MODEL 2520
RF CALIBRATOR
INSTRUCTION MANUAL

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SAFETY SUMMARY

The following general safety precautions must be observed during all phases of operation and maintenance of this instrument. Failure to comply with these precautions or with specific warnings elsewhere in this manual violates safety standards of design, manufacture, and intended use of the instruments. Boonton Electronics assumes no liability for the customer's failure to comply with these requirements.

THE INSTRUMENT MUST BE GROUNDED.
To minimize shock hazard the instrument chassis and cabinet must be connected to an electrical ground. The instrument is equipped with a three conductor, three prong a.c. power cable. The power cable must either be plugged into an approved three-contact electrical outlet or used with a three-contact to a two-contact adapter with the (green) grounding wire firmly connected to an electrical ground at the power outlet.

DO NOT OPERATE THE INSTRUMENT IN AN EXPLOSIVE ATMOSPHERE.
Do not operate the instrument in the presence of flammable gases or fumes.

KEEP AWAY FROM LIVE CIRCUITS.
Operating personnel must not remove instrument covers. Component replacement and internal adjustments must be made by qualified maintenance personnel. Do not replace components with the power cable connected. Under certain conditions dangerous voltages may exist even though the power cable was removed; therefore, always disconnect power and discharge circuits before touching them.

DO NOT SERVICE OR ADJUST ALONE.
Do not attempt internal service or adjustment unless another person, capable of rendering first aid and resuscitation, is present.

DO NOT SUBSTITUTE PARTS OR MODIFY INSTRUMENT.
Do not install substitute parts or perform any unauthorized modification of the instrument. Return the instrument to Boonton Electronics for repair to ensure that the safety features are maintained.

SAFETY SYMBOLS.

This safety requirement symbol (located on the rear panel) has been adopted by the International Electrotechnical Commission, Document 66 (Central Office) 3, Paragraph 5.3, which directs that an instrument be so labeled if, for the correct use of the instrument, it is necessary to refer to the instruction manual. In this case it is recommended that reference be made to the instruction manual when connecting the instrument to the proper power source. Verify that the correct fuse is installed for the power available, and that the switch on the rear panel is set to the applicable operating voltage.

CAUTION

The CAUTION sign denotes a hazard. It calls attention to an operation procedure, practice, or the like, which, if not correctly performed or adhered to, could result in damage to or destruction of part or all of the equipment. Do not proceed beyond a CAUTION sign until the indicated conditions are fully understood and met.

WARNING

The WARNING sign denotes a hazard. It calls attention to an operation procedure, practice, or the like, which, if not correctly performed or adhered to, could result in injury or loss of life. Do not proceed beyond a WARNING sign until the indicated conditions are fully understood and met.

Indicates dangerous voltages.

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Figure 1-1. 2520 Photo

SECTION 1
GENERAL INFORMATION

1-1. INTRODUCTION. This manual provides information on specifications, installation, operating instructions, applications, theory of operation, maintenance (including performance verification), parts list, and schematics for the 2520 RF Calibrator. Refer to **Figures 1-1 and 1-2.**

1-2. DESCRIPTION. The Model 2520 is a fixed frequency (30 MHz) source at 50 ohms that provides an accurate level from -70 dBm to +20 dBm in 0.1 dB steps. It's level is NBS traceable using thermal converter techniques at 0 dBm and with NBS certified fixed attenuators at other levels. The 2520 is generally used for calibrating RF power meters, however, it can also be used to calibrate attenuators or video detectors, etc. Or it can be used in an automatic test equipment (ATE) environment for maintenance and verification of equipment.

The output impedance is 50 ohms, however, compensation for the 0.177 dB loss that occurs when connected to 75 ohm systems is provided. The Model 2520 is GPIB bus programmable.

1-3. ACCESSORIES. A 50 ohm to 75 ohm mechanical adapter, type N, is available, Boonton P/N 950006, for use in 75 ohm systems. The 75 ohm version of the "N" connector has a smaller center conductor.

1-4. OPTIONS. The 2520 may be ordered with a high temperature display option, which extends the operating temperature on the top end from 50 to 55 degrees C.

1-5. SPECIFICATIONS. The performance specifications for the 2520 are listed in **Table 1-1.**

TABLE 1-1. SPECIFICATIONS

Output Frequency:	30 MHz +/- 0.1%
Output Level:	-70 to +20 dBm in 0.1 dB steps into 50 or 75 ohms (the 75 ohm application is a known fixed mismatch)
VSWR:	1.05 maximum at 50 ohms
Impedance:	50 Ohms; a 75 ohm adapter is available, Boonton P/N 950006, which is a straight through type (not impedance matched). The output level is corrected for the 0.177 dB mismatch loss.

continued on next page

TABLE 1-1 (Cont.)

Output Level Accuracy (23 +/-5 degrees C, 1 year accuracy, after 5 min. warmup:	At 0 dBm: .055 dB +20 to -39.9 dBm: .075 dB -40 to -59.9 dBm: 0.105 dB -60 to -64.9 dBm: 0.165 dB -65 to -70 dBm: 0.305 dB
Aging:	.002 dB per year max; typically .0003 dB per year.
Settling Time:	150 mS to settling within spec
Display:	40 x 2 LCD, backlit with an EL panel, shows power level in dBm, output enabled condition, impedance compensation setting, and bus address.
Bus :	GPIB standard. Implements SH1, AH1, T6, L4, SR1, RL1, DC1, and DT1.
Input Power:	100, 120, 220, 240 VAC +/-10%, 50 to 400 Hz, <24 VA
Operating Temp-erature:	0 to 50 Degrees C, standard. 0 to 55 Degrees C with extended temp-erature display option.
Storage Temperature:	-20 to 70 Degrees C, standard; -40 to 90 Degrees C with extended temperature display option.
Dimensions:	3.5" H x 8.24" W x 12.375" D (8.9 cm x 20.0 x 31.4)
Weight:	7.0 lbs (3.2 kg.)
Linearity of 1 dB Steps:	+/- .015 dB max from 0 to -9.9 dB relative to full scale on any given range, down to -59.9 dBm. From -60 to -65 dBm add .06 db; from -65 to -70 dBm add 0.2 dB.
Linearity of 10 dB Steps (cumulative):	+/- .004 dB per 10 dB
Fixed Error (non cumul-ative error of a fixed 10 dB step due to mismatch):	+/- .009 dB

See Section 4 for a description of these uncertainty terms.

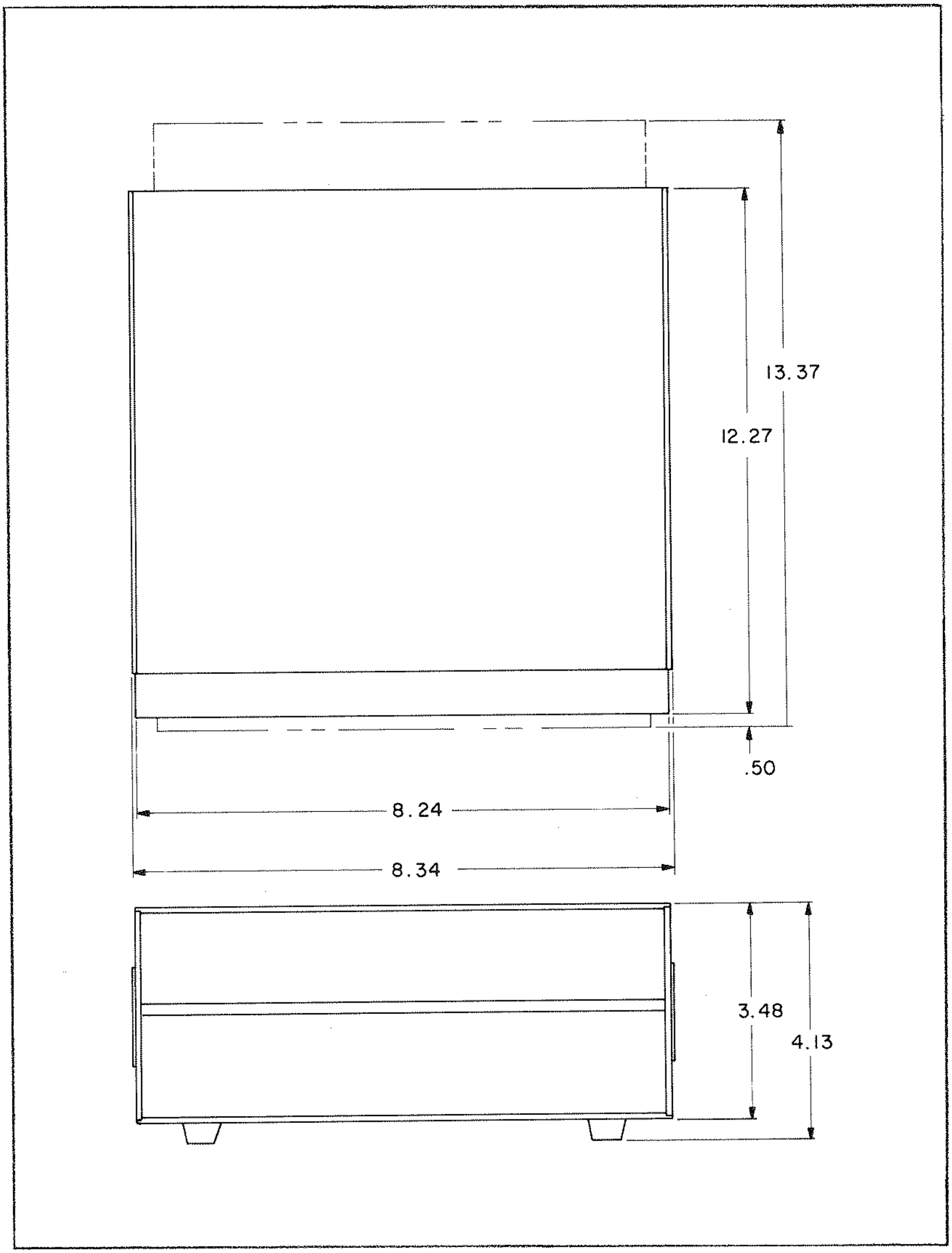


Figure 1-2. Outline Dimensions

SECTION 2
INSTALLATION

2-1. INTRODUCTION. This section contains instructions for the unpacking and installation of the Model 2520.

2-2. UNPACKING. The 2520 is shipped complete and is ready to use upon receipt. Unpack the instrument from it's shipping container and inspect it for damage that may have occurred during shipment. See **Figure 2-1.**

NOTE
Save the packing material and container for possible use in reshipment of the instrument.

2-3. MOUNTING. For bench mounting, choose a clean, sturdy, uncluttered mounting surface. For rack mounting, an accessory kit is available through Boonton that provides mounting ears and rear supports.

2-4. POWER REQUIREMENTS. The 2520 has a tapped power transformer and two line voltage selection switches which permit operation from 100, 120, 220, and 240 VAC single phase, +/-10%, from 50 to 400 Hz. Power consumption is approximately 20 VA.

CAUTION
Always make certain that the line voltage selection switches are set to the correct position most nearly corresponding to the voltage of the available AC power source, and that a fuse of the correct rating is installed in the fuse holder before connecting the 2520 to any power source.

The correct fuse is shown in **Table 2-1.**

TABLE 2-1. FUSE RATINGS

VOLTAGE	FUSE
100/120	0.3 A
220/240	0.2 A

2-5. CABLE CONNECTIONS. The RF output is on the front panel, type N female connector, and the GPIB bus connector is standard, on the rear panel. There is also a Control output on the rear panel, for special purposes. Refer to Section 3 for details on the connections.

2-6. PRELIMINARY CHECKOUT. The preliminary checkout ensures that the 2520 is functioning to a fair degree of confidence. For a full performance checkout, refer to "Performance Verification" in Section 6.

CAUTION
The line voltage selector switches must be set to the proper positions before conducting this test. Refer to Section **2-4** and to the rear panel.

The procedure for checkout is as follows :

1. Connect the instrument to the AC line and power up.

2. Connect the RF output to a

general purpose power meter capable of going from -60 to +20 dBm.

3. Press the "On/Off" key to enable the output, and verify that the indication on the display shows that the output is enabled.

4. Using the left and right arrow keys, position the cursor under the 1 dB digit.

5. Using the up and down arrow keys, vary the RF output from -60 to +20 and verify on the power meter that the power is changing and is accurate to about 0.1 dB (the accuracy is more determined by the power meter). Below -40 dBm, the tolerance is determined by noise and measurements can only be made to a rough degree. Consult the power meter specs for accuracy information.

6. Connect the GPIB connector on the rear panel to a controller and run a test program, following the program instructions.

This completes the checkout of the instrument.

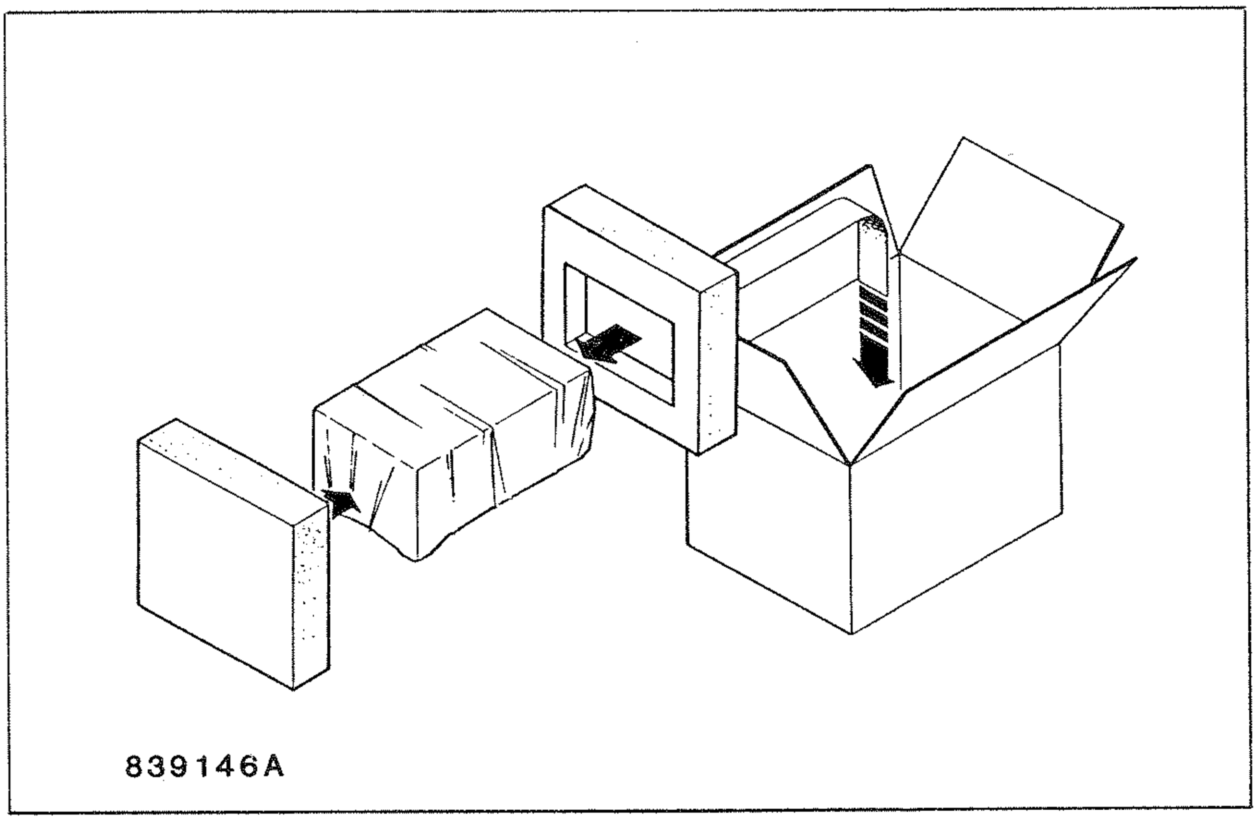


Figure 2-1. Packing and Unpacking Diagram

SECTION 3
OPERATION

3-1. INTRODUCTION. Section 3 contains information on the operating controls, indicators, and connectors, and operating instructions for the 2520. This section is broken down into two subsections :

1. Local Operation (3-3).
2. Remote (GPIB) operation (3-100).

3-2. OPERATING CONTROLS, INDICATORS, AND CONNECTIONS. The controls, indicators, and connections are listed in **Table 3-1,** and are shown in **Figures 3-1 and 3-2.**

TABLE 3-1. CONTROLS, INDICATORS, AND CONNECTIONS

Control/ Indicator/ Connector	Figure and Index No.	Function
Line On/Off	3-1, 1	Switches the AC Power on and off.
Display	3-1, 2	Controls the vertical viewing angle.
Up Arrow Key	3-1, 3	Modifies the selected parameter in an increasing direction.
Down Arrow Key	3-1, 4	Modifies the selected parameter in a decreasing direction.
Left Arrow Key	3-1, 5	Positions the cursor under a selected parameter.
Right Arrow Key	3-1, 6	Positions the cursor under a selected parameter.
Local Key	3-1, 7	Returns the operation from Bus to the front panel. Also used in some of the calibration modes.
On/Off Key	3-1, 8	Enables and disables the RF output without disturbing the level.
Output Connector	3-1, 9	The RF output, -70 to +20 dBm, 30 MHz.

continued

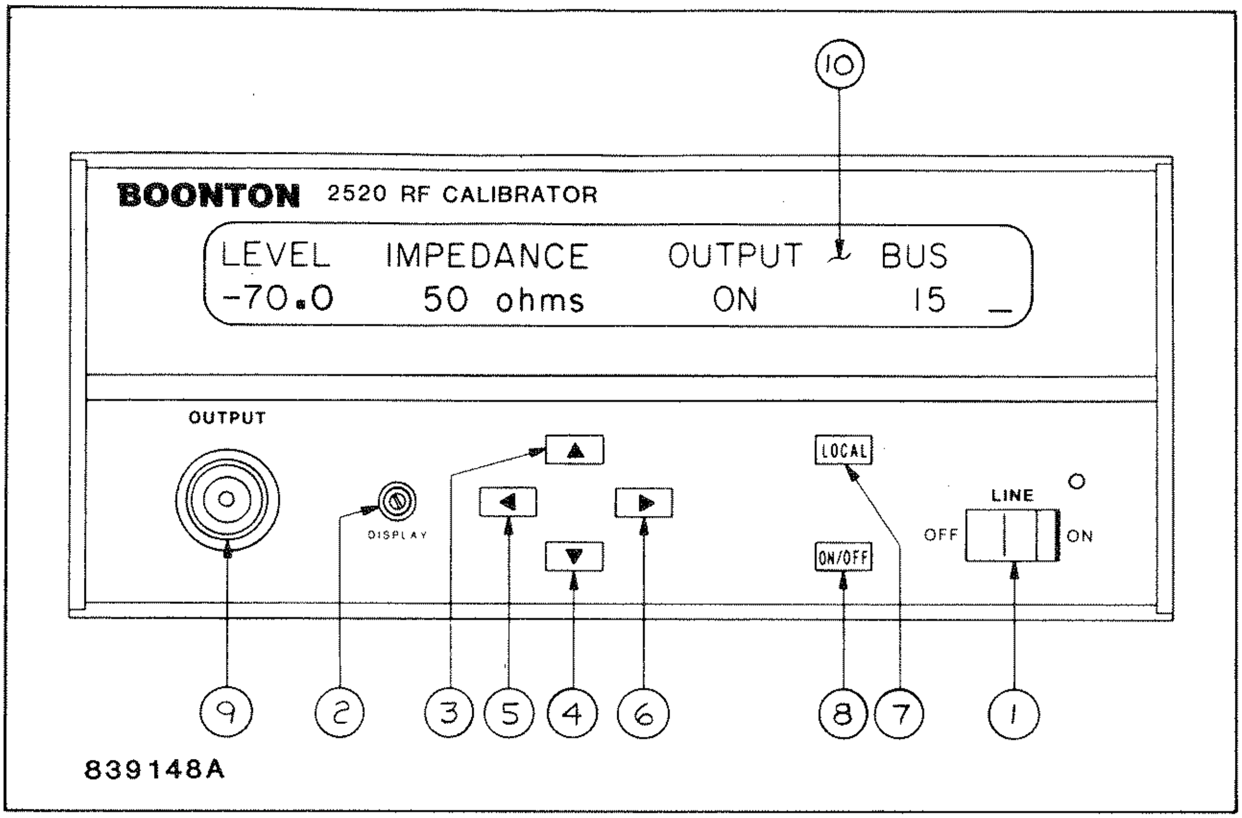


Figure 3-1. Front Panel

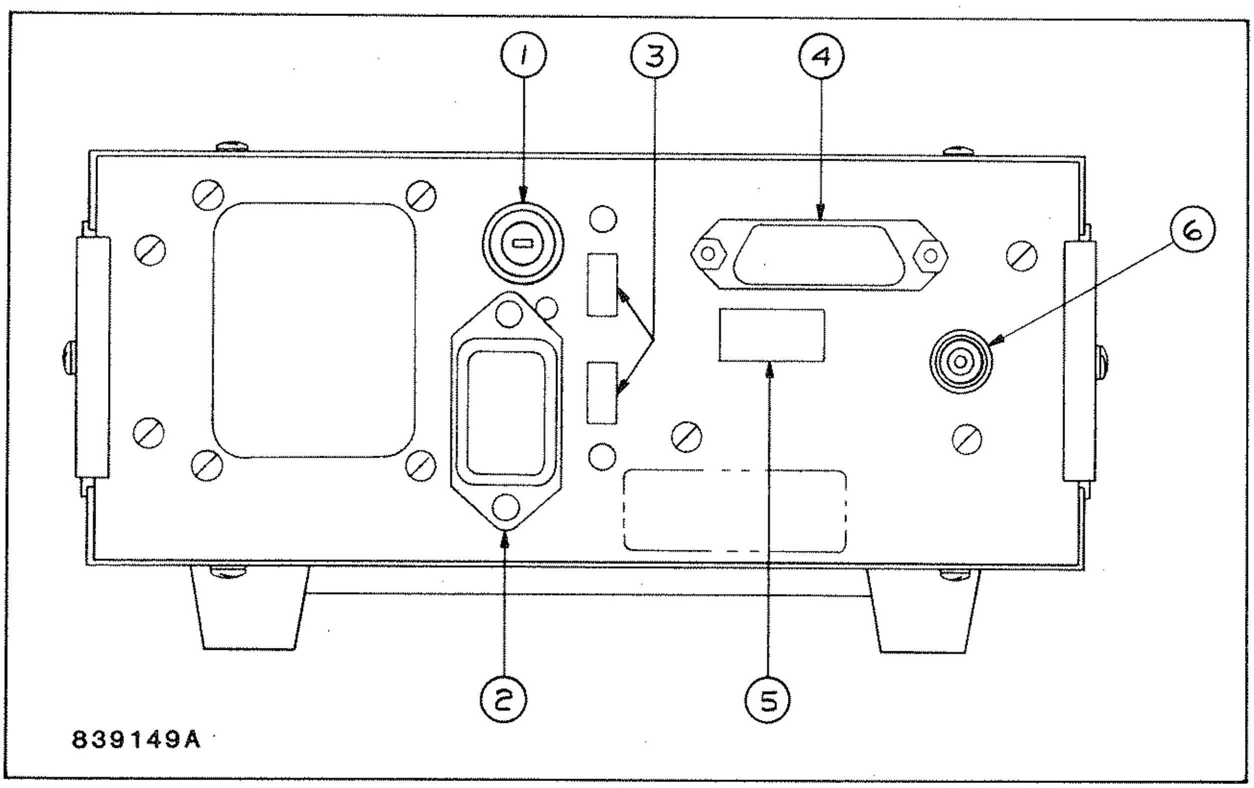


Figure 3-2. Rear Panel

TABLE 3-1 Continued.

Control/ Indicator/ Connector	Figure and Index No.	Function
Display	3-1,10	Display
Fuseholder	3-2, 1	AC power line fuse.
AC Connector	3-2, 2	AC power line input.
Line Voltage Selector Switches	3-2, 3	Changes the transformer taps to select the line voltage.
IEEE-488 Bus Connector	3-2, 4	Remote programming GPIB bus.
Bit Switch	3-2, 5	Sets the Bus address, terminating characters, and SRQ enabled. See **Table 3-3.**
Control Out BNC	3-2, 6	Set to logic level high when a Bus command "C1" is sent, and low when "C0" is sent. Used for controlling an amplifier or accessory.

