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MODEL SR510
LOCK-IN AMPLIFIER

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SAFETY AND PREPARATION FOR USE

****CAUTION****

This instrument may be damaged if operated with the LINE VOLTAGE SELECTOR set for the wrong applied ac input-source voltage or if the wrong fuse is installed.

LINE VOLTAGE SELECTION

The SR510 operates from a 100V, 120V, 220V, or 240V nominal ac power source having a line frequency of 50 or 60 Hz. Before connecting the power cord to a power source, verify that the LINE VOLTAGE SELECTOR card, located in the rear panel fuse holder, is set so that the correct ac input voltage value is visible.

Conversion to other ac input voltages requires a change in the fuse holder voltage card position and fuse value. Disconnect the power cord, open the fuse holder cover door and rotate the fuse-pull lever to remove the fuse. Remove the small printed circuit board and select the operating voltage by orienting the printed circuit board to position the desired voltage to be visible when pushed firmly into its slot. Rotate the fuse-pull lever back into its normal position and insert the correct fuse into the fuse holder.

LINE FUSE

Verify that the correct line fuse is installed before connecting the line cord. For 100V and 120V, use a 1/2 Amp fuse and for 220V and 240V, use a 1/4 Amp fuse.

LINE CORD

This instrument has a detachable, three-wire power cord with a three-contact plug for connection to both the power source and protective ground. The protective ground contact connects to the accessible metal parts of the instrument. To prevent electrical shock, always use a power source outlet that has a properly grounded protective-ground contact.

OPERATE WITH COVERS IN PLACE

To avoid personal injury, do not remove the product covers or panels. Do not operate the product without all covers and panels in place.

WARNING REGARDING USE WITH PHOTOMULTIPLIERS

It is relatively easy to damage the signal inputs if a photomultiplier is used improperly with the lock-in amplifier. When left completely unterminated, a PMT will charge a cable to a few hundred volts in a very short time. If this cable is connected to the lockin, the stored charge may damage the front-end transistors. To avoid this problem, provide a leakage path of about 100 KΩ to ground inside the base of the PMT to prevent charge accumulation.

SR510 Specification Summary

General

Power	100, 120, 220, 240 Vac (50/60 Hz); 35 Watts Max
Mechanical	17" x 17" x 3.5" (Rack Mount Included) 12 lbs.
Warranty	Two years parts and labor.

Signal Channel

Inputs	Voltage:	Single-ended or True Differential
	Current:	10^6 Volts/Amp
Impedance	Voltage:	100 MΩ + 25 pF, ac coupled
	Current:	1 kΩ to virtual ground
Full Scale Sensitivity	Voltage:	100 nV (10 nV on expand) to 500 mV
	Current:	100 fA to 0.5 μA
Maximum Inputs	Voltage:	100 Vdc, 10 Vac damage threshold 2 Vac peak-to-peak saturation
	Current:	10 mA damage threshold 1 μA ac peak-to-peak saturation
Noise	Voltage:	7 nV/√Hz at 1 kHz
	Current:	0.13 pA/√Hz at 1 kHz
Common Mode	Range:	1 Volt peak; Rejection: 100 dB dc to 1KHz Above 1KHz the CMRR degrades by 6 dB/Octave
Gain Accuracy	1% (2 Hz to 100KHz)	
Gain Stability	200 ppm/°C	
Signal Filters	60 Hz notch, -50 dB (Q=10, adjustable from 45 to 65 Hz) 120 Hz notch, -50 dB (Q=10, adjustable from 100 to 130 Hz)) Tracking bandpass set to within 1% of ref freq (Q=5)	
Dynamic Reserve	20 dB	LOW (1 μV to 500 mV sensitivity) NORM (100 nV to 50 mV sensitivity) HIGH (100 nV to 5 mV sensitivity) Bandpass filter adds 20 dB to dynamic reserve Line Notch filters increase dynamic reserve to 100 dB
	40 dB	
	60 dB	

Reference Channel

Frequency	0.5 Hz to 100 kHz
Input Impedance	1 MΩ, ac coupled
Trigger	SINE: 100 mV minimum, 1Vrms nominal PULSE: ±1 Volt, 1 μsec minimum width
Mode	Fundamental (f) or 2nd Harmonic (2f)
Acquisition Time	25 Sec at 1 Hz 6 Sec at 10 Hz 2 Sec at 10 kHz

Slew Rate	1 decade per 10 S at 1 kHz
Phase Control	90° shifts Fine shifts in 0.025° steps
Phase Noise	0.01° rms at 1 kHz, 100 msec, 12 dB TC
Phase Drift	0.1°/°C
Phase Error	Less than 1° above 10Hz

Demodulator

Stability	5 ppm/°C on LOW dynamic reserve 50 ppm/°C on NORM dynamic reserve 500 ppm/°C on HIGH dynamic reserve
Time Constants	Pre: 1msec to 100 sec (6 dB/Octave) Post 1sec, 0.1 sec, none (6 dB/Octave) or none
Offset	Up to 1X full scale (10X on expand)
Harmonic Rej	-55 dB (bandpass filter in)

Outputs & Interfaces

Outputs	X (RcosØ), X Offset, Noise
Output Meter	2% Precision mirrored analog meter
Output LCD	Four digit auto-ranging LCD display shows same values as the analog meters
Output BNC	±10 V output corresponds to full scale input <1 Ω output impedance
Reference LCD	Four digit LCD display for reference phase shift or frequency
RS232	Interface controls all functions. Baud rates from 300 to 19.2 K
GPIB	Interface controls all functions. (IEEE-488 Std)
A/D	4 BNC inputs with 13 bit resolution (±10.24 V)
	2 BNC outputs with 13 bit resolution (±10.24 V)
Ratio	Ratio output equals 10X signal output divided by the Denominator input.
Internal Oscillator	Range: 1 Hz to 100 kHz, 1% accuracy Stability: 150 ppm/°C Distortion: 2% THD Amplitude: 1% accuracy, 500 ppm/°C stability

Front Panel Summary

Signal Inputs	Single Ended (A), True Differential (A-B), or Current (I)
Signal Filters	Bandpass: Q-of-5 Auto-tracking filter (In or Out) Line Notch: Q-of-10 Notch Filter at line frequency (In or Out) 2XLine Notch: Q-of-10 Notch Filter at twice line frequency (In or Out)
Sensitivity	Full scale sensitivity from 100 nV to 500 mV RMS for voltage inputs or from 100 fA to 500 nA RMS for current inputs.

Dynamic Reserve

Select	Dynamic Reserve	Stability	Sensitivity Ranges	
LOW	20 dB	5 ppm	1 μV	to 500 mV
NORM	40 dB	50 ppm	100 nV	to 50 mV
HIGH	60 dB	500 ppm	100 nV	to 5 mV

Status Indicators	OVLD Signal Overload UNLK PLL is not locked to the reference input ERR Illegal or Unrecognized command ACT RS232 or GPIB interface Activity REM Remote mode: front panel has been locked-out
Display Select	X Signal Amplitude at the selected phase (AcosØ) OFST Display the offset which is being added to the signal output NOISE Compute and display the noise on the signal
Analog Meters	Displays Signal, Offset, or Noise as a fraction of full scale
Output LCD's	Displays Signal, Offset, or Noise in absolute units
Output BNC's	Output follows Analog Meters, ± 10 V for ± full scale
Expand	Multiplies the Analog Meter and Output voltage by a factor X1 or X10.
REL	Set the Offset to null the output: subsequent readings are relative readings.
Offset	Enables or Disables Offset, and allows any offset (up to full scale) to be entered.
Time Constants	Pre-filter has time constants from 1 mS to 100 S (6 dB/Octave) Post-filter has time constants of 0, 0.1 or 1.0 S (6 dB/Octave)
ENBW	Equivalent Noise Bandwidth. Specifies the bandwidth when making Noise measurements. (1Hz or 10 Hz ENBW)
Reference Input	1 MΩ Input, 0.5 Hz to 100 KHz, 100 mV minimum
Reference Trigger	Trigger on rising edge, zero crossing, or falling edge
f/2f Mode	PLL can lock to either X1 or X2 of the reference input frequency
Phase Controls	Adjust phase in smoothly accelerating 0.025° steps, or by 90° steps. Press both 90° buttons to zero the phase.
Reference LCD	Display reference phase setting or reference frequency
Power Switch	Instrument settings from the last use are recalled on power-up

Abridged Command List

A	Return the 'REL' Status
A0	Turn the 'REL' off
A1	Turn the 'REL' on
B	Return Bandpass Filter Status
B0	Take out the Bandpass Filter
B1	Put in the Bandpass Filter
C	Return the Reference LCD Status
C0	Display the Reference Frequency
C1	Display the Reference Phase Shift
D	Return Dynamic Reserve Setting
D0	Set DR to LOW range
D1	Set DR to NORM range
D2	Set DR to HIGH range
E	Return Expand Status
E0	Turn the Expand off
E1	Turn the Expand on
F	Return the Reference Frequency
G	Return the Sensitivity Setting
G1	Select 10 nV Full-Scale (G1-G3 with SRS preamp only)
G24	Select 500 mV Full-Scale
H	Return Preamp Status (1=installed)
I	Return the Remote/Local Status
I0	Select Local : Front panel active
I1	Select Remote: Front panel inactive
I2	Select Remote with full lock-out
J	Set RS232 End-of-Record to <cr>
Jn,m,o,p	Set End-of-record to n,m,o,p
K1	Simulates Key-press of button #1
...	(see un-abridged command list)
K27	Simulates Key-press of button #32
L1	Return Status of Line Notch Filter
L1,0	Remove Line Notch Filter
L1,1	Insert Line Notch Filter
L2	Return Status of 2XLine Filter
L2,0	Remove 2XLine Notch Filter
L2,1	Insert 2XLine Notch Filter
M	Return the f/2f Status
M0	Set reference mode to f
M1	Set reference mode to 2f
N	Return the ENBW setting
N0	Select 1 Hz ENBW
N1	Select 10 Hz ENBW
O	Return the Offset Status
O0	Turn off the Offset
O1,v	Turn on the Offset, v = offset
P	Return the Phase Setting
Pv	Set the Phase to v. Abs(v)< 999 deg
Q	Return the value shown on the Output LCD
R	Return the trigger mode
R0	Set the trigger for rising edge
R1	Set the trigger for + zero crossing
R2	Set the trigger for falling edge
S	Return the display status
S0	Display X = AcosØ
S1	Display Offset setting
S2	Display Noise
T1	Return pre-filter setting
T1,1	Set the pre-filter TC to 1 mS
...	
T1,11	Set the pre-filter TC to 100 S
T2	Return the post-filter setting
T2,0	Remove post filter
T2,1	Set the post filter TC to 0.1 S
T2,2	Set the post filter TC to 1.0 S
V	Return the value of the SRQ mask
Vn	Set the SRQ Mask to the value n (See the Status Byte definition)
W	Return the RS232 wait interval
Wn	Set RS232 wait interval to nX4mS
Xn	Return the voltage at the rear panel analog port n. (n from 1 to 6)
X5,v	Set analog port 5 to voltage v
X6,v	Set analog port 6 to voltage v
Y	Return the Status Byte value
Yn	Test bit n of the Status Byte
Z	Reset to default settings and cancel all pending commands.

Abridged Command List

A	Return the 'REL' Status
A0	Turn the 'REL' off
A1	Turn the 'REL' on
B	Return Bandpass Filter Status
B0	Take out the Bandpass Filter
B1	Put in the Bandpass Filter
C	Return the Reference LCD Status
C0	Display the Reference Frequency
C1	Display the Reference Phase Shift
D	Return Dynamic Reserve Setting
D0	Set DR to LOW range
D1	Set DR to NORM range
D2	Set DR to HIGH range
E	Return Expand Status
E0	Turn the Expand off
E1	Turn the Expand on
F	Return the Reference Frequency
G	Return the Sensitivity Setting
G1	Select 10 nV Full-Scale (G1-G3 with SRS preamp only)
G24	Select 500 mV Full-Scale
H	Return Preamp Status (1=installed)
I	Return the Remote/Local Status
I0	Select Local : Front panel active
I1	Select Remote: Front panel inactive
I2	Select Remote with full lock-out
J	Set RS232 End-of-Record to <cr>
Jn,m,o,p	Set End-of-record to n,m,o,p
K1	Simulates Key-press of button #1
...	(see un-abridged command list)
K27	Simulates Key-press of button #32
L1	Return Status of Line Notch Filter
L1,0	Remove Line Notch Filter
L1,1	Insert Line Notch Filter
L2	Return Status of 2XLine Filter
L2,0	Remove 2XLine Notch Filter
L2,1	Insert 2XLine Notch Filter
M	Return the f/2f Status
M0	Set reference mode to f
M1	Set reference mode to 2f
N	Return the ENBW setting
N0	Select 1 Hz ENBW
N1	Select 10 Hz ENBW
O	Return the Offset Status
O0	Turn off the Offset
O1,v	Turn on the Offset, v = offset
P	Return the Phase Setting
Pv	Set the Phase to v. Abs(v)< 999 deg
Q	Return the value shown on the Output LCD
R	Return the trigger mode
R0	Set the trigger for rising edge
R1	Set the trigger for + zero crossing
R2	Set the trigger for falling edge
S	Return the display status
S0	Display X = AcosØ
S1	Display Offset setting
S2	Display Noise
T1	Return pre-filter setting
T1,1	Set the pre-filter TC to 1 mS
...	
T1,11	Set the pre-filter TC to 100 S
T2	Return the post-filter setting
T2,0	Remove post filter
T2,1	Set the post filter TC to 0.1 S
T2,2	Set the post filter TC to 1.0 S
V	Return the value of the SRQ mask
Vn	Set the SRQ Mask to the value n (See the Status Byte definition)
W	Return the RS232 wait interval
Wn	Set RS232 wait interval to nX4mS
Xn	Return the voltage at the rear panel analog port n. (n from 1 to 6)
X5,v	Set analog port 5 to voltage v
X6,v	Set analog port 6 to voltage v
Y	Return the Status Byte value
Yn	Test bit n of the Status Byte
Z	Reset to default settings and cancel all pending commands.

Status Byte Definition

Bit	Meaning
0	Unprocessed commands are pending
1	Command Parameter is out-of-range
2	No detectable reference input
3	PLL is not locked to the reference
4	Signal Overload
5	Auto-offsat failed: signal too large
6	SRQ generated
7	Unrecognized or illegal command

Configuration Switches

There are two banks of 8 switches, SW1 and SW2, located on the rear panel. SW1 sets the GPIB address and SW2 sets the RS232 parameters. The configuration switches are read continuously and any changes will be effective immediately.

SW1:GPIB Mode Switches

Bit	Example	Function
1 }	up	GPIB Address Switches
2 }	up	Address 0 to 30 allowed
3 }	up	'up' for bit = 1
4 }	down	'down' for bit = 0
5 }	up	(Most Significant Bit)
6	down	'down' to echo on RS232 (normally 'up')
7	up	Not Used
8	up	Not Used

If the GPIB mode switches are set as shown in the example column above, then the lockin will be addressed as GPIB device #23, and all GPIB commands and data will be echoed over the RS232 for de-bugging purposes.

SW2:RS232 Mode Switches

Bit 1	Bit 2	Bit 3	Baud Rate
up	up	up	19200
down	up	up	9600
up	down	up	4800
down	down	up	2400
up	up	down	1200
down	up	down	600
up	down	down	300

Bit	Setting	Explanation
4	up	Odd parity
	down	Even parity
5	up	No parity
	down	Parity enabled
6	up	No echo (for computer)
	down	Echo mode (for terminal)
7	up	Two stop bits
	down	One stop bit
8		unused

Eight data bits are always sent, regardless of the parity setting. The most significant bit is always zero.

Example: Bit 1 'down' and all others 'up' for RS232 communication at 9600 baud, no parity, two stop bits, and no echo or prompts by the SR510.

SR510 Guide to Operation
Front Panel

The front panel has been designed to be almost self explanatory. The effect of each keypress is usually reflected in the change of a nearby LED indicator or by a change in the quantity shown on a digital display. This discussion explains each section of the front panel, proceeding left to right.

Signal Inputs

There are three input connectors located in the **SIGNAL INPUT** section of the front panel. The rocker switch located above the **B** input selects the input mode, either single-ended, **A**, differential, **A-B**, or current, **I**.

The **A** and **B** inputs are voltage inputs with 100 MΩ, 25 pF input impedance. Their connector shields are isolated from the chassis ground by 10 Ω. These inputs are protected to 100V dc but the ac input should never exceed 10V peak. The max ac input before overload is 1V peak.

The **I** input is a current input with an input impedance of 1 KΩ to a virtual ground. The largest allowable dc current before overload is 1 μA. No current larger than 10 mA should ever be applied to this input. The conversion ratio is 10^6 V/A, thus, the full scale current sensitivities range from 100 fA to 500 nA with a max ac input before overload of 1 μA peak. You should use short cables when using the current input.

Signal Filters

There are three user selectable signal filters available; a line frequency notch, a 2X line frequency notch, and an auto-tracking bandpass. Each of the filters has a pair of indicator LED's and a function key located in the **SIGNAL FILTERS** section of the front panel. Pressing a key will toggle the status of the appropriate filter. The status of each filter is displayed as **IN**, filter active, or **OUT**, filter inactive.

The notch filters have a Q of 10 and a depth of at least 50 dB. Thus, the line frequency notch is 6 Hz wide and the 2X line notch has a width of 12 Hz. Both of these filters can increase the dynamic reserve an additional 50 dB at the notch frequencies. The achievable reserve is limited by the maximum allowable signals at the inputs. The notch frequencies are set at the factory to either 50 Hz or 60 Hz. The user can adjust these frequencies. (See the Maintenance and Repair section for alignment details.) These filters precede the bandpass filter in the signal amplifier.

The bandpass filter has a Q of 5 and a 6 dB roll off in either direction. Thus, the pass band (between 70% pass points) is always equal to 1/5th of the center frequency. The center frequency is continually adjusted to be equal to the internal demodulator frequency. When the reference mode is f, the filter tracks the reference. When the mode is 2f, the filter frequency is twice the reference input frequency. The center frequency tracks as fast as the reference oscillator can slew and may be used during frequency scans. The bandpass filter adds up to 20 dB of dynamic reserve for noise signals outside the pass band, and increases the harmonic rejection by at least 13dB. (2nd harmonic attenuated by 13 dB, higher harmonics attenuated 6dB/octave more.) If not needed to improve the dynamic reserve or the harmonic rejection then the filter should be left **OUT**.

Sensitivity

The sensitivity is displayed as a value (1-500) and a scale (nV, μV, mV). When using the current input, which has a gain of 10^6 V/A, these scales are read fA, pA, and nA respectively. The two keys in the **SENSITIVITY** section move the sensitivity up and down. If either key is held down, the sensitivity will continue to change in the desired direction.

The full scale sensitivity can range from 100 nV to 500 mV. The sensitivity indication is not changed by the **EXPAND** function. The **EXPAND** function will increase the output sensitivity by 10 (Volts out /volts in) and increase the resolution of the digital output display.

Not all dynamic reserves are available at all sensitivities. If the sensitivity is changed to a setting for which the dynamic reserve is not allowed, the dynamic reserve will change to the next setting which is allowed. Sensitivity takes precedence over the dynamic reserve. The sensitivity range of each dynamic reserve is shown below.

Dynamic Reserve	Sensitivity Range
LOW	1 μV through 500 mV
NORM	100 nV through 50 mV
HIGH	100 nV through 5 mV

Dynamic Reserve

The dynamic reserve (DR) is set using the keys in the **DYNAMIC RESERVE** section. The reserve

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LOW	1 μV through 500 mV
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Dynamic Reserve

The dynamic reserve (DR) is set using the keys in the **DYNAMIC RESERVE** section. The reserve

REL function is turned off using the **REL** key, the offset is turned off but the value is not lost. If the manual **OFFSET** is now turned **ON**, the offset will be that set by the **REL** function.

Offset

The **OFFSET** section controls the manual **OFFSET**. The offset is turned **ON** and **OFF** using the upper key in the **OFFSET** section. When the offset is **ON**, the lower two keys are used to set the amount of offset. A single key press will advance the offset by 0.025% of full scale. If the key is held down, the offset advances in larger and larger increments, the largest increment being 10% of full scale. When the offset is turned **OFF** the applied offset returns to zero but the offset value is not lost. The next press of the upper offset key (returns to **ON**) sets the offset to the previously entered value.

If an attempt is made to advance the offset value beyond full scale, the **OFFSET ON** LED will blink. An offset up to 1.024 times the full scale sensitivity may be entered. When the expand is on, this is 10X the full scale output.

If the **REL** function is **ON** when the manual **OFFSET** is turned **ON**, the **REL** function is turned **OFF** but the offset value remains the same. The **OFFSET** keys may now be used to adjust this offset value.

Note that the offsets (either manual offset or those generated by the **REL** function) represent a fraction of the full scale reading, and so their absolute value will change when the sensitivity scale is changed. A signal which has been nulled by an offset will not be nulled when the sensitivity scale is changed. The analog meter and the output BNC indicate the value given by the equation:

$$V_{out} = 10A_e(A_V V_i \cos\varnothing - V_{os})$$

where...

- A_e = 1 or 10 depending on the Expand setting
- A_V = 1/Sensitivity
- V_i = magnitude of the signal
- $\varnothing$ = phase between signal & reference
- V_{os} = offset (fraction of FS < 1.024)

Time Constant

There are two post demodulator low pass filters, labeled **PRE** and **POST**. The **PRE** filter precedes the **POST** filter in the output amplifier. Each filter provides 6 dB/oct attenuation.

The **PRE** filter time constant ranges from 1 **mS** to **100 S** and is selected by the two keys below the **PRE** filter indicator LED's. Holding down either key will advance the time constant twice a second in the desired direction.

The **POST** filter time constant can be set to **1 S** or **0.1 S**, or can be removed altogether, **NONE**, using the two keys below the **ENBW** indicators. When set to **NONE**, the total attenuation is that of the **PRE** filter, or 6 dB/oct. When the **POST** filter is **1 S** or **0.1S**, the total attenuation is 12 dB/oct for frequency components beyond the larger of the **POST** and **PRE** filter bandwidths (reciprocal time constant).

Noise

When the **DISPLAY** is set to **NOISE**, none of the **PRE** and **POST** indicator LED's are on. Instead, one of the two **ENBW** indicators will be on, showing the Equivalent Noise Bandwidth of the rms noise calculation. The **ENBW** is set using the keys below the **ENBW** indicator LED's (same keys as used to set the **POST** filter). The **PRE** filter keys do nothing in this case. Pressing the upper key when the bandwidth is already **1 Hz** will reset the rms noise average (output) to zero, restarting the calculation. Likewise with pressing the lower key when **10 Hz** is already selected.

