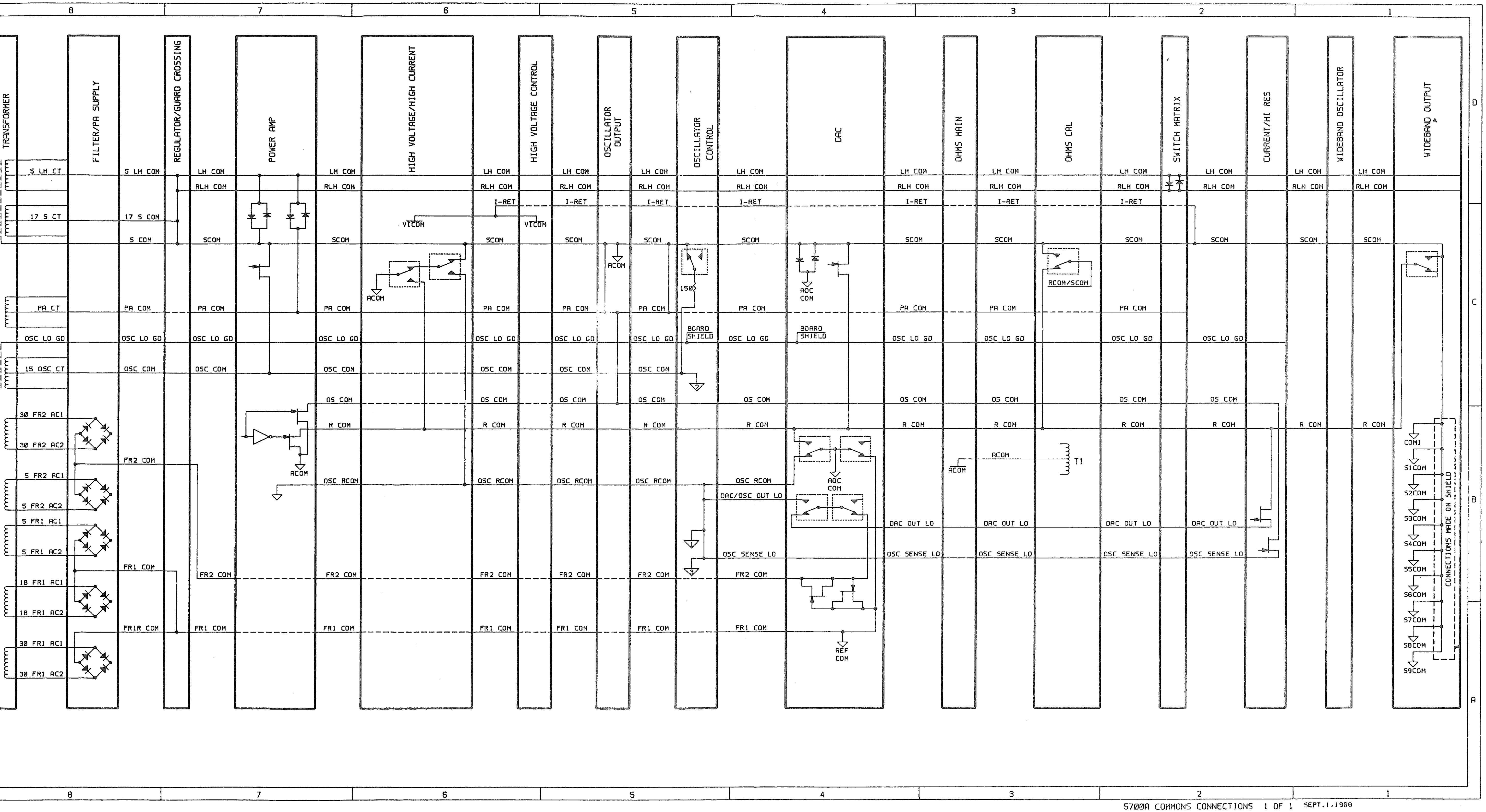


Figure 2-4. System Interconnections (cont)

2-18. Transformer Assembly (A22)

The Transformer assembly receives ac line inputs routed through the A4 Digital Motherboard. This assembly supplies outputs throughout the 5700A, all of which are routed through the A4 Digital Motherboard.

The Transformer assembly, the filter portion of the Filter/PA Supply assembly (A18), and the regulator portion of the Regulator/Guard Crossing assembly (A17) create the system power supply for all analog assemblies. The Transformer assembly also supplies ac voltages to the Digital Power Supply assembly which generates five regulated dc voltages for use by the CPU, Front Panel assembly, Rear Panel assembly, and the cooling fans.

2-19. Analog Motherboard Assembly (A3)

The Analog Motherboard contains the connectors for all assemblies in the guarded section of the calibrator. The Analog Motherboard also contains 13 relays, a fiber-optic transmitter, a fiber-optic receiver, a cable for binding post connections, and two cables for the interface to the Rear Panel assembly.

Table 2-1 lists Analog Motherboard connectors.

Table 2-1. Analog Motherboard Connectors

MOTHERBOARD CONNECTOR	CONNECTED TO ASSEMBLY
J101	Wideband Oscillator assembly (A6)
J111	Wideband Output assembly (A5)
J201 and J202	Switch Matrix assembly (A8)
J211 and J212	Current/Hi-Res assembly (A7)
J301 and J302	Ohms Main assembly (A10)
J311 and J312	Ohms Cal assembly (A9)
J401 and J402	DAC assembly (A11)
J501 and J502	Oscillator Control assembly (A12)
J511 and J512	Oscillator Output assembly (A13)
J601 and J602	High Voltage/High Current assembly (A15)
J611 and J612	High Voltage Control assembly (A14)
J701 and J702	Power Amplifier assembly (A16)
J801 and J802	Regulator/Guard Crossing assembly (A17)
J901 and J902	Filter/PA Supply assembly (A18)

The fiber-optic transmitter (J72) and the fiber-optic receiver (J71) provide the serial communication link between the Regulator/Guard Crossing assembly and the CPU assembly on the unguarded Digital Motherboard.