3-3. OPERATING INSTRUCTIONS: LOCAL OPERATION.

1. Initialization. Set the line voltage selector switches on the rear panel according to the labels for the proper line voltage. Connect the power cord to the power input connector. The rear panel Bit switch settings are used only for bus operation; see **Table 3-3** as required. Turn on the unit from the front panel. Refer to **Figure 1-1** for a typical display.

2. Adjusting the Display. Using a small screwdriver, adjust the "Display" potentiometer on the front panel for the best contrast at the given viewing angle. The pot adjusts the up/down viewing angle. The side to side viewing angle is fixed.

3. Setting the Output Impedance Compensation. The output impedance is fixed at 50 ohms, but the calibrator can be used in 75 ohm systems if the VSWR mismatch is tolerable. The "Impedance" setting raises the output level by 0.177 dB loss to compensate for the mismatch loss. This is calculated assuming a resistive load.

When connecting the 2520 to 75 ohm systems, it is necessary to use an adapter such as the Boonton 950006. This is a mechanical adapter only to mate up to the 75 ohm version of the N connector.

To set the impedance compensation to 75 ohms, position the cursor under the "Impedance" heading on the display and press the "up" cursor. The display should show 75 ohms. When the 2520 is powered down, the impedance will return to 50 ohms.

4. Toggling the Output On and Off. The RF output alternately changes between on and off, while keeping the internally stored level constant, by pressing the "On/Off" key.

5. Setting the Output Level. The output level is adjustable in either steps of 0.1 dB, 1 dB, or 10 dB. The step size is selected by positioning the cursor under the digit to be modified. Then that digit is modified with the up and down arrow keys. Holding the up or down arrow keys will cause the digit to scroll continuously. The output level is updated constantly while the digit(s) are scrolling. See Item 6 below.

6. Limit Function. The normal maximum output is +20 dBm, but a function is provided to limit the output to +10 dBm for safety purposes (burnout protection). This is done with the internal Bit switch on the Control board, position 1. To set the limit to +10, set this switch to "open". A bus command to set the level higher than +10 dBm will be recognized; only the front panel operation is affected.

SECTION 3-100.
REMOTE (GPIB) OPERATION.

3-101. Introduction. The remote operation of the 2520 is accomplished through an IEEE-488-1978 Interface. The IEEE-488 is a hardware standard which describes the communication and handshaking across the 8 bit parallel bus between a controller and up to 15 instruments. Refer to "IEEE Standard Digital Interface for Programmable Instrumentation", published by IEEE.

TABLE 3-2. GPIB CAPABILITIES

SH1	Source Handshake
AH1	Acceptor Handshake
T6	Basic Talker
L4	Basic Listener
RL1	Remote Local
SR1	Service Request (see par. **3-109**)
DC1	Device Clear (see par. **3-108**)
DT1	Device Trigger (see par. **3-110**)

The 2520 interfaces to the IEEE bus through a TI9914A bus interface IC and tristate buffers. No DMA operations are supported. The general capabilities of the 2520 are listed below. **Table 3-2** lists specific IEEE interface functions that are handled. Parallel Poll (PP) is not supported.

Features:

* Talk/Listen capability

* SRQ (Service Request)

* Serial Poll capability with masking

* All front panel operations supported on the bus, except power on/off.

* Talk Error mode

* Selectable output terminators

* Free format number handler

3-102. Local and Remote Operation. The Local mode is the front panel operation of the instrument. The local mode is the power on condition of the instrument and the remote condition becomes active only when the instrument is addressed by the controller. Once in the remote mode, there are three ways to return to local mode: 1) The controller issues a GTL command (go to local); 2) Power is removed from the instrument, and 3) The operator presses the Local key. This third method is disabled by issuing a local lockout command (LLO). In the remote mode, all key closures except the Local key are ignored. When in the remote mode, the message REM appears in the lower right corner of the display.

3-103. Setting the Bus Address. The bus address is set from the rear panel Bit switch, and is viewed on the display. The unit reads the Bit switch on power up only. See **Table 3-3.**

3-104. Terminating Characters. To inform the instrument that a complete message has been sent, the last character must be followed by a terminator. The termination can be done either by asserting the EOI line on the bus or by sending an in-line terminating character, or both. The terminating character is selectable from the rear panel Bit switch as CR, LF, or CRLF. When neither positions 2 or 3 are set to 1, EOI is used as a terminator. The Bit switch settings are determined by **Table 3-3.**

3-105. Listen Operation. The instrument may be addressed as a listener without regard for remote or local mode. When the listener state is set by the controller, the instrument will receive bytes over the bus and place them into it's input buffer and the LSN message will appear in the lower right corner of the display. Only one message can be put into the buffer at a time; a second cannot be sent until the instrument is done processing the previous message.

TABLE 3-3. REAR PANEL BIT SWITCH

Position	1	0
1	SRQ Enabled	SRQ Disabled
2	LF used as terminator	LF not used as terminator (can be used with position 3)
3	CR used as terminator	CR not used as terminator (can be used with position 2)
4	Bus address MSB	
5	Bus address	
6	Bus address	
7	Bus address	
8	Bus address LSB	

3-106. Talk Operation.

Only one instrument on the bus is allowed to talk at once, while many may be set up to listen. The instrument is set up to allow a talk message with a format as follows:

Example: -22.7,0,1,0
Format: SXY.Z,I,R,E

where S = Sign of current level (+ or -).

X, Y, Z represent the level in dBm.

I = Impedance compensation setting (50 ohms is 0 and 75 ohms is 1).

R = RF output enabled (1 = enabled).

E = an error number, see below.

3-107. Error Messages.

The error messages are "2", which is a function error such as an improper bus mnemonic, and "16", which is a number entry error such as a level that is out of range. A decimal 64 is added to these numbers with bit 6 of the serial poll byte, resulting in "66" and "80". Once polled, this bit is reset to zero.

3-108. Device Clear. The 2520 responds to the Device Clear (DC1) command by turning the output off and setting the level to -70 dBm. The impedance is set to 50 ohms. The IFC command (Interface Clear) performs essentially the same function.

3-109. Service Request and Serial Poll. The 2520 will output a service request (SRQ) when an error is encountered, if the Bit switch is set up to make SRQ active. The possible errors are listed in **Section 3-106, Talk Operation.**

Refer to the **Table 3-3**, Rear Panel Bit Switch, for setting up the SRQ mask bit. When the controller receives an SRQ, the 2520 may be polled serially to determine the source of the SRQ (which instrument). Bit 6 of the status byte indicates the SRQ condition.

3-110. Device Trigger. When the 2520 is triggered via this command, it will enable the output and go to the level that was previously set. It functions the same as the "ON" command. The GET command (Group Execute Trigger) will also perform this function.

3-111. Bus Commands. The bus commands specific to the 2520 are listed in **Table 3-4.**

TABLE 3-4. BUS COMMANDS.

Command	Function
xx.x DB	Sets the output level in dB where xx.x is the level. The number can be in any format such as -10.3E00, -10.3, -10, etc. The number is limited to -70 to +20 dBm. The output is not activated with this command.
Z0	Sets the output compensation for 50 ohms.
Z1	Sets the output compensation for 75 ohms.
OF	Turns output off. The level number that has been stored with the xx.x dB command is still retained.
ON	Turns the output on, to the level that was previously loaded with the xx.x DB command.
C0	Sets the Control output to logic zero. Used for amplifiers and other accessories.
C1	Sets the Control output to logic 1.
T0	Disables the trigger mode (the 2520 will not respond to a trigger).
T1	Enables the trigger mode. Reset when powered down.
B0	Blanks the display for security purposes.
B1	Enables the display. See B0.

SECTION 4
APPLICATIONS

4-1. GENERAL. This section contains information on typical uses for the 2520. It is assumed that the operator is familiar with the front panel operation of the instrument. Specific topics covered in this section are:

Power meter calibration, 4-2
Attenuator calibration, 4-3
Amplifier calibration, 4-4
Output impedance, 4-5
Calibration at the end of a cable, 4-6
Interpretation of uncertainties, 4-7

4-2. POWER METER CALIBRATION.

1. General. Power meter calibration is one of the primary uses of the 2520. It's accuracy is traceable to NBS power standards at 0 dBm and, through the use of NBS certified attenuators, at levels from +20 down to -70 dBm. Although it has a sensor element (diode) as part of it's leveling loop, the 2520 is more stable than a power meter since the internal leveling loop operates under a narrow range of power and at high levels. The attenuator stability is a function of precision resistors and only to a very slight degree the integrity of sealed precision relays. The 2520 therefore contains all the internal hardware needed for level calibration, replacing fixed 0 dBm sources or thermocouples at 0 dBm, attenuator banks, and number manipulating software to correct for non-integer valued attenuators.

2. Power Linearity. Power sensors for RF power meters, whether diode, thermocouple, or thermistor, have an efficiency associated with them that is roughly constant over their power range. However, for best accuracy, the linearity of the sensor should be calibrated out by calibrating at many levels, or, at least, the sensor should be calibrated at the power level(s) of most concern. The 2520 is ideal for this.

3. Frequency Flatness. All sensors exhibit a frequency ripple which must also be calibrated out. That is, above 1 or 2 GHz, the impedance and VSWR variation becomes significant, on the order of +/- 0.3 dB at a given frequency. The frequency variation is generally stable with level, and is usually calibrated at 0 dBm.

4. Choice of Calibration Frequency. Since the sensors are essentially flat at low (VHF) frequencies, almost any VHF frequency can be used to do the power linearity calibration. For example, the difference in efficiency at 10 MHz and 100 MHz is probably less than .02 dB for most sensors. 30 MHz was chosen for the 2520 because the primary attenuation standard, the piston attenuator, operates at this single frequency.

5. Technique. The procedure for sensor calibration is device dependent. The main consideration is that the sensor is calibrated at the 2520 output port with no cables. Even a 1 foot cable may upset the calibration if maximum accuracy is desired. If there is a need for a cable, it is possible to calibrate the 2520 for a known level at the cable end. See **Section 4-6.**

4-3. ATTENUATOR CALIBRATION.

1. General. The 2520 may be used to characterize attenuators or other lossy devices with the technique below. The accuracy of this method is not as good as a straight comparison with known certified attenuators or with piston attenuator techniques, since the measurements are quite a few steps removed from the piston attenuator that an individual 2520 is traced to. However, the 2520 is convenient for cases where accuracy to perhaps .08 db is sufficient. See **Section 4-7** for the derivation of uncertainties and how this relates to the measurements.

2. Technique. Refer to **Figure 4-1** for the setup. The power meter is used for the comparison of two measurements only, which are very close to each other (within 0.1 dB), and therefor need not be calibrated at all. The only requirement of the meter is that it is linear over that 0.1 db, and that it has adequate resolution.

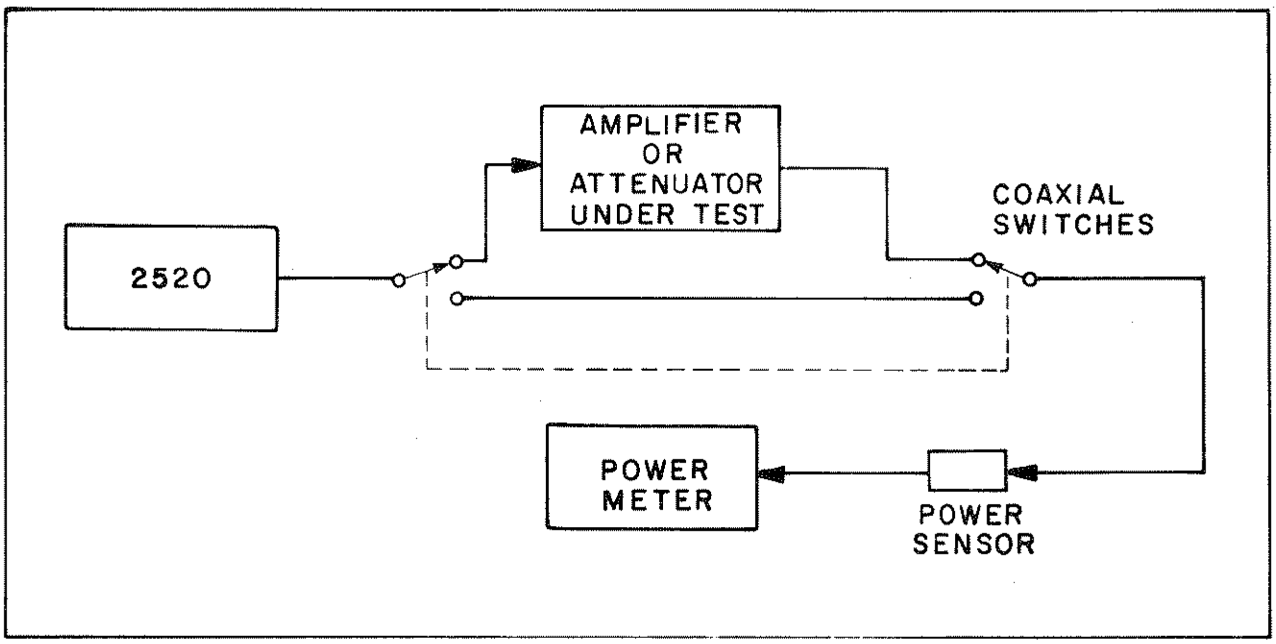


Figure 4-1. Attenuator and Amplifier Calibration

The technique is basically comparing the attenuators in the 2520 to the device under test (DUT). First, the DUT is switched in and the 2520 is set to a level that allows a stable reading on the power meter. A starting level of 0 dBm will result in the most accurate measurement since fewer attenuators are used in the entire measurement. A power reading is taken and the DUT is switched out. The 2520 is then adjusted so that the power meter reads the same as it did before. The attenuation of the DUT is the difference in the two settings of the 2520, with a correction for the change in power meter reading. For example, if the power meter changed from -30.05 to -30.01 when the DUT was removed, the attenuation is .04 dB less than the difference between the two 2520 readings.

4-4. AMPLIFIER CALIBRATION. Amplifiers that operate at 30 MHz can be tested for gain and compression point by connecting them as shown in **Figure 4-1**. The technique is similar to calibrating attenuators as shown in the previous section. That is, the amplifier gain is equal to the difference in 2520 settings, plus the correction factor as shown in the Attenuator Calibration example above, where the two settings are for the "DUT in" case and the "DUT out" case. As for the attenuator case above, the power meter is used for comparison of two measurements only and does not enter into the calculation.

4-5. OUTPUT IMPEDANCE. The output impedance is always 50 ohms, but it can be connected to 75 ohm systems with the Boonton adapter P/N 950006. The mismatch loss is the difference in power that would be absorbed in a 50 ohm load and that of the 75 ohm load, which is 0.960 or 0.177 dB.

4-6. CALIBRATION AT THE END OF A CABLE. If it is desired to have the calibrated port of the 2520 at another location than the instrument, a cable may be attached. This will reduce the accuracy unless the instrument is recalibrated with the cable.

The best way to calibrate with the cable is with a 3 to 10 dB attenuator at the far end of the cable (away from the instrument), at the test port. This will significantly reduce the effects of cable deficiencies (non ideal VSWR). The adjustment range of the 2520 is about +/- 1 dB so that the nonexact attenuation can be calibrated out. In operation the 2520 would then have to be set for a level higher than that desired by the nominal attenuation value. At the time of calibration or operation, the exact attenuation need not be known, because the whole link now becomes calibrated as a system.

4-7. INTERPRETATION OF UNCERTAINTIES.

1. General. The 2520 is traceable to NBS as described below. Subtleties of these methods, when understood, can result in a change in how the 2520 is used for maximum accuracy.

The 2520 is calibrated at the factory using a reference 2520, comparing the output level of the unit under calibration to the reference with a high resolution power meter. The reference 2520 is calibrated using 1) a 0 dBm thermal converter that has been sent to NBS for calibration (the EPM-1), and 2) fixed precision attenuators that have been sent to NBS for certification.

2. Ten dB Steps. The 0 dBm level is the reference for all other levels. For example, to calibrate at -40 dBm, a certified 40 dB attenuator is inserted in the path with the 2520 set to 0 dBm. The level is compared to the level measured using the 2520 internal attenuator (removing the certified attenuator and setting the 2520 to -40 dBm). An adjustment is made to the 2520 so that the readings match (actually, compensation has to be made for the fact that the certified attenuator is never exactly 40 dB).

3. One dB Steps. The 1 dB steps are also calibrated on each 2520 by comparison to the reference 2520. The reference 2520 is calibrated at -9 dB relative to full scale on the -20 dBm range. The 9 dB drop of the 2520 is compared to the drop with a certified attenuator and an adjustment is made. The setting of full scale and downscale (-20 and -29) fix the "in between" points since the linearity of these steps is extremely good (the individual 1 dB steps are generated in a 14 Bit DAC). However, these points are checked with certified attenuators also.

4. Linearity Uncertainties. The linearity uncertainties are listed below:

a. Linearity Uncertainty of 0.1 dB steps: +/- .015 dB max from 0 to -9.9 dB relative to full scale on any given range*, down to -59.9 dBm. From -60 to -65 dBm add .06 db and from -65 to -70 dBm add 0.2 dB.

* The full scale levels are +20, +10, 0, -10, -20, -30, -40, and -50 dBm . Levels below -50 dBm are generated using the 0.1 dB steps, downscale from -50 dBm. The .015 dB includes mismatch uncertainty of the 9 dB attenuator used to calibrate the -9 dBFS (dB Full Scale) point.

b. Linearity Uncertainty of 10 dB steps: +/- .004 dB per 10 dB.

This is the cumulative error resulting from the primary standard, the piston attenuator. The number is based on the certification of fixed pads from NBS. Actually, NBS specs .003 dB per 10 dB. The transfer error (errors introduced by the transfer of one standard to another) is not included in this number since that uncertainty is not a "dB per dB" type of spec, but rather a fixed error, which is included in item **c**.

c. Fixed Uncertainty: +/- .009 db. This is not a linearity spec per se, but is to be added to the uncertainty at any level other than 0 dBm. This term is due to 1) the mismatch error when the attenuators are inserted into the path (.004 dB), and 2) the resolution error of the comparison measurements (.005 dB). This uncertainty on each 10 dB step is independent from the others since each range is calibrated using 0 dBm as a reference. For example, -10 and -20 dBm may have fixed errors in opposite directions relative to their ideal values, of .006 dB each for a total of .012 dB.

Item **c** must be considered when

calculating the error between points such as -19 and -20 dBm. That is, although it is only a 1 dB step, these points are on different ranges. In this case the nonlinearity error has to be calculated by adding all the uncertainties as noted in **Table 4-1.** (This does not include the uncertainty at 0 dBm). The nonlinearity at -19 dBm due to the 10 dB step is .004 because the 2520 is on the -10 dBm range.

TABLE 4-1. LINEARITY UNCERTAINTY EXAMPLE

The linearity uncertainty at -19 due to 1 dB steps:	.015
The linearity uncertainty at -19 due to 10 dB steps:	.004
The linearity uncertainty at -20 due to 10 dB steps:	.008
The fixed uncertainty at -19:	.009
The fixed uncertainty at -20:	.009
Total :	.045 dB

Note that these are worst case uncertainties and that there are many terms; the RSS uncertainties would be considerably lower.

SECTION 5
THEORY

5-1. INTRODUCTION. This section contains circuit descriptions and software functions, and block diagrams for the 2520. Refer to the overall block diagram, **Figure 5-1,** which is described below.

5-2. BLOCK DIAGRAM DESCRIPTION. A fixed frequency 30 MHz oscillator feeds a gain controlled amplifier and switchable 10, 20, and 40 dB attenuators. The amplifier gain is controlled by comparing the detected output of the amplifier to the control voltage, which is generated from a Digital to Analog Converter (DAC).

The DAC is fed calibrated level information from the microprocessor, a Z80, which is supported with RAM, program ROM, and nonvolatile Electrically Erasable PROM (EEPROM). This EEPROM stores the calibration data for each of the attenuators and also the Generator assembly.

The calibration data is generated using a NBS traceable standards, using 0 dBm as a starting reference and using the 30 MHz piston attenuator at NBS for other levels. Attenuation is a traceable standard.