The noise is the rms deviation of the output within a 1 or 10 Hz equivalent noise bandwidth at the reference frequency. A dc output does not contribute to the noise, the noise is determined only by the ac 'wiggles' at the output. By measuring the noise at different frequencies, the frequency dependence of the noise density can be found. This usually has the form of $v_{noise} \sim 1/f$. The noise computation assumes that the noise has a Gaussian distribution (such as Johnson noise). Since the computation takes many time constants (reciprocal bandwidth), the noise output should be allowed to approach a steady value before a reading is taken. For the 1 Hz ENBW, this time is on the order of 15 to 30 seconds; for the 10 Hz ENBW, the output stabilizes much faster. The noise output will change since there will always be noise variations that are slow compared to the bandwidth. Any DC component in the output will not contribute to the noise. However, a large DC output will cause the noise computation to initially rise to a large value before approaching the final answer. As a result, the computation will take longer to settle.

To obtain a value for the noise density, the noise reading should be divided by the square root of

the ENBW. Thus, when the ENBW is 1 Hz, the noise output is the noise density, and when the ENBW is 10 Hz, the noise density is the noise output divided by √10. For example, if the input noise is measured to be 7 nV with the ENBW set to 1 Hz, the noise density is 7 nV/√Hz. Switching the ENBW to 10 Hz results in a faster measurement and a reading of 22 nV on the output. The noise density is 22 nV/√10 Hz or 7 nV/√Hz. At frequencies » 10 Hz, the noise density should be independent of the ENBW.

Reference and Trigger Level

The **REFERENCE INPUT BNC** is located in this section. The input is ac coupled and the impedance is 1 MΩ. The dc voltage at this input should not exceed 100 V and the largest ac signal should be less than 10 V peak. The three indicators above the input BNC display the **TRIGGER MODE**. The single key above the input BNC is used to select the **TRIGGER MODE**.

If the center **TRIGGER MODE** LED is on, the mode is **SYMMETRIC** and the reference oscillator will lock to the positive zero crossings of the ac reference input. The ac signal must be symmetric (e.g. sine wave, square wave, etc.) and have a peak to peak amplitude greater than 100 mV. A signal with 1 Vrms amplitude is recommended. The phase accuracy of the reference channel is specified for a 1Vrms sinewave in the symmetric trigger mode.

If the upper **TRIGGER MODE** LED is on, the mode is **POSITIVE**. The trigger threshold is +1V and the reference oscillator will lock to the positive going transitions of the reference input. This mode triggers on the rising edges of a TTL type pulse train. The pulse width must be greater than 1 µS.

If the lower **TRIGGER MODE** LED is on, the mode is **NEGATIVE**. The trigger threshold is -1V and the reference oscillator will lock to the negative going transitions of the reference input. This mode triggers on a negative pulse train or on the falling edges of a TTL type pulse train (remembering that the input is ac coupled). The pulse width must be greater than 1 µS.

Above the **TRIGGER MODE** indicators are the **REFERENCE MODE** LED's. The key below the **REFERENCE MODE** indicators toggles between **f** and **2f**. When the **MODE** is **f**, the lock-in will detect signals at the reference input frequency. When the **MODE** is **2f**, the lock-in detects signals at twice the reference input frequency. In either case, the reference oscillator has a maximum frequency of 100 KHz, thus, when in the **2f** mode, the reference input frequency may not exceed 50 KHz.

The **REFERENCE DIGITAL DISPLAY** shows either the reference oscillator frequency or phaseshift. The displayed parameter toggles between the two whenever the **SELECT** key is pressed. The appropriate scale indicator below the display will be on. It is useful to check the frequency display to verify that the lock-in has correctly locked to your reference. The reference frequency is measured to 1 part in 256 resolution.

Phase Controls

The phase shift between the reference oscillator and the reference input is set using the four keys in the **PHASE** section. The two keys below the **FINE** label increment the phase setting in small amounts. A single key press will change the phase by 0.025 degrees in the desired direction. Holding the key down will continue to change the phase with larger and larger steps with the largest step being 10 degrees. The two **90°** keys are used to change the phase by 90 degree increments. The upper key will add 90 degrees and the lower key will subtract 90 degrees. Holding both keys down at once sets the phase shift back to zero. The **REFERENCE DIGITAL DISPLAY** automatically displays the phase whenever any of the **PHASE** keys are pressed. The phase ranges from -180 degrees to +180 degrees and is the phase delay from the reference input signal.

Power

This is the instrument's **POWER** switch. When the power is turned off, the front panel settings are retained so that the instrument will return to the same settings when the power is next turned on.

When the power is turned on, the **OUTPUT DIGITAL DISPLAY** will show the **SERIAL NUMBER** of the instrument and the **REFERENCE DISPLAY** will show the firmware **VERSION**. Both displays return to normal after 2 seconds.

Local and Remote

When the instrument is programmed via the computer interface to be in the **REMOTE** state **WITHOUT LOCK-OUT**, the **DISPLAY UP** key will return the instrument to **LOCAL** front panel control. If the instrument is in the **REMOTE WITH LOCK-OUT** state, no front panel key will return the status to **LOCAL**. In this case, a

RETURN to LOCAL command must be sent over the computer interface or the power must be turned off and back on.

Defaults

If the **REL** key is held down when the **POWER** is turned on, the instrument settings will be set to the defaults shown below instead of the settings in effect when the power was turned off.

Parameter	Setting
BANDPASS	OUT
LINE	OUT
LINE X 2	OUT
SENSITIVITY	500 mV
DYN RES	LOW
DISPLAY	X
EXPAND	OFF
REL	OFF
OFFSET	OFF (value=0)
PRE TIME CONSTANT	100 mS
POST TIME CONSTANT	0.1 S
ENBW	1 Hz
REFERENCE MODE	f
TRIGGER MODE	SYMMETRIC
REFERENCE DISPLAY	FREQUENCY
PHASE	0°

Whenever default values are used at power up, the red **ERR** LED will turn on for about 2 seconds. If the **ERR** LED is on when the instrument is powered on without the **REL** key down, then the instrument is ignoring the retained settings. This can be due to a low battery.

SR510 Guide to Operation
Rear Panel

AC Power

The ac line voltage selector card, line fuse, and line cord receptacle are located in the fuse holder at the left side of the rear panel. See the section, **Preparation for Use** at the front of this manual for instructions on setting the ac voltage selector and choosing the correct fuse.

GPIB Connector

The SR510 has an IEEE 488 (GPIB) interface built in. The GPIB address is set using **SW1** located to the right of the interface connectors. Refer to page 6 for switch setting details.

RS232 Connector

The SR510 has an RS232 interface. The connector is configured as a **DCE**. The baud rate, parity, stop bits, and echo mode are selected using **SW2** located to the right of the interface connectors. Refer to Page 6 for switch setting details.

Signal Monitor Output

This BNC provides the buffered output of the signal amplifiers and filters. This is the signal just before the demodulator. The output impedance is <1 Ω. When a full scale input is applied, the peak-to-peak amplitude at this output is 20 mV, 200 mV or 2 V for dynamic reserve settings of high, norm, and low, respectively.

Preamp Connector

This 9 pin "D" connector provides power and control signals to external peripherals such as pre-amplifiers. The available power is described below.

Pin	Voltage	Current Available
1	+20	100 mA
2	+5	10 mA
6	-20	100 mA
7	Signal ground	
8	Digital ground	

General Purpose A/D and D/A

There are four analog input ports, labeled **X1** through **X4**. These inputs may be digitized and read via the computer interfaces. The range is -10.24 V to +10.24 V and the resolution is 0.0025 V. The input impedance is 1 MΩ. A digitization can be performed in about 1 mS but the result may take longer to transmit over the interface being used.

There are two analog output ports, labeled **X5** and **X6**. The voltages at these ports may be programmed via the computer interfaces. The range is -10.24 V to +10.24 V and the resolution is 0.0025 V. The output impedance is <1 Ω and the output current is limited to 20 mA.

Ratio

Output **X5** is the ratio output when not programmed by the computer interface. **X5** becomes the ratio output whenever the unit is turned on.

The voltage at **X5** is the ratio of the detected signal output, **X**, to the analog voltage at port **X1**. An output of 10 V corresponds to a ratio of 1. The ratio is computed by digitizing the demodulator output and the voltage at port **X1** and then taking the ratio. The resolution is 0.0025 V. For best accuracy, the sensitivity should be set to provide at least a 50% full scale signal and the analog denominator (**X1**) should be 5V or greater. The ratio is updated approximately every 1.5 mS. For the Ratio feature to work, the voltage at the denominator input must exceed 40 mV.

Internal Oscillator

The **INTERNAL OSCILLATOR** is a voltage controlled oscillator with a sine wave output . To use the oscillator as the reference source, connect the **REF OUTPUT** on the rear panel to the **REF INPUT** on the front panel. The **REF OUTPUT** is a 1 Vrms sine wave. The **SINE OUTPUT** may be used as the stimulus to the experiment. The **SINE OUTPUT** can be set to three amplitudes, 1 V, 100 mV, and 10 mV (rms) using the amplitude switch. The output impedance is 600 Ω. The **AMP CAL** screw adjusts the amplitude.

The oscillator frequency is controlled by the **VCO INPUT** voltage. A voltage from 0V to 10V will adjust the frequency according to the **VCO RANGE** selected. Three ranges are available, 1 Hz/V, 100 Hz/V, and 10 KHz/V. The input impedance is 10 kΩ. The **FREQUENCY CAL**

screw adjusts the frequency.

There are four ways to set the frequency:

1) Connect **X5** or **X6** (D/A outputs) to the **VCO INPUT**. The frequency is now controllable via the computer interfaces.

2) If the **VCO INPUT** is left open, then the oscillator will run at the top of its range (i.e. 10 Hz, 1 KHz, or 100 KHz).

3) A 10 KΩ potentiometer may be connected from the **VCO INPUT** to ground. This pot will then set the frequency.

4) Connect the VCO INPUT to an external voltage source which can provide 0 to 10V.

In all four cases, if the **REF OUTPUT** is connected to the **REF INPUT** on the front panel, the frequency may be read on the front panel **REFERENCE DIGITAL DISPLAY** or via the computer interfaces.

SR510 Guide to Programming

The SR510 Lock-in Amplifier is remotely programmable via both RS232 and GPIB interfaces. It may be used with laboratory computers or simply with a terminal. All front panel features (except signal input selection and power) may be controlled and read via the computer interfaces. The SR510 can also read the analog outputs of other laboratory instruments using its four general purpose analog input ports. There are also two programmable analog output ports available to provide general purpose control voltages.

Communicating with the SR510

Before using either the RS232 or GPIB interface, the appropriate configuration switches need to be set. There are two banks of 8 switches, **SW1** and **SW2**, located on the rear panel. **SW1** sets the GPIB address and **SW2** sets the RS232 parameters. The configuration switches are read continuously and any changes will be effective immediately. For details on switch settings, see page 6 at the front of this manual.

Command Syntax

Communications with the SR510 are done using ASCII characters. Commands to the SR510 may be in either UPPER or lower case.

A command to the SR510 consists of a single command letter, arguments or parameters if necessary, and an ASCII carriage return (<cr>) or linefeed (<lf>) or both. The different parts of the command do not need to be separated by spaces. If spaces are included, they will be ignored. If more than one parameter is required by a command, the parameters must be separated by a comma. Examples of commands are:

G 5 <cr>	set the sensitivity to 200 nV
T 1,4 <cr>	set the pre filter to 30 mS
F <cr>	read the reference frequency
P 45.10 <cr>	set phase shift to 45.10°
X 5,-1.23E-1 <cr>	set port X5 to -0.123 V

Multiple commands may be sent on a single line. The commands must be separated by a semicolon (;) character. The commands will not be executed until the terminating carriage return is sent.

An example of a multiple command is:

G 5; T 1,4; P 45.10 <cr>

It is not necessary to wait between commands. The SR510 has a command input buffer of 256 characters and processes the commands in the order received. Likewise, the SR510 has an output buffer (for each interface) of 256 characters.

In general, if a command is sent without parameters, it is interpreted as a request to read the status of the associated function or setting. Values returned by the SR510 are sent as a string of ASCII characters terminated usually by carriage return, line feed. For example, after the above command is sent, the following read commands would generate the responses shown below.

Command	Response from the SR510
G <cr>	5<cr><lf>
T 1 <cr>	4<cr><lf>
P <cr>	45.10<cr><lf>

The choice of terminating characters sent by the SR510 is determined by which interface is being used and whether the 'echo' feature is in use. The terminating sequence for the GPIB interface is always <cr><lf> (with EOI). The default sequence for RS232 is <cr> when the echo mode is off, and <cr><lf> when the echo mode is on. The terminating sequence for the RS232 interface may be changed using the J command.

Note that the terminating characters are sent with each value returned by the SR510. Thus, the response to the command string G;T1;P<cr> while using the RS232 non-echo mode would be 5<cr>4<cr>45.10<cr>.

Front Panel Status LED's

The **ACT** LED flashes whenever the SR510 is sending or receiving information over the computer interfaces.

The **ERR** LED flashes whenever an error has occurred, such as an illegal command has been received or a parameter is out of range, or a communication buffer has exceeded 240 characters. This LED flashes for about two seconds on power-up if the battery voltage is insufficient to retain previous instrument settings.

The **REM** LED is on whenever the SR510 is programmed to be in the remote state.

RS232 Echo and No Echo Operation

In order to allow the SR510 to be operated from a

terminal, an echo feature has been included which causes the unit to echo back commands received over the RS232 port. This feature is enabled by setting switch 6 on **SW2** to the DOWN position. In this mode, the SR510 will send line-feeds in addition to carriage returns with each value returned and will also send the prompts 'OK>' and '?>' to indicate that the previous command line was either processed or contained an error. Operating the SR510 from a terminal is an ideal way to learn the commands and responses before attempting to program a computer to control the SR510. When the unit is controlled by a computer, the echo feature should be turned off to prevent the sending of spurious characters which the computer is not expecting.

Try-Out with an ASCII Terminal

Before attempting any detailed programming with the SR510, it is best to try out the commands using a terminal. Connect a terminal with an RS232 port to the RS232 connector on the rear panel of the SR510. Set the baud rate, parity, and stop bits to match the terminal by setting **SW2** per the switch setting table given on page 6. The echo mode should be enabled (switch 6 DOWN). After setting **SW2** and connecting the terminal, hold down the **REL** key while turning the unit on. This causes the SR510 to assume its default settings so that the following discussion will agree with the actual responses of the SR510. The **ACT** and **ERR** LED's on the front panel will flash for a second and the sign-on message will appear on the terminal. Following the message, the prompt 'OK>' will be displayed. This indicates that the SR510 is ready to accept commands.

Type the letter 'P' followed by a carriage return (P<cr>). The SR510 responds by sending to the terminal the characters 0.00 indicating that the phase is set to 0 degrees. In general, a command with no arguments or parameters reads a setting of the unit. To set the phase to 45 degrees, type command, P45<cr>. To see that the phase change, use the **SELECT** key on the front pa to display the phase on the **REFERENC DIGITAL DISPLAY**. Typing the phase re command, P<cr>, will now return the string 45. to the terminal.

Now read the gain using the sensitivity re command, G<cr>. The response should be meaning that the sensitivity is at the 24th setting 500 mV. Change the sensitivity by typi G19<cr>. The sensitivity should now be 10 m Check the front panel to make sure this is so.

The output of the lock-in is read by typing th command, Q<cr>. The response is a signe floating point number with up to 5 significant digi plus a signed exponent. Change the gain to 1 uV using the G10 command. The response to th Q command now will be similar to the previous on except that the exponent is different.

Attach a DC voltmeter to the **X6** output on the rea panel. The range should allow for 10V readings The voltage at the **X6** output can be set using the **X6** command. Type X6,5.0<cr> and the X6 output will change to 5.0V. To read this back to the terminal, just type **X6**<cr>. When setting the **X6** voltage, the voltage may be sent as an integer (5), real (5.000), or floating point (0.500E1) number. Now connect the **X6** output to the X1 input (also on the rear panel). **X1** through X4 are analog input ports. To read the voltage on X1, simply type X1<cr>. The response 5.000 should appear on the terminal. The **analog** ports X1 through **X6** can be used by your computer to read outputs of other instruments as well as to contro other laboratory parameters.

At this point, the user should experiment with a few of the commands. A detailed command lis follows.

SR510 Command List

The first letter in each command sequence is the command. The rest of the sequence consists of parameters. Multiple parameters are separated by a comma. Those parameters shown in {} are optional while those without {} are required. Variables m and n represent integer parameters while v represents a real number. Parameters m and n must be expressed in integer format while v may be in integer, real, or floating point format.

A {n}
If n is "1", the A command causes the **auto offset** routine to run. Every time an "A 1" command is received, the auto offset function is executed. If n is "0", then the auto offset is turned off. If n is absent, then the auto offset status is returned. Note that if the manual offset is on, an "A 1" command will turn off the manual offset before executing the auto offset function.

B {n}
If n is "1", the B command sets the **bandpass** filter in. If n is "0", the bandpass filter is taken out. If n is absent, then the bandpass filter status is returned.

C {n}
If n is "1", the C command sets the **reference LCD display** to show the phase setting. If n is "0", the LCD will display the reference frequency. If n is absent, the parameter being displayed (frequency or phase) is returned. Note that the P and F commands are used to read the actual values of the phase and frequency.

D {n}
If n is included, the D command sets the **dynamic reserve**. If n is absent, the dynamic reserve setting is returned.

n	Dyn Res
0	LOW
1	NORM
2	HIGH

Note that not all dynamic reserve settings are allowed at every sensitivity.

E {n}
If n is "1", the E command turns the output **expand** on. If n is "0", the expand is turned off. If n is absent, the expand status is returned.

F
The F command reads the reference **frequency**. For example, if the reference frequency is 100 Hz, the F command returns the string "100.0". If the reference frequency is 100.0 kHz, the string "100.0E+3" is returned. The F command is a read only command.

G {n}
If n is included, the G command sets the **gain** (sensitivity). If n is absent, the gain setting is returned.

n	Sensitivity
1	10 nV
2	20 nV
3	50 nV
4	100 nV
5	200 nV
6	500 nV
7	1 µV
8	2 µV
9	5 µV
10	10 µV
11	20 µV
12	50 µV
13	100 µV
14	200 µV
15	500 µV
16	1 mV
17	2 mV
18	5 mV
19	10 mV
20	20 mV
21	50 mV
22	100 mV
23	200 mV
24	500 mV

Note that sensitivity settings below 100 nV are allowed only when a pre-amplifier is connected.

H
The H command reads the **pre-amplifier status**. If a pre-amplifier is connected, a "1" is returned, otherwise, a "0" is returned. The H command is a read only command.

I {n}
If n is included, the I command sets the **remote-local** status. If n is absent, the remote-local status is returned.

n	Status
0	Local: all front panel keys are operative
	Remote: front panel keys are not operative. The display up key returns the status to local.
2	Lock-out: front panel keys are not operative. No key returns the status to local. Another I command is needed to return to local.

When using the GPIB interface, the REN, LLO, and GTL commands are not implemented. The I command is used by both interfaces to set the remote-local status.

J {n1,n2,n3,n4}
The J command sets the RS232 **end-of-record** characters sent by the SR510 to those specified by the ASCII codes n1-n4. If no argument is included, the end-of-record sequence returns to the default (a carriage return), otherwise, up to four characters may be specified. The end-of-record required by the SR510 when receiving commands is not affected.

K n
The K command simulates a front panel **key press**. The effect is exactly the same as pressing the selected key once. The parameter n is required.

n	Key
1	Post Time Constant Up
2	Post Time Constant Down
3	Pre Time Constant Up
4	Pre Time Constant Down
5	Offset Up
6	Offset Down
7	Zero Phase (Simultaneous 90° Up and Down)
8	Line Notch Filter
9	Bandpass Filter
10	Line X 2 Notch Filter
11	Relative (Auto Offset)
12	Offset (On/Off)
13	Expand
14	Local (Display Up when REMOTE)
15	Reference Trigger Mode
16	Reference Mode (f/2f)
17	Degrees Up
18	Degrees Down
19	Quad Up
20	Quad Down
21	Select Display (f/phase)
22	Sensitivity Up
23	Sensitivity Down
24	Dyn Res Up
25	Dyn Res Down
26	Display Up
27	Display Down

L m {,n}
The L command sets and reads the status of the line **notch filters**. If m is "1", then the 1X line notch is selected, if m is "2", the 2X line notch is selected. The parameter m is required. If n is "1", the L command sets the selected filter in. If n is "0", the selected filter is taken out. If n is absent, the status of the selected filter is returned.

M {n}
If n is "1", the M command sets the reference **mode** to 2f. If n is "0", the reference mode is set to f. If n is absent, the reference mode is returned.

N {m}
If m is "1", the N command sets the **ENBW** to 10 Hz. If m is "0", the ENBW is set to 1 Hz. If m is absent, the ENBW setting is returned.

O {n} {,v}
If n is "1", the O command turns the **offset** on. If n is "0", the offset is turned off. If n is absent, the offset status (on or off) is returned. (The value of the offset is read using the S and Q commands.) If n is included, then v may also be sent. v is the offset value up to plus or minus full scale in units of volts. For example, to offset half of full scale on the 100 μV sensitivity, v should be "50.0E-6" or an equivalent value. However, if the sensitivity is then changed to 200 μV, the offset is now half of the new full scale or 100 μV. When the sensitivity is changed, the offset is retained as a constant fraction of full scale rather than as a voltage referred to the input. The expand function will, on the other hand, preserve the value of the offset as an input referred voltage. Once a value of v is sent, the offset may be turned off and on without losing the offset value by using the O command without the v parameter. Note that if the auto offset is on, an "O 1" command will turn the auto offset off and turn the manual offset on without changing the actual offset value.

P {v}
If v is absent, the P command returns the phase setting from -180 to +180 degrees. When v is included, the phase is set to the value of v up to ±999 degrees.

Q
The Q command returns the output reading in units of volts. For an input signal of 50 μV on a full scale sensitivity of 100 μV, the Q command will return the string "50.00E-6". The parameter read is the same as that being shown on the output display and can be changed with the S command.

R {n}
If n is included, the R command sets the **reference input trigger** mode. If n is absent, the trigger mode is returned.

n	Mode
0	Positive
1	Symmetric
2	Negative

S {n}
If n is included, the S command selects the parameter shown on the analog meter and output digital **display** as well as the output BNC. If n is absent, the parameter being displayed is returned.

n	Display
0	X
1	Offset
2	Noise

T m {,n}
The T command sets and reads the status of the **time constants**. If m is "1", the pre time constant is selected, if m is "2", the post time constant is selected. The parameter m is required. If n is included, the T command sets the selected time constant. If n is absent, the setting of the selected time constant is returned.

n	Pre Time Constant (m=1)
1	1 mS
2	3 mS
3	10 mS
4	30 mS
5	100 mS
6	300 mS
7	1 S
8	3 S
9	10 S
10	30 S
11	100 S

n	Post Time Constant (m=2)
0	none
1	0.1 S
2	1 S

U m {,n}
The U command sets and reads the unit's ROM **calibration** bytes. m is the address offset of the byte, 0-255. If n is absent, the value of the addressed calibration byte is returned. If n is included, the addressed calibration byte is set to the value of n, 0-255. The new value will be in effect until the power is turned off or a reset command is issued. Use of this command is not recommended.

V {n}
If n is included, the V command sets the GPIB **SRQ** (service request) mask to the value n. If n is absent, the value of the SRQ mask is returned.

W {n}
The W command sets and reads the RS232 character **wait** interval. If n is included, the SR510 will wait n*4 mS between characters sent over the RS232 interface. This allows slow computer interfaces to keep up. n can range from 0 to 255. If n is absent, the wait value is returned. The wait interval is set to 6 on power-up.

X n {,v}
n designates one of the 6 general purpose **analog ports** located on the rear panel. If n is 1,2,3, or 4, the X command will return the voltage on the designated analog input port (X1-X4) in volts. If n is 5 or 6, then v may also be sent. If v is included, the designated analog output port (X5 or X6) will be set to v volts where v has the range -10.24V to +10.24V. If v is absent, the output value of the selected port is returned. On power-up, port X5 is the ratio output. An "X 5" command will read the ratio output. An "X 5" command with the parameter v will set port X5 to v volts, overriding the ratio output. Port X5 will return to the ratio output on power-up or reset.

Y {n}
The Y command reads the **status** byte. (See below for a definition of the Status Byte.) n designates one bit, 0-7, of the status byte. If n is included, the designated bit of the status byte is returned. The bit which is read is then reset. If n is absent, the value of the entire byte is returned and all status bits are then reset. This status byte may also be read over the GPIB using the serial poll command.

Z
The Z command causes an internal **reset**. All settings return to their default values. The **ERR** LED will be on for about 2 seconds to indicate that the stored instrument settings are being ignored. If the RS232 echo mode is on, the sign-on message is sent over the RS232 interface.

Status Byte

The SR510 maintains an 8-bit status register which the user may read to obtain information on the unit's status. The status byte may be read in two ways: by sending the Y command, which returns the value of the byte in ASCII coded decimal, or, when using the GPIB, by performing a serial poll. The returned status byte reflects all of the status conditions which have occurred since the last time the byte was read. After the status byte has been read, it is cleared. Thus, the status byte should be read initially to clear all previous conditions (especially after a power up or after settings have been changed).

The definitions for each bit of the status byte are given below:

Bit 0
Busy. When this bit is set, it indicates the SR510 has unprocessed commands pending on its command queue. For RS232 communications, this bit is always high since the Y command itself will be an unprocessed command. This bit is not reset when read but only when there are no pending commands. Since the SR510 buffers incoming commands, it is not necessary to read this bit before sending each command. Commands received while the SR510 is executing a previous command are stored until all previously received commands have been executed.

Bit 1
Command Parameter Out of Range. This bit is set if a parameter associated with a command is not in the allowed range.

Bit 2
No Reference. This bit is set when no reference input is detected, either because the amplitude is too low or the frequency is out of range.

Bit 3
Unlock. This bit is set when the reference oscillator is not locked to the reference input. If there is no reference input, bit 2 (no reference) will be set but bit 3 (unlock) may not be.

Bit 4
Overload. This bit is set if there is a signal overload. This can happen when the sensitivity is too high, the dynamic reserve is too low, the offset is on, or the expand is on. Overloads on the general purpose A/D inputs or the ratio output are not detected.

Bit 5
Auto Offset Out of Range. This bit is set if the auto offset function cannot zero the output because the output exceeded 1.024X full scale.

Bit 6
SRQ. This bit is high if the SR510 has generated an SRQ on the GPIB interface. This bit is reset after the SR510 has been serial polled. This bit is set only for status reads via a serial poll, ie., Bit 6 always zero for the RS232.

Bit 7
Command Error. This bit is set when an illegal command string is received.

Errors

Whenever a 'parameter out of range' or an 'unrecognized command' error occurs, the appropriate status bits are set and the **ERR** LED flashes. In addition, any commands remaining on the current command line (up to the next <cr>) are lost. The **ERR** LED will also light if any of the internal communication buffers overflows. This occurs when 240 characters are pending on the command queue or output queue. The **ERR** LED will go off as soon as all buffers drop below 200 characters again.

Reset

The Z command resets the unit to its default state. The default front panel settings are listed in the **DEFAULTS** section of the **Guide** to **Operations**. In addition, the interface status returns to LOCAL, the SRQ mask is cleared, the RS232 character WAIT interval is set to 6, and the terminating sequence is reset to the proper defaults.

The command and output buffers are cleared by the Z command. Therefore, it is bad practice to use the Z command before all previous commands have been processed and all responses have been received.

Trouble-Shooting Interface Problems

If you are having difficulty getting your computer to communicate with the SR510 look to the sections on the RS232 and GPIB interfaces for some tips specific to your particular interface.

An ASCII terminal is a valuable aid for debugging interface problems. You can use it to:

1) become familiar with the SR510's command structure,

2) see GPIB bus transactions by using the GPIB echo mode,

3) eavesdrop on transactions when using the RS232 interface,

4) substitute a human for the SR510 by using a null modem cable (to make the DTE a DCE) and attaching the terminal to the port to which you would normally have connected the SR510. This allows you to test your program's responses to inputs which you provide from the terminal.

Common Hardware Problems include:

1) The RS232 or GPIB cables are not properly attached.

2) The configuration switches for the RS232 characteristics or GPIB address are not set correctly (Make sure the RS232 echo is off when using the RS232 interface with a computer. The GPIB with RS232 echo mode should be off when not debugging the GPIB interface.)

3) Your computer requires an RS232 control line to be asserted, but your cable does not pass it between the SR510 and the computer, or, your computer is not asserting the DTR line on the RS232.

Common Software Problems include:

1) You have sent the wrong command to ask for data from the SR510. Your program will wait forever for a response which is not going to come. This may not be your fault; we have seen Microsoft's Interpreted Basic on the IBM PC occasionally send a curly bracket (ASCII 253) when it was supposed to have sent a carriage return (ASCII 13).

2) Your computer's baud rate has been changed and no longer matches the SR510's baud rate.

3) The initial command sent to the SR510 was invalid due to a garbage character left in the command queue from power-up, or, the first character in you computer's UART is garbage, also due to power-up. It is good practice to send a few carriage returns to the SR510 when your program begins, and have your program clear-out its UART at the start of your program.

4) The SR510 is not sending the correct 'end-of-record' marker for your computer. For example, it appears that Microsoft's Rev 3.2 FORTRAN on the IBM PC under DOS 2.1 requires two carriage returns for an end-of-record marker. The J command can be used to set the SR510 end-of-record marker to 2 carriage returns. [The end-of-record marker is that sequence which indicates that the response is complete. From the keyboard, a single carriage return is the end-of-record marker.]

5) Answers are coming back from the SR510 too fast, overwriting the end-of-record markers, and causing the computer to hang waiting for a complete response. In this case, the W command can be used to slow down the response time of the SR510 preventing overwriting.

6) Answers are coming back from tthe SR510 too slowly due to the W6 default setting for the character interval time. Use the W command to speed up the transmission from the SR510. This can cause problems for the GPIB interface if the echo mode is on (switch 6 of SW21).

The SR510 with the RS232 Interface

The RS232 is a popular serial interface standard for bit serial communication. Despite the existence of the standard there are many permutations of control lines, baud rates, and data formats. If you do not have a lot of experience interfacing RS232 equipment you should read Appendix B for a description of the RS232 and interfacing tips.

Data Communications Equipment (DCE)

The SR510 is configured as DCE so that it may be connected directly to a terminal. If the SR510 is to be interfaced with another DCE device, a special cable (sometimes referred to as a 'modem' cable) is required. To use the RS232 interface you must set the switches in **SW2** to match your computer's baud rate, parity, and number of stop bits. Refer to Page 6 for details.

Wait Command

The SR510 normally waits until the RS232 'Clear to Send' control line (CTS) is asserted before sending characters. However, some computers do not set and reset the CTS line, possibly causing the SR510 to send data when the computer is not ready to read it. The SR510 may be 'slowed down' using the W command. Sending

'Wn' causes the unit to wait nX4 mS before sending each character over the RS232 bus. The command W0 sets the wait interval to zero and results in the fastest transmission. The wait interval is set to 6 (24 mS) on power-up.

Termination Sequences

The default RS232 termination characters are sufficient to interface with most computers, however, it will occasionally be necessary to send special terminating sequences to fit the requirements of some computers. This can be done with the J command. The format for the command is:

J [n1,n2,n3,n4]

where n1, n2, n3, and n4 are decimal values between 0 and 255 corresponding to the decimal ASCII codes of the desired termination characters. For instance, if the desired termination sequence is an asterisk, (ASCII 42), two carriage returns, (ASCII 13), and a line feed, (ASCII 10), the appropriate command is:

J 42,13,13,10

If a G command is sent requiring an answer of 24 (sensitivity = 500 mV), the SR510 would respond with the string

24*<cr><cr><lf>

Up to four terminating characters may be specified by the J command. If no arguments are sent with the J command, the terminating sequence returns to the default (echo on: <cr><lf>; echo off: <cr>).

The J command does not affect the terminating character (<cr>) required at the end of commands received by the SR510. It also does not affect the terminating sequence sent with data over the GPIB interface.

The SR510 with the GPIB Interface

For a brief introduction to the GPIB standard, please read Appendix C at the back of this manual. Before using the GPIB interface you must set the switches in **SW1** per the instructions on page 6.

GPIB Capabilities

The GPIB capabilities of the SR510 consistent with IEEE standard 488 (1978) are shown in the table below. Also shown are the responses of the SR510 to some standard commands.

Code	Function
SH1	Source handshake capability
AH1	Acceptor handshake capability
T5	Basic Talker, Serial Poll, Unaddressed to talk if addressed to listen
L4	Basic Listener, Unaddressed to listen if addressed to talk
SR1	Service request capability
PP0	No parallel poll capability
DC1	Device Clear capability
RL0	REN,LLO, GTL not implemented. 'I' command sets Remote-Local.

SR510 Response to GPIB Commands

Mnemonic	Command	Response
DCL	Device Clear	Same as Z command
SDC	Selected Device Clear	Same as Z command
SPE	Serial Poll Enable	Send Status Byte, & clear status byte

Because the SR510 can be controlled by an RS232 interface as well as the GPIB, the remote-local functions are not standard. There is no local with lock out state. When in the local state, remote commands are processed, even without the REN command being issued. This is because the RS232 interface has no provision for bus commands and remote commands over the RS232 interface would never be enabled.

Serial Polls and Service Requests

The status byte sent by the SR510 when it is serial polled is the same status byte which is read using the Y command (except for bit 6, SRQ). Of course, when the SR510 is serial polled, it does not encode the status byte as a decimal number. The SR510 can be programmed to generate a service request (SRQ) to the GPIB controller every time a given status condition occurs. This is done using the V{n} command. The mask byte, n (0-255), is the SRQ mask byte. The mask byte is always logically anded with the status byte. If the result is non-zero, the SR510 generates an SRQ and leaves the status byte unchanged until the controller performs a serial poll to determine the cause of the service request. When the unit has been serial polled, the status byte is reset to reflect all of the status conditions which have occurred since the SRQ was generated.

For example, if we want to generate an SRQ whenever there is an overload or unlock condition, we need an SRQ mask byte equal to 00011000 binary, or 24 decimal ("V24" command). The byte 00011000 binary corresponds to the status byte

with the 'no reference' and 'unlock' status bits set. If an overload occurs, then an SRQ will be generated. The serial poll will return a status byte showing SRQ and overload. If an unlock condition occurs before the serial poll is concluded, another SRQ will be generated as soon as the serial poll is finished. A second serial poll will reflect the unlock condition.

Any SRQ generated by the 'no reference, 'unlock', 'overload', and 'auto over-range' conditions will also reset the corresponding bit in the SRQ mask byte. This is to prevent a constant error condition (such as no reference applied to the input) from continually interrupting the controller. When such an SRQ occurs, the controller should change some parameter so as to solve the problem, and then re-enable the SRQ mask bit again using the V command.

GPIB with RS232 Echo Mode

It is sometimes useful when debugging a GPIB system to have some way of monitoring exactly what is going back and forth over the bus. The SR510 has the capability to echo all characters sent and received over the GPIB to its RS232 port. This mode of operation is enabled by setting switch 6 of **SW1** to the DOWN position. The baud rate, stop bits, and parity of the RS232 port are still set by **SW2**. Of course, the RS232 port operates at much lower speeds than the GPIB and will slow down the GPIB data rate in this mode. (Use the W0 command to allow the RS232 interface to run at full speed, otherwise, the GPIB transactions may take so long that the controller can hang.) During actual use, this mode should be disabled.

The SR510 with BOTH Interfaces

If both interfaces are connected, commands may be received from either interface. Responses are always sent to the source of the request (except in GPIB echo mode). It is unwise to send commands from the two interfaces at the same time since the characters from different sources can become interleaved on the command queue and result in 'unrecognized command' errors.

The Lock-in Technique

The Lock-in technique is used to detect and measure very small ac signals. A Lock-in amplifier can make accurate measurements of small signals even when the signals are obscured by noise sources which may be a thousand times larger. Essentially, a lock-in is a filter with an arbitrarily narrow bandwidth which is tuned to the frequency of the signal. Such a filter will reject most unwanted noise to allow the signal to be measured. A typical lock-in application may require a center frequency of 10 KHz and a bandwidth of 0.01 Hz. This 'filter' has a Q of 10^6 - well beyond the capabilities of passive electronic filters.

In addition to filtering, a lock-in also provides gain. For example, a 10 nanovolt signal can be amplified to produce a 10 V output--a gain of one billion.

All lock-in measurements share a few basic principles. The technique requires that the experiment be excited at a fixed frequency in a relatively quiet part of the noise spectrum. The lock-in then detects the response from the experiment in a very narrow bandwidth at the excitation frequency.

Applications include low level light detection, Hall probe and strain gauge measurement, micro-ohm meters, C-V testing in semiconductor research, electron spin and nuclear magnetic resonance studies, as well as a host of other situations which require the detection of small ac signals.

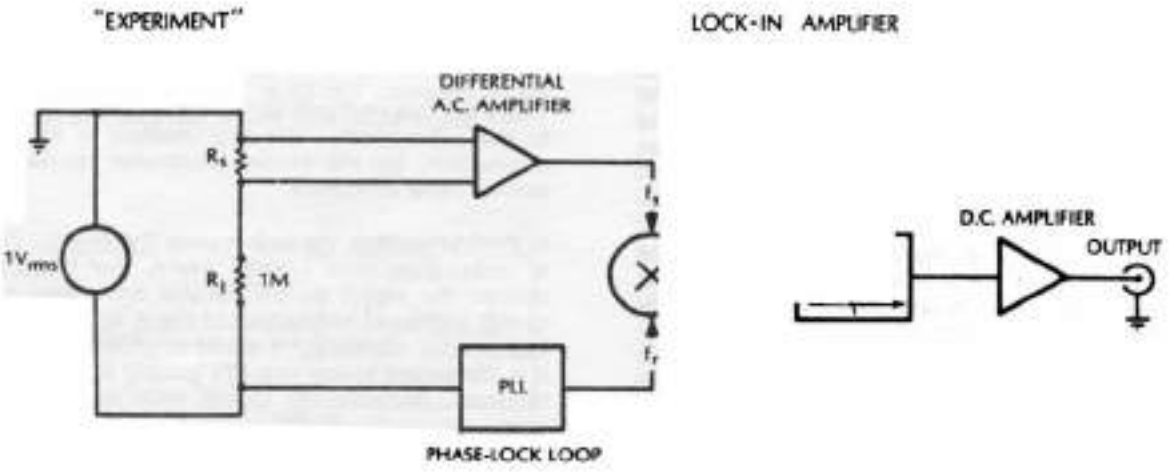
A Measurement Example

Suppose we wish to measure the resistance of a material, and we have the restriction that we must not dissipate very much power in the sample. If the resistance is about 0.1 Ω and the current is restricted to 1 μA, then we would expect a 100 nV signal from the resistor. There are many noise signals which would obscure this small signal -- 60Hz noise could easily be 1000 times larger, and dc potentials from dissimilar metal junctions could be larger still.

In the block diagram shown below we use a 1Vrms sine wave generator at a frequency w_r as our reference source. This source is current limited by the 1 MΩ resistor to provide a 1 μA ac excitation to our 0.1 Ω sample.

Two signals are provided to the lock-in. The 1V ac reference is used to tell the lock-in the exact frequency of the signal of interest. The lock-in's Phase-Lock Loop (PLL) circuits will track this input signal frequency without any adjustment by the user. The PLL output may be phase shifted to provide an output of $\cos(w_r t+\varnothing)$.

The signal from the sample under test is amplified by a high gain ac coupled differential amplifier. The output of this amplifier is multiplied by the PLL output in the Phase-Sensitive Detector (PSD). This multiplication shifts each frequency component of the input signal, w_s, by the



reference frequency, w_r, so that the output of the PSD is given by:

$$V_{psd} = \cos(w_r t+\emptyset)\cos(w_s t)$$

$$1/2\cos[(w_r + w_s)t+\emptyset] + 1/2\cos[(w_r - w_s)t+\emptyset]$$

The sum frequency component is attenuated by the low pass filter, and only those difference frequency components within the low pass filter's narrow bandwidth will pass through to the dc amplifier. Since the low pass filter can have time constants up to 100 seconds, the lock-in can reject noise which is more than .0025 Hz away from the reference frequency input.

For signals which are in phase with the reference, the phase control is usually adjusted for zero phase difference between the signal and the reference. This can be done by maximizing the output signal. A more sensitive technique would be to adjust the phase to null the signal. This places the reference oscillator at 90 degrees with respect to the signal. The phase control can now be shifted by 90 degrees to maximize the signal. Alternatively, since the phase control is well calibrated, the phase of the signal can be measured by adding 90 degrees to the phase setting which nulls the signal.

Understanding the Specifications

The table below lists some specifications for the SR510 lock-in amplifier. Also listed are the error contributions due to each of these items. The specifications will allow a measurement with a 2% accuracy to be made in one minute.

We have chosen a reference frequency of 5 kHz so as to be in a relatively quiet part of the noise spectrum. This frequency is high enough to avoid low frequency '1/f' noise as well as line noise. The frequency is low enough to avoid phase shifts and amplitude errors due to the RC time constant of the source impedance and the cable capacitance.

The full-scale sensitivity of 100 nV matches the expected signal from our sample. The sensitivity is calibrated to 1%. The instrument's output stability also affects the measurement accuracy. For the required dynamic reserve, the output stability is 0.1%/°C. For a 10°C temperature change we can expect a 1% error.

A front-end noise of 7 nV/√Hz will manifest itself as a 1.2 nVrms noise after a 10 second low-pass filter since the equivalent noise bandwidth of a single pole filter is 1/4RC. The output will converge exponentially to the final value with a 10 second time constant. If we wait 50 seconds, the output will have come to within 0.7% of its final value.

The dynamic reserve of 60 dB is required by our expectation that the noise will be a thousand times larger than the signal. Additional dynamic reserve is available by using the bandpass and notch filters.

A phase-shift error of the PLL tracking circuits will cause a measurement error equal to the cosine of the phase shift error. The SR510's 1° phase accuracy will not make a significant contribution to the measurement error.

Specifications for the Example Measurement

Specification	Value	Error
Full Scale Sensitivity	100 nV	
Dynamic Reserve	60 dB	
Reference Frequency	5 kHz	
Gain Accuracy	1%	1%
Output Stability	0.1%/°C	1%
Front-End Noise	< 7 nV/√Hz	1.2%
Output Time Constant	> 10 S	0.7%
Total RMS Error		2%

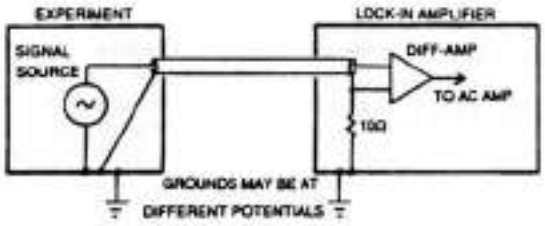
Shielding and Ground Loops

In order to achieve the 2% accuracy given in this measurement example, we will have to be careful to minimize the various noise sources which can be found in the laboratory. (See Appendix A for a brief discussion on noise sources and shielding) While intrinsic noise (Johnson noise, 1/f noise and alike) is not a problem in this measurement, other noise sources could be a problem. These noise sources can be reduced by proper shielding.

There are two methods for connecting the lock-in to the experiment: the first method is more convienient, but the second eliminates spurious pick-up more effectively.

In the first method, the lock-in uses the 'A' input in a 'quasi-differential' mode. Here, the lock-in detects the signal as the voltage between the center and outer conductors of the A input. The lock-in does not force A's shield to ground, rather it is connected to the lock-in's ground via a 10Ω resistor. Because the lock-in must sense the shield voltage (in order to avoid the large ground loop noise between the experiment and the lock-in) any noise pickup on the shield will appear as noise to the lock-in. For a low impedance source (as is the case here) the noise picked up by the shield will also appear on the center conductor.

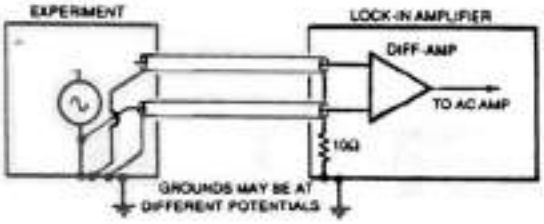
This is good, because the lock-in's 100 dB CMRR will reject most of this common mode noise. However, not all of the noise can be rejected, especially the high frequency noise, and so the lock-in may overload on the high sensitivity ranges.



Quasi-Differential Connection

The second method of connecting the experiment to the lock-in is called the 'true-differential' mode. Here, the lock-in uses the difference between the center conductors of the A & B inputs as the input signal. Both of the signal sources are shielded from spurious pick-up.

With either method, it is important to minimize both the common mode noise and the common mode signal. Notice that the signal source is held near ground potential in both cases. A signal which appears on both the A & B inputs will not be perfectly cancelled: the common mode rejection ratio (CMRR) specifies the degree of cancellation. For low frequencies the CMRR of 100 dB indicates that the common mode signal is canceled to 1 part in 10^5, but the CMRR decreases by about 6 dB/octave (20 dB/Decade) starting at 1KHz. Even with a CMRR of 10^5, a 10 mV common mode signal behaves like 100nV differential signal.



True-Differential Connection

There are some additional considerations in deciding how to operate the lock-in amplifier:

Dynamic Reserve (DR) is the ratio of the largest noise signal that the lock-in can tolerate before overload to the full scale input. Dynamic reserve is usually expressed in dB. Thus a DR of 60 dB means that a noise source 1000 times larger than a full scale input can be present at the input without affecting the measurement of the signal. A higher DR results in a degraded output stability since most of the gain is DC gain after the phase sensitive detector. In general, the lowest DR which does not cause an overload should be used.