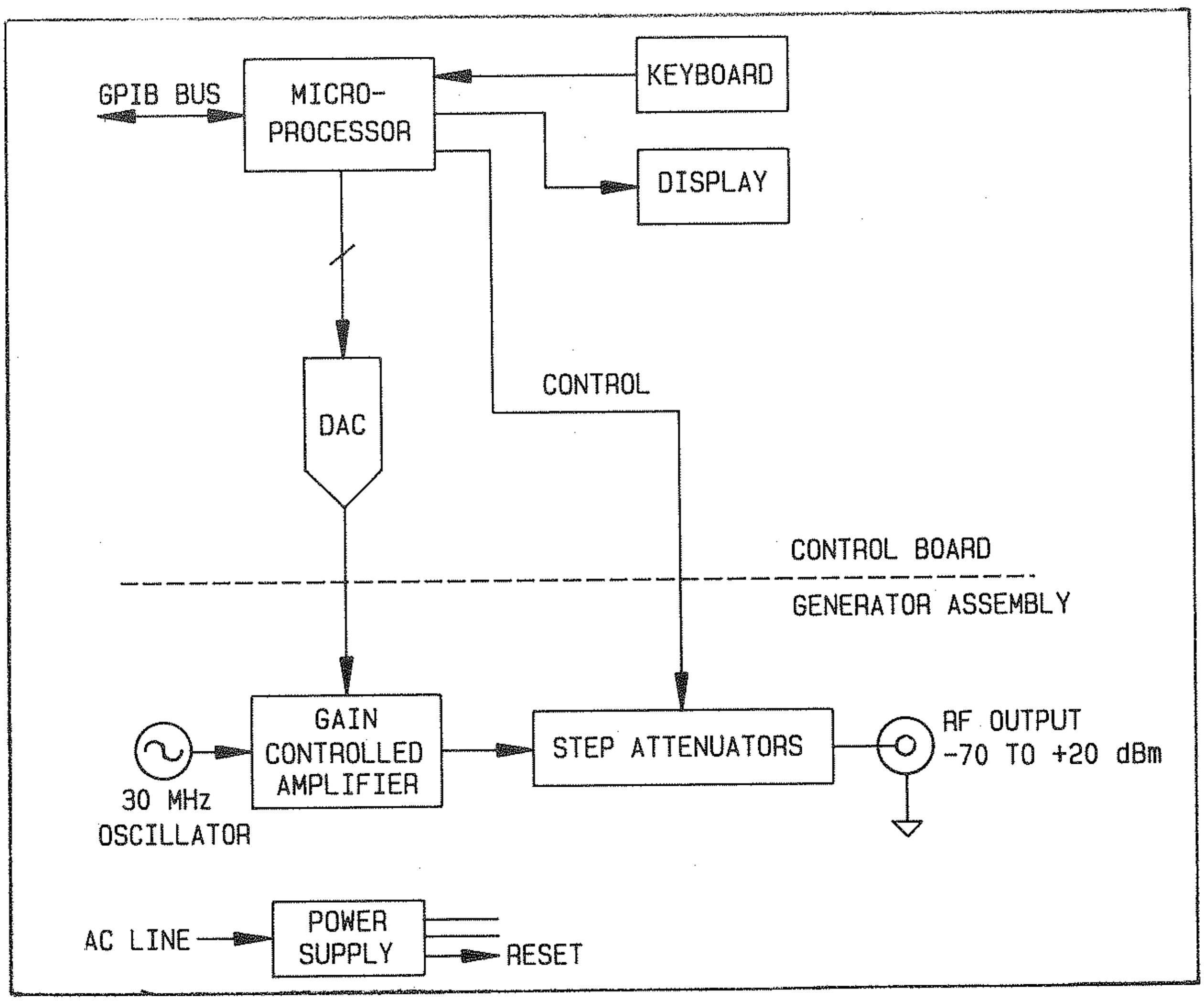
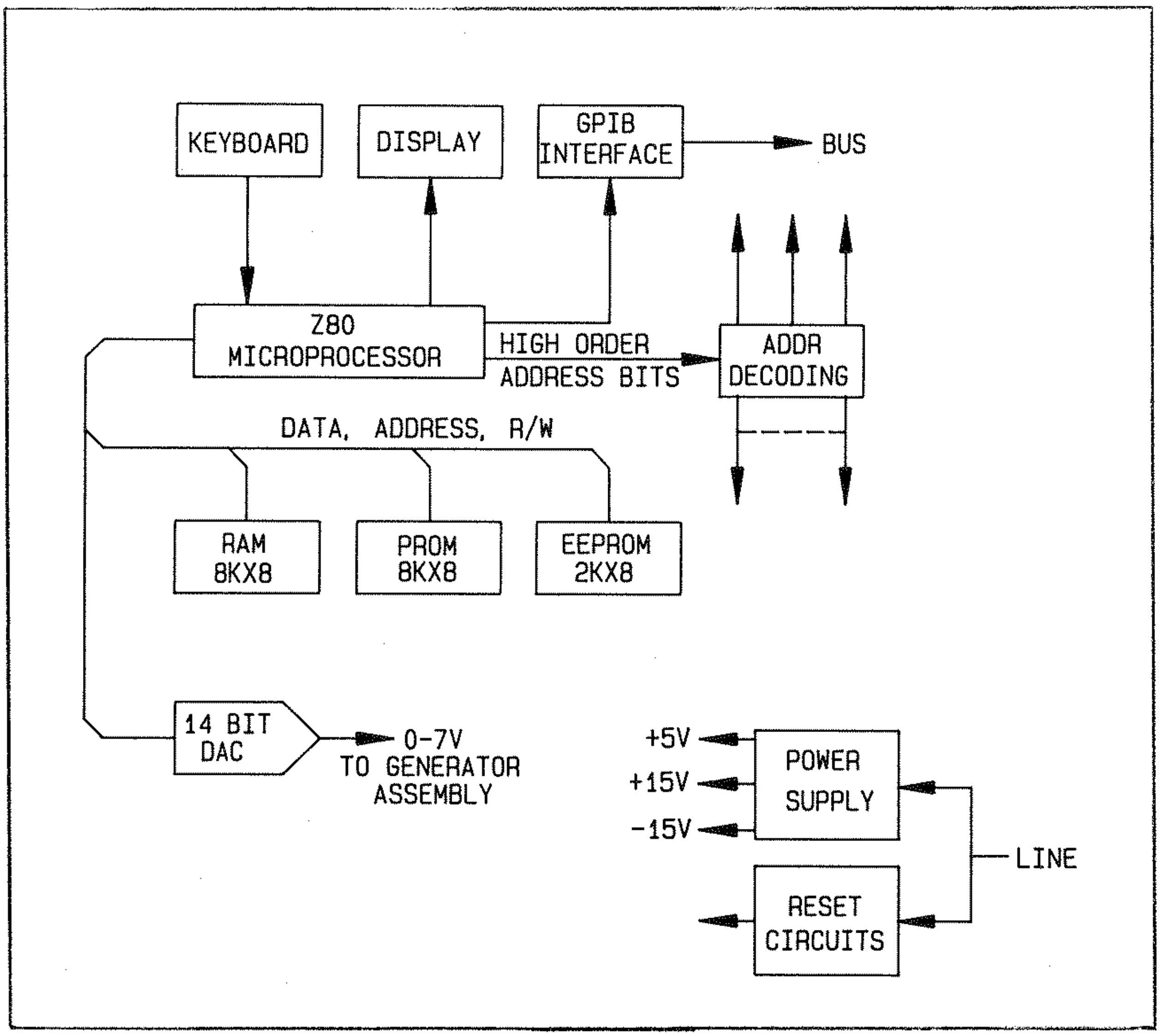


Figure 5-1. Overall Block Diagram

The GPIB bus is controlled with a dedicated I/C. The display is sent ASCII information and control bytes from the microprocessor. The keyboard is a simple hardware scan.

5-3. CONTROL BOARD DESCRIPTION.

1. General. Refer to the Control board schematic in Section 7 and to the Control board block diagram, **Figure 5-2.** Microprocessor U4 operates on stored instructions from PROM U6. All three of the memories U6, U9, and U10 operate on the common data, address, and control bus. The control bus consists of the read and write lines, and the chip selects. The data bus is bidirectional,



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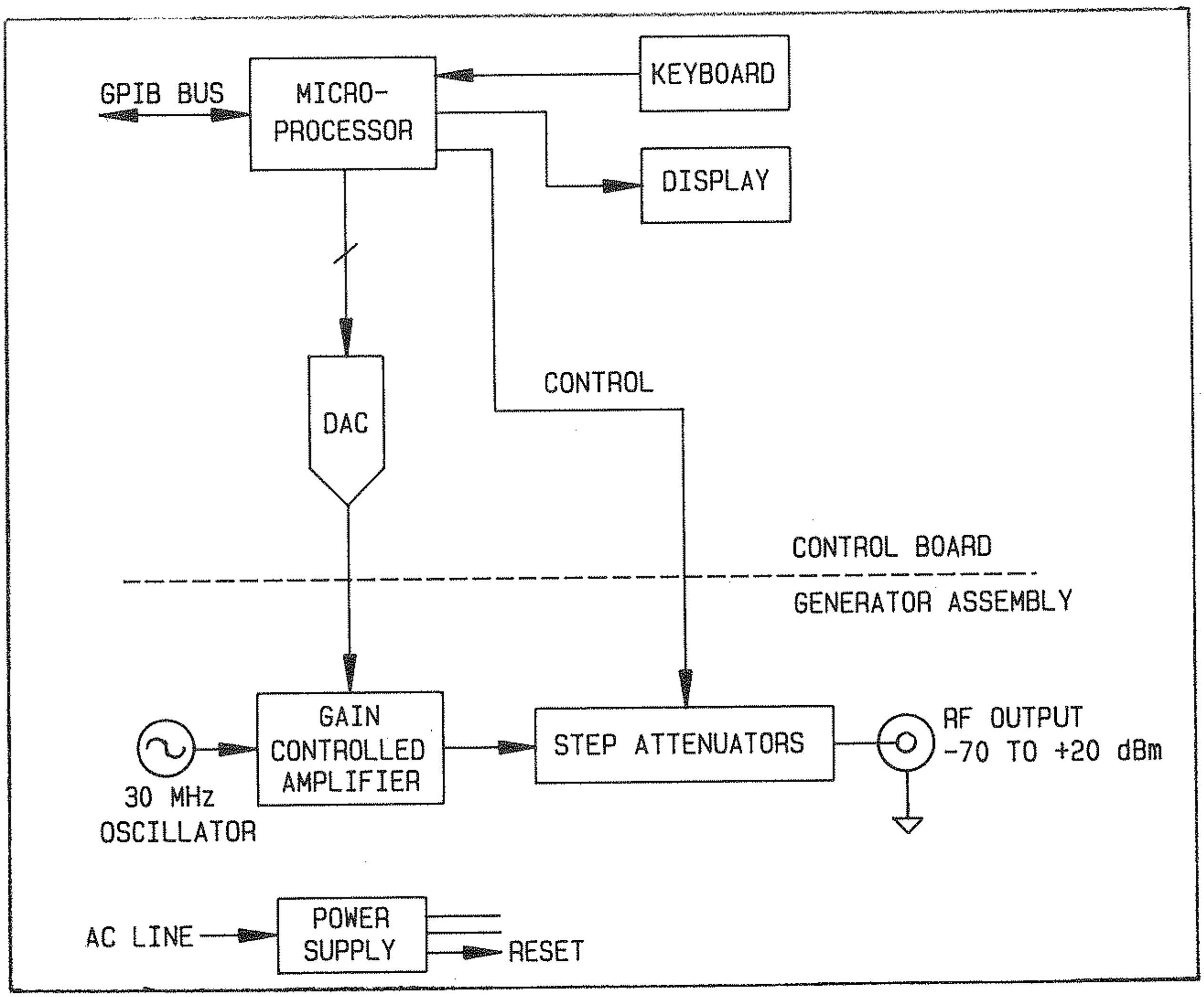

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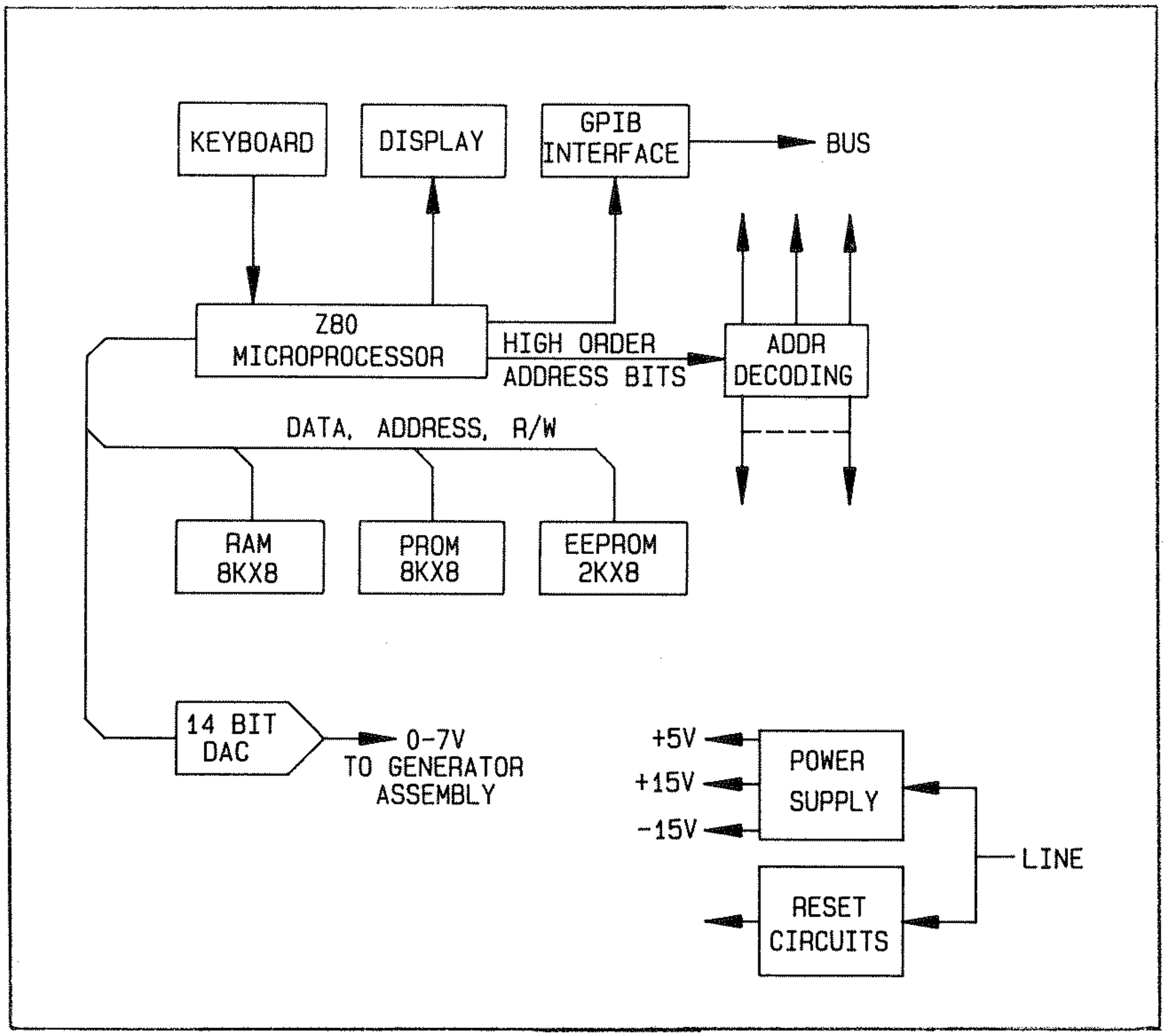

Figure 5-2. Control Board Block Diagram

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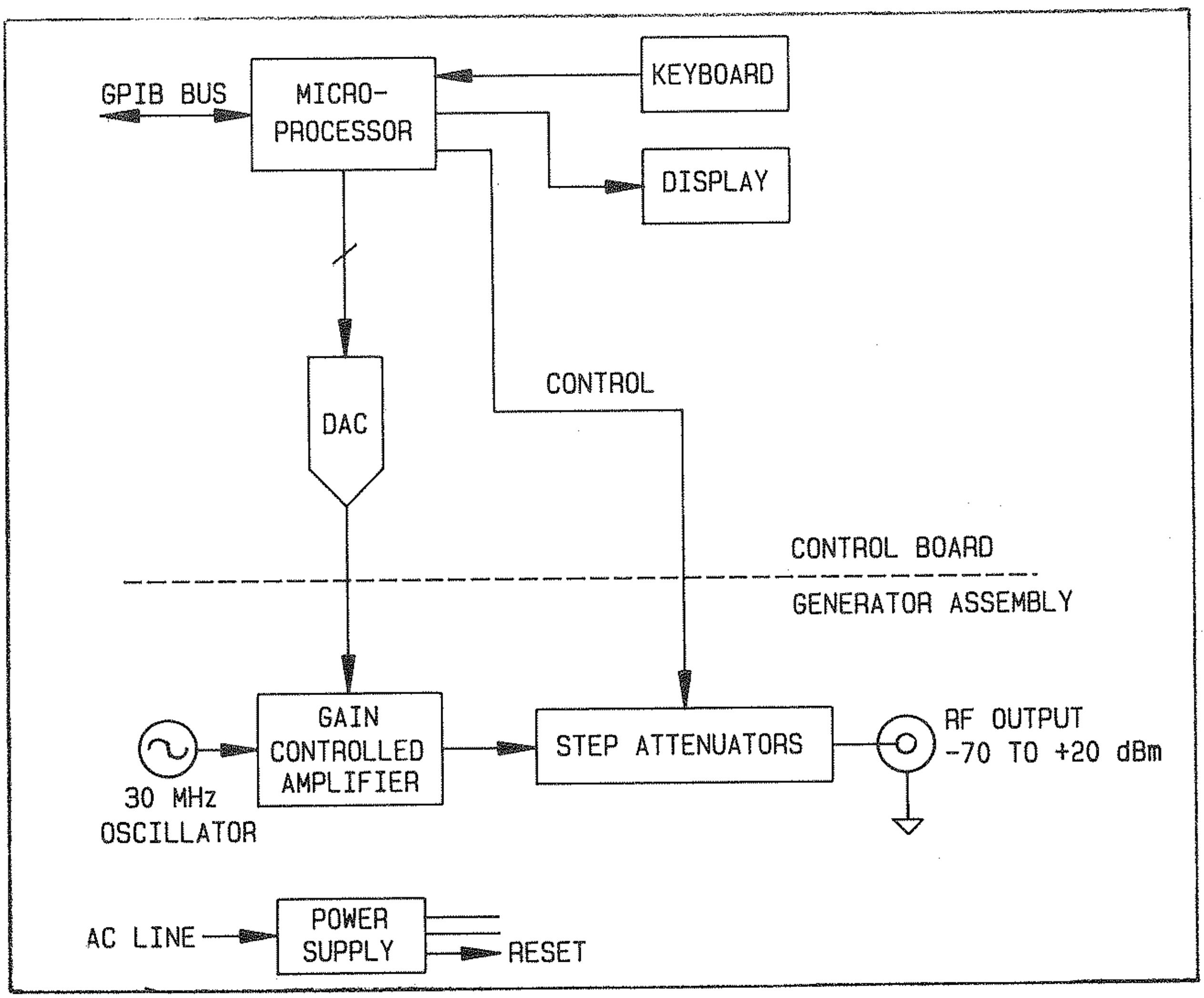

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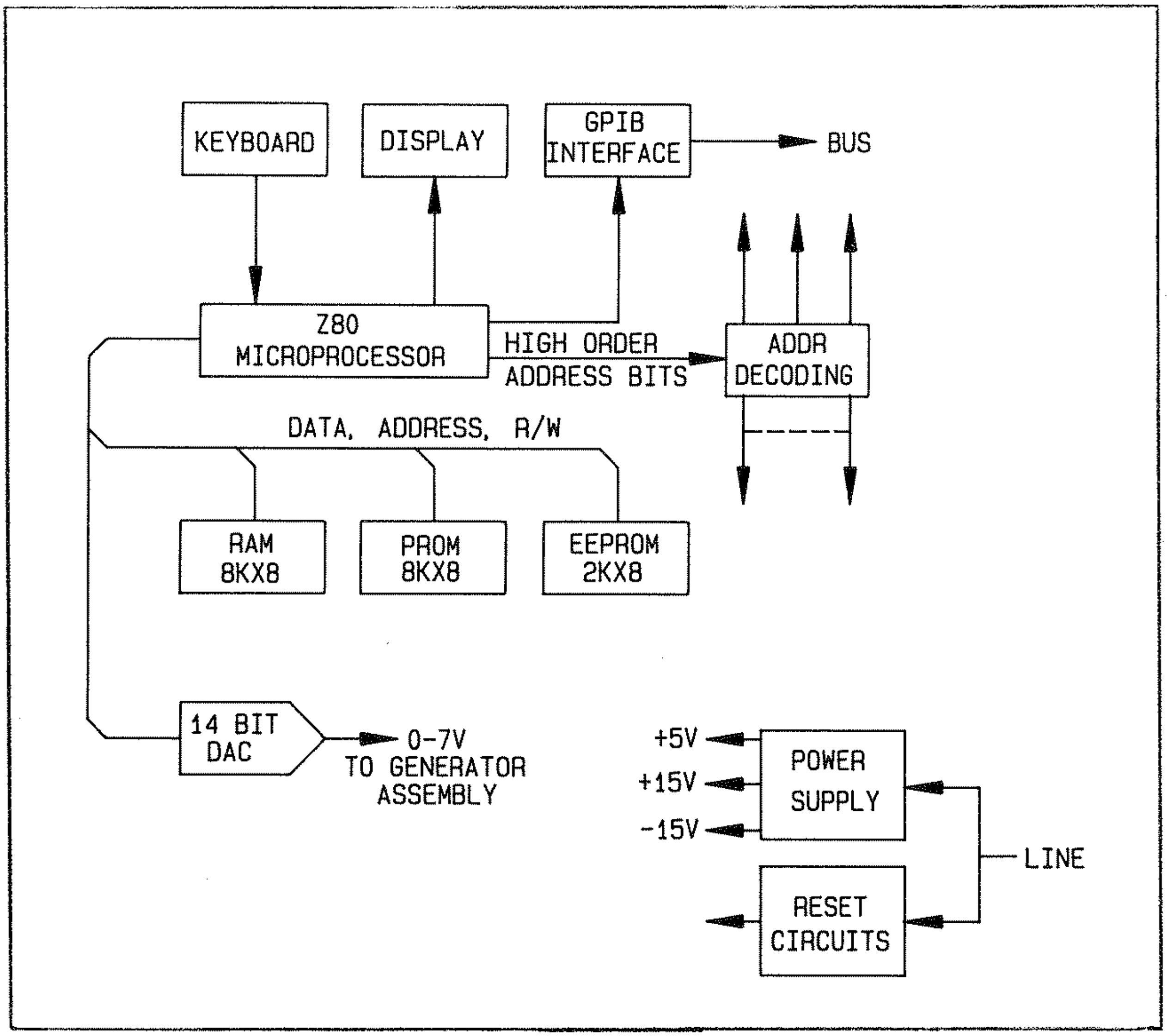

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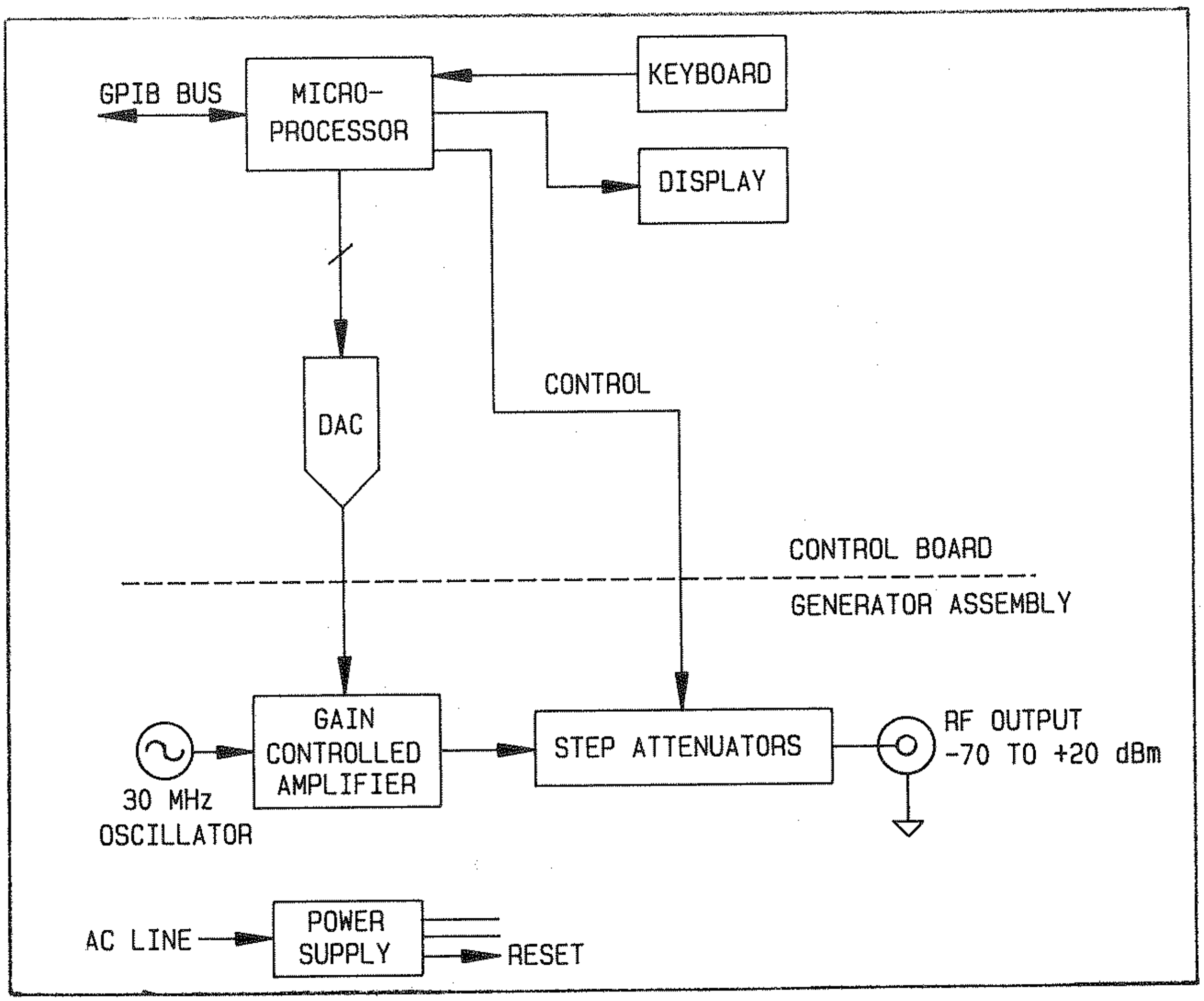

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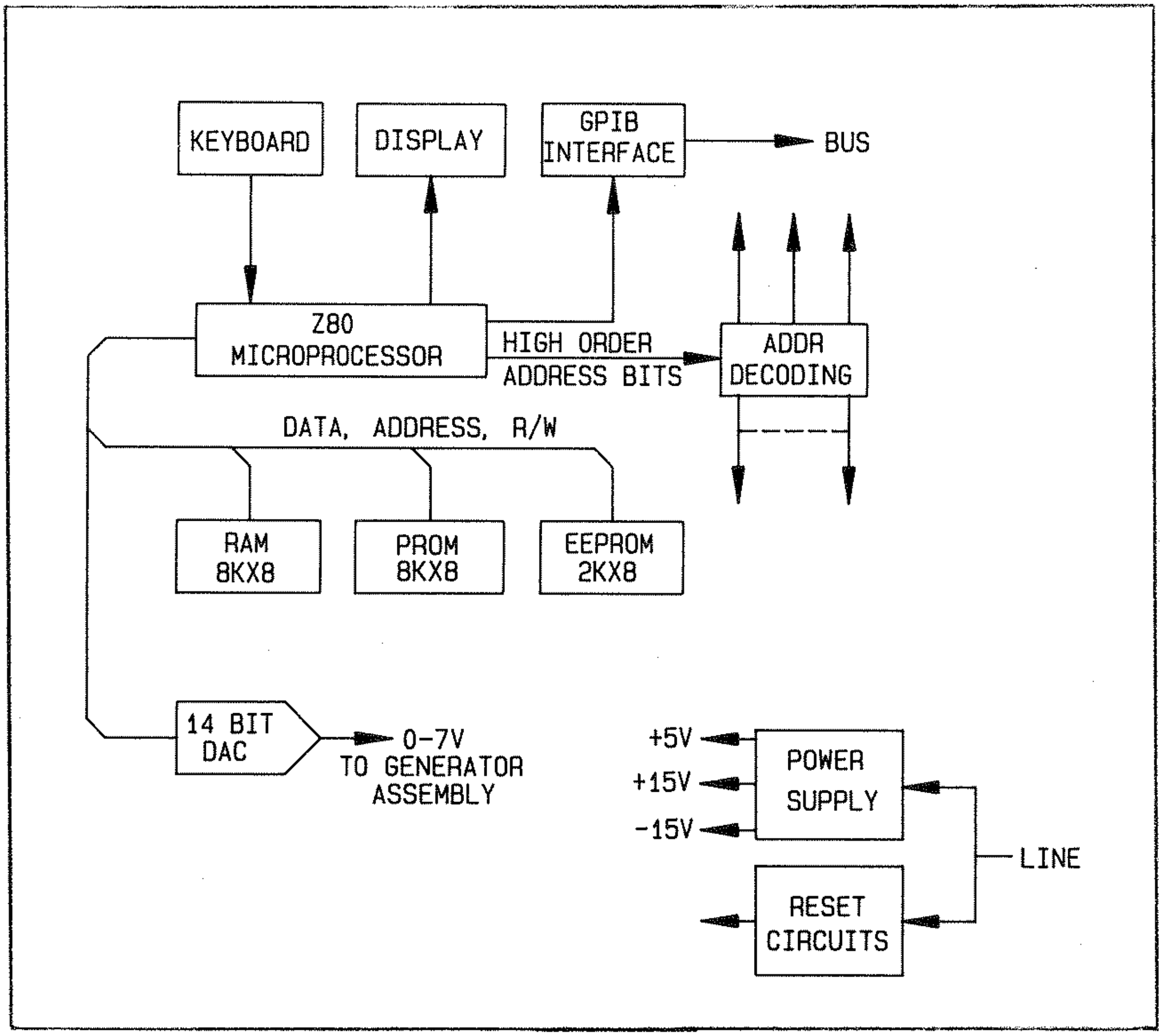


Figure 5-2. Control Board Block Diagram

and all "talk" devices are tri-stated (open) unless addressed to output data, so that only one device talks at a time. The Z80 controls the address and control lines at all times.