The Current Input has a 1 kΩ input impedance and a current gain of 10^6 Volts/Amp. Currents from 500 nA down to 100 fA full scale can be measured. The impedance of the signal source is the most important factor to consider in deciding between voltage and current measurements.

For high source impedances, (>1 MΩ) or small currents, use the current input. Its relatively low impedance greatly reduces the amplitude and phase errors caused by the cable capacitance-source impedance time constant. The cable capacitance should still be kept small to minimize the high frequency noise gain of the current preamplifier.

For moderate source impedances or larger currents, the voltage input is preferred. A small value resistor may be used to shunt the source. The lock-in then measures the voltage across this resistor. Select the resistor value to keep the source bias voltage small while providing enough signal for the lock-in to measure.

The Auto-Tracking Bandpass Filter has a Q of 5 and follows the reference frequency. The passband is therefore 1/5 of the reference frequency. The bandpass filter can provide an additional 20 dB of dynamic reserve for noise signals at frequencies outside the passband. The filter also improves the harmonic rejection of the lock-in. The second harmonic is attenuated an additional 13dB and higher harmonics are attenuated by 6 dB/octave more. You may wish to use the bandpass filter and select a low dynamic reserve setting in order to achieve a better output stability. Since the processor can only set the bandpass filter's center frequency to within 1% of the reference frequency, this filter can contribute up to 5° of phase shift error and up to 5% of amplitude error when it is used. In addition, the bandpass filter adds a few nanovolts of noise to the front end of the instrument when it is in use.

Line Notch Filters should be used in most measurement situations. The filters will reject about 50 dB of line frequency noise (about a factor of 300). If your reference frequency is one octave away, then these filters will introduce a 10° phase shift error, and a few percent amplitude error. Their effect on your signal is negligible if your reference frequency is more than two octaves away.

The frequency range of the SR510 lock-in amplifier extends from 0.5Hz to 100KHz. No additional cards are required for the instrument to cover its full frequency range. The SR510 can be used to detect a signal at the reference frequency or at twice the reference frequency to allow for convenient measurement of the harmonic of the signal.

Noise measurement is a feature which allows direct measurement of the noise density of the signal at the reference frequency. This is a useful feature to assess at what frequency you should run your experiment.

Output Filters can have one pole (6 dB per octave) or two poles (12 dB/octave). A two-pole filter provides a signal to noise improvement over a single-pole filter due to its steeper roll off and reduced noise bandwidth. Single-pole filters are preferred when the lock-in is used in a servo system to avoid oscillation.

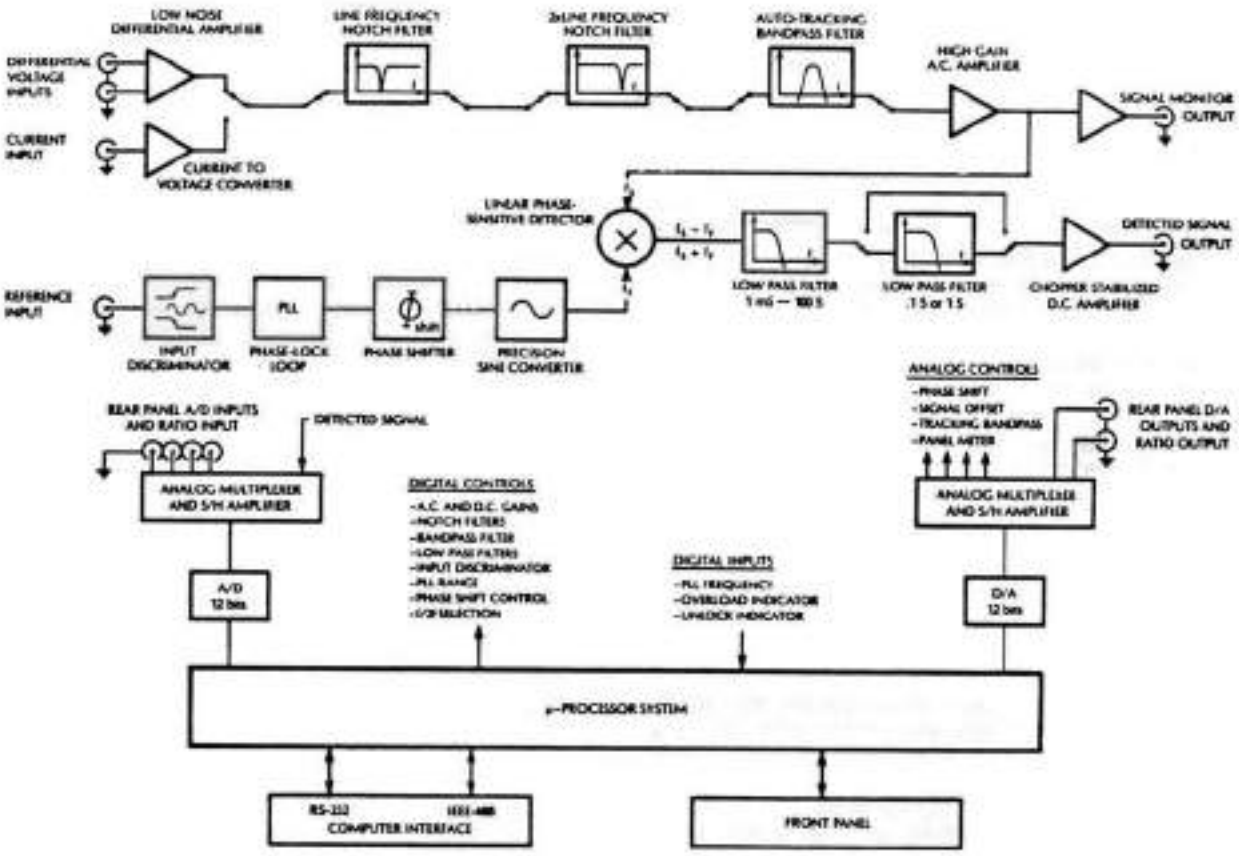
In many servo applications, no output filtering is needed. In this case, the SR510 may be modified to reduce the output time constant to about 20 μS. Contact the factory for details.

Ratio Capability allows the lock-in's output to be divided by an external voltage input. This feature is important in servo applications to maintain a constant loop gain, and in experiments to normalize a signal to the excitation level.

Computer Interface allows a computer to control and to record data from the instrument. This is the single most important feature for extending the lock-in's capabilities and it's useful lifetime. Measurements which are impractical without a computer become simple when a computer is used to coordinate various parts of the experiment.

The Internal Oscillator provides a reference source for the lock-in. This allows the lock-in's frequency to be set without an additional signal generator. It also provides a sine wave to be used as the signal stimulus in an experiment. The frequency may be set via the computer interface as well as manually.

MODEL SR510 LOCK-IN AMPLIFIER BLOCK DIAGRAM



SR510 Block Diagram

Several new concepts are used to simplify the design of SR510 lock-in amplifier. In addition to implementing recent advances in linear integrated circuit technology, the instrument was designed to take full advantage of its microprocessor controller to improve performance and to reduce cost.

As an example of the new techniques used in the SR510, consider the harmonic rejection problem. Previously, lock-in amplifiers used a PLL with a square wave output. The Fourier components of the square wave created a serious problem -- the lock-in would respond to signal and noise at f, 3f, 5f,..ad infinitum. Quite often, one component of this picket fence of frequencies would land on some noise source, giving a spurious result. To overcome this difficulty designers employed tuned amplifiers or heterodyning techniques. All of these 'fix-ups' had drawbacks, including phase and amplitude errors, susceptiblity to drift, and card-swapping to change frequencies.

In contrast, the SR510 detects the signal by mixing a reference sine wave in a precision analog multiplier. Because of the low harmonic content of this sine wave, the instrument is insensitive to harmonics. This approach has eliminated the difficulty, performance compromises, and cost of the older techniques.

The Signal Channel

The instrument has both current and voltage inputs. The current input is a virtual ground, and the 100 MΩ voltage inputs can be used as single-ended or true differential inputs.

There are three signal filters. Each of these filters may be switched 'in' or 'out' by the user. The first filter is a line notch filter. Set to either 50 or 60 Hz, this filter provides 50 dB of rejection at the line frequency. The second filter provides 50 dB of rejection at the first harmonic of the line frequency. The third filter is an auto-tracking bandpass filter with a center frequency tuned by the microprocessor to the frequency of the signal. These three filters eliminate most of the noise from the signal input before the signal is amplified.

A high-gain ac amplifier is used to amplify the signal before entering the phase sensitive detector. The high gain which is available from this programmable amplifier allows the lock-in to operate with a lower gain in its dc amplifier. This arrangement allows high stability operation even when used on the most sensitive ranges.

Reference Channel

The processor controlled reference input discriminator can lock the instrument's PLL to a variety of reference signals. The PLL can lock to sine waves or to logic pulses with virtually no phase error. The PLL output is phase shifted and shaped to provide a precision sine wave to the phase sensitive detector.

Phase Sensitive Detector

The Phase Sensitive Detector is a linear multiplier which mixes the amplified and filtered signal with the reference sine wave. The difference frequency component of the multiplier's output is a dc signal that is proportional to the amplitude of the signal. The low-pass filter which follows can reject any frequency components which are more than a fraction of a Hertz away from the signal frequency.

DC Amplifier and System Gain

A dc amplifier amplifies the output of the low pass filters. The total system gain is the product of the ac and dc amplifier gains. The partitioning of the system gain between these two amplifiers will affect the stability and dynamic reserve of the instrument. The output is most stable when most of the gain is in the ac amplifier, however, high ac gain reduces the dynamic reserve.

For the most demanding applications, the user may specify how the system gain is partitioned. However, with prefilters that are able to provide up to 100 dB of dynamic reserve, and with chopper stabilized dc amplifiers, most users will not be concerned with just how the system gain is allocated.

A Microprocessor Based Design

The instrument was designed to take full advantage of its microprocessor controller. This approach provides several key advantages...

The instrument may be interfaced to a laboratory computer over the RS-232 and IEEE-488 interfaces. In addition to simply reading data from the lock-in, the computer can control all of the instrument settings with simple ASCII commands.

A key feature of the instrument is its four A/D inputs and two D/A outputs. These analog I/O ports may be used to read and supply analog voltages to an experiment or measurement. All of the input and output ports have a full scale range of ±10.24Vdc with 2.5 mV resolution and 0.05% accuracy.

Computer control can eliminate set-up errors, reduce tedium, allow more complete data recording and post measurement analysis. Also, the computer can play an active role in the data acquisition by adjusting gains, etc., in response to changing measurement conditions.

The microprocessor based design eliminates many analog components to improve performance, reliability, and reduce cost. Each unit is computer calibrated at the factory, and calibration constants are placed in the instrument's read-only memory. The SR510 has only one-fifth of the analog trimming components that are found in older designs.

Creative programming on the user's part can extend the instrument's capabilities. For example, the lab computer can instruct the lock-in to measure the signal at zero and ninety degrees of phase. Doing so allows both the amplitude and phase of the signal of interest to be measured.

Circuit Description

Introduction

The SR510 Lock-in amplifier is an integrated instrument combining state of the art analog design with advanced microprocessor based control and interfaces. This discussion is intended to aid the advanced user in gaining a better understanding of the instrument.

The SR510 has 8 main circuit areas: the signal amplifier, the reference oscillator, the demodulator, the analog output and controls , the front panel, the microprocessor, the computer interfaces, and the power supplies. With the exception of the front panel and a few pieces of hardware, the entire lock-in is built on a single printed circuit board. Each section is isolated from the others as much as possible to prevent spurious signal pickup. To aid in the location of individual components, the first digit of each part number generally refers to the schematic sheet number on which it occurs. To help find the part on the circuit board, the parts list includes a location on the circuit board for each component.

Signal Amplifier

Assuming the input selector switch is set to a voltage input, the signal is coupled in through capacitors C101 and C102. The input impedance is set by the 100 MΩ resistors R101 and R102 over the operating frequency range. Note that R103 isolates the signal shields from the instrument ground forcing the return signal current back along the cable shields. The signal is then applied differentially to the gates of Q101. Q101 is a low noise dual JFET. The drain current through R109 is kept constant by 2/2 U101. The other half of U101 maintains a virtual null between the drains of the two transistors and thus an identical current flows through R110. Any input that would cause a differential between the two drains is amplified by 1/2 U101 and fed back via R112 in such a way as to reduce that differential. Since the two transistors are at equal and constant currents, their gate-source potentials are constant. Thus, the fed back signal which appears at the source of the right hand transistor exactly matches the input. Likewise, this signal will match the input to the left hand transistor but with the opposite sign. Resistors R112 and R110 attenuate the fed back signal from the output of U101 resulting in a differential input, single ended output, fixed gain of 10 amplifier. P101 adjusts the current balance between the two transistors and therefore their gain match and common mode rejection.

The output of the pre-amp is scaled by resistors R119-R122 and analog switch U103 which make up a 1-2-5-10 attenuator. The signal is then amplified by 2/2 U102. Input overload is sensed through diodes D101-D104.

Current Amplifier

When the input selector is set to current, the input to the pre-amp comes from the output of the current to voltage converter, 1/2 U102. U102 is a low voltage-noise bipolar op amp. Q102 serves as an input buffer to provide low current-noise to the input. The op amp always maintains a null at the gates of Q102 thus providing an input impedance of 1KΩ (R128). The input current is converted to a voltage by R135 and the op amp. Q103 bootstraps out the summing junction capacitance of Q102.

Notch Filters

U107 is a high Q, line frequency, notch filter which can be switched in and out by analog switch 1/4 U106. The frequency and depth of the filter can be adjusted with P102 and P103. Resistors R146-R149 and switch U108 make up a selectable attenuator. U118 is a line frequency 2nd harmonic notch filter selected by 2/4 U106. P104 and P105 adjust the frequency and depth. The second notch filter has a gain of 3 and its output is scaled by U110 and resistors R156-R159. The signal then takes two paths; to inverting amplifier U111 and to the input of the tracking bandpass filter. U111 has the same gain as the bandpass filter. The output of either U111 or the bandpass filter is selected by 3/4 U112 and 4/4 U106 and amplified by U113. U114 and U115 provide a last stage of gain and scaling and the final output is ac coupled and buffered by 4/4 U208.

Bandpass Filter

The bandpass filter is a three op amp state-variable active filter. 3/4 of U201 make up the three op amps of the standard filter. U203, U204, and U205 are analog switches which select the feedback capacitors for the 5 decades of operation. The two halves of U202 are matched transconductance amplifiers operating as programmable, voltage controlled, current sources which take the place of the normal, frequency setting, resistors. A voltage proportional to the reference frequency is converted into a current by 1/4 U208 and Q201. This current programs the effective "resistance" of the two transconductance amplifiers and thus, tunes the center frequency of the filter to follow the reference. The output of the filter is buffered by 4/4 U201. The two remaining op amps in U208 are used to detect signal overloads throughout the amplifier chain.

Reference Oscillator

The reference input signal is ac coupled and buffered by U301. R378 isolates the reference shield from the lock-in ground to prevent ground loop currents. 1/2 U303 switches the polarity of the reference reaching comparator U304. U305 is a retriggerable one-shot whose output indicates a no reference condition if no comparator pulses are generated for 3 seconds.

U309 is a dual transconductance amplifier in a triangle VCO configuration. U310 selects the integrating capacitor depending on the frequency range. The VCO frequency is determined by the programming current through R318 and therefore by the output voltage of U308. C306 is the phase-locked loop low pass filter which is buffered by U308. U307 is a programmable current source used to charge and discharge C306. The amount of current available to U307 is determined by the VCO control voltage, thus, the tracking rate of the VCO is proportional to the VCO frequency. The triangle output is compared to a constant voltage by U314. 1/2 U313 and 1/2 U312 select f or 2f operation. This signal is fed back to the phase detector U306 to be compared with the reference output of U304. U315 compares the triangle output with a variable voltage to generate a square-wave signal phase-shifted from the reference. The range of this fine phase shift control is -5 to 95 degrees.

The output of U315 serves as the reference to a second phase-locked loop. This second PLL uses a similar proportional tracking triangle VCO. Comparator U329 looks at the square wave output of the VCO while comparator U328 detects the zero crossings of the triangle output. 1/2 U327 selects one these comparators to feed back to the phase detector, U316. Since the square and triangle outputs are in quadrature, U327 selects either an in-phase or quadrature relationship between the two VCO's. Thus, the output of the second VCO can be shifted from -5 to 185 deg from the reference.

The triangle output is divided by R363 and R362 before reaching transconductance amplifier 2/2 U322. The amplitude of the triangle input to this amplifier is enough to just saturate the input and provide a sine wave output. 2/2 U325 then amplifies the sine wave before it goes to the demodulator. U324 is a comparator which generates a square wave in-phase with the sine output. U326 divides the frequency of the square wave by 8 and 2/2 U327 selects the frequency of the square wave chopper.

Demodulator and Low Pass Amplifier

Amplifier U402 and switch U401 select the polarity of the reference sine wave. This allows phase shifts up to 360 degrees from the reference input. The sine wave is ac coupled by U403 and inverted by U404. U405 selects alternating polarities of the sine wave at the chopper frequency, f/2 or f/16. This chopped sine wave is then multiplied by the output of the signal amplifiers by the analog multiplier U406. The synchronous output of the multiplier that corresponds to the in-phase signal is a square wave at the chopper frequency. The output is ac coupled by U407 to remove the dc offset of the multiplier. U408 inverts the signal and U405 chops the square wave to recover a dc output. U409 buffers the chopper output before the first low pass time constant. Op amps U416 and 2/2 U402 make up the first low pass amplifier with relays U411-U415 and U417 selecting the time constant. The second low pass amplifier is U419. Analog switch U418 selects the time constant and gain. The full scale output of U418 is 5 volts.

Analog Output and Control

The dc output of the demodulator/low pass amplifiers is passed to the reference input of multiplying DAC U502. The DAC is programmed with the appropriate attenuation to calibrate the overall gain of the lock-in. Every gain setting in each dynamic reserve is calibrated independently and the proper attenuations are stored in the unit's ROM.

A/D's

Analog multiplexer U504 selects the signal to be digitized by the microprocessor. This signal can be either the lock-in output or one of the four independent analog inputs buffered by U501. These general purpose inputs are located on the rear panel of the instrument. The selected signal is sampled and held on capacitor C502 and buffered by 4/4 U508. The A/D conversion is done by successive approximation using comparator U514 to compare the sampled and held signal with known outputs of U505, a 12 bit DAC with a precision reference. Note that the output of U506, an 8 bit DAC is summed with the output of U505. This 8 bit DAC corrects for offset errors which can accumulate as analog voltages pass through buffers, S/H amps, and comparators. These offsets are measured after each unit is manufactured, and values to compensate for these offsets are placed in the unit's ROM. The polarity of the offset-corrected 12 bit DAC is set by 2/4 U511 and the SIGN bit yielding 13 bits of resolution from -10.24 to +10.24 volts.

D/A's

In addition to providing reference voltages for A/D conversion, the DAC output voltage may be multiplexed by U507 to one of eight sample and hold amplifiers which provide analog output and control voltages. The microprocessor refreshes each S/H amplifier every few milliseconds to prevent droop. Two of these outputs are available as general programmable outputs on the rear panel. Two are used to program the band pass filter and the reference oscillator phase shift. One output is subtracted from the lock-in output in U508 to provide a variable offset and another is the rms noise output. Two outputs are not used.

Expand

Amplifier 3/4 U511 is the X10 expand amplifier. U516 selects the display and output, either the output of U511 or one of the DAC outputs. Overload is detected by 1/4 and 2/4 U515 and the signal monitor is driven by 3/4 U515.

Front Panel

There are 62 led's on the front panel controlled by 8 serial-in, parallel-out shift registers. All 8 shift registers are written to simultaneously and 8 consecutive write operations are required to set the LED's. The liquid crystal displays are managed by the display controllers, U601 and U602. Exclusive-or gates U605 and U606 drive the left over segments. Octal latch U604 provides the logic bits for these extra segments as well as the keyboard row strobes. U603 reads the switch closures as the rows are scanned.

Microprocessor Control

The microprocessor, U701, is a Z80A CPU clocked at 4 Mhz. 16K bytes of firmware are stored in the ROM, U702. U703 is a 2K byte static RAM, backed-up by a lithium battery. A power-down standby circuit, Q701, preserves the RAM contents when the power is turned off. The battery has a life of 5-10 years. The CPU has power-up and power-down resets to prevent erroneous execution during turn-on or short sags in the line voltage.

U704 is a 3-channel counter. One channel generates the baud rate for the RS232 interface while the other two are used to measure the frequency or period of the reference oscillator. U709 provides a gate pulse to counter 0. Multiplexer U708 selects whether the gate is a single period of the reference (period measurement) or a gate of known duration (frequency measurement). Counter 1 is a programmable divide by N counter whose output is either counted for one period of the reference, or, generates the gate pulse during which reference pulses are counted.

I/O addresses are decoded by U705, U706, and U707. The microprocessor controls the lock-in functions through I/O ports U714-U721. U713 generates an interrupt to the CPU every 4 msec to keep the microprocessor executing in real time.

RS232 Interface

The RS232 interface uses an 8251A UART, U801, to send and receive bytes in a bit serial fashion. Any standard baud rate from 300 to 19.2K baud may be selected with the configuration switches. The X16 transmit and receive clock comes from counter 2 of U704. The RS232 interface is configured as DCE so that a terminal may be connected with a standard cable. When a data byte is received by the UART, the RxRDY output interrupts the CPU to prevent the data from being overwritten.

GPIB Interface

The interface to the GPIB is provided by U802, an MC68488 General Purpose Interface Adapter (GPIA). The GPIB data and control lines are buffered by drivers U808 and U811. Because the GPIA uses a 1 MHz clock, wait states are provided by U805 to synchronize I/O transactions with the 4 MHz CPU. The GPIA interrupts the CPU whenever a GPIB transaction occurs which requires the CPU's response. (The GPIB address is set by switch bank SW1.)

Power Supplies

The line transformer provides two outputs, 40Vac and 15Vac, both center -tapped. The transformer has dual primaries which may be selected by the voltage selector card in the fuse holder. The 15Vac is rectified by diode bridge BR2 and passed to 5V regulator U909. The output of U909 powers the microprocessor and its related circuitry. The 40Vac output is half-wave rectified by BR1 and regulated by U901 and U902 to provide +20V and -20V. These two dc voltages are then regulated again by 15V regulators U903-U908. Each 15V regulator powers a separate section of the lock-in to reduce coherent pick up between sections. U911 and U912 provide plus and minus 7.5V and U910 generates +5V for the analog circuits.

Internal Oscillator

The internal oscillator is on a small circuit board attached to the rear panel of the instrument. Local

regulators, Q1 and Q2, provide power to the board. The VCO input is internally pulled up by R12. This pulls the VCO input to 10V when the VCO input is left open. 2/4 U1 translates the VCO input voltage to provide a negative control voltage to U2, the function generator. P3 adjusts the VCO calibration. U2 is a sine wave generator whose frequency range is selected by the VCO Range switch and capacitors, C4-C6. P2 adjusts the sine wave symmetry at low frequencies. 4/4 U1 buffers the output of U2. P1 adjusts the amplitude of the output sine wave. The output amplitude on the Sine Out is selected by the amplitude switch. The output impedance is 600 Ω.