2. RAM and EEPROM. The RAM U9 is used for temporary storage of variables and program data. This data is not retained on power down; the instrument always starts at -70 dBm, etc.

Calibration data consisting of gain constants are stored at the time of calibration in the EEPROM U10. Even though U10 is electrically erasable and can be written to any time, it is used only for calibration and not normal program execution since writing to this device takes many milliseconds per byte.

3. Decoding. Address bits A13 and A14 break the address map into four major sections, RAM, PROM, EEPROM, and miscellaneous. The miscellaneous section is further segregated by A10, A11, and A12 into 1K blocks (400 hex) which select the display, the DAC, etc. as shown in **Table 5-1.** Most of these 1K blocks is wasted, only one or two bytes per block being used, for simplicity of decoding. For devices such as the DAC, which have two address locations, the LSB's of the address do the final decoding to one exact address in the device itself, although intensive decoding is not used (that is, not all of the 14 address bits are used to select a given device).

4. Keyboard Circuits. The keys are scanned by the Z80 with U28. When the nonlatching buffer U28 is active (closed), the status of each key switch is put on the data bus.

Table 5-1. Memory Map.

Address (Hex)	Function
0000-1FFF	PROM
2000-BFFF	RAM
4000-5FFF	EEPROM
6000-63FF	KEYBOARD
6400	REAR SWITCH
6800	INTERNAL SW
6C00	LATCH 1
7000	LATCH 2
7400	GPIB
7801	DAC LSB
7802	DAC MSB
7803	DAC CONTROL
7C00	DISPLAY CNTL
7C01	DISPLAY DATA

5. Display. The display is sent characters in ASCII in a similar way to a data terminal. The Z80 sends control characters at power up to set the display up for certain modes such a non-blinking cursor, shifting or nonshifting mode, etc. The Nand and And gates that precede the display convert the Read and Write lines to a single "Read/Write" line and delay the enable line so that the data is settled before the display latches it.

Also supplied to the display is a control voltage that controls the vertical viewing angle and the contrast. The display is a self contained non-repairable unit.

6. GPIB Circuits. The General Purpose Interface Bus is controlled by U15 which handles most of the protocol between the bus and the Z80. It serves as a one character buffer. When a character is received on the bus, U15 interrupts the Z80 and the Z80 fetches it. The hardware lines such as SRQ, IFC, and ATN are all handled by U15. U16 and U17 are buffers.

7. Power On Reset Circuits. The requirement for the reset signal is that it comes up some time after the power supply has stabilized, and that in the event of a short power glitch, it goes low immediately, before the +5V begins to droop, and stays low for a short period after the glitch has gone away. These aspects of the reset line assure that the microprocessor is operating only when the +5V is fully stabilized.

Comparator U24B monitors the unregulated +5V, which is about +8V with ripple. When this line drops to about 8V, the regulator U22 can no longer guarantee 5V at it's output, and at this point U24B drops low. U25 is an open collector output which discharges C23 rapidly through 100 ohms. U24A and U25E then go low. The microprocessor takes a few microseconds to complete it's current operation, while the electrolytic capacitors are decaying. On power up, C23 has to charge through 47.5 K ohms, providing a time delay of about one half of a second.

8. Miscellaneous Latches. U2, U3, and U8 read the Bit switches and control the attenuator switches. U2 and U3 are actually not latches but tristated buffers. The attenuator control lines going to the Generator assembly follow the level as shown in **Table 5-2.**

9. DAC. The Digital to Analog Converter U19 is fed data in two bytes for a total of 14 bits. See the manufactures' data sheet for specific requirements on the sequence of data and control bytes. U23 provides the voltage output to the Generator assembly. The voltage at the top of any given range (+20, +10, etc.) is about 6.5 VDC, dependent on the specific unit (this is set in the calibration routine), and at other levels drops by the factor in **Table 5-3.** For example, if the full scale voltage at -30 dBm is 6.654 VDC, then at -34 it is 6.654 x 0.6310 = 4.199 V. This voltage is held quite accurately by the 14 Bit DAC.

TABLE 5-2. ATTENUATOR LINE CONTROL

Level	10dB	20dB	40dB
+20	HI	HI	HI
+10	LO	HI	HI
0	HI	LO	HI
-10	LO	LO	HI
-20	HI	HI	LO
-30	LO	HI	LO
-40	HI	LO	LO
-50	LO	LO	LO
-60	LO	LO	LO
-70	LO	LO	LO

TABLE 5-3. CONTROL VOLTAGE

-dB Step	Ideal Voltage Ratio
0 dB	1.000
-1	0.8913
-2	0.7943
-3	0.7079
-4	0.6310
-5	0.5623
-6	0.5012
-7	0.4467
-8	0.3981
-9	0.3548

5-4. GENERATOR ASSEMBLY.

1. General. Refer to the Oscillator board schematic in Section 7 and to the Generator block diagram, **Figure 5-3.**

2. Oscillator and Amplifier Circuits. Transistor Q1, crystal Y1, and the associated components form an oscillator, which is buffered by Q4. The oscillator is powered through Q2, whose base is pulled low when turned on, supplying about 14.5 V to the oscillator.

Transistor Q5 operates in Class C mode, driven at all times with about 0 dBm, not dependent on the output level. The power output of this stage is dependent on the supply voltage via Q3 and the control loop. Q5 feeds a series tank and a low pass filter. The four 200 ohm resistors parallel to make 50 ohms, which is the output impedance to the attenuators that follow. (The impedance at the input to these resistors is very near zero ohms since the detector and control loop adjust for a specific level at that point).

3. Control Loop. During calibration, compensation data peculiar to a specific set of attenuators is stored on the Control board. One constant is stored for each 10 dB full scale step (from -50 dBm to +20 dBm). The steps from 0 to -9.9 dB relative to full scale on a given 10 dB range, and to -20

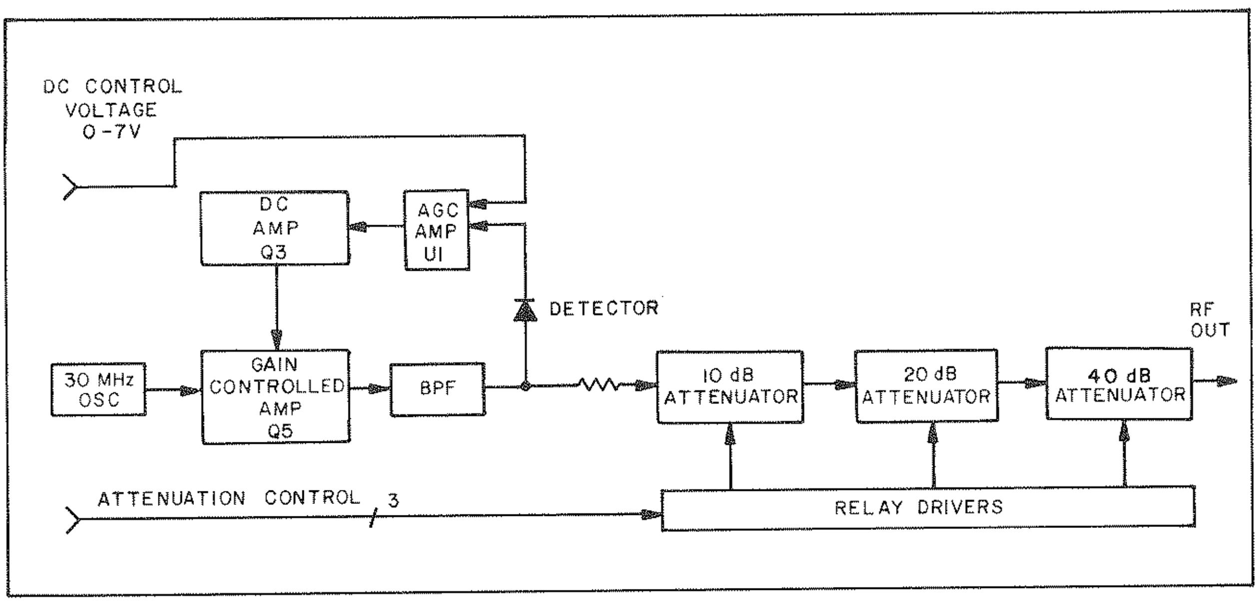


Figure 5-3. Generator Block Diagram

dB relative to full scale on the -50 dBm range, are calculated and are fixed in the firmware. The the overall control loop and oscillator combination is linear to .01 dB over 9.9 dB.

During operation, the calibration data and the 0.1 dB step data is used to generate the DAC voltage, from 0 to about 6.6 V. This is temperature compensated with RT1 and applied to the integrator as a setpoint. The 30 MHz signal is detected by CR3 and applied to pin 2 of AR1. The detected voltage is compared to the DAC voltage in the integrator. Unequal loading resistors on the AC detector diode and the DC compensation diode compensate for the slight inefficiency of the AC detector (rather than a straight peak detect, it tends to have an output component that is a result of the diode integrating over the 30 MHz cycle). The downscale adjustment pot R11 compensates for the change in efficiency that occurs at -9 dB relative to full scale output. Finally, the integrator controls the Vcc supply to Q5, which feeds the attenuators.

4. Attenuators. The attenuators are sealed relays operating in conjunction with 0.1 % resistors. The exact attenuation is measured at the time of calibration and is compensated for in the software. The 3.01 K ohm resistors compensate for the 0.1 ohm series resistance of the relays. The relays are burned in and cycled at the factory to "wear in" the contacts, maximizing the surface area. Q6, Q7, and Q8 turn on when pulled low, activating the relays.

50 ohm PC board transmission line and extensive shielding provide an accurate 50 ohm output and good VSWR.

SECTION 6
MAINTENANCE

6-1. INTRODUCTION. This section contains the following items related to maintenance: safety requirements, test equipment, cleaning procedures, inspection procedures, removal and replacement of module procedures, and also three major subsections:

6-100. PERFORMANCE VERIFICATION
6-200. ADJUSTMENTS (CALIBRATION)
6-300. TROUBLESHOOTING

6-2. SAFETY REQUIREMENTS. Although this instrument has been designed in accordance with international safety standards, general safety precautions must be observed during all phases of operation, service, and repair of the instrument. Failure to comply with the precautions listed in the Safety Summary located at the beginning of this manual or with the specific warnings given throughout this manual could result in serious injury or death. Service and adjustments should be performed only by qualified service personnel.

6-3. TEST EQUIPMENT. The test equipment required for the performance tests, adjustments, and troubleshooting is listed in **Table 6-1.** Some of the equipment is listed as optional because there are two methods of calibrating the unit. See the text for the requirements.

TABLE 6-1. MAINTENANCE TEST EQUIPMENT

Equipment	Pertinent Specifications	Suggested Model
Level Generator (optional, see text)	30 MHz, -70 to +20 dBm	Boonton 2520, or HP3335A, or HP3336A/B/C
Milliwatt Test Set (optional, see text)	+/- 0.015 dB at 0 dBm	Wandel Goltermann EPM-1 with TK-10 sensor (HP432A with HP 478A-H75 sensor may also be used; see text)
Counter	50 MHz	Ballantine 5500B
RF Power Meter	-70 to +20 dBm; resolution .01 dB; 30 MHz	Boonton 4300 with 4G (51051) and 6E (51015) sensors

continued on next page

TABLE 6-1 Continued

Equipment	Pertinent Specifications	Suggested Model
Oscilloscope	Bandwidth 100 MHz, 5 mV per division	HP1740A or Tek 475A; with 10X probe
50 Ohm Termination	50 +/-1 Ohm, 1 Watt	Weinschel M1404N
DC Voltmeter	.05% basic accuracy	Fluke 8840A
Attenuators: 1, 3, 5, 9 dB, +/- 0.3 dB; 10, 20 dB, +/- 0.5 dB; 30, 40, 50 dB, +/- 0.75 dB (optional, see text)	Type N connector, 50 ohm	Weinschel Model 1
Calculator	Scientific key for log function	HP # 21
Coaxial Switch (optional, see text)	N type connectors	HP 8761B
90 Degree Adapters (optional, see text)	Type N, male to female	Pomona 3843
Variac	+/- 30% of nominal line voltage	
30 MHz Amplifier (optional, see text)	1 dB compression point at 0 dBm or higher. Gain 20 to 30 dB.	See text

6-4. CLEANING PROCEDURE.
Painted surfaces can be cleaned with a commercial spray type window cleaner or with a mild soap and water solution. Or, use isopropyl alcohol or kelite reduced by water 20:1.

CAUTION

Avoid the use of chemical cleaning agents which might damage the plastics used in the instrument.

6-5. REMOVAL AND REPLACEMENT OF BOARDS AND ASSEMBLIES.

1. Instrument Covers. Disconnect the power cord and all cables. Remove the screws on the top and bottom of the instrument at the rear. Slide the cover(s) off toward the rear of the unit.

2. Control Board. With the top cover removed, remove the ribbon cables that go to the display and keyboard, and remove the multiwire connector that goes to the Generator assembly. Remove the two connectors at the front of the unit that go to the inverter assembly and to the pilot LED. Also remove the five pin connector that comes from the transformer, and the 24 pin GPIB cable.

Remove the right side panel and the two screws that hold the heat sink assembly to the side frame. Remove the rest of the screws that secure the Control board, and remove the board.

3. Keyboard. Remove the bottom cover. Turn the unit upside down and remove the bottom trim strip at the front of the unit. Tilt the lower section of the front panel away and remove the keyboard (the ribbon cable can remain attached). Remove the screws that secure the keyboard and remove the ribbon cable that goes to the Control board.

4. Generator Assembly. Remove the top and bottom covers, and unplug the multiconductor cable that goes from the Control board to the Generator. Turn the unit upside down and remove the bottom trim strip at the front of the unit. Tilt the lower section of the front panel away and remove the keyboard (the ribbon cable can remain attached). Remove the screw(s) that hold the Generator to the subpanel, and the screws that secure the main body of the Generator to the frame. Remove the Generator.

NOTE

The generator can be troubleshooted out of the frame while it is still connected with the ribbon cable. However, calibration should be done in the frame with the screws in place.

5. Display. Remove the top cover and the trim strip at the front of the unit. Tilt the upper section of the front panel away and unplug the ribbon cable at either end. Unsolder the two wires at the right of the display. (If desired, the inverter can be removed also with the display; this will eliminate the need to unsolder. To do this, remove the 2 screws that secure the inverter and unplug it from the Control board. Remove the screws that secure the display and remove it.

6-6. INSPECTION. If an equipment malfunction occurs, perform a visual inspection of the 2520. Inspect for signs of damage caused by excessive shock, vibration, or overheating, such as broken wires, loose hardware, loose electrical connections, electrical shorts, or accumulations of dirt and foreign matter. Correct any problems discovered, and do the Performance Verification tests in Section 6-100. If a malfunction persists or the instrument fails any of the performance tests, refer to the Adjustments Section, 6-200. If the instrument cannot be adjusted, refer to the Troubleshooting Section, 6-300.

SECTION 6-100
PERFORMANCE TESTS

6-101. INTRODUCTION. There are two methods for verifying the 2520 depending on what equipment is available. The first method uses a reference 30 MHz Level Generator which can be another 2520, or an HP 3335A or HP 3336A/B/C. With this method, the 2520 under test is compared against the reference.

The second method uses a 0 dBm test set, the EPM-1, to verify the level at 0 dBm and uses fixed attenuators to verify other levels. This method is more involved but yields better accuracy.

The uncertainty of the 2520 is calculated, and cannot be measured to within specs, since it is calibrated to as close as degree as possible. If the remaining uncertainties after calibration were measurable, they could be canceled out. Therefore, the performance tests do not actually test to specification, but the tests below can be used for incoming inspection if desired.

6-102. PERFORMANCE VERIFICATION, METHOD 1.

1. Setup. Refer to **Table 6-1**, Test Equipment Required, for a description of the test equipment used in this test. Refer to the Operation section as required. Power up the equipment and let it warm up for 5 or 10 minutes. Connect the 2520 and the 30 MHz Reference to the input of a coaxial RF switch, as shown in **Figure 6-101**, and connect the output of the switch to a high sensitivity power sensor (to -70 dBm). Do not use cables, but instead use four rigid 90 degree type N adapters such as Pomona 3843. Then connect the sensor output to an RF power meter. Put the power meter in watts mode for best resolution. In the steps below, convert the reading in milliwatts to dBm with :

dBm = 10 log P

where P is in milliwatts.

2. Range Checks. Power up the 2520 and set the reference and the 2520 to the levels shown in **Table 6-101.** Use the high sensitivity sensor (-70 dBm) for readings below 0 dBm and the high range sensor (+20 dBm or greater) for 0 dBm and above. Zero the power meter often when making the low level measurements, with the sensor having settled for 10 seconds first.

NOTE

For readings at and below -45 dBm, a 30 MHz amplifier of about 20 to 30 dB gain may be inserted in series with the sensor for greater accuracy. The gain is not important since the sensor is used only for comparison of two measurements, however, short term stability (minute to minute) is important.

The tolerances in the table are the 2520 specifications plus the noise for a typical high sensitivity sensor such as the Boonton 4G (51051) when used with a ten second filter. Also added in is .01 dB for resolution error. The accuracy of the reference used for this test is not included in the table and must be added in.

Compare readings of the reference to the 2520 by switching the coaxial switch back and forth. The readings should match within the tolerance shown in the table, plus the reference generator accuracy.

Disconnect the coaxial switch and connect the RF output of the 2520 to an oscilloscope. A termination is not necessary for this test. Vary the output from -10 dBm to +10 dBm in 0.1 dB steps and verify that the voltage varies smoothly and continuously with no dropouts. This completes the performance verification, method 1.

TABLE 6-101. VERIFICATION OF LEVELS, METHOD 1

Level	Tolerance Without Amplifier *1	Tolerance Using Amplifier *1
-70 dBm	--	+/- 0.32 dB
-65	+/- 0.70 dB	0.27
-60	0.31	0.18
-55	0.16	0.12
-50	0.14	0.12
-45	0.13	0.12
-40	0.12	0.12
-35	0.09	0.09
-30	0.09	0.09
-29	0.09	0.09
-28	0.09	0.09
-27	0.09	0.09
-26	0.09	0.09
-25	0.09	0.09
-24	0.09	0.09
-23	0.09	0.09
-22	0.09	0.09
-21	0.09	0.09
-20	0.09	0.09
-15	0.09	0.09
-10	0.09	0.09
-5	0.09	0.09
0	0.07	0.07
5	0.09	0.09
10	0.09	0.09
15	0.09	0.09
20	0.09	0.09

*1. The tolerance of the reference source must be added to this table.