Calibration and Repair

This section details calibration of the instrument. Calibration should be done only by a qualified electronics technician.

********* **WARNING** *********

The calibration procedure requires adjusting the instrument with power applied and so there is a risk of personal injury or death by electric shock. Please be careful.

Most of the calibration parameters are determined by a computer aided calibration procedure after burn-in at the factory. These calibration parameters are quite stable and so will not need to be adjusted. Calibration parameters which may need field adjustment are detailed below.

Multiplier Adjustments

On the **HIGH** dynamic reserve setting, there can be some reference frequency feedthrough. This section describes how to null this unwanted output.

This adjustment requires an oscilloscope and a signal generator which can provide a 500Hz reference signal.

Allow the unit to warm up for about 1 hour.

Reset the unit by turning it off and back on while holding the **REL** key down.

Select voltage input **A** and connect a 50 Ω terminator or shorting plug to the **A** input BNC connector. Connect the 500 Hz reference signal to the reference input. Set the **SENSITIVITY** to **1mV** and the **DYN RES** to **HIGH**. The **PRE TIME CONSTANT** should be set to **1mS** and the **POST TIME CONSTANT** to **NONE**. Connect the scope to the **OUTPUT** on the front panel. Set the scope to 2V/div and 5mS/div. Externally trigger the scope using the reference input signal.

After about 60 seconds, the scope display should show a 500 Hz sine wave on a 30 Hz (500/16 Hz) square wave. Remove the 4 screws holding the top panel on. Slide the top panel back about half way. Using a small screwdriver, adjust P402 at location D2 to minimize the 500 Hz output. Adjust P403 at location C2 to minimize the 30 Hz output.

Now set the both time constants to 1S. Adjust P404 at location F4 to zero the output. This adjustment has a range of 20% of full scale on the HIGH dynamic reserve setting. (2% on NORM and 0.2% on LOW). This zeroes the DC output of the unit on all dynamic reserve ranges.

Replace the top panel.

Amplifier and Filter Adjustments

This section describes how to adjust the Common Mode Rejection and Line notch filter frequencies. An oscilloscope and a signal generator which can provide an accurate line frequency and twice line frequency signal are required.

Allow the unit to warm up for about 1 hour.

Reset the unit by turning it off and back on while holding the **REL** key down.

Remove the 4 screws holding down the top panel. Slide the panel back about halfway.

CMRR

Set the reference frequency to 100 Hz. It is convenient to use the SYNC output of the signal generator as the reference input if it is available. Connect the sine output of the signal generator to the **A** input and set the input selector to **A**. With the **SENSITIVITY** at **100mV**, adjust the amplitude of the input signal to 100 mV (full scale).

Now set the input selector to **A-B** and connect the signal to both the **A** and **B** inputs. Set the **SENSITIVITY** to **20μV**, the **DYN RES** to **NORM** and the **BANDPASS** filter **IN**. Connect the scope to the **SIGNAL MONITOR** output on the rear panel. Set the scope to AC coupled, 0.2V/div, and 10mS/div. Externally trigger the scope using the reference input signal.

The CMRR is adjusted by the single turn potentiometer located at A1 under the single hole at the front of the signal shield. (The shield is the aluminum box on the left side of the main board). Using a small screwdriver, carefully adjust the pot to minimize the 100 Hz output on the scope. After nulling the output, set the sensitivity to **2μV** and null the output again.

Notch Filters

Set the reference frequency to 60 Hz (50 Hz). It is convenient to use the SYNC output of the signal generator as the reference input if it is available. Connect the sine output of the signal generator to the **A** input and set the input selector to **A**. With the **SENSITIVITY** at **100mV**, adjust the amplitude of the input signal to 100 mV (full scale).

Set **LINE NOTCH** to **IN**, the **SENSITIVITY** to **10mV**, the **DYN RES** to **LOW**. Connect the scope to the **SIGNAL MONITOR** output on the rear panel. Set the scope to AC coupled, 0.2V/div, 10mS/div. Trigger the scope externally using the reference input signal.

The **LINE NOTCH** frequency and depth are adjusted by the pair of 20 turn potentiometers located under the middle two holes in the signal shield (row 4 on the circuit board). Using a small screwdriver, carefully adjust one pot until the line output on the scope is minimized. Then adjust the other pot until the output is minimized. Iterate between the two pots until there is no further improvement. Set the **SENSITIVITY** to **5mV**, **2mV**, and **1mV**, repeating the adjustments at each sensitivity.

Repeat this procedure using a reference frequency of 120 Hz (100 Hz) and the **LINEX2 NOTCH** filter. The **LINEX2 NOTCH** is adjusted by the pair of 20 turn potentiometers located under the back two holes in the signal shield (row 5 on the circuit board).

Replace the top panel.

Replacing the Front-End Transistors

Both the voltage and current front end transistors (Q101 and Q102) are 2N6485 (IMF6485) dual JFETS. These transisitors are selected at the factory to meet the noise specifications.

This section outlines their replacement procedure in the event that they become damaged during use.

1)**Remove the AC power cord from the unit.**

2)Remove top and bottom panels.

3)Remove the blue side panels.

4)Release the rail which extends across the chasis above the circuit board by removing the screws at each end. Swivel the rail 90 degrees so that it runs front to back.

5)Release the signal shields by removing the 4 screws which hold it onto the circuit board. Be careful not to lose the the nuts. Carefully slide the shields back and then lift them out.

6)The input transistors are located on the main board, just behind the input selector switch. Q101 is the voltage (A, A-B) front end, and Q102 is the current (I) front end. Desolder and replace the appropriate transistor.

7)Replace the signal shields. Be careful to check that the shields do not touch any circuit board traces around their edges.

8)Swivel the rail back to its original position and replace the screws.

9)Replace the side panels.

10)Replace the top panels.

11)If Q101, the voltage front end has just been replaced, the Common Mode Rejection needs to be readjusted using the procedure described in the Amplifier Adjustments section.

Appendix A:
Noise Sources and Cures

Noise, random and uncorrelated fluctuations of electronic signals, finds its way into experiments in a variety of ways. Good laboratory practice can reduce noise sources to a manageable level, and the lock-in technique can be used to recover signals which may still be buried in noise.

Intrinsic Noise Sources

Johnson Noise. Arising from fluctuations of electron density in a resistor at finite temperature, these fluctuations give rise to a mean square noise voltage,

$$\bar{V}^2 = \int 4kT\,\mathrm{Re}[Z(f)]\,df = 4kTR\,\Delta f$$

where k=Boltzman's constant, 1.38×10^{-23} J/°K; T is the absolute temperature in Kelvin; the real part of the impedance, Re[z(f)] is the resistance R; and we are looking at the noise source with a detector, or ac voltmeter, with a bandwidth of Δf in Hz. For a 1MΩ resistor,

$$(\bar{V}^2)^{1/2} = 0.13\ \mu V/\sqrt{Hz}$$

To obtain the rms noise voltage that you would see across this 1MΩ resistor, we multiply $0.13\mu V/\sqrt{Hz}$ by the square root of the detector bandwidth. If, for example, we were looking at all frequencies between dc and 1 MHz, we would expect to see an rms Johnson noise of

$$(\bar{V}^2)^{1/2} = 0.13\ \mu V/\sqrt{Hz}\cdot(10^6\ Hz)^{1/2} = 130\ \mu V$$

'1/f Noise'. Arising from resistance fluctuations in a current carrying resistor, the mean squared noise voltage due to '1/f' noise is given by

$$\bar{V}^2 = A R^2 I^2 \Delta f/f$$

where A is a dimensionless constant, 10^{-11} for carbon, R is the resistance, I the current, Δf the bandwidth of our detector, and f is the frequency to which the detector is tuned. For a carbon resistor carrying 10 mA with R = 1k, Δf = f = 1Hz, we have

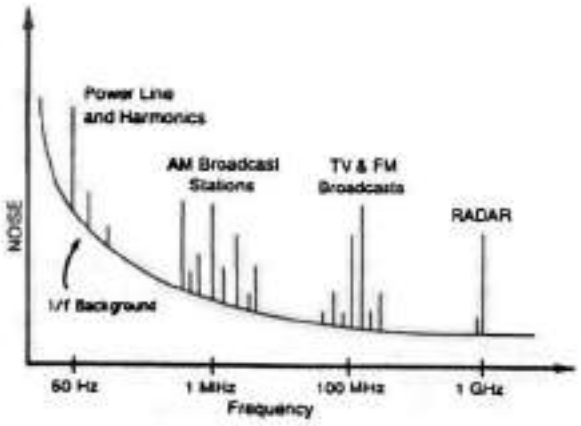
$$V_{noise} = 3\ \mu V\mathrm{rms}$$

And Others. Other noise sources include flicker noise found in vacuum tubes, and generation and recombination noise found in semiconductors.

All of these noise sources are incoherent. Thus, the total noise is the square root of the sum of the squares of all the incoherent noise sources.

Non-Essential Noise Sources

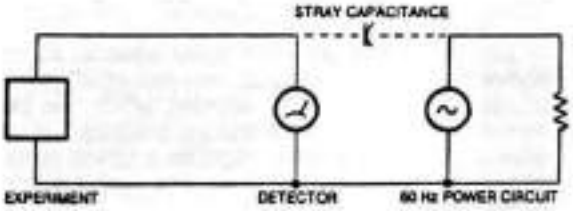
In addition to the "intrinsic" noise sources listed above there are a variety of "non-essential" noise sources, i.e. those noise sources which can be minimized with good laboratory practice. It is worthwhile to look at what might be a typical noise spectrum encountered in the laboratory environment:



Noise Spectrum

Some of the non-essential noise sources appear in this spectrum as spikes on the intrinsic background. There are several ways which these noise sources work their way into an experiment.

Capacitive Coupling. A voltage on a nearby piece of apparatus (or operator) can couple to a detector via a stray capacitance. Although C_{stray} may be very small, the coupled in noise may still be larger than a weak experimental signal.



Capacitive Noise Coupling

To estimate the noise current through C_{stray} into the detector we have

$$i = C_{stray}\frac{dV}{dt} = j\omega C_{stray}V_{noise}$$

where a reasonable approximation to C_{stray} can be made by treating it as parallel plate capacitor. Here, w is the radian frequency of the noise source (perhaps $2 \cdot \pi \cdot 60Hz$), V_{noise} is the noise voltage source amplitude (perhaps 120 Vac). For an area of $A = (.01\ m)^2$ and a distance of $d = 0.1m$, the 'capacitor' will have a value of 0.009 pF and the resulting noise current will be 400pA. This meager current is about 4000 times larger than the most sensitive current scale that is available on the SR510 lock-in.

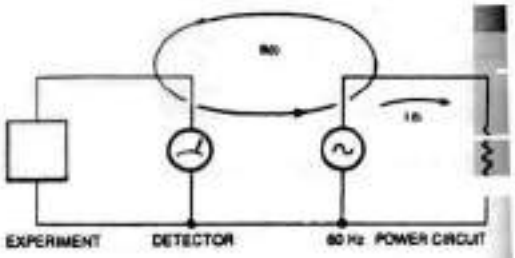
Cures for capacitive coupling of noise signals include:

1) removing or turning off the interfering noise source,

2) measuring voltages with low impedance sources and measuring currents with high impedance sources to reduce the effect of i_{stray},

3) installing capacitive shielding by placing both the experiment and the detector in a metal box.

Inductive Coupling. Here noise couples to the experiment via a magnetic field:



Inductive Noise Coupling

A changing current in a nearby circuit gives rise to a changing magnetic field which induces an emf in the loop connecting the detector to the experiment. ($emf = d\Phi_B/dt$.) This is like a transformer, with the experiment-detector loop as the secondary winding.)

Cures for inductively coupled noise include:

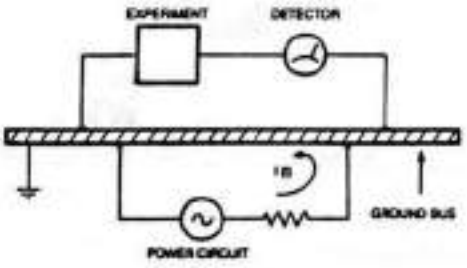
1) removing or turning off the interfering noise source (difficult to do if the noise is a broadcast station),

2) reduce the area of the pick-up loop by using twisted pairs or coaxial cables, or even twisting the 2 coaxial cables used in differential hook-ups,

3) using magnetic shielding to prevent the magnetic field from inducing an emf (at high frequencies a simple metal enclosure is adequate),

4) measuring currents, not voltages, from high impedance experiments.

Resistive Coupling (or 'Ground Loops'). Currents through common connections can give rise to noise voltages.



Resistive Coupling

Here, the detector is measuring the voltage across the experiment, plus the voltage due to the noise current passing through the finite resistance of the ground bus. This problem arises because we have used two different grounding points which are not at exactly the same potential. Some cures for ground loop problems include:

1) grounding everything to the same physical point,

2) using a heavier ground bus to reduce the potential drop along the ground bus,

3) removing sources of large currents from ground wires used for small signals.

Microphonics provides a path for mechanical noise to appear as electrical noise in a circuit or experiment. Consider the simple circuit below:



The capacitance of a coaxial cable is a function of its geometry so mechanical vibrations will cause the cable capacitance to vary with time. Since C=Q/V, we have

$$C\frac{dV}{dt} + V\frac{dC}{dt} = \frac{dQ}{dt} = i$$

so mechanical vibrations will cause a dC/dt which in turn gives rise to a current i, which will affect the detector. Ways to eliminate microphonic signals include:

1) eliminate mechanical vibrations,

2) tie down experimental cables so they will not sway to and fro,

3) use a low noise cable that is designed to reduce microphonic effects.

Thermocouple Effect. The emf created by dissimilar metal junctions can give rise to many microvolts of dc potential, and can be a source of ac noise if the temperature of the junction is not held constant. This effect is large on the scale of many low level measurements.

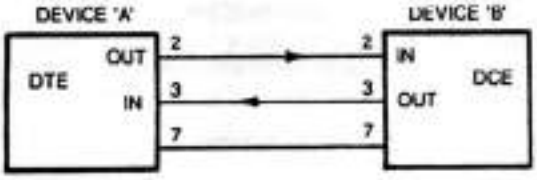
Appendix B:
Introduction to the RS232

The 'RS232' is a standard for bit serial asynchronous data communication. The standard defines the format for data transmission, the electrical specifications for the signal levels, and the mechanical dimensions of connectors.

Despite the definition of a standard, there are so many permutations of control lines, data formats, and transmission speeds, that getting two RS232 devices to communicate usually requires some work.

In this section, we will provide some basic information to aid you in connecting your RS232 device to the SR510 Computer Interface.

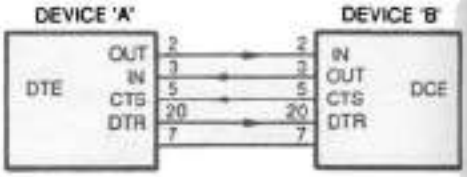
CASE 1 - The Simplest Configuration.



In this case, one wire is used to send data from device A to device B and another wire is used to send data from device B to device A. Notice that pin 2 is an output on device A and an input on device B. (It is good practice to run the ground, pin 7, between the devices as well). The RS232 defines two types of devices; DTE (Data Terminal Equipment) and DCE (Data Communications Equipment.) An RS232 port on a computer may be either a DTE or DCE but nearly every terminal with an RS232 port is a DTE. RS232 ports on a computer which are intended to connect to a modem, such as the COM1: port on the IBM PC, are DTE. The SR510 is configured as DCE, and so it may be directly connected to ASCII terminals and to the COM: ports on IBM PC's and compatibles.

As an example, consider connecting an RS232 ASCII computer terminal to the SR510 using a 2 wire link. The terminal is a DTE and the SR510 is a DCE. To operate correctly, the SR510 and the terminal must have the same settings for baud rate, parity, and number of stop bits. The control lines in the RS232 Standard, which are used to indicate that a device is ready to accept data, must also be connected correctly at the terminal end. If the terminal responds to a control line, it will believe that the SR510 is not ready to accept data (because the line is not passed in this example) and will therefore not send any data.

CASE 2 - RS232 with Control Lines.



The data lines are the same as in Case 1. In addition to the data lines, there are two control lines used:

CTS - Pin 5
"Clear to send" is a signal asserted by the DCE to tell the DTE that the DCE is ready to receive data.

DTR - Pin 20
"Data Terminal Ready" is a signal asserted by the DTE to tell the DCE that the DTE is ready to receive data.

The SR510 responds to the control lines as follows:

1) If the lines are not connected, the SR510 assumes that you are ready to receive data.

2) Data will not be transmitted from the SR510 if the DTR line (pin 20) is low. This is useful in the case when your program is not yet ready to receive data. If data transmission is not suspended, then data may be overwritten in your computer's UART (as it is not being retrieved by the program and so will be lost.) When this happens, the 'over-run' flag will be set in your computer's UART and it may be recognized by the operating system, generating an error message such as "I/O Device Error" (See the "W" command in the SR510 Command List for another way to slow data transmission.)

Baud Rate

The RS232 baud rate of the SR510 is switch selectable from 300 to 19.2K baud (see configuration switch setting in the front of this manual.) 19.2K baud means that data is transmitted at 19,200 bits/second. With one start bit, 2 stop bits, 8 data bits, and no parity bits, each ASCII character requires 573 µsec to be transmitted (11bits/19.2K baud.) The typical data string 5.1270<cr> has 7 characters, requiring 4 msec to be sent.

Stop Bits

Generally, selection of 2 stop bits will result in fewer data transmission errors.

Parity

The Parity bit provides a check against faulty data transfer. It is not commonly used in local data transmission environments. If the parity option is selected, the SR510 will transmit 8 data bits and a parity bit, however, no parity check of incoming data is done.

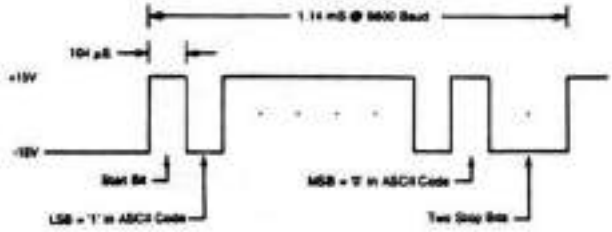
Voltage Levels

The RS232 uses bipolar voltage levels:



The control lines use positive logic. For example, the DCE tells the DTE that it is clear to send (CTS) by placing > +3 VDC on pin 5 of the interface. Similarly, the DTE can tell the DCE that it is not ready by placing -3 VDC on pin 20 (DTR) of the interface.

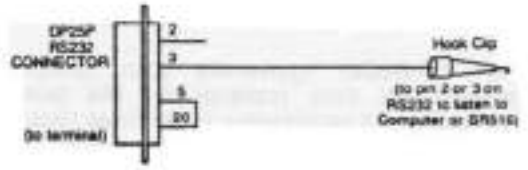
The data lines, pins 2 and 3, use negative logic. A 'zero' bit is represented by a positive voltage and a 'one' bit is represented by a negative voltage. A start bit is a positive voltage and a stop bit is a negative voltage. Data is transmitted with the least significant bit first. The letter 'A', which has the ASCII code 41H (0100 0001), would appear as follows:



If a parity option was selected, the parity bit would be sent after the 8th data bit, but before the first stop bit.

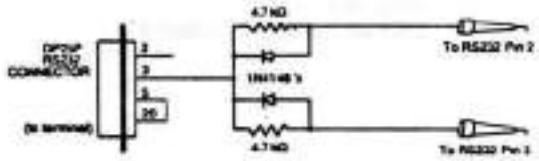
Final Tip

When you are trying to get the RS232 to work with your computer, it is helpful to be able to 'eavesdrop' on the RS232 data lines going between the SR510 and the computer. This can be done with an ASCII RS232 terminal and the following connector:



To test the connector, place the hook clip on pin 2 of the same connector (shorting pin 2 to pin 3.) Now, when you type at the terminal keyboard, data transmitted from pin 2 is received at pin 3 and displayed on the terminal screen. To use as a debugging tool, attach the hook clip to either pin 2 or pin 3 of the RS232 cable on the SR510 to show either data sent from the Computer or the SR510. The baud rate, parity, and stop bits of the terminal must match those of the SR510 and the computer. If your terminal has a mode which will display control characters (such as carriage returns and line feeds) it is helpful to operate in that mode.

A variant of the 'eavesdropping' approach is diagrammed below:



With this cable arrangement, the ASCII terminal can listen to the data passing in both directions. The only drawback is that the terminal will display garbled data if both devices transmit data at the same time.

Appendix C:
Introduction to the GPIB

The IEEE-488 Standard specifies the voltage levels, handshake requirements, timing, hardware details, pinout and connector dimensions for a 16 line, bit parallel bus. Many instruments may be connected in series to communicate over the same cable. Because the bits are passed in parallel, the GPIB is faster than the RS232.

The controller (generally your computer) coordinates data transfer on the bus by designating all participating instruments (including itself) as either a talker or a listener. Listeners can receive data placed on the bus by the Talker. Devices can have the capacity to operate in either mode. The address of each device is set by switches in the device and must be between 0 and 30.

Bus Description

Byte Transfer Control Group. This consists of 3 negative logic lines that implement the GPIB handshaking. The NRFD (Not Ready For Data) line is held low by any designated listener who is not ready to accept data. When every listener is ready, the line goes high and the talker may release data to the bus. After data is on the bus, the talker pulls the DAV (Data Valid) line down. At this point, each listener retrieves the data. Before and during the retrieval of the data, the listener holds the NDAC (No Data Accepted) line down. When every listener has received the data, the NDAC line goes high, allowing the talker to release the DAV line high. Finally, the listener pulls down the NDAC line until another transfer is initiated.

Data Bus: There are eight data lines which u negative logic and pass the bits of each byte parallel.

General Interface Lines: These five li operate independently of the handshake li and use negative logic.

1) The EOI (End or Identify) line is used by talker to designate the end of message.

2) The SRQ (Service Request) line is used by ar device to ask for service. The controller can seri poll each device (each device returns an 8 b status byte) to determine who needs attention. can also do a parallel poll using the EOI and AT lines where each device is assigned a single dat line.

3) The ATN (Attention) line makes both talkers an listeners accept information and passes control c the DAV line to the controller. This line is used b the controller to identify talkers and listener through their addresses.

4) The REN (Remote Enable) line changes th status of an instrument from local to remote.

5) The IFC (Interface Clear) line clears the bus of a data and activity.

Though GPIB is a very powerful interface, stric protocol must be observed for it to operate successfully.

Appendix D:
Program Examples

All of the program examples which follow do the same thing, only the computer, language, or interface is changed. The programs read the Output and write the result to the computer screen. In addition, the X6 analog output port is ramped from 0 to 10V.

Program Example 1:
IBM PC, Basic, via RS232

In this example, the IBM PC's ASYNC port (known as COM1: or AUX: to DOS users) will be used to communicate with the SR510. Only two wires between the IBM PC's ASYNC port and the SR510 are needed (pins #2 & #3 of the RS232), but pins 5,6,8 and 20 should be connected together on the connector at the IBM end.

```
10 '    EXAMPLE PROGRAM TO READ THE SR510 OUTPUT AND RAMP THE X6 ANALOG OUTPUT
20 '    USING IBM PC BASICA AND THE COM1: RS232 PORT.
30 '
40 '
50 '    ON THE REAR PANEL OF THE SR510, SET SWITCH #1 OF SW2 DOWN
60 '    AND ALL OTHER SWITCHES IN SW2 UP. (9600 BAUD, NO PARITY)
70 '
80 OPEN "COM1:9600,N,8,2,CS,DS,CD" AS #1
90 '    SET UP COM1: PORT TO 9600 BAUD, NO PARITY, 8 DATA BITS, 2 STOP BITS,
100 '                        IGNORE CTS (CLEAR TO SEND), DSR (DATA SET READY),
110 '                       AND CD (CARRIER DETECT).
120 '
130 PRINT #1,"    "     'CLEAR UART BY SENDING SPACES
140 PRINT #1,"I"        'RESET SR510
150 FOR I = 1 TO 200: NEXT I    'WAIT FOR RESET TO FINISH
160 '
170 X = 0       'INIT X6 OUTPUT TO ZERO
180 '
190 PRINT #1,"Q"        'READ OUTPUT
200 INPUT #1,V1         'INTO V1
210 '
220 PRINT "OUTPUT = ";V1
230 '
240 X = X + .0025       'INCREMENT X6 OUTPUT BY 2.5 mV
250 IF X > 10 THEN X = 0        'RESET X6 RAMP
260 PRINT #1, USING "X6,##.###";X       'SET X6 OUTPUT VOLTAGE
270 '
280 GOTO 190            'LOOP FOREVER
```

Program Example 2: IBM PC, Microsoft Fortran v3.3, via RS232

Machine language routines to interface to the COM1: RS232 port are provided in the file RS232.OBJ found on the SR565 disk. These routines allow for simple interfacing to the SR510 at 19.2 kbaud from FORTRAN programs.

To use these routines, the file 'for232.inc' (also c the SR565 disk) must be 'included' in th FORTRAN source.

Only two wires between the IBM PC's ASYNC pc and the SR510 are needed (pins #2 & #3 of th RS232), but pins 5,6,8 and 20 should b connected together on the connector at the IB end.

```
$storage:2
$include:'for232.inc'
c       for232.inc must be included to call subroutines in RS232.OBJ
c       link with RS232.OBJ (on SR565 disk)
c       RS232.OBJ defines:
c             init
c                          initializes COM1: to 19.2 kbaud
c             txstr (str)  str is a string terminated with '$'
c                          transmits str to COM1:
c             rxstr (str)  str must be declared with length of 15 or greater
c                          fills str with string received from COM1:
c             If and error occurs, nocom is called.
c             Nocom should be a FORTRAN subroutine in your program.

        program test

        character*20 str1,str2

c       Example program to read the SR510 outputs and ramp the
c       X6 analog output using Microsoft FORTRAN v3.3 and the
c       COM1: port. Set all switches in SW2 to UP on SR510
c       for 19.2 kbaud.

c       initialize COM1: port to 19.2 kbaud
        call init
c       set character wait interval to zero
        call txstr('w0$')

c       reset X6 to zero
        x6=0.0

c       read output into string variable str1
20      call txstr('q$')
        call rxstr(str1)

c       convert string variable into real variable v1
        read (str1,1000) v1
1000    format (bn,f10.0)

c       print results to screen
        write(*,2000) v1
2000    format(' Output 1=',G10.3)
```

Program Example 2: IBM PC, Microsoft Fortran v3.3, via RS232

Machine language routines to interface to the COM1: RS232 port are provided in the file RS232.OBJ found on the SR565 disk. These routines allow for simple interfacing to the SR510 at 19.2 kbaud from FORTRAN programs.

To use these routines, the file 'for232.inc' (also c the SR565 disk) must be 'included' in th FORTRAN source.

Only two wires between the IBM PC's ASYNC pc and the SR510 are needed (pins #2 & #3 of th RS232), but pins 5,6,8 and 20 should b connected together on the connector at the IB end.

```
$storage:2
$include:'for232.inc'
c       for232.inc must be included to call subroutines in RS232.OBJ
c       link with RS232.OBJ (on SR565 disk)
c       RS232.OBJ defines:
c             init
c                          initializes COM1: to 19.2 kbaud
c             txstr (str)  str is a string terminated with '$'
c                          transmits str to COM1:
c             rxstr (str)  str must be declared with length of 15 or greater
c                          fills str with string received from COM1:
c             If and error occurs, nocom is called.
c             Nocom should be a FORTRAN subroutine in your program.

        program test

        character*20 str1,str2

c       Example program to read the SR510 outputs and ramp the
c       X6 analog output using Microsoft FORTRAN v3.3 and the
c       COM1: port. Set all switches in SW2 to UP on SR510
c       for 19.2 kbaud.

c       initialize COM1: port to 19.2 kbaud
        call init
c       set character wait interval to zero
        call txstr('w0$')

c       reset X6 to zero
        x6=0.0

c       read output into string variable str1
20      call txstr('q$')
        call rxstr(str1)

c       convert string variable into real variable v1
        read (str1,1000) v1
1000    format (bn,f10.0)

c       print results to screen
        write(*,2000) v1
2000    format(' Output 1=',G10.3)
```

Program Example 3: IBM PC, Microsoft C v3.0, via RS232

Machine language routines to interface to the COM1: RS232 port are provided in the file RS232.OBJ found on the SR565 disk. These routines allow for simple interfacing to the SR510 at 19.2 kbaud from C programs.

To use these routines, the large model must be used. Compile with the /AL switch and link with RS232.OBJ.

Only two wires between the IBM PC's ASYNC port and the SR510 are needed (pins #2 & #3 of the RS232), but pins 5,6,8 and 20 should be connected together on the connector at the IBM end.

```
#include <stdio.h>

/*      Compile with >MSC program name/AL;
        link with RS232.OBJ (on SR565 disk)
                RS232.OBJ defines:
                init ()
                                        initializes COM1: to 19.2 kbaud
                txstr (str)
                    char *str;          str must terminate with '$' char
                                        sends string str to COM1:
                rxstr (str)
                    char *str;          str must be declared with 15 characters
                                          or more length.
                                        fills str with string received from COM1:

                If an error occurs, your procedure nocom() is called.
                Nocom() must be a C procedure in your program.

        Example program to read the SR510 outputs and ramp the
        16 analog output using Microsoft C v3.0 (large model) and the
        COM1: port. Set all switches in SW2 to UP on SR510
        for 19.2 kbaud.

*/

main ()
      {
      char str1[20], str2[20];
      float v1,x;

      init ();                  /* init COM1: port to 19.2 kbaud */
      txstr ("w09");            /* set character interval to 0 */

      x = 0;
      while (1)
            {
            txstr ("q1");             /* read channel 1 output */
            rxstr (str1);              /* into str1 */
            sscanf (str1, "%f", &v1); /* scan str1 for a float variable */
```

```
            x += 0.0025;              /* increment x6 output by 2.5 mV */
            if (x >= 10) x = 0;
            sprintf (str2, "I6,I#f", x);      /* make x6 command string */
            txstr (str2);                     /* send x6 command */

            /* print results to screen */
            printf ("Output = I10.3f\n", v1);
            }
        }
/* ********************************************** */
nocom ()
       /* error handling routine goes here */
       {
       printf("RS232 Timeout Error\n");
       putch (7);
       exit (1);
       }
```

Program Example 4: IBM PC,Microsoft Basic, via GPIB

This program requires the Capital Equipment Corporation GPIB card for the IBM PC or XT. It has firmware in ROM to interface high level languages to the GPIB.

Subroutine calls in Microsoft BASIC are done to memory locations specified by the name of the subroutine. The address is relative to the segment address specified by the DEF SEG statement preceding CALL.

In this program, the CEC card's ROM starts at OC0000H, the system controller's address is 21, and the SR510 has been assigned as GPIB address 23.

To monitor the GPIB activity with an RS232 terminal, SW1-6 should be down, and the ASCII terminal should be attached to the rear panel RS232 connector.

```
10 '    EXAMPLE PROGRAM TO READ THE SR510 OUTPUT AND RAMP THE X6 ANALOG OUTPUT
20 '    USING IBM PC BASICA AND THE CAPITAL EQUIPMENT CORP. GPIB INTERFACE CARD
30 '
40 '
50 '    ON THE SR510 REAR PANEL, SET SWITCHES #4 AND #6 ON SW1 TO DOWN (DEVICE
60 '    ADDRESS = 23, RS232 ECHO ON) AND SWITCH # 1 ON SW2 TO DOWN (RS232 BAUD
70 '    RATE = 9600). ALL OTHER SWITCHES SHOULD BE UP.
80 '    NOTE THAT THE RS232 ECHO IS FOR DEBUGGING AND DEMONSTRATION PURPOSES,
90 '   UNDER NORMAL CONDITIONS, SWITCH # 6 OF SW1 SHOULD BE UP SINCE THE RS232
100 '   ECHO SLOWS DOWN THE GPIB INTERFACE.
110 '
120 DEF SEG = &HC000    'BASE ADDRESS OF CEC CARD
130 INIT=0: TRANSMIT=3: RECV=6:          'ADDRESSES OF CEC FIRM WARE ROUTINES
140 ADDR%=21: SYS%=0                     'CONTROLLER ADDRESS
150 INZ$ = "IFC UNT UNL MTA LISTEN 23 DATA 'I' 13"
160 '
170 Q$ = "IFC MTA LISTEN 23 DATA 'Q' 13"
180 X6$ = "IFC MTA LISTEN 23 DATA 'X6,"
190 LISN$ = "IFC UNT UNL MLA TALK 23"
200 '
210 '
220 CALL INIT(ADDR%,SYS%)        'INIT CEC CARD
230 CALL TRANSMIT(INZ$,STATUS%) 'RESET SR530
240 GOSUB 540                   'CHECK TRANSMIT STATUS
250 '
260 I = 0       'INIT X6 OUTPUT TO ZERO
270 '
280 CALL TRANSMIT(Q$,STATUS%)   'READ OUTPUT
290 GOSUB 540
300 GOSUB 450                   'GET RESULT
310 V1 = VAL(ANS$)              'INTO V1
320 '
330 '
340 PRINT "OUTPUT = ";V1
350 '
360 I = I + .0025       'INCREMENT X6 OUTPUT BY 2.5 MV
370 IF I>10 THEN I = 0          'RESET RAMP
380 X$ = X6$ + STR$(I) + "' 13"         'MAKE X6 COMMAND STRING
390 CALL TRANSMIT (X$,STATUS%)          'SET NEW X6 VOLTAGE
400 GOSUB 540
410 '
420 GOTO 280    'LOOP FOREVER
```

```
430 '
440 '    GET AN ANSWER STRING FROM THE SR530
450 CALL TRANSMIT(LISN$,STATUS%)          'MAKE SR530 A TALKER
460 GOSUB 540
470 ANS$=SPACE$(10)                       'INIT ANSWER STRING
480 CALL RECV(ANS$,LENGTH%,STATUS%)       'READ RESULT INTO ANS$
490 GOSUB 540
500 RETURN
510 '
520 '
530 '    CHECK STATUS OF LAST TRANSMISSION FOR ERRORS
540 IF STATUS%=0 THEN RETURN    'STATUS OKAY
550 PRINT "STATUS CODE = ";STATUS%;" ON GPIB: ERROR"
560 STOP
```

Program Example 5: HP85 via GPIB

This program provides an example of an HP85 program using the GPIB interface which could be used to control the lockin amplifier. In this example, the SR510 should be addressed as device #16 by setting the switch bank SW1 per the instructions Page 6.

```
10 X=0
20 OUTPUT 716 ; "Q"
30 ENTER 716 ; V1
40 DISP "OUTPUT = " ; V1
50 X = X + .0025
60 IF X>10 THEN X=0
70 OUTPUT 716 ; "X6,";X
80 GOTO 20
```

SR565 v2.00 IBM PC Software

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Introduction

The SR565 Lock-in Data Acquisition software package adds a new dimension to your SR510 lock-in amplifier. With the SR565 you can easily acquire, display, and manipulate data from your lock-in amplifier directly on your personal computer. The SR565 has been extensively tested and can be running on your computer in just a few minutes. And since the source code for the SR565 program is available (for a nominal charge) you can modify the program to include any special features that may be required in your application.

To help familiarize yourself with the program we will guide you through a detailed example which illustrates many of its features. In order to follow the example, you do not have to connect your computer to an SR510; the program is configured when shipped in a special demonstration mode that allows it to be used without an SR510. Of course, you won't be able to acquire any data in this mode, but we've provided a data file on your program disk to a illustrate some of the SR565's graphics and data manipulation capabilities.

Before starting the example please read the section below which describes the few simple steps necessary to get the SR565 running on your computer.

Hardware Environment

The requirements for running SR565 v.2.0 are as follows

IBM PC/XT/AT or compatible
512Kbytes of RAM
DOS 2.1 or higher (3.2 is supported)

When using the SR565 with a PC or PC/XT it is strongly reccomended that an 8087 numeric coproccessor be included in the system. Use of the coprocessor will significantly improve program performance with these slower computers

To connect your computer to the lock-in amplifier you'll also need one of the following:

RS232 port (COM1: or COM2:)
or
National Instruments GPIB card
or
CEC GPIB card (either version)

A wide variety of graphics hardware is supported by the SR565 program. Among the many graphics cards supported are:

AT&T DCB
AT&T DEB
IBM CGA
IBM EGA
Sigma Designs Color-400 Card
Hercules Graphics Card
STB Graphics Plus-II Card
Tecmar Graphics Master:
Vega Video-7 Deluxe
Wyse-700
IBM PC-3270
Everex Edge

Of course, the resolution of the screen display and the program's use of color will depend on the particular graphics hardware in use.

Software Environment

Before running the SR565 program it is necessary to install both the graphics driver and the printer driver. These two programs are located on the SR565 GRAPHICS DISK. To load the printer driver, type PRTSCRN<cr>. Once the printer driver is loaded, you can obtain a hard copy of the current screen display by pressing <Shift-PrtSc>. The following options may be specified when loading the printer driver:

PRTSCRN /1	Use LPT1: printer
PRTSCRN /2	Use LPT2: printer
PRTSCRN /n	normal video
PRTSCRN /i	inverse video
PRTSCRN /l	"landscape" mode
PRTSCRN /p	"portrait" mode
PRTSCRN /s	show options in effect

The PRTSCRN program may be re-executed at any time to change the options in effect.

The graphics driver provides a hardware independent interface between the program and the various graphics cards that may be present in the system. To install the graphics driver, type METAWNDO<cr>. A message will be displayed confirming that the driver was successfully loaded.

Because the driver occupies about 100K of RAM, you may wish to remove the driver at some point after it has been loaded. To do this, type METAWNDO/k<cr>.

The graphics driver makes use of the font files (SYSTEM??.FNT) found on your SR565 graphics disk. Make sure that these font files have been copied to the drive and directory from which you will be running the SR565 program.

To run a program that makes use of the graphics driver, simply type the program name, as you would for any other program.

(Note that HGC FULL, VIDEO, and PRNSRS are no longer necessary. In no case should you use these earlier programs) METAWNDO and PRTSCRN can be included in your AUTOEXEC.BAT file.

Before you run SR565 v.2.0 for the first time you will need to run the SR5CON configuration program. The SR565.CFG file produced by SR5CON and used by SR565 v. 2.0 is incompatible with the file used by earlier versions. You must rerun SR5CON before attempting to run SR565 v. 2.0.

To run SR5CON (after installing METAWNDO and PRTSCRN), simply type

C> SR5CON

The program will attempt to determine the current graphics evironment and displays this information on the screen. If the information displayed is correct, type <Enter>to continue. If not, type <Ctl-C> to abort the program and rerun SR5CON with one of the following switches to force the correct graphics environment:

SR5CON/A	AT&T Graphics Adaptor	640x400 2-color
/A:1	AT&T Graphics Adaptor	640x400 2-color
/A:2	AT&T Display Enhancement Board (DEB)	640x200 16-color.
/A:3	AT&T Display Enhancement Board (DEB)	640x400 16-color.
/C	IBM Color Graphics Adaptor (CGA)	640x200 2-color.
/C:1	IBM Color Graphics Adaptor (CGA)	640x200 2-color.
/D	Sigma Design Color-400 Adaptor	640x400 16-color.
/E	IBM Enhanced Graphics Adaptor (EGA)	640x200 16-color.
/E:1	IBM Enhanced Graphics Adaptor (EGA)	640x350 monochrome.
/E:3	IBM Enhanced Graphics Adaptor (EGA)	640x200 16-color.
/E:4	IBM Enhanced Graphics Adaptor (EGA 128Kb)	640x350 16-color.
/E:5	IBM PS/2 Video Graphics Array (VGA)	640x480 16-color.
/E:6	IBM Enhanced Graphics Adaptor (EGA)	640x350 2-color.
/E:7	IBM PS/2 MultiColor Graphics Array (MCGA)	640x480 2-color.
/H	Hercules/AST Monochrome Graphics Adaptor	720x348 monochrome.
/L	Tseng Labs EVA/480 or NEC GB-1 Adaptor	640x480 16-color.
/O	Toshiba 3100	640x400 monochrome.
/S	STB GraphicsPlus-II Adaptor	640x352 monochrome.
/S:1	STB GraphicsPlus-II Adaptor	640x352 monochrome.
/S:3	STB GraphicsPlus-II Adaptor	640x200 4-color.
/S:5	STB GraphicsPlus-III Adaptor	640x400 monochrome.
/T	Tecmar Graphics-Master Adaptor	720x352 monochrome.
/T:1	Tecmar Graphics-Master Adaptor	720x352 monochrome.
/T:2	Tecmar Graphics-Master Adaptor	720x704 monochrome.
/T:3	Tecmar Graphics-Master Adaptor	640x200 16-color.
/T:4	Tecmar Graphics-Master Adaptor	640x400 16-color.
/U	Video-7 Vega Deluxe or Quadram ProSync	640x480 16-color.
/U:1	Video-7 Vega Deluxe or Quadram ProSync	640x480 16-color.
/V	Everex Edge Adaptor	640x200 16-color.
/V:1	Everex Edge Adaptor	640x200 16-color.
/V:2	Everex Edge Adaptor	640x400 4-color.
/W	Wyse WY-700 Graphics Display	640x400 monochrome.
/W:1	Wyse WY-700 Graphics Display	640x400 monochrome.
/X	IBM 3270 PC	720x350 monochrome.
/X:1	IBM 3270 PC	720x350 monochrome.

Note that the SR565 programs will run only on graphics cards with horizontal resolutions of 640 or 720 pixels. TheSR565 requires a horzontal resolution of at least 640 pixels. (I.e. the CGA multi-color modes are not supported)

If the program appears to be running, but no text appears on the screen, you probably have not transferred the .FNT files from the graphics disk to the default directory from which you are running the program. These font files must be present for the program to run normally!

The SR5CON program should now display the correct graphics information. Type <Enter> to continue with the program. When SR5CON finishes, it produces the file SR565.CFG which contains the configuration information for the SR565 program. The SR565.CFG file must always be on the same drive and directory as the SR565.EXE file when the SR565 progam is run. This file can be used without further modification **if:** 1) you are using RS-232 or 2) if you are using GPIB and you have left the I/O addresses on your GPIB card set to their default values. If the I/O addresses (**not** the GPIB addresses) have been changed from their default values, you will have to further edit SR565.CFG as described below.

After running SR5CON you should connect either the COM1: port or the GPIB port on your computer to the corresponding connector on the back panel of your SR510 with either a GPIB cable or a standard (NOT a null modem) RS232 cable. If you're using RS232 you should set the baud rate of the lock-in to 19.2 Kbaud. This is done by turning all the switches of SW2 on the back panel of the SR510 to the "up" postion. If you're using the GPIB, you'll have to set the lock-in address to the value you selected using SR5CON. The GPIB address is set using switches 1-5 of SW1 on rear panel of the SR510. Also make sure that switch 6 of SW1 is in the "up" position to turn off the GPIB - RS232 echo.

The SR565.CFG File

Unlike previous versions, SR565 v. 2.0 uses an ASCII, not binary, SR565.CFG configuration file. This allows the user to change the configuration information contained in SR565.CFG with any 9standard text editor. The default SR565.CFG file is shown below

```
    2     0    87    55  C
49152   696   737     1
    0    15    10    11      14
```

The format of the file is given below:

Line 1: (format 4i4,a1) Communications card identifier, GPIB address for computer (CEC card only), GPIB talk address for SR510 (GPIB address + 64), GPIB listen address for SR510 (GPIB address + 32), Default disk drive.

Line 2: (format 4i5) CEC card base address (both CEC cards), CEC I/O address (NEC 7210 CEC card only), National Instruments base I/O address, National Instruments board type identifier

Line 3: (format 5i5) background color, normal pen color, channel 1 color, channel 2 color, channel 3 color

The communications card identifier is a single integer coded as follows:

Identifier	Implies
1	RS-232 COM1:
2	National Instruments
3	CEC w/ TMS 9914A
4	Demonstration Mode
5	CEC w/ NEC7210
6	RS232 COM2:

In the case of the National Instruments GPIB card a further identifier is given on line 2:

Identifier	Implies
0	PC2 card
1	PC2A card
2	PC3 card

All addresses are specified as **decimal** numbers in SR565.CFG even though the addresses are normally given in hexidecimal. Thus, the base firmware address for the CEC card, 0C000H, is specified in the file as 49,152. Default address for the various GPIB cards are shown below:

Card	Hex	Decimal
Old CEC: (w/ TMS9914A)	C000	49152
New CEC: (w / NEC 7210)	C000	49152
New CEC I/O	02B8	696
National PC2	02B8	
National PC2A	02E1	
National PC3	0280	

If you have changed the address on your card, you must edit the SR565.CFG file to reflect the new address settings.

Line 3 of SR565.CFG gives the opportunity for the

user to change the colors used by the program. The program assumes color codes for the EGA card. These are:

Code	Color
0	black
1	blue
2	green
3	cyan
4	red
5	magenta
6	brown
7	white
8	dark grey
9	light blue
10	light green
11	light cyan
12	light red
13	light magenta
14	yellow
15	bright white

If you are using a different type of color adapter, experiment with the color values to arrive at a satisfactory display.

Using the National Instruments GPIB Card

When using the National Instruments PC2, PC2A, or PCIII GPIB card, or the IBM GPIB card (shich is functionally identical to the PC2A card) you must specify certain communication parameters using the program IBCONF suppled by National Instruments.