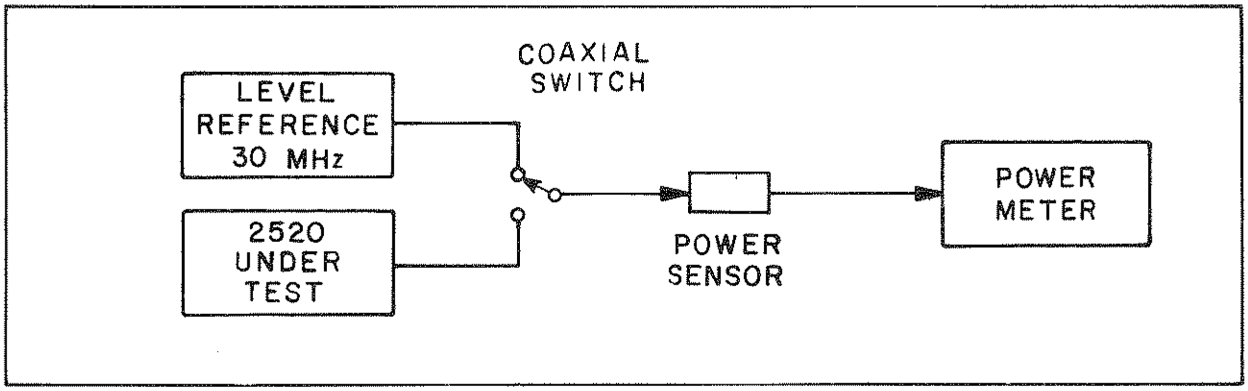


Figure 6-101. Comparison of Measurements on a Power Meter

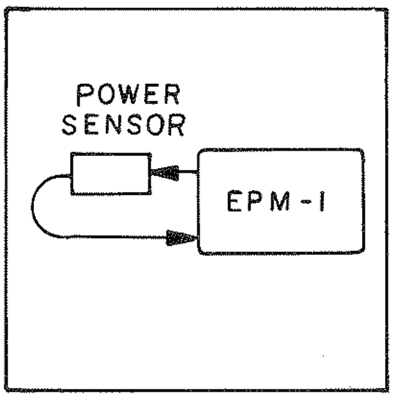


Figure 6-102. Zeroing the EPM-1

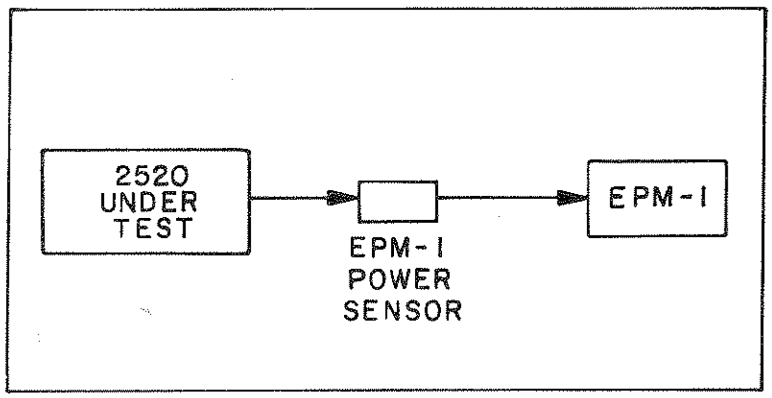


Figure 6-103. Measurement at 0 dBm

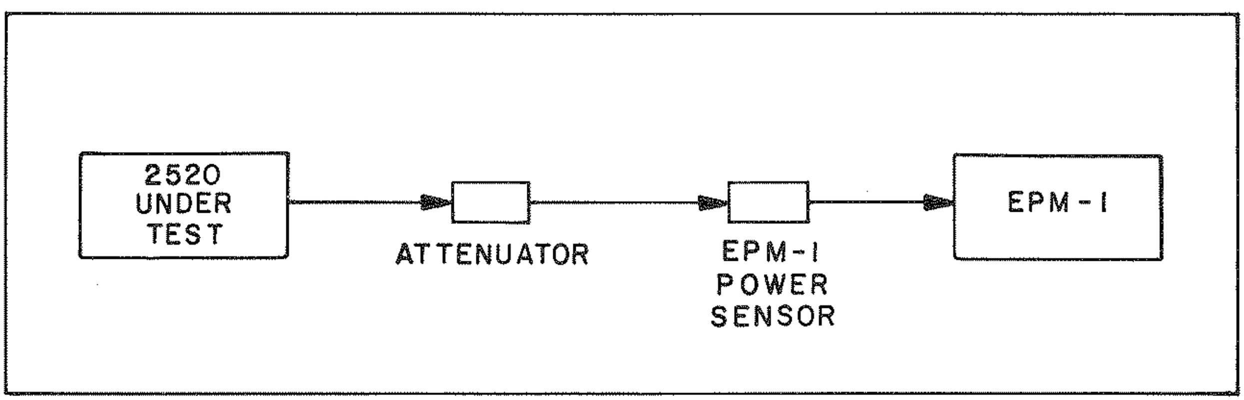


Figure 6-104. Measurements above 0 dBm

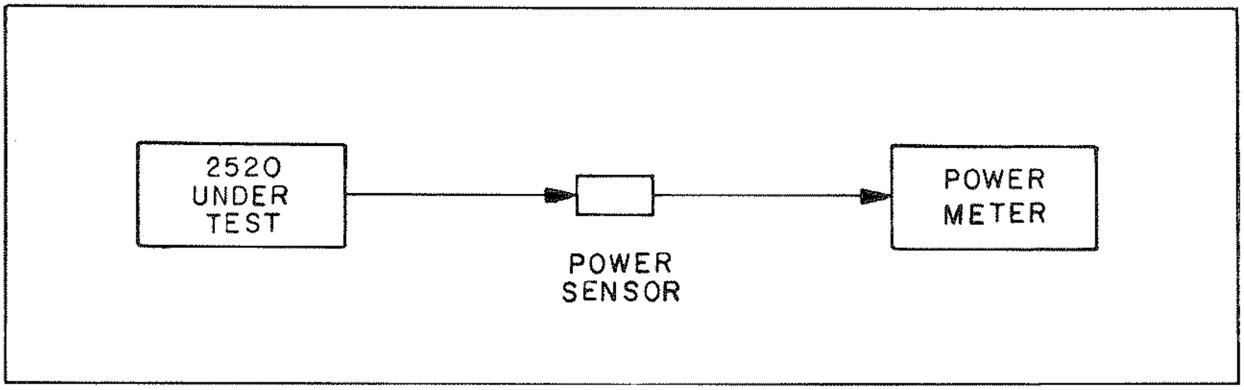


Figure 6-105. Reference Measurements

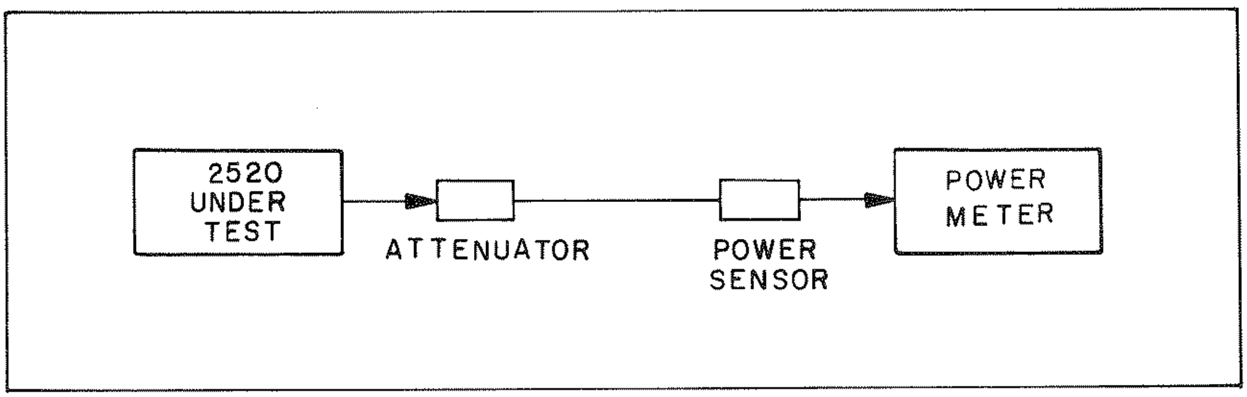


Figure 6-106. Comparison of Internal to External Attenuator

6-103. PERFORMANCE VERIFICATION, METHOD 2.

1. Setup. Refer to **Table 6-1**, Test Equipment Required, for a description of the test equipment used in this test.

This method as described uses a Wandel Goltermann milliwatt test set to set the 0 dBm level, and fixed attenuators such as Weinschel Model 1's to set the 2520 internal attenuators. The EPM-1 is traceable to NBS, or to the German National Physics Lab. Alternatively, an HP432A power meter may be used along with a DVM for the measurement at 0 dBm. The HP478A-H55 and HP478-H75 power head calibrations are traceable to NBS. In this case refer to the HP 432 instructions for "Precision Power Measurements", and in the procedures below, substitute the HP432A and a DVM for the EPM-1.

Power up the equipment and let it warm up for 5 or 10 minutes. Set up the EPM-1 as described in the manufacturer's manual (50 ohms, etc.), and connect the EPM-1 sensor to it's own output to calibrate it as shown in **Figure 6-102**, and "zero" it.

2. Attenuator Calibration: If the exact attenuation of the test attenuators is not known, they can be measured at DC. The DC attenuation is extremely close to the attenuation at 30 MHz, since the type N attenuators are being used at about 0.2 % of their maximum frequency. If this is done, the traceability to NBS is not formal. Alternatively, the attenuators may be sent to NBS for certification at 30 MHz. To make the measurement, connect a stable DC source through two 50 ohm resistors to ground with a pair of N connectors at the resistor midpoint. Soldered joints are essential to keep the ground offsets low. Adjust the center point voltage of the resistors for about 2 V, and record as V1. Now connect the attenuator under test between the resistors, and measure the voltage at the output of the attenuator (V2). Calculate ATTEN = 20 log (V2 / V1). The tolerance of the 50 ohm resistors does not affect the accuracy of this measurement on a first order approximation since the initial voltage was measured taking their actual values into account.

3. Verification of 0 dBm: Set the 2520 to 0 dBm. See the caution note below, and then connect the equipment as shown in **Figure 6-103** and take a reading on the EPM-1. It should be 0 dBm to within the tolerance shown in **Table 6-102.**

CAUTION

The EPM-1 operates only from -1 to +1 dBm and is sensitive to overloads. Be sure to set the RF level first, then connect the sensor.

4. Verification of +20 dBm: Set the 2520 to +20 dBm and connect the equipment as shown in **Figure 6-104.** using the 20 dB attenuator. Take a reading on the EPM-1. The range switch on the EPM-1 may have to be used to get an on-scale reading (the range switch setting gets added to the meter reading). The reading should be 20 - ATTEN where ATTEN is the exact attenuation of the attenuator, to within the tolerance in **Table 6-102**. The tolerances in the table are derived approximately as follows:

TABLE 6-102. VERIFICATION OF LEVELS, METHOD 2

Level	Tolerance Without Amplifier	Tolerance Using Amplifier
-70 dBm	--	+/- 0.39 dB
-60	+/- 0.31 dB	0.24
-50	0.19	0.18
-40	0.18	0.18
-30	0.14	0.14
-29	0.14	0.14
-25	0.14	0.14
-23	0.14	0.14
-20	0.14	0.14
-10	0.12	0.12
0	0.10	0.10
10	0.12	0.12
20	0.14	0.14

a. Above 0 dBm: The tolerance is the 2520 spec plus the EPM-1 spec, plus the attenuator uncertainty, plus .01 dB resolution error. NBS certification of the attenuators is assumed.

b. At 0 dBm: The tolerance is the 2520 spec plus the EPM-1 error plus .01 dB resolution error.

c. Below 0 dBm: The tolerance is roughly twice the attenuator uncertainty (twice because the attenuators used for calibration may have been off in the other direction from those used in the performance test), plus .01 dB resolution error, plus noise. The noise is that of the Boonton high sensitivity sensor, the 4G (51015), with a ten second filter. The EPM-1 error does not add in because the measurement is that of comparing attenuators (internal attenuators to the test attenuators).

5. Verification of +10 dBm: Using the same method as for the +20 dBm range, take a reading at +10 dBm and verify the tolerance. In this case use the 10 dB attenuator; the reading should be 10.00 - ATTEN.

6. Verification of -10 dBm through -50 dBm: Connect the 2520 to the power meter as shown in **Figure 6-105**, with no attenuator. Turn off the 2520 output and let the sensor settle for 20 seconds. Then zero the power meter per the manufacturer's instructions.

a. INTERNAL ATTENUATOR READINGS. Enable the 2520 output and set it's levels to those shown in **Table 6-102**, starting with -70 dBm, up to 0 dBm. Record the readings. Work quickly at the lower levels so the power meter doesn't drift, and rezero as required. When zeroing, disable the RF power for 10 seconds or more before zeroing.

NOTE

For readings at and below -40 dBm, a 30 MHz amplifier of about 20 to 30 dB gain may be inserted in series with the sensor for greater accuracy. The gain of the amplifier is not important since the sensor is used only for comparison of two measurements, however, short term stability (minute to minute) is important.

b. EXTERNAL ATTENUATOR READINGS. Now set the 2520 to 0 dBm and insert a 10 dB attenuator, as shown in **Figure 6-107.** Disable the 2520 output and zero the power meter. Then enable it and take a reading. Record the reading along with the exact attenuation of the test attenuator as shown in the example in **Table 6-103.** Calculate the deviation of the attenuator from it's nominal value as shown in the example. The readings are carried out to three decimal places; the power readings were taken in Watts mode and converted to dBm using a calculator for better resolution. The conversion is done with :

$$\text{dBm} = 10 \log P$$

where P is in milliwatts.

Calculate the error per the example, and verify that the error is less than that shown in **Table 6-102.**

Connect a 20 dB pad in the path, as shown in **Figure 6-106,** disable the RF power and zero the power meter. Enable the RF and take a reading at -20 dBm. In a manner similar to the -10 dBm measurement above, calculate the error and verify that it is less than that shown in the **Table 6-102.**

Continue taking attenuated readings at the levels shown in **Table 6-102** and verify that they are within the tolerances listed.

This completes the performance verification, method 2.

TABLE 6-103. EXAMPLE VERIFICATION AT -10 dBm.

ATTEN (Exact pad attenuation)	:	9.859 dB
Power reading with external pad	:	-9.683 dBm
Pad deviation from nominal (10 - 9.859)	:	0.141 dB
Corrected reading (difference of above two numbers)	:	-9.824 dBm
Power reading with 2520 internal pad	:	-9.820 dBm
Error (difference of above two numbers)	:	.004 dB

SECTION 6-200
ADJUSTMENTS

6-201. INTRODUCTION. The adjustments listed here are to be used for periodic maintenance (every 12 months typically), or on a unit which has been repaired. Repairs on the Control board will not affect the RF calibration, except for replacement of U10 (EEPROM) or U19 (DAC), or circuits in the vicinity of U19. Also, if circuits in the power up reset area of the control board are repaired, the trip voltage adjustment (R13) should be adjusted.

If any of the RF relays have been replaced in the Generator assembly, they need to be "burned in" by cycling. This is done by setting the internal Bit switch on the Control board to the positions in **Table 6-201** and turning the power on. The relays will cycle every few seconds, accumulating 20,000 counts in 16 hours. This is sufficient to "wear in" the contacts. The contacts are rated for more than one million counts.

TABLE 6-201. INTERNAL BIT SWITCH SETTING FOR BURN IN

Position	Setting
1	Closed
2	Closed
3	Closed
4	Closed
5	Open
6	Closed
7	Closed
8	Closed

6-202. POWER UP RESET ADJUSTMENT. Connect the 2520 to the AC line through a variac. Monitor Control board **TP4** (regulated 5 V) and **U24 pin 10** (Reset) on a scope. With the scope set to 5 mS per division, drop the variac down from the nominal AC voltage to the point where the regulated 5 V just begins to drop out. Now increase the AC line voltage by 10 V if operating from 120 volts and by 20 V if operating from 220/240 V. Now set the pot **R13** so that the reset line is just at the point of not going low (to where it is stable). Power down and remove the variac from the line.

6-203. OUTPUT LEVEL CALIBRATION. There are two methods for calibrating the 2520 depending on what equipment is available. The first method uses a reference 30 MHz Level Generator which can be another 2520, or an HP 3335A or HP 3336A/B/C. With this method, the 2520 under test is adjusted to the reference.

The second method uses a 0 dBm test set, the Wandel Goltermann EPM-1, to verify the level at 0 dBm and uses fixed attenuators to verify other levels. This method is more involved but yields better accuracy.

6-204. OUTPUT LEVEL CALIBRATION, METHOD 1.

1. **Switch Settings:** Put jumper **P1** in place on the Control board (this enables writing of the calibration data) and set the Bit switch on the Control board as shown in **Table 6-202.**

TABLE 6-202. INTERNAL BIT SWITCH SETTING FOR INITIALIZATION AND CALIBRATION

Position	Setting
1	Closed
2	Closed
3	Closed
4	Closed
5	Closed
6	Open
7	Closed
8	Closed

In this mode, the left and right arrow keys set the cursor to the display field to be modified. The left field is the output range (-50, -40, etc.) and the right field sets one of three functions to be modified:

a. Peaking Adjust: Sets the output to maximum on the 0 dBm range to allow peaking of C12 on Generator Assembly.

b. Output Adjust: Allows adjustment of the 10 dB ranges.

c. Initialize: In this mode, when "Local" is pressed, default gain settings for each range will be loaded into the EEPROM, erasing previous calibration data.

2. Initialization. If it is desired to initialize (see above), set the cursor to the right field with the right arrow key and use the up/down arrow keys to put the function on "Initialize". Then press "Local" twice. Note: this will erase all previously stored calibration data. If it is desired to calibrate only some of the ranges, and the instrument is known to be working on the others, do not initialize.

3. Peaking Adjust. C12 is a tank circuit which is adjusted for resonance at the time of manufacture. Normally this would not have to be readjusted unless repairs have been made, or unless the output level cannot reach +20 dBm. However, if it is desired to do the peaking adjustment here, proceed as follows: Set the cursor on the right field and using the up/down keys, set the function to "Peaking". Connect a power meter to the output of the 2520. Adjust C12 on the Generator Assembly for a maximum output (1 to 3 dBm or so). (The Generator has to be removed from the frame on early units to access this adjustment. The Generator can still be electrically connected while out of the unit). On later units, there is a hole in the Control board which can be used for access.

4. Connections for Calibration. Connect the 2520 and the 30 MHz Reference to the input of a two position coaxial RF switch, and connect the output of the switch to a power sensor as shown in **Figure 6-101.** Do not use cables, but instead use four rigid 90 degree type N adapters. Then connect the sensor output to a power meter. Put the power meter in watts mode for best resolution.

5. Downscale Adjustment. Using the left/right arrow keys, set the cursor to the right hand field, and using the up/down arrow keys, set the right field to "Output Adjust". Move the cursor to the left hand field and set the range to be adjusted to -20 dBm.

Switch the coaxial switch to the reference and take a power reading. Then switch it to the 2520, and using the "Local" and

"On/Off" keys, adjust the calibrated output of the 2520 so that is matches the reference reading. (The "Local" key increases the output; the "On/Off" key decreases the output). Switch back and forth between the reference and the 2520 as necessary.

Using the up and down arrow keys, set the level to -29 dBm (This is a special range in the calibration mode which sets the output to -29 dBm. It is included so that the unit does not have to be put back in operating mode to adjust the downscale).

Also set the reference to -29 dBm. Set the coaxial switch to the reference and take a reading. Now set the coaxial switch to the 2520 and adjust the downscale adjustment pot R11 on the 30 MHz Generator assembly so that the readings match. R11 is on the right side of the Generator assembly.

Go back to -20 dBm on both the reference and the 2520 and see if the readings still match. If they don't, perform the upscale calibration again at -20 dBm, then do the downscale again at -29 dBm. Repeat the process as required.

6. 10 dB Steps. Turn off the reference RF power by pressing "On/Off" on the reference and turn off the 2520 RF power by setting the level to "Off" using the Up / Down keys. (The "off" position is next to the -50 dBm adjustment in the menu).

Wait at least 20 seconds for the power sensor to settle and zero the power meter. Then set the reference and the 2520 to -50 dBm.

Set the coaxial switch to the reference and take a reading. If the reading is drifting, disable the RF power to the sensor and zero the meter again. Now set the switch to the 2520 and note the reading. Press the "Local" key to adjust the level up and press the "On/Off" key to adjust it down. Holding the key in will make the level ramp.

Switch back to the reference and see that it hasn't drifted. When the reference and the 2520 match, go to the next range (-40 dBm) by pressing the up arrow.

Continue with each range as in the previous steps, up to and including 0 dBm. (The -20 dBm range has been adjusted, just check it). Then change the power sensor to a higher range type for the +10 and +20 dBm ranges, and adjust those.

Except for checking, this completes the calibration; remove the jumper P1, and set the Control board Bit switch as shown in **Table 6-203.** Power down the 2520 and power it up again. This will put the unit in operate mode.

7. Operational Check. This test verifies that the calibration data was stored in the EEPROM during the above steps. Power down the unit and power it up again, and set the power meter to dBm mode if desired for simplicity of measurement.

Set the reference and the 2520 to the levels shown in **Table 6-204.** Use the high sensitivity sensor for readings below 0 dBm and the high power sensor for 0 dBm and above. If desired, a 30 MHz amplifier with about 20 dB gain may be inserted in series with the 2520 output when

TABLE 6-203. INTERNAL BIT SWITCH SETTING FOR NORMAL OPERATION

Position	Setting
1	Closed
2	Closed
3	Closed
4	Closed
5	Closed
6	Closed
7	Open
8	Closed

taking readings at and below -50 dBm. Zero the power meter often when making the low level measurements.

Compare readings of the reference to the 2520 by switching the coaxial switch back and forth. If any of the readings differ by more than the tolerance shown in the table, recalibrate the ranges that are off.

NOTE

The tolerances in **Table 6-204** are valid for the case where the reference 2520 that was used for calibrating the instrument under test is was the same unit as was used for calibration. Traceability to NBS at these tolerances is not implied.

Disconnect the coaxial switch and connect the RF output of the 2520 to a scope. A termination is not necessary. Vary the output from -10 dBm to +10 dBm in 0.1 dB steps and verify that the voltage varies smoothly and continuously with no dropouts, except at the range change points (at -10, 0 and +10 dBm there are dropouts).

This completes the level calibration. Remove jumper **P1** and power down the unit.

6-205. OUTPUT LEVEL CALIBRATION, METHOD 2. This method as described uses a Wandel Goltermann milliwatt test set to set the 0 dBm level, and fixed attenuators such as Weinschel Model 1's to set the 2520 internal attenuators. The EPM-1 is traceable to NBS, or to the German National Physics Lab. Alternatively, an HP432A power meter may be used along with a DVM; the HP478A-H55 and HP478-H75 power head calibrations are traceable to NBS. In this case refer to the HP 432 instructions for "Precision Power

TABLE 6-204. VERIFICATION OF LEVELS AFTER CALIBRATION

Level	Tolerance
-60	0.05
-55	0.03
-50	0.03
-45	0.02
-40	0.02
-35	0.02
-30	0.02
-29	0.02
-28	0.02
-27	0.02
-26	0.02
-25	0.02
-24	0.02
-23	0.02
-22	0.02
-21	0.02
-20	0.02
-15	0.02
-10	0.02
-5	0.02
0	0.02
5	0.02
10	0.02
15	0.02
20	0.02

Measurements", and in the procedures below, substitute the HP432A and a DVM for the EPM-1.

1. Attenuator Calibration. If the exact attenuation of the test attenuators is not known, they can be measured at DC. The DC attenuation is extremely close to the attenuation at 30 MHz, since the type N attenuators are being used at about 0.2 % of their maximum frequency. If this is done, the traceability to NBS is not formal. Alternatively, the attenuators may be sent to NBS for certification at 30 MHz. To make the measurement, connect a stable DC source through two 50 ohm resistors to ground with a pair of N connectors at the resistor midpoint. Soldered joints are essential to keep the ground offsets low. Adjust the center point voltage of the resistors for about 2 V, and record as V1. Now connect the attenuator under test between the resistors, and measure the voltage at the output of the attenuator (V2). Calculate ATTEN = 20 log (V2 / V1). The tolerance of the 50 ohm resistors does not affect the accuracy of this measurement on a first order approximation since the initial voltage was measured taking their actual values into account.

2. Switch Settings. With power off, put **P1** in place on the Control board (this enables calibration) and set the internal Bit switch on the Control board as shown in **Table 6-202** (Initialization and Calibration).

In this mode, the left and right arrow keys sets which display field to be modified. The left field is the output range (-50, -40, etc.) and the right field sets one of three functions to be modified:

a. Peaking Adjust: Sets the output to maximum on the 0 dBm range to allow peaking of C12 on Generator Assembly.

b. Output Adjust: Allows adjustment of the 10 dB ranges.

c. Initialize: In this mode, when "Local" is pressed, default gain settings for each range will be loaded into the EEPROM, erasing previous calibration data. Note: this will erase all previously stored calibration data. If it is desired to calibrate only some of the ranges, and the instrument is known to be functioning on the others, do not initialize.

3. Initialization. If it is desired to initialize (see above), set the cursor to the right field with the right arrow key and use the up/down arrow keys to put the function on "Initialize". Then press "Local" twice. Note: this will erase all previously stored calibration data. If it is desired to calibrate only some of the ranges, and the instrument is known to be functioning on the others, do not initialize.

4. Peaking Adjust. C12 is a tank circuit which is adjusted for resonance at the time of manufacture. Normally this would not have to be readjusted unless repairs have been made, or unless the output level cannot reach +20 dBm. However, if it is desired to do the peaking adjustment here, proceed as follows: Set the cursor on the right field and using the up/down keys, set the function to "Peaking". Connect a power sensor to the output of the 2520. Adjust C12 on the Generator Assembly for a maximum output (+1 to +3 dBm or so). (The Generator has to be removed from the frame on early units to access this adjustment. The Generator can still be electrically connected while out of the unit). On later units, there is a hole in the Control board which can be used for access.

5. Zeroing the EPM-1. Set up the EPM-1 as described in the manufacturer's manual (50 ohms, etc.), and connect the EPM-1 sensor to it's own output to calibrate it as shown in **Figure 6-102**, and "zero" it. This should be done every 10 minutes or so.

6. Setting 0 dBm. Using the right arrow key, position the cursor on the right field and set that field to "Output Adjust". Then position the cursor on the left field and set the level to be adjusted to 0 dBm. Note: This should be done before connecting the EPM-1 because the EPM-1 is sensitive to overloads. Now connect the EPM-1 probe to the 2520 output as shown in **Figure 6-103** and note the EPM-1 reading. Using the up/down arrow keys, adjust the level until the reading is exactly 0 dBm.

7. Setting +10 dBm. Disconnect the EPM-1 sensor from the 2520 and set the left field on the 2520 to +10 dBm (still in "Output Adjust" mode. Then put a 10 dB attenuator on the 2520 output as shown in **Figure 6-104** and connect the EPM-1. Adjust the level of the 2520 using the up/down arrow keys until the EPM-1 reads 10.00 - ATTEN where ATTEN is the exact attenuation of the 10 dB test attenuator. The range switch on the EPM-1 may have to be used to get an onscale reading; in this case the switch setting gets added to the meter reading.

8. Downscale Adjustment. Disconnect the EPM-1 and set the left field on the 2520 to +1 dBm. Put a 1 dB attenuator on the 2520 output as shown in **Figure 6-104** and connect the EPM-1. Adjust the downscale pot R11 on the Generator assembly until the EPM-1 reads 1.00 - ATTEN. (R11 is accessible on the right side of the Generator assembly). Now remove the 1 dB attenuator and set the 2520 to +10 dBm (still in "Output Adjust" mode). Using the 10 dB attenuator, verify the 10 dBm reading. If it has changed, recalibrate it at 10 dBm and then readjust the downscale pot. Continue going back and forth between the 10 dBm and the 1 dBm settings until both read correctly.

9. Setting +20 dBm. Using the same method as was used for the +10 dBm adjustment, use the 20 dB attenuator and set the level to 20.00 - ATTEN, where ATTEN is the exact attenuation of the 20 dB test attenuator.

10. Setting -50 dBm. Connect the equipment as shown in **Figure 6-106** using the 50 dB attenuator or stacked attenuators that equal 50 dB. Use a high sensitivity power sensor (to -70 dBm). Use the watts mode on the power meter for greater resolution and convert the readings to dB using:

$$\text{dBm} = 10 \log P$$

where P is in milliwatts.

Carry the calculations out to three decimal places.

With the 2520 still set to the "Output Adjust" mode, set the level to 0 dBm. Take a reading on the power meter and call it "A". Now set the level to -50 dBm and remove the attenuator from the path. Adjust the -50 dBm level so that the power meter reads A + ATTEN + (-50.000) where ATTEN is the exact attenuation of the 50 dB test attenuator. For example:

```
Reading A     = -50.551
ATTEN         =  50.400
Desired Level = -50.000
                ------
Adjust for      -50.151 dBm
```

If desired, a 30 MHz amplifier may be inserted in series with the power sensor (for both measurements) to lower the noise and get a better reading. The amplifier should have about a 20 dB gain. The exact gain is not important since it is used for comparison of measurements only. The calculation shown above still holds.

11. Setting -40 dBm through -10 dBm. Perform these adjustments the same as the -50 dBm adjustment, using the attenuators appropriate to the level (40 dB attenuator for the -40 dbm setting, etc.).

Except for checking, this completes the calibration; remove the jumper P1, and set the Control board Bit switch as shown in **Table 6-203.** Power down the 2520 and power it up again. This will put the unit in operate mode.

12. Verification. Perform the "Operational Check" as shown in **Section 6-204,** Output Level Calibration Method 1, part 7, to verify that the calibration data got stored properly. This completes the Output Level Calibration, Method 2.

SECTION 6-300
TROUBLESHOOTING

6-301. GENERAL. An instrument malfunction will generally be evident from the front panel or the output level. Or, the unit may not be able to be calibrated. If either of these conditions are present, refer to the theory of operation, Section 5, and to the troubleshooting steps below. After an instrument is repaired, the adjustments (calibration) should be done as listed in Section 6-200, or the performance tests as listed in Section 6-100, or both.

Some of the Control board repairs that are strictly digital in nature will not affect the calibration, except for replacement of the EEPROM, which contains the calibration data. Replacement of the DAC or any of the analog circuits will require calibration. In any case, the performance tests should be run to assure that the calibration data has not dropped out.

6-302. ACCESS TO BOARDS AND ASSEMBLIES. Refer to Section **6-5** for instructions on removal and replacement of boards and assemblies.

6-303. TROUBLESHOOTING. Refer to **Table 6-301** and proceed to the appropriate section according to the malfunction.

TABLE 6-301. TROUBLESHOOTING

Malfunction	Refer to
Display dark and no RF power output	6-304, Power supply
Display active and functional; no output or wrong output; one or more levels bad	6-305, Isolation to Assy
Output controllable but display is out	6-306, Control Board
Bus not working	6-306, Control Board
Generator section (casting assembly) known to be non-operative	6-307, Generator

6-304. POWER SUPPLY. The power supply consists of the bridge rectifiers and the three regulators, and the power up reset circuit. The power up circuit generates a reset pulse that goes high a half second or so after the application of power; if this does not go high the instrument will appear dead. Refer to the paragraphs below.

1. **Basic Power Supply.** First check the fuse and check that the line voltage selector switch is in the proper position for the line voltage that is being used. If the fuse keeps blowing, the bridge rectifier(s) are probably shorted. Replace as required. Also, the regulators may be shorted.

If the fuse and the line selector switch appear OK, apply power and measure the DC voltages (+5, +15, -15) at TP4, TP1, and TP3 respectively. If any are faulty, unplug the cable that goes to the Generator assembly and to the display. If the suspect voltage comes up, refer to the troubleshooting section for that item that was removed. If it doesn't, measure the DC voltages at the electrolytic capacitors C7, C5, and C6. There should be about 9 VDC on C7, and +/-22 VDC on the others, with many volts of ripple. The best way to measure these is with a scope. If any of these voltages is not correct, check the transformer secondaries for AC voltage. Replace the transformer as required, or check the line voltage selector switch wiring and related circuitry for broken wires.
If a given regulator has input but no output, that line may be shorted through some component in the unit. If replacing the regulator does not help, this is probably the case. One of the suspect parts could be the filter capacitors. Replace the component(s) as required.

2. **Power Up Reset Circuit.** Assuming at this point that the three power supplies check out OK, look at pin 10 of U25. This is the reset pulse. This should go high one half second after power is applied, and stay high. If it doesn't, look at pins 2 and 13 of U24, the comparator. These should do the same, with perhaps faster timing and not so clean waveforms. Also, U25 pin 4 should do the same. If not, replace U24 or U25 as required. Finally, check U24 pin 10 for about 2.7 VDC.

6-305. ISOLATION TO ASSEMBLY. With this test, it can be determined with reasonable accuracy if the problem is on the Control board or in the Generator assembly. This is done by monitoring the control signals that go the the Generator. Refer to the Theory of Operation for a description of the control voltage, and to **Tables 5-2** and **5-3**.

Set the 2520 to the levels shown in **Table 5-2,** and check the three DC attenuator control voltages (roughly TTL levels) going into the Generator according to that table. These points may be checked either on the Control board or at the Generator rear section. If any of these are not correct, disconnect the Generator and check again. If they are still not correct, the Control board is at fault; go to **Section 6-306,** Control board. If the voltages are correct only with the Generator disconnected, there is a short in the harness or in the

Generator. Check the wiring and refer to the Generator troubleshooting section.

Also check the analog control voltage going at pin 5 of J6 on the Control board. This should be about 6.5 VDC at 0 dBm, and lower at -1, etc. according to **Table 5-3,** Generator Control Voltage. For example, if the control voltage is 6.4 VDC at -10 dBm, it should be 6.4 x 0.5012 = 3.207 V at -16 dBm. This should be checked using a good chassis ground with the Generator secured with at least one screw. The voltages at each 1 dB step should be checked. If any are faulty, the DAC or the Op Amp may be suspect. However, if some points are good and only one or two are off, the calibration data may be suspect. Try calibrating the unit again.

If the control voltage and the three attenuator control lines appear OK, but the Generator output is bad, the problem lies with the Generator. Proceed to that troubleshooting section. If these lines are not OK, troubleshoot the Control board.

6-306. CONTROL BOARD TROUBLESHOOTING. Refer to Section 5, Theory of Operation and to the Control board schematic. The first things to check are the clock and the power up reset. Check for 2 MHz at pin 6 of the Z80 (U4), and check for a logic high at pin 26. If these are OK, check for activity on all the data and address lines on the Z80. All lines should have some activity; even very short pulses are to be considered valid. If all the data lines are "dead", the microprocessor may be at fault.

Since the RAM, PROM, and EEPROM are intimately tied in to the Z80, a failure of one of these components would in general cause the Z80 to appear non-functional. The easiest way to check these components is by replacement. The PROM is of course replaceable only by the Boonton equivalent since it is a programmed part. The EEPROM can be replaced, but the unit will have to be "Initialized" as shown in the Adjustments section (Section 6-200), then calibrated.

If the failure can be identified with a particular section such as the display, look for activity on data lines in that particular area. Generally, failures will be manifested as nonactivity. A gross malfunction in the 2520 may be due to failed decoder IC's U11 and U12 since they control all the other chip selects in the unit. This can be checked by looking for activity on all the output lines of those IC's.

6-307. GENERATOR TROUBLESHOOTING. The Generator may be troubleshooted out of the 2520 frame with the cable still connected. One or both of the covers on the Generator may be removed. (For calibration, the Generator should be secured in the frame). The tests below can be performed to isolate the trouble in the Generator.

1. Isolation. To determine what section of the Generator the problem lies in, perform the following test. With the 2520 set to 0 dBm, check the AC voltage at relay K1, pin 8. If it differs significantly from 6.33 Volts peak to peak (by more than 1 volt), the problem is the amplifier or the oscillator. Go to the oscillator test, Item **2** below. If it appears normal, go to the attenuator test, Item **5** below.

2. Oscillator. Connect a scope to TP1 on the Generator and set the level to 20 dBm via the front panel. There should be a 30 MHz signal at about 6 V peak to peak. If there is, proceed to the amplifier test, Item **3** below. If not, check for the following conditions: Note: Q1, Q2, and Q4 operate independently from the rest of the Generator. Even if there is trouble elsewhere, there should be oscillation in this circuit.

a. The collector of Q2 should be greater than 14 VDC. If not, check for a low at J46 pin 8. Replace Q2 as necessary.

b. The emitter of Q1 should be 1 VDC +/- 0.5 V. Replace Q1 and other components as suspected. Replace the crystal as required.

c. The emitter of Q4 should be from 6 to 10 VDC and oscillating at 3.5 to 5.8 V peak to peak. Replace Q4 as required.

Once oscillation has been verified, if there is still a malfunction, proceed to the amplifier test below, Item **3**.

3. Amplifier Q5. Set the 2520 level to 0 dBm. Check TP2 using the scope. There should be from 16 to 24 V peak to peak at 30 MHz. If there is, proceed to the attenuator test, Item **5**. If the voltage is low, short the emitter to the collector of Q3 and try again. If this brings up the voltage, the problem is in the control loop; go to Item **4**. If the voltage is still too low, replace Q5. Also, replace suspected passive components that follow Q5 (C14, etc.). With Q3 still shorted, adjust C12 for a maximum level at K1 pin 8. Once the problem is found and repaired, go to Item **6**, conclusion.

4. Control Loop. The control loop consists of U1, CR2, CR3, Q3, and the associated components. The circuit compares the DC voltage at the CR2 anode to the AC voltage at the CR3 anode. U1 then applies the proper DC voltage to the Q5 amplifier (through Q3) to maintain the balance. If the oscillator or amplifier are not functioning, the voltage at U1 pin 6 will be high, in an effort to bring up the output. Similarly, if Q3 were shorted, the full DC voltage would be applied to the amplifier and the loop would try to compensate by forcing U1 pin 6 to near ground.

First check the op amp by measuring the DC voltages at pins 2, 3, and 6. The op amp is to be suspect if any of the conditions below are present:

a. Pin 2 is higher than pin 3 by more than 10 mV and pin 6 is greater than 2 VDC.

b. Pin 2 is less than pin 3 by more than 10 mV and pin 6 is less than 12 VDC. (It may be necessary to remove Q3 and CR1 for this test if the voltage appears to be shorted to ground).

Check to see that the DC voltage at pin 2 of the op amp is roughly equal to the peak voltage at the CR3 anode, and that the voltage at pin 3 of the op amp is about 0.5 V lower than that of the CR2 anode. If not, replace the diodes as required. Also, replace Q3 as required. Once the control loop has been repaired proceed to Item 6, conclusion.

5. Attenuator. The attenuator consists of three sections of 10, 20, and 40 dB. The resistors are precision for stability. Errors in resistance of one percent or so can be tolerated because errors are calibrated out in software. Most attenuator faults will occur with the switch driver transistors and with the relays. Check Q6 through Q8 by setting the 2520 level in 10 dB increments as shown in **Table 5-2**. When the base drives are low, the transistors should be on and their collectors should be from 3.2 to 4.2 VDC. Otherwise they should be 0 VDC +/- 100 mV. Replace the transistors as required. The switching of the relays should be audible. If there is relay drive but no "clicking", the relay(s) are probably at fault.

Check the voltages according to **Table 6-302** and replace the relays or the precision resistors as required.

6. Conclusion. Button up the Generator and check the output at various levels. If repairs have been made to the analog circuits recalibration will be necessary. Replacement of the relay(s) will require calibration since the contact resistance varies slightly from unit to unit. Additionally, the contacts must be "burned in" by cycling for about 20,000 counts. This is done with a special Bit switch setting. For this procedure, refer to Section 6-200, Adjustments.

TABLE 6-302. RF VOLTAGES

Level	Output at N Connector, terminated, volts p-p
20 dBm	6.30 V
10	2.00 V
0	630 mV
-10	200 mV
-20	63 mV
-30	20 mV
-40	6.3 mV
-50	2.0 mV

SECTION 7
PARTS LIST

7-1. INTRODUCTION

Table 7-2. Replaceable Parts, lists all the replaceable parts and includes: the reference symbol, description, Mfr., Mfr's Part No. and the BEC Part No. Table 7-1. Manufacturer's Federal Supply Code Numbers, list the manufacturer's federal supply numbers.

TABLE 7-1. MANUFACTURER'S FEDERAL SUPPLY CODE NUMBERS

Number	Name	Number	Name
00241	Fenwal Electronics	31313	Components Corp.
01121	Allen Bradley	31918	ITT Schadow, Inc.
01247	Sprague Electric Company	32575	AMP
01295	Texas Instruments	32897	Erie
02660	Amphenol	32997	Bourns, Inc., Trimpot Div.
02735	RCA Solid State Division	33297	NEC
03888	Pyrofilm (KDI)	33883	RMC
04713	Motorola Semiconductor	34335	Advanced Micro Devices
04901	Boonton Electronics	51640	Analog Devices, Inc.
06383	Panduit Corp.	52464	OKI
06776	Robinson Nugent, Inc.	54420	Dage — MTI
07263	Fairchild Semiconductor	54426	Buss Fuses
07326	Fairchild Semiconductor	54473	Panasonic
13812	Dialco Div. of Amperex	56289	Sprague Electric Company
14655	Cornell-Dubilier	56708	Zilog, Inc.
17801	Panel Corp. (Schurter)	57582	Kahgan Electronics Corp.
19701	Mepco Electra	61637	Kemet-Union Carbide
20307	Arco — Micronics	71450	CTS Corp.
24226	Gowanda Electronics	73138	Beckman Instr., Helipot Div.
27014	National Semiconductor	81073	Grayhill
27264	Molex, Inc.	91293	Johanson
27735	F-Dyne Electronics	91506	Augat
27777	Varo Semiconductor	98291	Sealectro Corp.
28480	Hewlett-Packard Corp.	99942	Centralab
		S4217	United Chemicon, Inc.

TABLE 7-2. REPLACEABLE PARTS

99101200A 2520 RF CALIBRATOR
MODEL: 2520

REFERENCE DESIGNATOR	DESCRIPTION	FED. CODE	MANUFACTURER PART NUMBER	QTY	BEC PART NUMBER
A1	PWA 4300 30 MHz OSCILLATOR	04901	04312700E	1	04312700E
A2(9)	POWER SWITCH FINAL ASSY	04901	04311703A	1	04311703A
A4(8)	INVERTER ASSY (EL)	04901	04313300A	1	04313300A
A3(13)	PWA 2520 CONTROL	04901	02510201A	1	02510201A
A7(12)	PWA 2510 KEYBOARD	04901	02510000A	1	02510000A
A5(1)	DISPLAY LCD DOT MAT STD TEMP	62483	LM24E2C40CTW	1	55500002A

02510701B FRAME ASSY 2520
MODEL: 2520

REFERENCE DESIGNATOR	DESCRIPTION	FED. CODE	MANUFACTURER PART NUMBER	QTY	BEC PART NUMBER
C1-8	CAP FT 3000pF 100V	32575	859617-1	8	227123000
C9	CAP MICA 22pF 5% 300V	14655	CD5CC220J	1	205036000
J43	CONNECTOR TYPE "N"	24253	4889	1	47945500A
L1	INDUCTOR 0.05 uF	04901	40044700A	1	40044700A
W6	CABLE ASSY	04901	57122301A	1	57122301A
W46	CABLE ASSY	04901	57122300A	1	57122300A
U6	PROM 2510/20 A3 U6 CONTROL	04901	53447300A	1	53447300A
W2	CABLE FLAT ASSY	04901	57222801A	1	57222801A
W5	(G) CABLE UNIT 16 PIN	04901	92004600B	1	92004600B
MP1(4)	LAMP EL (SPARE FOR 555000)	62483	ELS4000	1	55500021A
LC1	LINE CORD	UNION	568106000	1	568106000
W31	CABLE ASSEMBLY 2 CONNECTOR	04901	57222903A	1	57222903A

02510600B PANEL REAR ASSY 2510/2520
MODEL: 2510/2520

REFERENCE DESIGNATOR	DESCRIPTION	FED. CODE	MANUFACTURER PART NUMBER	QTY	BEC PART NUMBER
F1	FUSE 0.3 AMP 250V MDL	54426	MDL 0.3	1	545507000
J12	CONN COAX BNC	54420	UG-625/U	1	479123000
P5	CONNECTOR 5 CIRCUIT	06383	CE156F24-5-C	1	479394000
T1	TRANSFORMER POWER	04901	44609100A	1	44609100A
W1	CABLE ASSY FLAT (GPIB)	04901	57223001A	1	57223001A
W7	CABLE ASSEMBLY 2 CONNECTOR	04901	57222908A	1	57222908A
XF1A(2)	FUSE HOLDER	SCHURT	FEU031.1673	1	482117000
XF1B(4)	FUSE CARRIER GRAY 1/4 x 1-1/4	SCHURT	FEK031.1666	1	482114000

04311703A POWER SWITCH FINAL ASSY
MODEL: 2510/2520

REFERENCE DESIGNATOR	DESCRIPTION	FED. CODE	MANUFACTURER PART NUMBER	QTY	BEC PART NUMBER
DS1	LED YELLOW DIFF 5082-4684	28480	HLMP-1401	1	536034000
J13(11)	CONNECTOR HOUSING 4 PIN	27264	03-06-2043	1	477306000
R1	RES MF 267 OHM 1% 1/4W	19701	5043ED267R0F	1	341241000
S1	SWITCH ROCKER DPDT	13812	572-2121-0103-010	1	465286000
W29	CABLE ASSEMBLY 2 CONNECTOR	04901	57222907A	1	57222907A

02510201A
MODEL: 2520

PWA 2520 CONTROL

REFERENCE DESIGNATOR	DESCRIPTION	FED. CODE	MANUFACTURER PART NUMBER	QTY	BEC PART NUMBER
C1	CAP MICA 430pF 1% 500V	14655	CD15FD431F03	1	200037000
C2-3	CAP MICA 100pF 5% 500V	14655	CM05FD101J03	2	200001000
C4	CAP EL 10uF 20% 25V	S4217	SM-25-VB-10-M	1	283336000
C5-6	CAP EL 2200uF -10%+50% 35V	57582	KSMM-2200-35	2	283351000
C7	CAP EL 4700uF -10%+50% 16V	S4217	SM-25-VB-100-M	1	283352000
C8	CAP CER 0.1uF 20% 50V	04222	SR215E104MAA	1	224268000
C9-11	CAP EL 100uF 20% 25V	S4217	SM-25-VB-100-M	3	283334000
C12-22	CAP CER 0.1uF 20% 50V	04222	SR215E104MAA	11	224268000
C23	CAP EL 10uF 20% 25V	S4217	SM-25-VB-10-M	1	283336000
C24	CAP CER 0.1uF 20% 50V	04222	SR215E104MAA	1	224268000
C25	CAP EL 10uF 20% 25V	S4217	SM-25-VB-10-M	1	283336000
CR1	DIODE BRIDGE KBP-02	15281	KBP02	1	532013000
CR2	DIODE BRIDGE VS-248 6A 200 PIV	27777	VS-248	1	532014000
CR3-5	DIODE SIG 1N4001	04713	1N4001	3	530151000
CR6	DIODE HSCH1001 (1N6263)	28480	HSCH-1001	1	530174000
CR7	DIODE ZENER 1N5231B 5.1V 5%	04713	1N5231BSZ	1	530169000
J2	CONN M 02 CIR .1 SP PLZ STRAIT	06383	MPSS100-2-A	1	47740702A
J3	SOCKET IC 14 PIN	06776	ICN-143-S3-G	1	473019000
J4	SOCKET IC 24 PIN	06776	ICN-246-S4-G	1	473043000
J5	HEADER 5 PIN STRAIGHT	06383	MPSS156-5-D	1	477345000
J6	HEADER 9 PIN STRAIGHT .1 SPACE	06383	HPSS100-9-C	1	477374000
J7-9	CONN M 02 CIR .1 SP PLZ STRAIT	06383	MPSS100-2-A	3	47740702A
J10	HEADER 5 PIN STRAIGHT	06383	MPSS156-5-D	1	477345000
J11	SOCKET IC 16 PIN	06776	ICN-163-S3-G	1	473042000
L1	INDUCTOR 15uH 10%	24226	10M152K	1	400373000
MP1(3)	INSULATOR SIL PAD	52653	7403-09FR-51	1	720797000
P1	SHUNT 2 CIRCUIT	27264	15-38-1024	1	483253000
Q1	TRANS NPN 2N3904	04713	2N3904	1	528071000
R1	RES MF 332 OHM 1% 1/4W	19701	5043ED332R0F	1	341250000
R2-3	RES NTWK 10K 2% 1.5W 10-SIP	71450	750-101-R10K	2	345038000
R4	RES MF 4.75K 1% 1/4W	19701	5043ED4K750F	1	341365000
R5	RES MF 10.0K 1% 1/4W	19701	5043ED10K00F	1	341400000
R6	RES MF 4.75K 1% 1/4W	19701	5043ED4K750F	1	341365000
R7	RES MF 100 OHM 1% 1/4W	19701	5043ED100R0F	1	341200000
R8	RES MF 10.0K 1% 1/4W	19701	5043ED10K00F	1	341400000
R9	RES MF 2.00K 1% 1/4W	19701	5043ED2K000F	1	341329000
R10-11	RES MF 10.0K 1% 1/4W	19701	5043ED10K00F	2	341400000
R12	RES MF 3.01K 1% 1/4W	19701	5043ED3K010F	1	341346000
R13	RES VAR 1K 10% 0.5W	73138	72PR1K	1	311316000
R14	RES MF 1.00K 1% 1/4W	19701	5043ED1K000F	1	341300000
R15	RES MF 47.5K 1% 1/4W	19701	5043ED47K50F	1	341465000
R16	RES MF 100 OHM 1% 1/4W	19701	5043ED100R0F	1	341200000
R17-18	RES MF 4.75K 1% 1/4W	19701	5043ED4K750F	2	341365000
R19	RES MF 1.00K 1% 1/4W	19701	5043ED1K000F	1	341300000
R20	RES MF 4.75K 1% 1/4W	19701	5043ED4K750F	1	341365000
R21	RES NTWK 10K 2% 1.5W 10-SIP	71450	750-101-R10K	1	345038000
R22	RES MF 10.0K 1% 1/4W	19701	5043ED10K00F	1	341400000
R23	RES MF 681 OHM 1% 1/4W	19701	5043ED681R0F	1	341280000
R24	RES MF 1.21K 1% 1/4W	19701	5043ED1K210F	1	341308000
S1	SWITCH PIANO 8PST DIP	LAMB	BT-8-2	1	46529908A
S2	SWITCH ROCKER 8PST DIP	81073	76SB08	1	465225000
U1	IC 7404 HEX INVERTER	01295	SN7404N	1	534042000
U2-3	IC 74HCT541 OCTAL BUFFER	01295	74HCT541N	2	534383000
U4	IC Z80C CPU CMOS	TOSHIB	TMPZ84C00AP	1	53440900A
U5	IC 74LS02 2 INPT POS NOR	01295	SN74LS02N	1	534154000
U7-8	IC 74HCT373 OCTAL LATCH	02735	CD74HCT373E	2	534417000
U9	IC 5564 8Kx8 RAM CMOS 28 DIP	TOSHIB	TC5564PL-15	1	534403000
U10	IC 2816 EEPROM 2KX8 200NS	34649	2816B-2	1	53447000A
U11	IC 74HCT139 DUAL DEMUX	02735	CD74HCT139E	1	53444208A
U12	IC 74HCT138 1 OF 8 DECODER	ZYTREX	ZX74HCT138-2N	1	534375000
U13	IC 74LS00 2 INP POS NAND	01295	SN74LS00N	1	534167000
U14	IC 74LS08 QUAD 2 INPUT AND	18324	SN74LS08N	1	534156000
U15	IC 9914ANL IEEE BUS PROCESSOR	01295	TMS9914ANL	1	534288000
U16	IC 75160 IEEE BUS TRANSCEIVER	01295	SN75160BN	1	534286000
U17	IC 75161 IEEE BUS TRANSCEIVER	01295	SN75161BN	1	534287000
U18	IC AD581JH VOLT REF	51640	AD581JH	1	535053000
U19	IC 7134 14 BIT DAC	32293	ICL7134UKCJI	1	53446900A
U20	IC UA7815 REGULATOR	07263	uA7815	1	535056000