Consult your GPIB card manual for detailed information on running IBCONF. The required parameters are:

Device Name	Set to 'lockin'
EOS Byte	Set to 0AH (LF)
Terminate Read on EOS	YES
SET EOI with EOS on write	NO
SET EOI w/ last bye of write	NO

Note that the SR510's GPIB address may be set to any value as long as the value set on the instrument agrees with the value entered with IBCONF and SR5CON.

Running the Program

You are now ready to run the SR565 program. Two versions of the program are provided on your disk. The first, SR565.EXE is intended for systems that do not have an 8087/80287 numeric coprocessor. The second, SR567.EXE, is intended to be used with systems that do have a coprocessor. If you don't have an 8087/80287 you should save the file SR567.EXE, as acquiring a coprocessor significantly enhances the performance of the program. If you do have a coprocessor, you can rename the file SR567.EXE SR565.EXE. Be sure to first save the original non-coprocessor version under a different name in case it is ever needed.

To run the program, type SR565 at the DOS prompt. If a message appears displaying the correct graphics adaptor, then type <enter> to continue. If the message is incorrect, type <ctrl-c> to exit the program. Retype SR565 followed by the appropriate graphics switch from the table above. A title screen will come up giving the version number of the program. After a second or so, the title screen will be replaced by the main stripchart display screen. If the computer is connected to an SR510, the green activity LED should be continually flashing, indicating the progam is communicating successfully with the lock-in.

If the the program is not running at this point, check that:

1. You have the correct hardware. (check the list on the previous page)
2. Your computerhas at least 512Kbytes of RAM. (use the DOS CHKDSK command)
3. You have run METAWNDO and SR5CON

The main display screen has 4 major display areas. The **status bar**, at the top of the screen displays important status information about the SR510 and the SR565. The **stripchart display** in the center of the screen acts as an electronic stripchart recorder where data from the lock-in is plotted as a function of time. The **virtual front panel**, located at the bottom left of the screen, allows the front panel settings of the lock-in to be viewed and modified from the computer. The menu area, at the bottom right of the screen displays the menu selections currently available to the user. In general, items in the menu area are selected either by pressing the appropriate function key F1- F10 or by manipulating the cursor with the cursor control keys on the computer keyboard. Be sure when running the program that the Num Lock key is off; this allows the numeric keypad on the keyboard to function as cursor control keys.

A Measurement Example

Assuming you have the program running, it's now time to try an example measurement. We will illustrate how the SR565 program can be used to measure the amplitude response of the SR510's

120 Hz notch filter. We'll do this by using the program to generate a voltage ramp on one of the SR510's back panel D/A outputs. This ramp will be used to drive the VCO input of the SR510's internal oscillator generating a frequncy ramp. (If you have an older SR510 without the internal oscillator you may use a suitable external VCO) The SR565 will plot the output of the lock-in as the frequency is ramped through the the notch filter at 120 Hz.

If you are running the program in the demonstration mode, without an SR510, read through the description of how data is acquired and follow the instructions in the section entitled "Using the Demo File." This section will tell you how to recall a file which contains the results of the measurement described below. If you're already talking to an SR510, follow the instructions below for performing the example measurement.

We first need to set up the SR510's internal oscillator. Connect a BNC cable from the SR510's back panel X5 output to the VCO input of the internal oscillator. Since we'll want to scan from about 80 Hz-160 Hz and the range of the SR510's D/A outputs is -10.24 to + 10.24 volts, set the internal oscillator for 100Hz/Volt. Also set the oscillator for a 0.1 Volt output sine-wave. Connect the oscillator's reference out BNC to the front panel reference input of the SR510. Connect the sine out BNC of the oscillator to the signal input of the SR510.

Now press the F6 function key to activiate the "lock-in-setup" menu. This will allow you to change the lock-in front panel settings through the virtual front panel. Note that a cursor appears next to the sensitivity indicator. To adjust the sensitivity of the lock-in use the up and down arrow cursor control keys. Note that the senstivity is changed both on the computer screen and on the lock-in front panel. To change the phase setting of the SR510, for instance, use the left and right arrow cursor control keys to move the cursor next to the phase indicator on the virtual front panel. The phase can now be adjusted with the up and down arrow keys.

The lock-in settings for the example measurement are stored in a file "NOTCH.LIA" found on your program disk. To use the file, press F1 in the lock-in setup menu we've just entered. The program will prompt you for a filename. Type A:NOTCH <CR> at the prompt. (Replace A: by whatever drive your program disk is on) The virtual front panel, as well as the SR510 front panel, will change to reflect the settings stored in the file. ".LIA" files are a convenient way to store a set of lock-in settings that can be instantly recalled.

Next hit the <Esc> key to return to the main menu. Throughout the program the <Esc> key is used to exit the current function and move upwards towards the main menu. When the main menu appears, press F8 in order to program the SR510's D/A output for our frequency scan. The program will ask which D/A you wish to program; select X5 by moving the cursor over X5 and pressing <CR>. Since we wish to scan from 80-160 Hz and the oscillator is set for 100 Hz/Volt, use the keypad to select an initial voltage of 0.800 Volts. Note that after this is done the virtual front panel will show a frequency of about 80 Hz. Select a final voltage of 1.600 Volts, a scan time of 100 sec, a single scan, and a linear scan using the cursor keys and the <CR> key. The main menu should now be visible in the menu area.

We would like to record two things during our example scan; the frequency of the oscillator and the output of the SR510. To select the values recorded by the program press the F3 key. You will notice that the lock-in output (denoted by V) has already been selected. To select frequency, move the cursor over the frequency indicator and turn it "on" with the up arrow key. When you press <CR> notice that "freq" appears on the status bar indicating that it is one of the values recorded by the SR565. To have the program plot frequency press the "2" key on the keypad. A labeled Y Axis will appear on the right-hand side of the stripchart display and the status bar will display "freq" in reverse video indicating it is being plotted as well as recorded. Each of the recorded values shown on the status bar can be plotted or not plotted by pressing the correspondingly numbered key on the keypad.

The last thing to be done before actually beginning the scan is to scale the display. Press F7 to enter the scaling menu. The program will ask you to select which one of the quantities on the status bar you wish to scale. Select V using the cursor keys. Pressing F2 now allows you to enter the minimum and maximum values displayed on the screen. Enter "0" for Y_{min} and "0.2" for Y_{max}. The program will rescale the "V" axis and return to the main menu. Now try scaling the frequency axis for values between 70Hz and 170Hz. When finished, you are ready to begin the scan.

Begin the scan by pressing F1. The frequency and lock-in output will be plotted on the stripchart display in real time. When the plot reaches the right edge of the screen, the display will begin to scroll off to the left. You should see the frequency linearly increasing from 80 Hz to 160 Hz. It will also be easy to see the effect of the notch filter as the frequency approaches 120 Hz. After 100 sec the scan will stop at about 160 Hz and program will

stop taking data.

Using the Demo File

If you are running the program in the demonstration mode you can see the data resulting from the meausrement just decribed by recalling the file "NOTCH.LID" from your program disk. To do this press the F4 key in the main menu. Press F1 to recall a file and type "A:NOTCH" at the filename prompt. The data will appear on the stripchart display. The remainder of the example can now be followed as if an SR510 was connected to the computer.

Manipulating Data on the Screen

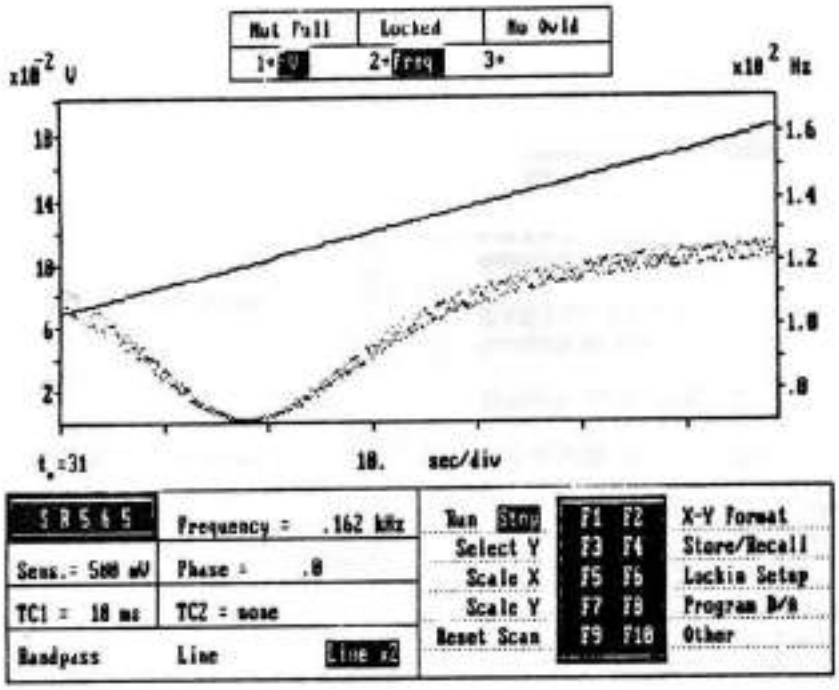
Now scroll through the data on the screen using the left and right arrow keys on the keypad. Note that the time corresponding to the left-hand side of the graph is displayed near the bottom left-hand corner of the stripchart display. You can change the scaling of the time axis by pressing F5 from the main menu. Select a time window of 150 seconds with the cursor, press <CR> and then <Esc> to return to the main menu. The data is replotted to reflect the new time axis scaling.

To plot the scan data in a form more suited for presentation, press F2 from the main menu. This causes the program to enter its other main mode of operation, the X-Y mode. The "X-Y mode" allows a full screen plot of any of the recorded quantities shown on the status bar vs. any other recorded quantitiy. Select the entire graph using the cursors which appear on the screen. Select frequency as the X-axis quantity and V as the Y-axis quantity. Select linear axes for both X and Y and select "yes" for both "Draw Grid?" and "Connect Points?" After a few seconds, you should see a full screen plot of lock-in output vs. frequency with labeled axes appearing on the monitor. The display should be similar to the one shown on page 53.

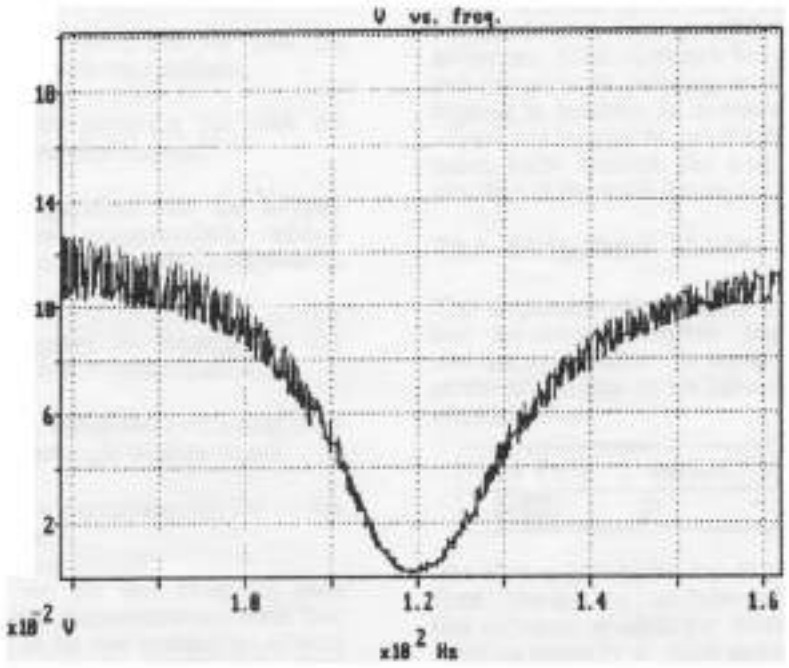
Note the cursor which appears on the title line of the display. You can move the cursor over the graph with the keypad arrow keys. Text typed at the keyboard appears on the screen at the cursor location.

Now press F1. A pop-up menu will appear in the middle of the screen. Select F1 to smooth the data. The noise in the original data is due to the short time constant which was used while acquiring the data. Select a 9 point smooth and press <CR>. The plot will be smoothed and replotted. Now select F4. The Y-axis will be automatically scaled to reflect the range of Y values plotted on the screen. If you have an Epson-type printer connected to your computer type <PrtSc> 2 to get a dump of the screen on your printer. (Note that <PrtSc> is a single shifted character) Finally, type <Esc> to remove the pop-up menu and <Esc> again to return to the main display screen.

The preceeding example has just scratched the surface of the possible operations that can be performed with the SR565. For instance, you can fit lines and exponential curves to the data in the X-Y display by selecting F2 from the pop-up menu. Take a while now to explore through the menus and experiment with different selections.



Stripchart Mode (above), and X-Y mode (below) displays of data from the example measurement.



SR565 Reference Guide

General

The SR565 is the data acquisition program for the Stanford Research Systems SR510 Lock-in Amplifier. About 70% of the program is written in Microsoft FORTRAN, version 3.3. The remainder of the program is written in Intel 8086 Assembly Language. The program is designed to be run with the following hardware configurations:

IBM PC-AT or Compatible with or without 80287 Numeric Coprocessor.

IBM PC or PC/XT or Compatible with 8087 Numeric Coprocessor

In addition, the program will run, although performance will be sacrificed, with the following hardware configuration:

IBM PC or PC/XT or Compatible without 8087 Numeric Coprocessor

In all cases, at least 512 Kbytes of memory must be installed and the display must have a horizontal resolution of either 640 or 720 pixels (see previous section for a list of compatible graphics adapters).

The Program Disk

SR565.EXE: SR565 program for use on machines without a numeric coprocessor.

SR567.EXE: SR565 program for use on machines with a numeric coprocessor.

SR565.CFG: Configuration file for SR565 program. Contains information about communications hardware. (Comes Configured in demo mode)

SR5CON.EXE: Program for configuring the SR565 for different communication setups.

NOTCH.LIA: Lock-in setup file containing front panel settings for the example measurement.

NOTCH.LID: Data file containing results of the example measurement.

The SR565.CFG file on the program disk configures in a special demonstration mode that allows the program to be run without an SR510 lock-in amplifier. **You must run SR5CON.EXE and specify the communications hardware to create a new .CFG file before the program will run with an SR510.**

The Graphics Disk

METAWNDO.EXE: Graphics Driver for SR565 program.

PRTSCRN.EXE: Printer Driver for SR565 program.

SYSTEM??.FNT: Font files for different graphics adapters.

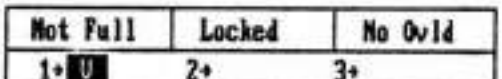
Using the SR565

The SR565 has two major operating modes, the stripchart mode and the X-Y mode. Data is first acquired as a function of time in the stripchart mode. In this mode the program resembles an electronic stripchart recorder. The X-Y mode is used to generate full screen plots of the data acquired in the stripchart mode. Both operating modes contain powerful tools for manipulating both the data and the display.

The program is menu driven and has been designed so that it can be operated almost entirely from the function keys F1-F10 and from the numeric keypad on the IBM keyboard. Actual typing of text has been kept to a minimum. Selections of program items are made either by pressing the appropriate function key or moving a cursor with the arrow keys over the item to be selected and typing <CR> to confirm the selection. (The NumLock key must be off when the program is running to allow the numeric keypad to function as cursor control keys) The <Esc> key is used to exit the current function and move back through the tree of menus in the direction of the main menu.

The Stripchart Mode

The stripchart-mode display contains the status bar, the stripchart display , the virtual front panel, and the menu area. To dump the contents of the stripchart display to an Epson-type printer, type <Shift-PrtSc>.



The **status bar**, at the top of the display, has two lines. The top line has three status indicators. The first indicates whether the SR565 has reached its memory capacity of 4000 points/array. If so, the indicator will display "FULL." No further data

acquisition is allowed once the arrays are full. The second indicates whether the SR510 is locked to the reference input. The third indicates whether the SR510 is in an overload condition.

The second line of the status bar displays which lock-in functions are currently being recorded by the SR565. Each function is shown next to the array number to which it corresponds. If a function is currently plotted on the stripchart display it is shown on the status bar in reverse video.

The **stripchart display**, in the center of the screen, is the area in which data from the SR510 is plotted. Up to two lock-in functions may be plotted on the stripchart display at once. Plotting a function inwolves pressing the key on the keypad corresponding to the array number of that function.

The amount of time plotted accross the stripchart display is variable from 10 seconds to 4500 seconds. This is controlled from the "Scale X" menu discussed below. If data acquisition lasts longer than this time, the display will scroll off to the left and new points will be plotted at the right edge of the graph. No data is lost when the display begins to scroll.

The most important lock-in front panel settings can be viewed on the **virtual front panel**, at the bottom left of the screen. This display is constantly updated to reflect the current lock-in front panel settings. The three SR510 signal filters at the bottom of the display are shown in reverse video when on, and in standard video when off. The front panel settings can be changed through the virtual front panel using the "Lock-in Setup" selection described below.

The stripchart mode has two major **menus**, both of which appear in the menu area at the bottom right of the screen. These are the "main" menu and the "other" menu. In the following section the funtions of each menu selection are explained in detail.

Main Menu Functions

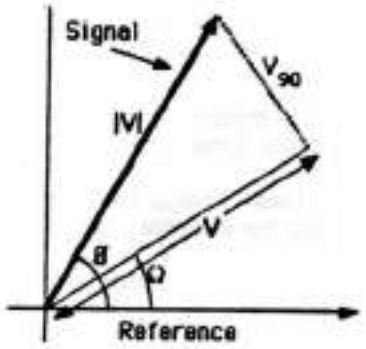
F1 Key (Run/Stop): The F1 key is used to start and stop data acquisition. The current Run/Stop status of the program is shown in reverse video on the main menu.

F3 Key (Select Y): The F3 key is used to select which values will be recorded by the program when data acquisiton begins. The SR565 has three data "arrays" into which data from the SR510 is placed. Each array has room for 4000 data points. Each of the arrays is associated with a particular lock-in function such as output, frequency, A/D voltage, etc.. When F3 is pressed, the program displays the 10 possible function choices in the menu area. They are:

|V|	Vector Amplitude of the Input
Ø	Phase of the Input Signal Relative to the Reference Signal
V	Normal Single Phase Lock-in output.
freq.	Frequency of the Reference Input.
X1-6	Voltage at the 6 general purpose D/As and A/Ds found on the back panel of the SR510.

Up to three functions may be selected at one time. A function is selected by moving the cursor arrow over it and using the up or down arrow on the keypad to turn it on and off. When you are finished selecting, press <CR> to confirm the selections. The functions you have picked will appear on the status bar next to their corresponding array number indicating that they are being recorded. This does not imply that the function is currently being plotted on the stripchart display. To plot a function press the number on the keypad corresponding to the array number of the desired function. The function will now appear on the status bar in reverse video indicating that it is being plotted. To turn it off, press the array number again.

The exact relation between V, |V|, and Ø is shown in the following phasor diagram. In the diagram, Ø is the phase angle returned by the SR565 and Ω is the phase setting on the SR510's front panel.



It is apparent that a single phase lock-in amplifier such as the SR510 cannot measure the vector amplitude and phase of a signal with a single measurement. Thus, when asked to record either

|V| or Ø, the program takes the following steps.

1. Takes a meaurement at the current phase setting. (V)
2. Advances the phase of the lock-in by 90°.
3. Waits for a period of about 10 ti e-constants to allow the lo.k-in output to settle.
4. Takes a measurement of the output at the new phase setting. (V_{90})
5. Returns the phase to its original setting.

The vector amplitude and phase of the signal is then computed from the quantities V and V_{90} as follows:

$$|V| = (V^2 + V_{90}^2)^{1/2}$$

$$Ø = \tan^{-1}(V_{90}/V) + \Omega$$

where Ω is the phase setting of the lock-in. Phase is alway returned by the program in units of degrees.

Because the program must wait a certain number of time constants for the output to settle each time the phase is switched, the sampling rate at which the program can acquire data when |V| or Ø is selected is related to the time constant setting of the instrument. This is more fully explained in the discussion of the F5 key. In addition, the other function keys, F2-F10, are disabled while data is being acquired with |V| or Ø selected. You must first stop data acquisition with the F1 key before using any of the other keys.

F5 Key (Scale X): This key has two functions. The first allows you to select the amount of time plotted accross the screen on the stripchart display. This is done by moving the cursor over the appropriate value and pressing <CR>. An <Esc> at this point will take you back to the main menu. If you continue, you can select the data acquisition sampling rate by scrolling the value displayed with the cursor keys. The SR565 displays the sampling rate and the maximum time for which data can be acquired at that rate. Pressing F1 will cause the program to select a sampling rate based on the current time constant setting of the SR510. The program chooses the sampling rate that is most nearly equal to 5/(time constant).There are a few situations where the SR565 will overide the user's selection of sampling rate or time window size. Although any time window may be selected when the program is not acquiring data, there is a minimum window size for each sampling rate that applies when the program is acquiring data. If you try to start taking data when the window is below this minimum the SR565 will rescale the time window and display a message notifying you that this has been done.

When either |V| or Ø have been selected the sampling rate is limited by the rate at which the phase can be toggled which is in turn limited by the time constant setting. Thus, when acquiring data with either of these functions selected, the SR565 will adjust both the sampling rate and the time window size to reflect the current time constant.

If for any reason the SR565 cannot acquire data at the rate entered in the F5 menu it will simply go as fast as it can. The actual times associated with data points may always be read off with the cursor. (See the discussion of the cursor function)

F7 (Scale Y): This menu allows you to scale the Y values displayed on the stripchart display. If there are two arrays currently being plotted the program will ask you to select which one you wish to scale. Use the arrow keys to move the blinking cursor on the status bar over the array you wish to scale. The minimum and maximum displayed values for that array will appear in the menu area. Two scaling options are allowed. Pressing F2 will allow you to explicitly enter the minimum and maximum values for that array. Pressing F1 "autoscales" the graph. That is, it scans the data plotted on the screen and adjusts the Y-axis scaling to appropriately display the data.

The up and down arrow keys are used in the scaling menu to "zoom" the Y axis. Pressing the down-arrow key zooms <u>in</u> on the Y axis while pressing the up-arrow key zooms <u>out</u>.

The units and multiplier for each array are shown above the axis corresponding to that array. In addition, the SR565 will sometimes display the message "Origin = <value>" above the axis. This will occur, for instance if you select 1.0 for Y minimum and 1.00001 for Y maximum. Since there is not enough room on the screen to display "1.00001", the program will label the axis in units of 10^{-6} and display the message "Origin = 1.0". The actual Y value is the sum of the origin value and the value displayed on the Y axis.

F9 (Reset Scan): Pressing F9 stops any data acquisition that may be in progress, clears all the data arrays and resets all D/A scans to their initial values.

|V| or Ø, the program takes the following steps.

1. Takes a meaurement at the current phase setting. (V)
2. Advances the phase of the lock-in by 90°.
3. Waits for a period of about 10 ti e-constants to allow the lo.k-in output to settle.
4. Takes a measurement of the output at the new phase setting. (V_{90})
5. Returns the phase to its original setting.