02510201A PWA 2520 CONTROL
MODEL: 2520

REFERENCE DESIGNATOR	DESCRIPTION	FED. CODE	MANUFACTURER PART NUMBER	QTY	BEC PART NUMBER
U21	IC UA7915UC REGULATOR	07263	uA7915UC	1	535103000
U22	IC UA7805UC VOLT REG	07263	uA7805UC	1	53511700A
U23	IC OP-07EP OP AMP	06665	OP-07EP	1	535110000
U24	IC 339 QUAD COMPARATOR	27014	LM339N	1	535018000
U25	IC 7407 HEX BUFFER	01295	SN7407N	1	534066000
U26	IC 74HCT541 OCTAL BUFFER	01295	74HCT541N	1	534383000
U27	IC 79L05 VOLT REG	04713	MC79L05ACP	1	535090000
XU1	SOCKET IC 14 PIN	06776	ICN-143-S3-G	1	473019000
XU2-3	SOCKET IC 20 PIN	06776	ICN-203-S3-G	2	473065000
XU4	SOCKET IC 40 PIN	06776	ICN-406-S4-TG	1	473052000
XU5	SOCKET IC 14 PIN	06776	ICN-143-S3-G	1	473019000
XU6	SOCKET IC 28 PIN	06776	ICN-286-S4-TG	1	473044000
XU7-8	SOCKET IC 20 PIN	06776	ICN-203-S3-G	2	473065000
XU9	SOCKET IC 28 PIN	06776	ICN-286-S4-TG	1	473044000
XU10	SOCKET IC 24 PIN	06776	ICN-246-S4-G	1	473043000
XU11-12	SOCKET IC 16 PIN	06776	ICN-163-S3-G	2	473042000
XU13-14	SOCKET IC 14 PIN	06776	ICN-143-S3-G	2	473019000
XU15	SOCKET IC 40 PIN	06776	ICN-406-S4-TG	1	473052000
XU16-17	SOCKET IC 20 PIN	06776	ICN-203-S3-G	2	473065000
XU19	SOCKET IC 28 PIN	06776	ICN-286-S4-TG	1	473044000
XU23	SOCKET IC 8 PIN	06776	ICN-083-S3-G	1	473041000
XU24-25	SOCKET IC 14 PIN	06776	ICN-143-S3-G	2	473019000
XU26	SOCKET IC 20 PIN	06776	ICN-203-S3-G	1	473065000

02510000A PWA 2510 KEYBOARD
MODEL: 2510

REFERENCE DESIGNATOR	DESCRIPTION	FED. CODE	MANUFACTURER PART NUMBER	QTY	BEC PART NUMBER
J1	SOCKET IC 16 PIN	06776	ICN-163-S3-G	1	473042000
MP1(2)	BUTTON MARKED "LOCAL"	04901	77553716B	1	77553716B
MP2(3)	BUTTON MARKED "ON/OFF"	04901	77553712B	1	77553712B
MP3(4)	BUTTON MARKED "RIGHT ARROW"	04901	77553736B	1	77553736B
MP4(5)	BUTTON MARKED "UP ARROW"	04901	77553737B	1	77553737B
R1	RES VAR 25K 10% 0.5W	73138	72PR25K	1	311400000
S1-6	SWITCH PUSHBUTTON SPST	31918	210272	6	465230000

04312700E PWA 4300 30 MHz OSCILLATOR
MODEL: 4321/4322

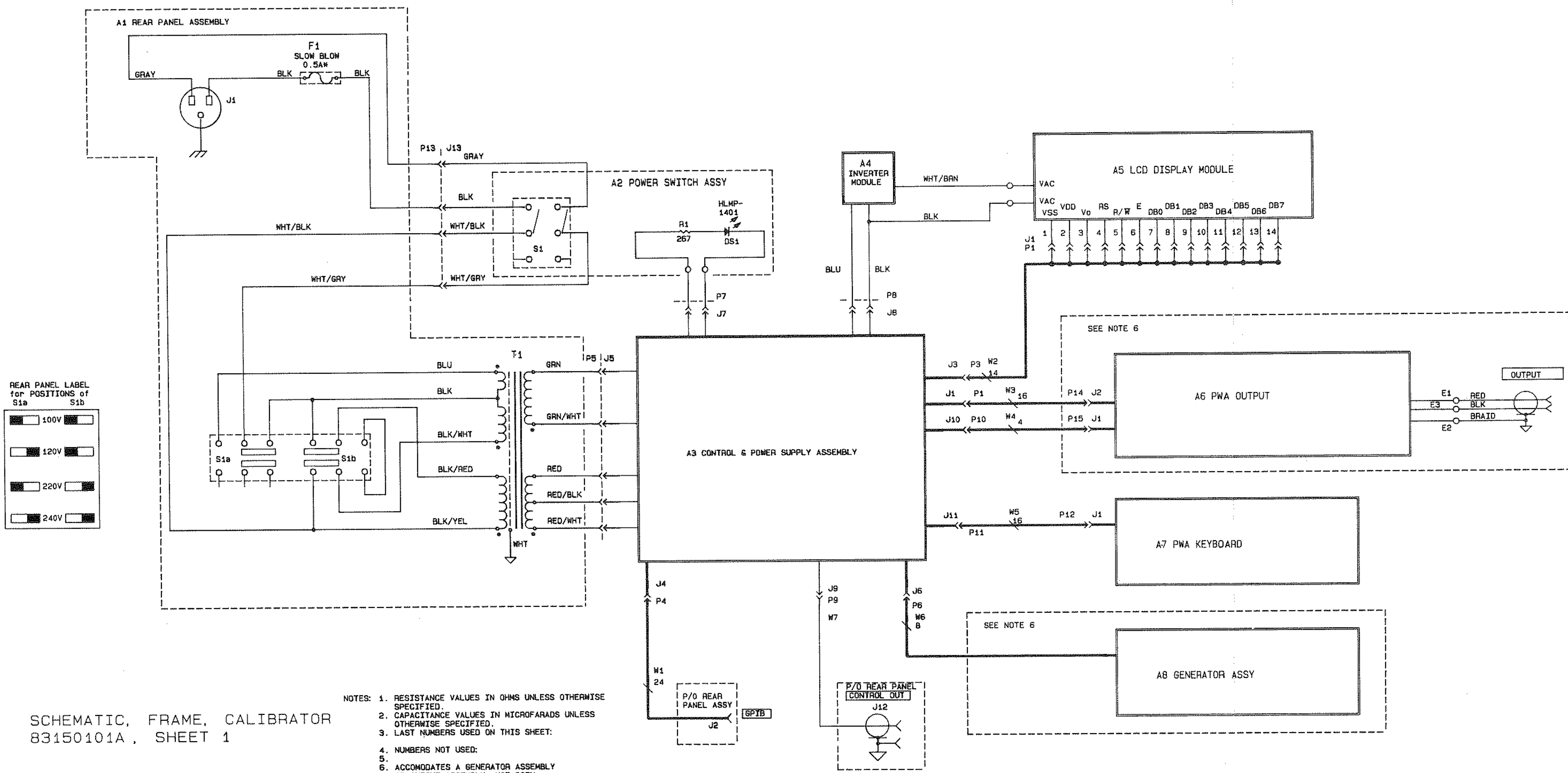
REFERENCE DESIGNATOR	DESCRIPTION	FED. CODE	MANUFACTURER PART NUMBER	QTY	BEC PART NUMBER
R36	RES MF 3.01K 1% 1/4W	19701	5043ED3K010F	1	341346000
R37	RES MF 10.0K 1% 1/4W	19701	5043ED10K00F	1	341400000
R38	RES MF 1.00K 1% 1/4W	19701	5043ED1K000F	1	341300000
R39	RES MF 61.11 OHM 0.1% 1/2W	64537	PME65-T2	1	326998000
R40	RES MF 247.5 OHM 0.1% 1/2W	64537	PME65-T2	1	326995000
R41	RES MF 30.56 OHM 0.1% 1/2W	64537	PME65-T2	1	32699200A
R42	RES MF 247.5 OHM 0.1% 1/2W	64537	PME65-T2	1	326995000
R43	RES MF 61.11 OHM 0.1% 1/2W	64537	PME65-T2	1	326998000
R44	RES MF 6.19K 1% 1/4W	19701	5043ED6K190F	1	341376000
R45	RES MF 100 OHM 1% 1/4W	19701	5043ED100R0F	1	341200000
R46	RES MF 49.9 OHM 1% 1/4W	19701	5043ED49R90F	1	341167000
R47	RES MF 3.01K 1% 1/4W	19701	5043ED3K010F	1	341346000
R48	RES MF 100 OHM 1% 1/4W	19701	5043ED100R0F	1	341200000
R49	RES MF 1.50K 1% 1/4W	19701	5043ED1K500F	1	341317000
RT1	THERMISTOR 1.0K DISK RDL LEADS	00241	JB31J1	1	32501700A
U1	IC OP-16GJ OP AMP	06665	OP-16GJ	1	535048000
Y1	CRYSTAL 30 MHz QTZ 3RD HC-43/U	32897	30MHz HC18/V	1	547037000

04312700E PWA 4300 30 MHz OSCILLATOR
MODEL: 4321/4322

REFERENCE DESIGNATOR	DESCRIPTION	FED. CODE	MANUFACTURER PART NUMBER	QTY	BEC PART NUMBER
C1	CAP EL 10uF 20% 25V	S4217	SM-25-VB-10-M	1	283336000
C2-4	CAP CER 0.1uF 20% 50V	04222	SR215E104MAA	3	224268000
C5	CAP MICA 120pF 5% 100V	14655	CD5FC121J	1	205022000
C6-9	CAP CER 0.1uF 20% 50V	04222	SR215E104MAA	4	224268000
C10	CAP CER 0.01uF 10% 100V	04222	SR201C103KAA	1	224269000
C11	CAP MICA 10pF 5% 300V	14655	CD5WCC100J	1	205002000
C12	CAP VAR 6-55pF 250V GRN	91293	9305	1	281009000
C13	CAP CER 0.1uF 20% 50V	04222	SR215E104MAA	1	224268000
C14	CAP MICA 30pF 5% 300V	14655	CD5EC300J	1	205019000
C15	CAP MICA 390pF 5% 50V	14655	CD5FY391J	1	205028000
C16	CAP MICA 20pF 5% 300V	14655	CD5CC200J	1	205017000
C17	CAP MICA 51pF 5% 300V	57582	KD5510J301	1	205020000
C18	CAP MICA 10pF 5% 300V	14655	CD5WCC100J	1	205002000
C19	CAP CER 0.1uF 20% 50V	04222	SR215E104MAA	1	224268000
C20	CAP MICA 120pF 5% 100V	14655	CD5FC121J	1	205022000
C21-24	CAP CER 0.1uF 20% 50V	04222	SR215E104MAA	4	224268000
C25	CAP MICA 2.0pF +-0.5pF 300V	57582	KD05020D301	1	205054000
C26-27	CAP CER 0.001uF 10% 100V	04222	SR151C102KAA	2	224270000
C28	CAP CER 0.1uF 20% 50V	04222	SR215E104MAA	1	224268000
CR1	DIODE SIG 1N914	01295	1N914	1	530058000
CR2-3	DIODE SIG 5082-2800	28480	5082-2800	2	530122000
CR4-6	DIODE SIG 1N914	01295	1N914	3	530058000
CR7	DIODE ZENER 1N5230B 4.7V 5%	04713	1N5230B	1	530103000
CR8	DIODE SIG 1N914	01295	1N914	1	530058000
J46	CONN M 09 CKT SP PLZ .1CT	06383	MPAS100-9-A	1	47740909A
K1-3	RELAY DPDT 5V TO -5 CASE	11532	712-5	3	47105400A
L1	INDUCTOR 5.6uH 10%	24226	15/561	1	400308000
L2	INDUCTOR 0.27uH 10%	24226	10/270	1	400250000
L3	INDUCTOR 15uH 10%	24226	10M152K	1	400373000
L4	INDUCTOR 5.6uH 10%	24226	15/561	1	400308000
L5-6	INDUCTOR 2.2uH 10%	24226	10/221	2	400389000
L7-8	INDUCTOR 0.47uH 10%	24226	10/470	2	400368000
L9	INDUCTOR 0.27uH 10%	24226	10/270	1	400250000
Q1	TRANS NPN 2N3904	04713	2N3904	1	528071000
Q2	TRANS PNP 2N5194	04713	2N5194	1	528137000
Q3	TRANS NPN 2N5191	04713	2N5191	1	528136000
Q4	TRANS NPN 2N3904	04713	2N3904	1	528071000
Q5	TRANS NPN 2N3866	04713	2N3866	1	528116000
Q6-8	TRANS PNP 2N5194	04713	2N5194	3	528137000
Q9	TRANS NPN 2N5191	04713	2N5191	1	528136000
R1	RES MF 47.5K 1% 1/4W	19701	5043ED47K50F	1	341465000
R2	RES MF 150 OHM 1% 1/4W	19701	5043ED150R0F	1	341217000
R3	RES MF 100 OHM 1% 1/4W	19701	5043ED100R0F	1	341200000
R4	RES MF 10.0K 1% 1/4W	19701	5043ED10K00F	1	341400000
R5	RES MF 100 OHM 1% 1/4W	19701	5043ED100R0F	1	341200000
R6	RES MF 681 OHM 1% 1/4W	19701	5043ED681R0F	1	341280000
R7	RES MF 100 OHM 1% 1/4W	19701	5043ED100R0F	1	341200000
R8	RES MF 49.9 OHM 1% 1/4W	19701	5043ED49R90F	1	341167000
R9	RES MF 221 OHM 1% 1/4W	19701	5043ED221R0F	1	341233000
R10	RES MF 1.00K 1% 1/4W	19701	5043ED1K000F	1	341300000
R11	RES VAR 1M 10% 0.5W	73138	72XWR1M	1	31142300A
R12-13	RES MF 499K 1% 1/4W	19701	5043ED499K0F	2	341567000
R14-15	RES MF 10.0K 1% 1/4W	19701	5043ED10K00F	2	341400000
R16	RES COMP 12M 5% 1/4W	01121	CB1265	1	343708000
R17	RES MF 100K 1% 1/4W	19701	5043ED100K0F	1	341500000
R18	RES MF 1.21K 1% 1/4W	19701	5043ED1K210F	1	341308000
R19-22	RES MF 200 OHM 1% 1/4W	19701	5043ED200R0F	4	341229000
R23	RES MF 10.0K 1% 1/4W	19701	5043ED10K00F	1	341400000
R24	RES MF 1.00K 1% 1/4W	19701	5043ED1K000F	1	341300000
R25	RES MF 96.25 OHM 0.1% 1/2W	64537	PME65-T2	1	326996000
R26	RES MF 71.15 OHM 0.1% 1/2W	64537	PME65-T2	1	326997000
R27	RES MF 96.25 OHM 0.1% 1/2W	64537	PME65-T2	1	326996000
R28	RES MF 8.25K 1% 1/4W	19701	5043ED8K250F	1	341388000
R29	RES MF 3.01K 1% 1/4W	19701	5043ED3K010F	1	341346000
R30	RES MF 10.0K 1% 1/4W	19701	5043ED10K00F	1	341400000
R31	RES MF 1.00K 1% 1/4W	19701	5043ED1K000F	1	341300000
R32	RES MF 61.11 OHM 0.1% 1/2W	64537	PME65-T2	1	326998000
R33	RES MF 247.5 OHM 0.1% 1/2W	64537	PME65-T2	1	326995000
R34	RES MF 61.11 OHM 0.1% 1/2W	64537	PME65-T2	1	326998000
R35	RES MF 6.81K 1% 1/4W	19701	5043ED6K810F	1	341380000

SECTION 8
SCHEMATIC DIAGRAMS

AND COMPONENT LOCATION DIAGRAMS



SCHEMATIC, FRAME, CALIBRATOR
83150101A, SHEET 1

NOTES:
1. RESISTANCE VALUES IN OHMS UNLESS OTHERWISE SPECIFIED.
2. CAPACITANCE VALUES IN MICROFARADS UNLESS OTHERWISE SPECIFIED.
3. LAST NUMBERS USED ON THIS SHEET:
4. NUMBERS NOT USED:
5.
6. ACCOMODATES A GENERATOR ASSEMBLY OR OUTPUT ASSEMBLY, NOT BOTH.

Figure 8-1. Frame Schematic

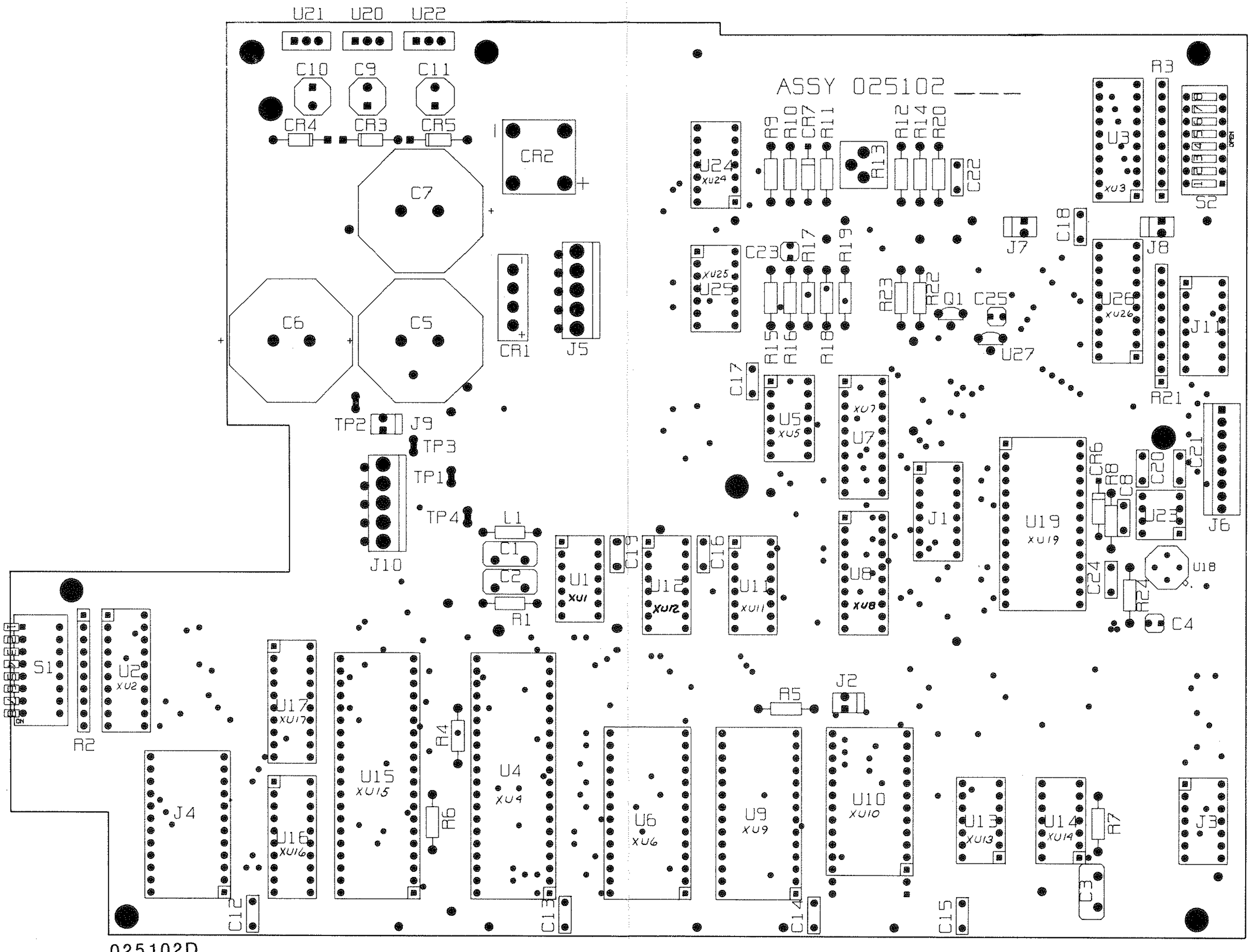
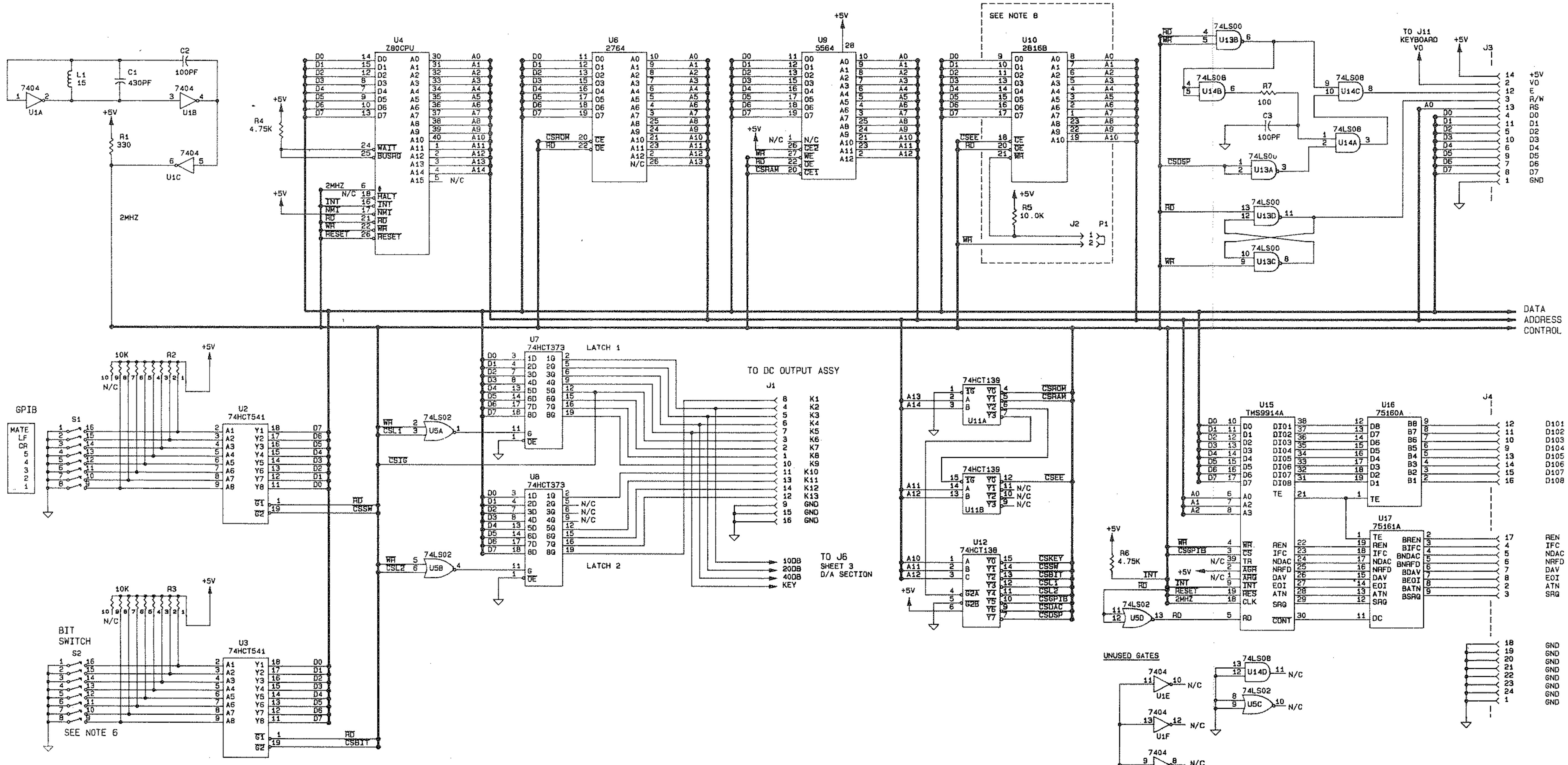


Figure 8-2. Control Component Location Diagram



SCHEMATIC, CONTROL (DIGITAL)
83150102A, SHEET 2

NOTES:
1. RESISTANCE VALUES IN OHMS UNLESS OTHERWISE SPECIFIED.
2. CAPACITANCE VALUES IN MICROFARADS UNLESS OTHERWISE SPECIFIED.
3. INDUCTANCE VALUES IN MICROHENRIES UNLESS OTHERWISE SPECIFIED.
4. LAST NUMBERS USED ON THIS SHEET: C3, J4, R7, S2, U17
5. NUMBERS NOT USED:
6. BIT SWITCH POSITION CONFIGURES FOR MODELS 2510 OR 2520 OPERATING AND CALIBRATION MODES.
7. BOXES ENCLOSE MARKINGS EXTERNAL TO ASSY. ▭
8. PARTS NOT USED ON MODEL 2510.

Figure 8-3. Control Schematic Sht 1

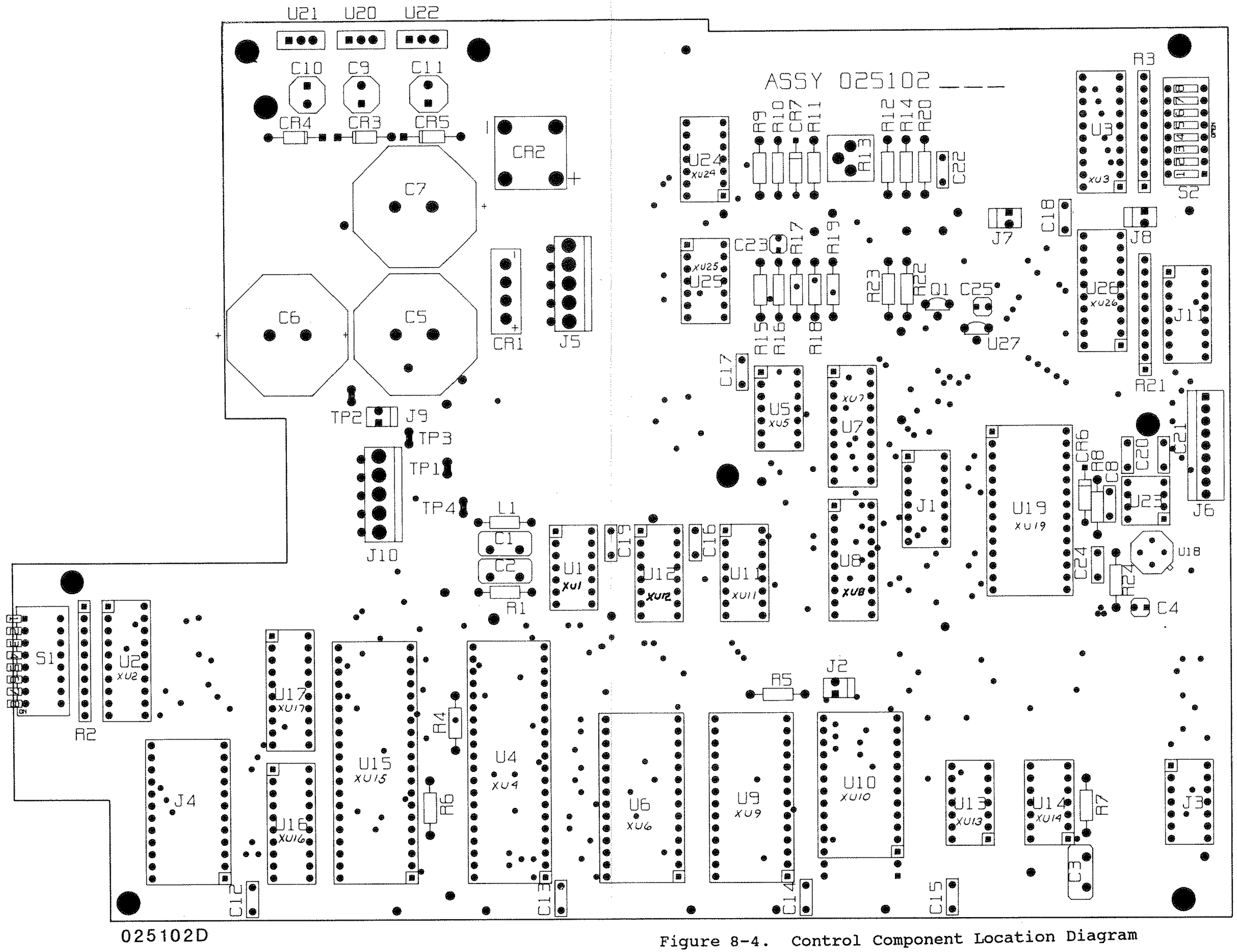
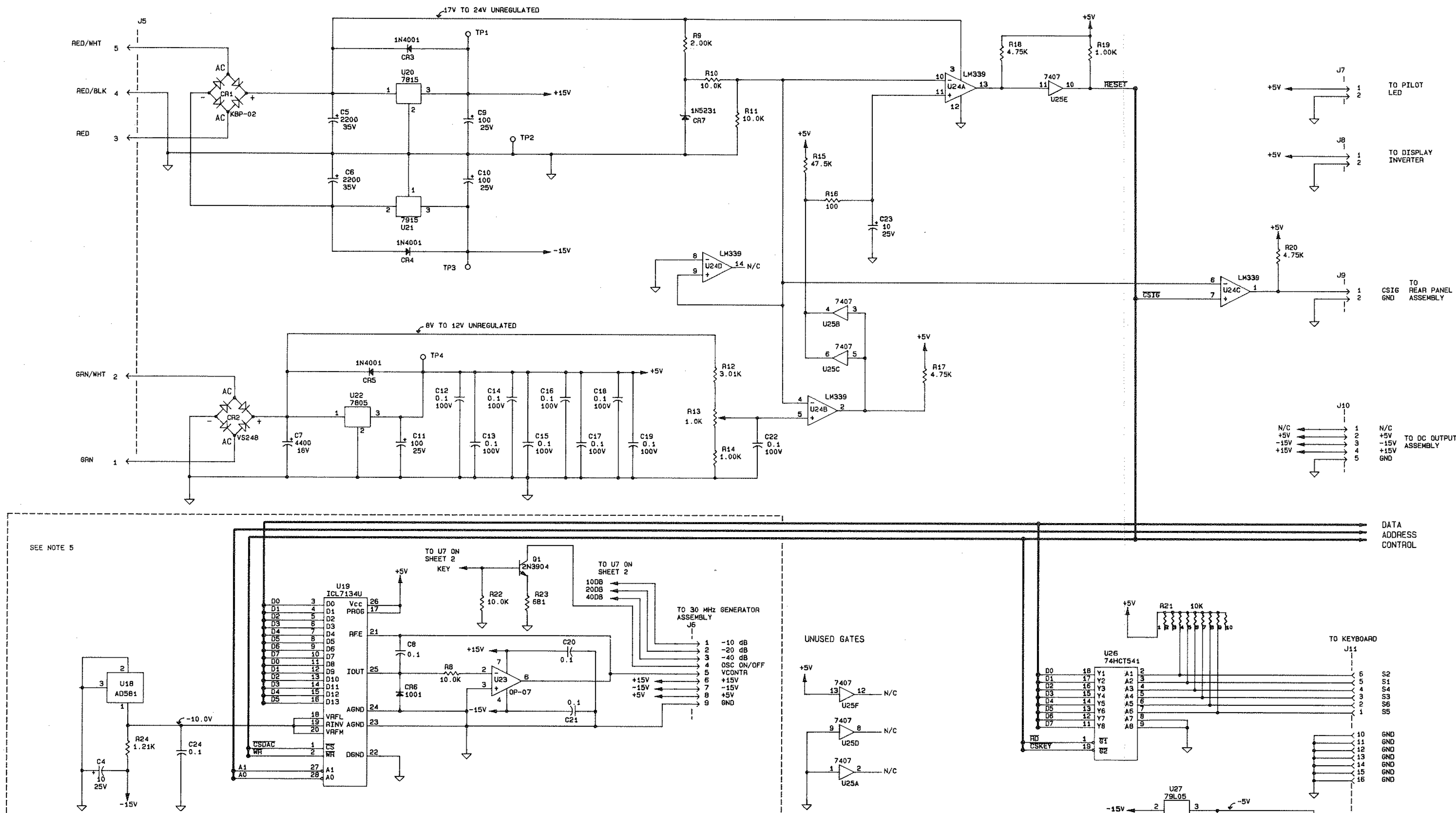


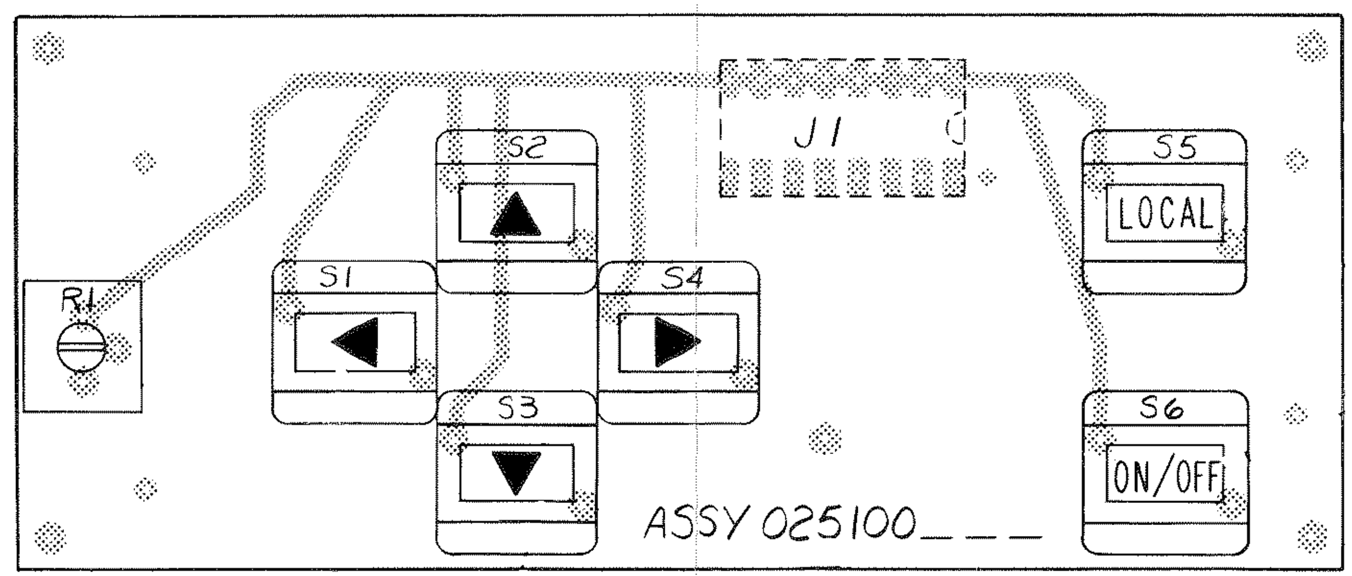
Figure 8-4. Control Component Location Diagram



SCHEMATIC, CONTROL (P/S)
83150103A, SHEET 3

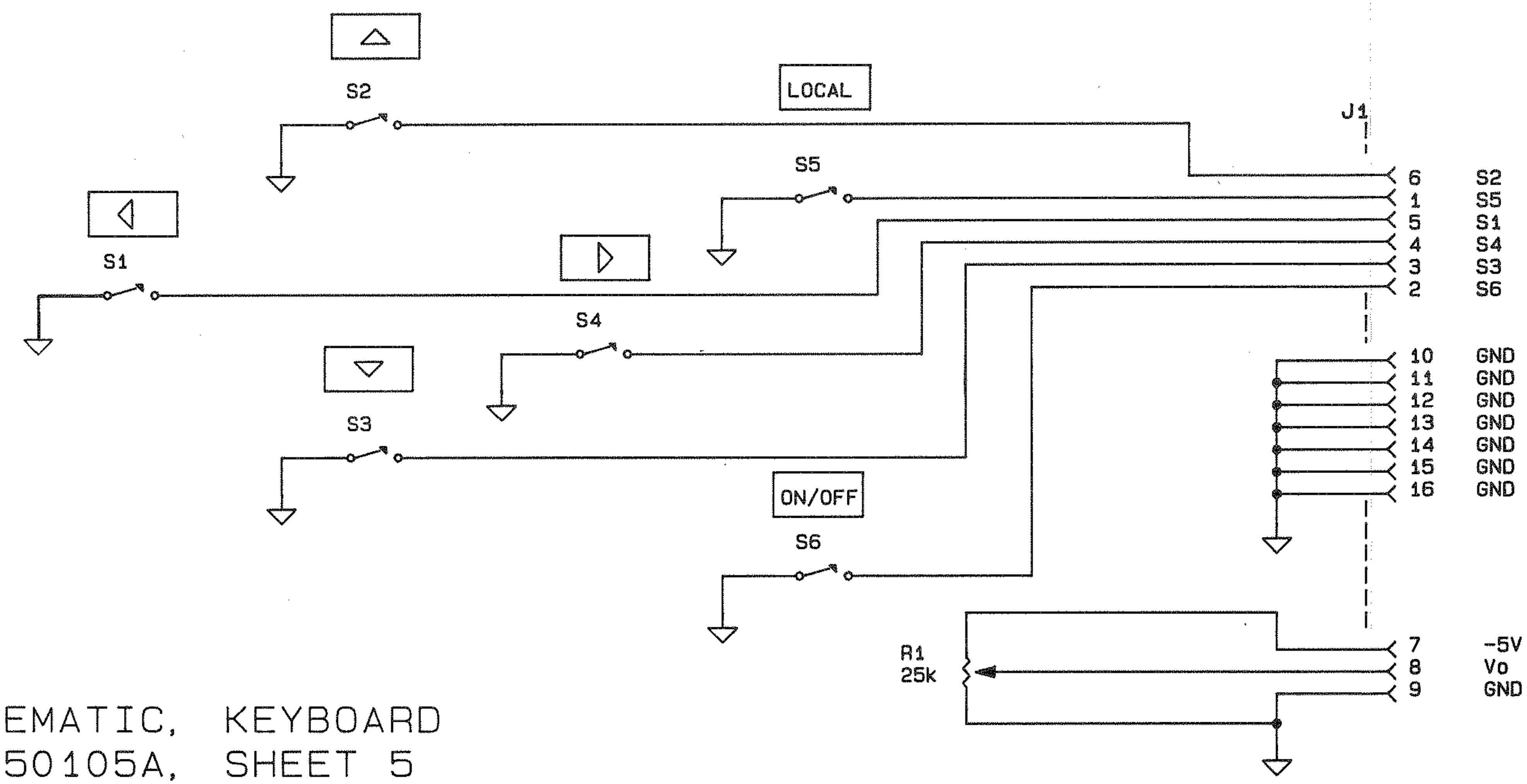
NOTES:
1. RESISTANCE VALUES IN OHMS UNLESS OTHERWISE SPECIFIED.
2. CAPACITANCE VALUES IN MICROFARADS UNLESS OTHERWISE SPECIFIED.
3. LAST NUMBERS USED ON THIS SHEET:
4. NUMBERS NOT USED:
5. THESE PARTS USED FOR ASSY 02510201* .

Figure 8-5. Control Schematic Sht 2



025100A

Figure 8-6. Keyboard Component Location Diagram



SCHEMATIC, KEYBOARD
83150105A, SHEET 5

NOTES:
1. RESISTANCE VALUES IN OHMS UNLESS OTHERWISE SPECIFIED.
2. CAPACITANCE VALUES IN MICROFARADS UNLESS OTHERWISE SPECIFIED.
3. LAST NUMBERS USED ON THIS SHEET: J1, R1, S6
4. NUMBERS NOT USED:
5. BOX DENOTES EXTERNAL MARKING.

Figure 8-7. Keyboard Schematic

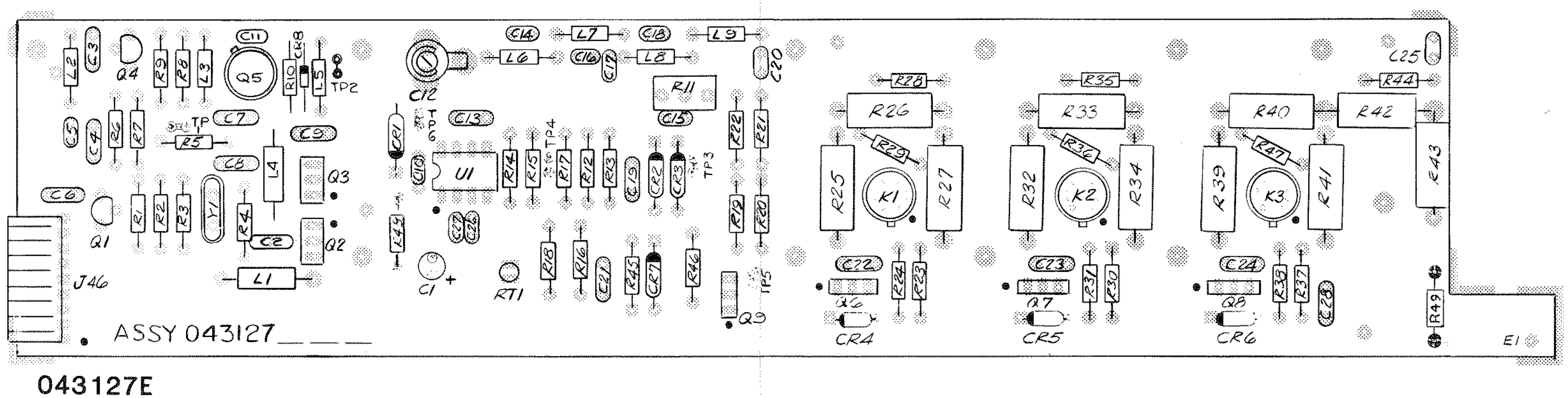
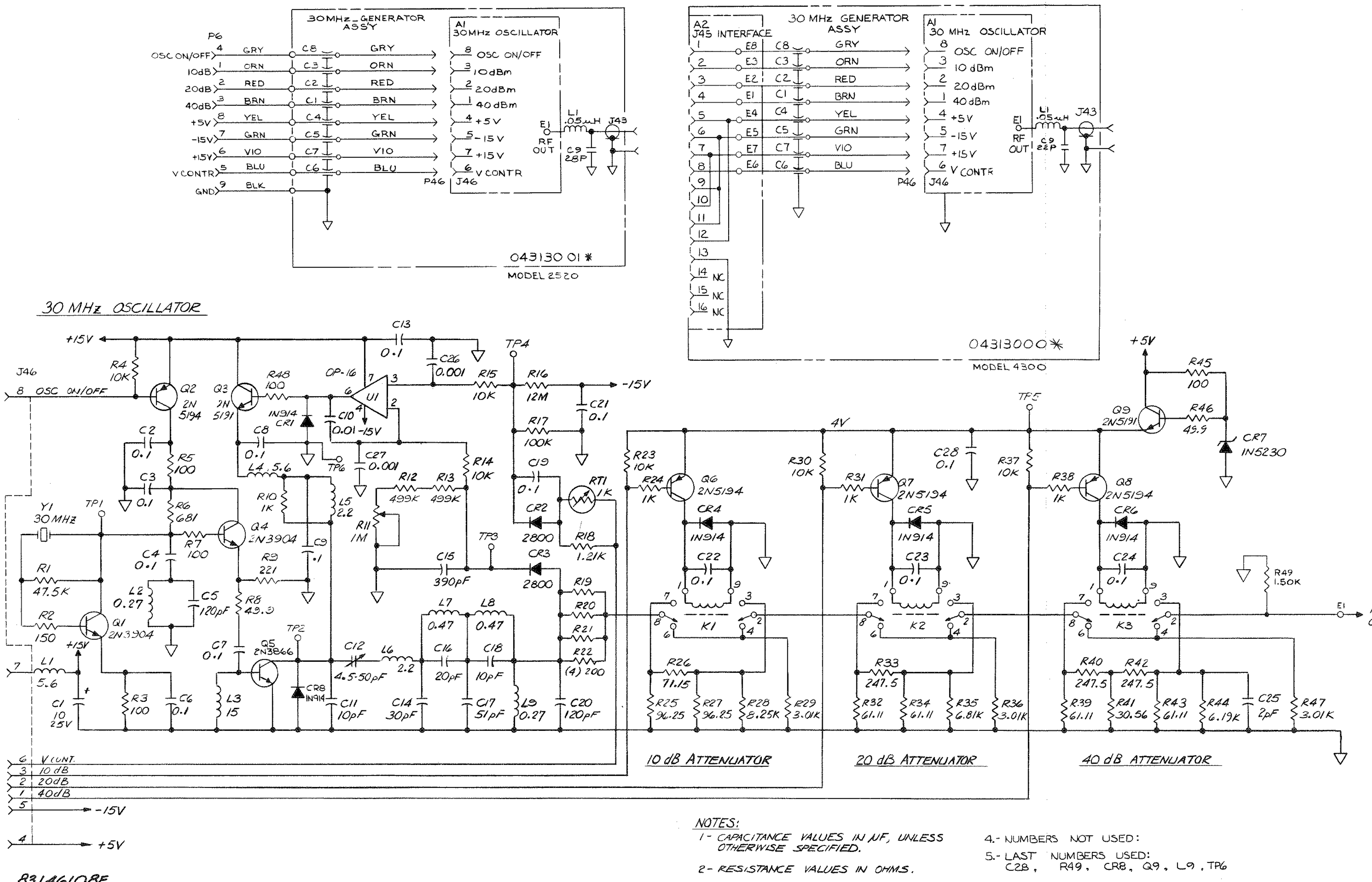


Figure 8-8. 30 MHz Oscillator Component Location Diagram



NOTES:
1- CAPACITANCE VALUES IN μF, UNLESS OTHERWISE SPECIFIED.
2- RESISTANCE VALUES IN OHMS.
3- INDUCTANCE VALUES IN MH.
4.- NUMBERS NOT USED:
5.- LAST NUMBERS USED: C28, R49, CR8, Q9, L9, TP6

Figure 8-9. 30 MHz Oscillator Schematic