The vector amplitude and phase of the signal is then computed from the quantities V and V_{90} as follows:

$$|V| = (V^2 + V_{90}^2)^{1/2}$$

$$Ø = \tan^{-1}(V_{90}/V) + \Omega$$

where Ω is the phase setting of the lock-in. Phase is alway returned by the program in units of degrees.

Because the program must wait a certain number of time constants for the output to settle each time the phase is switched, the sampling rate at which the program can acquire data when |V| or Ø is selected is related to the time constant setting of the instrument. This is more fully explained in the discussion of the F5 key. In addition, the other function keys, F2-F10, are disabled while data is being acquired with |V| or Ø selected. You must first stop data acquisition with the F1 key before using any of the other keys.

F5 Key (Scale X): This key has two functions. The first allows you to select the amount of time plotted accross the screen on the stripchart display. This is done by moving the cursor over the appropriate value and pressing <CR>. An <Esc> at this point will take you back to the main menu. If you continue, you can select the data acquisition sampling rate by scrolling the value displayed with the cursor keys. The SR565 displays the sampling rate and the maximum time for which data can be acquired at that rate. Pressing F1 will cause the program to select a sampling rate based on the current time constant setting of the SR510. The program chooses the sampling rate that is most nearly equal to 5/(time constant).There are a few situations where the SR565 will overide the user's selection of sampling rate or time window size. Although any time window may be selected when the program is not acquiring data, there is a minimum window size for each sampling rate that applies when the program is acquiring data. If you try to start taking data when the window is below this minimum the SR565 will rescale the time window and display a message notifying you that this has been done.

When either |V| or Ø have been selected the sampling rate is limited by the rate at which the phase can be toggled which is in turn limited by the time constant setting. Thus, when acquiring data with either of these functions selected, the SR565 will adjust both the sampling rate and the time window size to reflect the current time constant.

If for any reason the SR565 cannot acquire data at the rate entered in the F5 menu it will simply go as fast as it can. The actual times associated with data points may always be read off with the cursor. (See the discussion of the cursor function)

F7 (Scale Y): This menu allows you to scale the Y values displayed on the stripchart display. If there are two arrays currently being plotted the program will ask you to select which one you wish to scale. Use the arrow keys to move the blinking cursor on the status bar over the array you wish to scale. The minimum and maximum displayed values for that array will appear in the menu area. Two scaling options are allowed. Pressing F2 will allow you to explicitly enter the minimum and maximum values for that array. Pressing F1 "autoscales" the graph. That is, it scans the data plotted on the screen and adjusts the Y-axis scaling to appropriately display the data.

The up and down arrow keys are used in the scaling menu to "zoom" the Y axis. Pressing the down-arrow key zooms <u>in</u> on the Y axis while pressing the up-arrow key zooms <u>out</u>.

The units and multiplier for each array are shown above the axis corresponding to that array. In addition, the SR565 will sometimes display the message "Origin = <value>" above the axis. This will occur, for instance if you select 1.0 for Y minimum and 1.00001 for Y maximum. Since there is not enough room on the screen to display "1.00001", the program will label the axis in units of 10^{-6} and display the message "Origin = 1.0". The actual Y value is the sum of the origin value and the value displayed on the Y axis.

F9 (Reset Scan): Pressing F9 stops any data acquisition that may be in progress, clears all the data arrays and resets all D/A scans to their initial values.

the selected quantity with the up and down arrow keys. The SR565 will send the appropriate commands to the lock-in to set the new values.

Note that the virtual front panel will also reflect any changes made at the SR510. The SR565 is constantly interrogating the SR510's front panel settings and updating the virtual front panel to reflect any changes. The update rate varies depending on the current workload of the program but in no case will it be more than 4 or 5 seconds between the time a front-panel setting is changed and the time the change appears on the virtual front panel.

When phase is selected there are additional keys you can use to adjust the front-panel setting. <Home> will zero the phase. <PgUp> will increase the phase by 90°. <PgDn> will decrease the phase by 90°.

The Lock-in Setup menu also enables you to access ".LIA" files. ".LIA" files allow you to store an entire set of lock-in front panel settings and recall them at once. To use a ".LIA" file enter the lock-in setup menu and press the F1 key. You can store the current front panel settings with the F2 key or recall an existing file of settings with the F1 key. In either case, the SR565 will prompt you to enter a filename. The same remarks apply for entering ".LIA" filenames as did for data files.

F8 (Program D/A): This menu selection allows you to program either of the SR510's rear panel D/A outputs (X5 or X6) for a linear or exponential voltage ramp. The program first asks which D/A you wish to program. The program next asks you to set the initial and final voltages in the ramp. Note that the program will actually set the D/A voltage to the value displayed on the screen. Thus, if you are using the D/A to drive the VCO input of the internal oscillator, for instance, you can watch the oscillator frequency change on the virtual front panel as you set the voltages for the ramp. The SR565 will then ask the following questions:

Enter Ramp Time: Enter the duration of the ramp in seconds. Typing <CR> causes the ramp time to default to the value shown on the screen.

Repeat or Single: "Repeat" causes the ramp to restart each time it reaches its final voltage. Selecting "Single" causes the ramp to terminate, and will turn off data acquisiton, after reaching its final voltage. In either case, the scan is reinitialized each time "Reset Scan" (F9) is selected from the main menu.

Linear or Log. Selecting "Linear" causes the voltage to ramp in a linear fashion. Selecting "Log" causes the voltage to ramp according to the equation:

$$V(t) = V_o e^{kt}$$

where k is determined by:

$$k = (\ln(V_f/V_o))/\Delta t)$$

If a log scan is chosen, both the initial and final voltages must be positive. The SR565 will display an error message if this is not the case.

Pressing the F1 key in the Program D/A menu turns off the selected D/A scan. The scan will remain inactive until it is reprogramed.

F10 (Other): Pressing F10 causes the menu area to display the "other" menu rather than the main menu. The description of the "other" menu items are given below.

"Other" Menu

F1 (Smooth): Typing F1 in the "other" menu allows you to smooth data on the stripchart display. After selecting which array you want to smooth by moving the cursor on the status bar, the program will ask you whether you want a 3-point or 9-point smooth. The smoothing coefficients for the 3-point smooth are .25, .5 , .25. For the 9-point smooth, the coefficients are .04, .08, .12, .16, .20, .16, .12, .08, .04. Select the appropriate smoothing method with the cursor and press <CR>. The program will smooth and replot the entire array, not just the portion visible on the screen.

F2 (Printer): Selecting Printer causes the SR565 to plot the contents of the stripchart arrays on an Epson type printer. All of the data will be plotted, not just the portion visible on the screen. To abort the plot type <Esc>.

F3 (Calculator): The calculator is a powerful tool which allows a wide range of arithmetic manipulations to be performed on data acquired in the stripchart mode. First select the array you wish to work on. It is important to remember that operations with the calculator will alter the data values stored in the selected array. Therefore, be sure to save any important data before changing it with the calculator. When an array has been changed with the calculator a "*"character appears next to it on the status bar to remind you that it has been changed.

Next select the operation you wish to perform on the array with the cursor. The operations "+", "-",

the selected quantity with the up and down arrow keys. The SR565 will send the appropriate commands to the lock-in to set the new values.

Note that the virtual front panel will also reflect any changes made at the SR510. The SR565 is constantly interrogating the SR510's front panel settings and updating the virtual front panel to reflect any changes. The update rate varies depending on the current workload of the program but in no case will it be more than 4 or 5 seconds between the time a front-panel setting is changed and the time the change appears on the virtual front panel.

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Next select the operation you wish to perform on the array with the cursor. The operations "+", "-",

array 3	R4	third data array
timer	I4	timing array
EOF		

Only the number of data arrays given by nrcrd are in the file. The timing array is always in the file.

The function codes have the following meanings:

Code	Array Function
1	|V|
2	Ø
3	V
4	frequency
5	X1
.	
.	
.	
10	X6
11	Null
12	Temp1
13	Temp 2

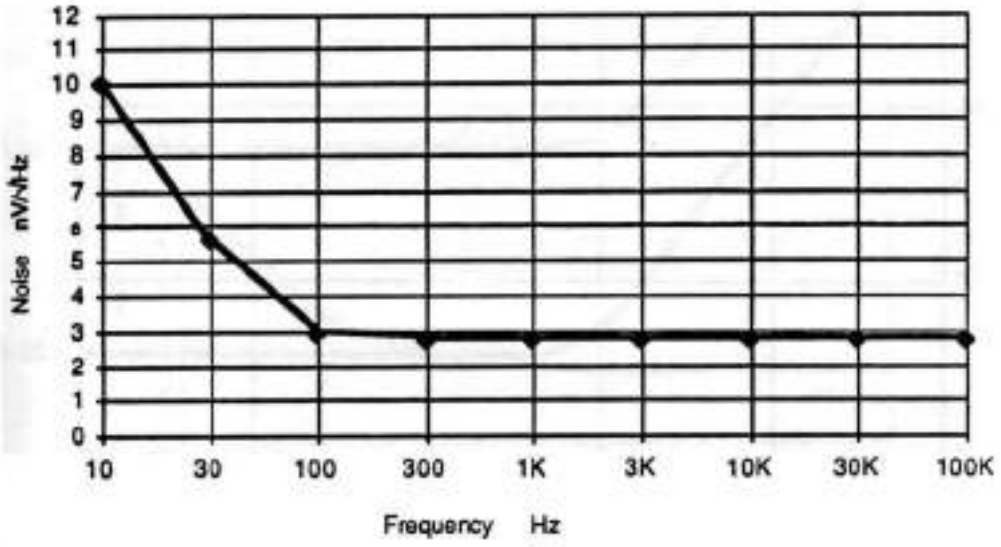
The timing array is an array of 4 byte integers. Each integer gives the time since the beginning of the scan of the corresponding data points in units of .0549254 seconds. (This number is the period of the PC's internal clock).

Source Code

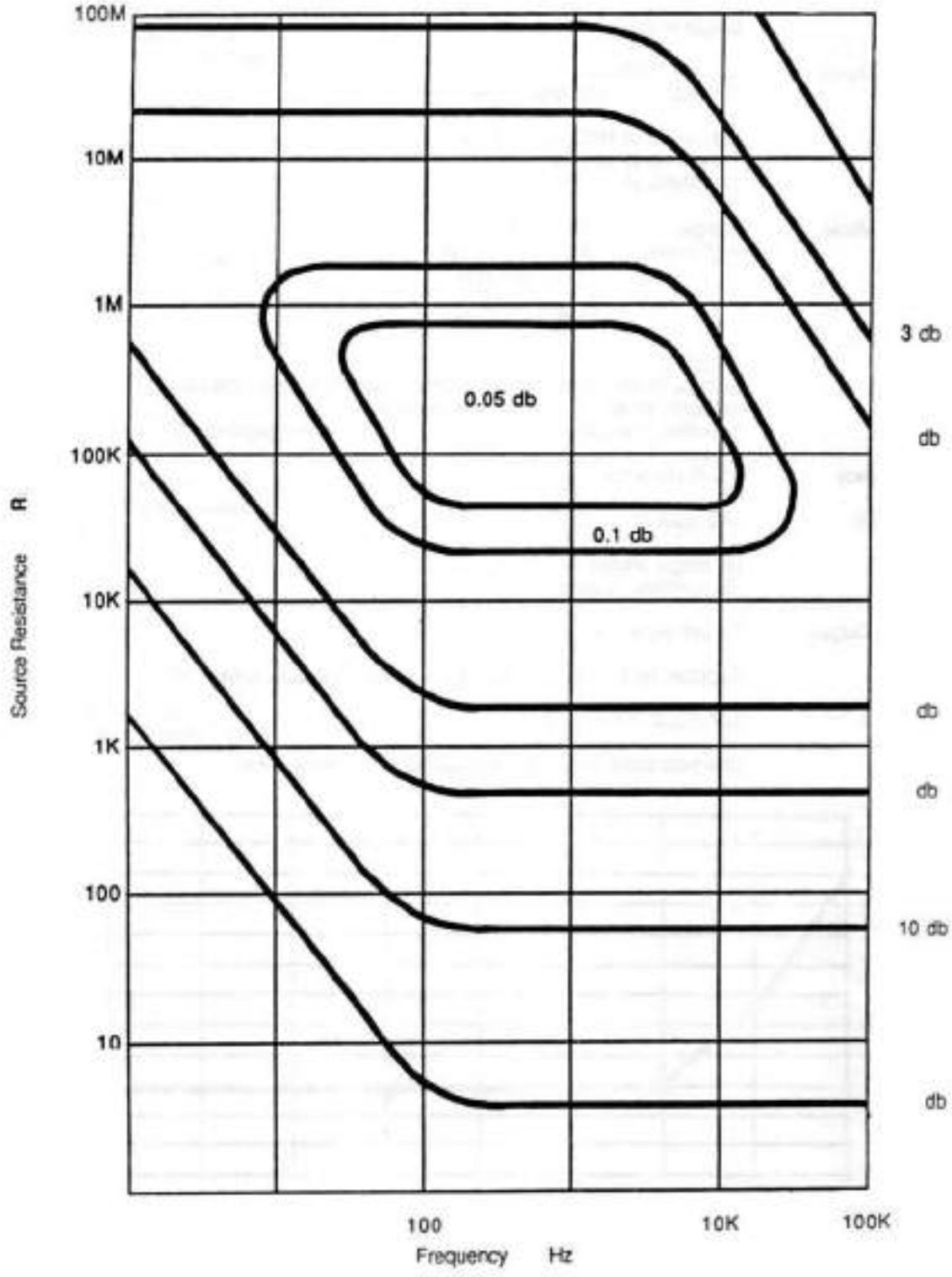
The complete source code for the SR565 is available from Stanford Research Systems. The source code disk also contains a brief guide on how to modify the program to include custom features.

SR550 Preamplifier Specification Summary

Input Impedance	100 MΩ + 25 pF
Inputs	Single ended or differential (switch selectable)
Maximum Inputs	250 mV RMS for overload 100 Vdc, 10 Vac damage threshold
Noise	2.8 nV//Hz at 1000 Hz (typical) 3.0 nV//Hz at 100 Hz 10 nV//Hz at 10 Hz
Common Mode	Range: 1 Volt peak Rejection: 110 dB at 100 Hz 110 dB at 1 kHz 90 dB at 10 kHz 70 dB at 100 kHz
Gain	1,2,5,10 Automatically set by SR510 or SR530 Lock-in depending on full scale sensitivity and dynamic reserve. Sensitivity ranges from 10 nV to 200 mV full scale (expand off)
Gain Accuracy	1% (2 Hz to 100 kHz)
Gain Stability	100 ppm/ C
Outputs	(A) single ended (600 Ω impedance) (B) shielded ground
Maximum Output	7 Volts peak to peak
Power	Supplied by SR510 or SR530 Lock-in via connector cable.
Mechanical	1.3" X 3.0" X 5.1" , 1 lb.
Warranty	One year parts and labor on materials and workmanship.

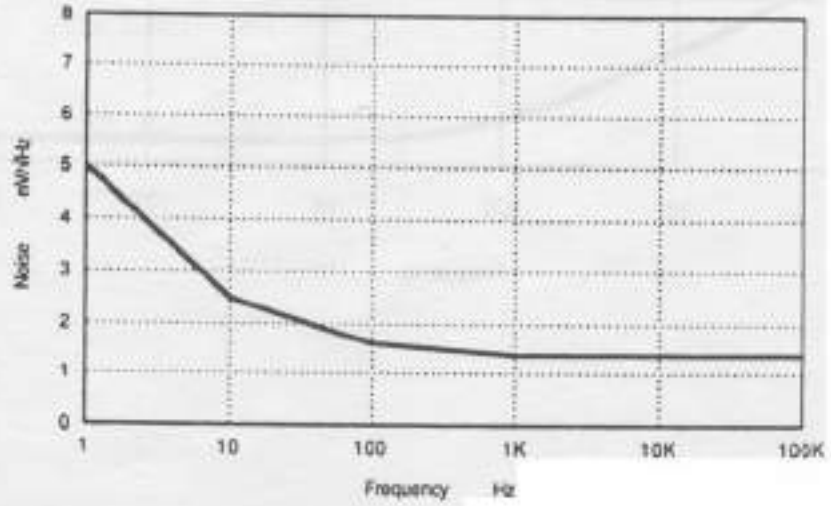


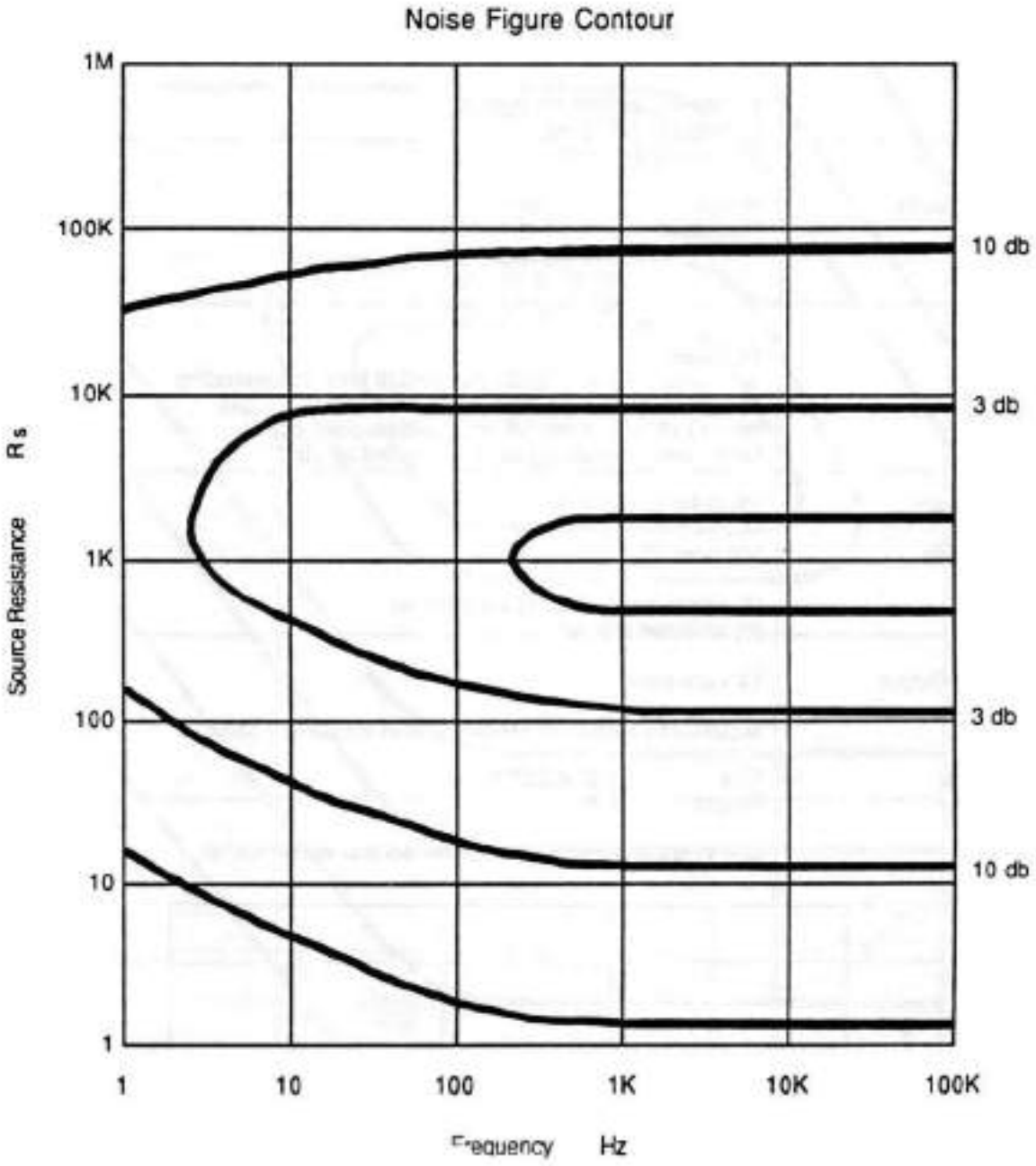
Noise Figure Contour



SR552 Preamplifier Specifications Summary

Input Impedance	100 KΩ + 25 pF
Inputs	Single ended or differential (switch selectable)
Maximum Inputs	70 mV rms for overload Damage threshold: 20 Vac, 50 Vdc
Noise	1.4 nV/√Hz at 1000 Hz (typical) 1.6 nV/√Hz at 100 Hz 2.5 nV/√Hz at 10 Hz
Common Mode	Range: 1 Volt peak Rejection: 110 dB at 100 Hz 100 dB at 1 kHz 80 dB at 10 kHz 60 dB at 100 kHz
Gain	10,20,50,100 Automatically set by SR510 or SR530 Lock-In depending on sensitivity and dynamic reserve. Sensitivity ranges from 10 nV to 200 mV full scale (with expand off). Note: Lock-in readings must be divided by 10.
Gain Accuracy	1% (2 Hz to 100 kHz)
Gain Stability	200 ppm/°C
Outputs	(A) single ended (600 Ω impedance) (B) shielded ground
Maximum Output	10 Volts peak
Power	Supplied by SR510 or SR530 Lock-In via control cable.
Mechanical	Size 1.3" X 3.0" X 5.1" Weight 1 lb.
Warranty	One year parts and labor on materials and workmanship.




Noise Figure Contour
1M
100K
10K
1K
100
10
1
Source Resistance Rs
10 db
3 db
3 db
10 db
1
10
100
1K
10K
100K
Frequency Hz

Documentation

This section contains the parts lists and schematics for the SR510 lock-in amplifier.

The first digit of any part number can be used to locate the schematic diagram for the part. For example, R415 is located on sheet 4 of the schematic diagrams.

Main Assembly

REF#	VALUE	DESCRIPTION
BR1	BR-81D	Integrated Circuit
BR2	BR-81D	Integrated Circuit
BT1	BR-2/3A	Battery
C 101	.1U	Capacitor, Mylar/Poly, 50V, 5%, Rad
C 102	.1U	Capacitor, Mylar/Poly, 50V, 5%, Rad
C 103	10U	Capacitor, Electrolytic, 16V, 20%, Rad
C 104	22P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 105	100P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 106	22P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 107	2200U	Capacitor, Electrolytic, 16V, 20%, Rad
C 108	2200U	Capacitor, Electrolytic, 16V, 20%, Rad
C 110	10U	Capacitor, Electrolytic, 16V, 20%, Rad
C 111	1P	Capacitor, Silver Mica, 250V, 5%
C 116	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 117	47U	Capacitor, Electrolytic, 25V, 20%, Rad
C 118	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 120	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 121	47U	Capacitor, Electrolytic, 25V, 20%, Rad
C 122	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 123	1.0U	Capacitor, Stacked Metal Film
C 124	1.0U	Capacitor, Stacked Metal Film
C 125	2200U	Capacitor, Electrolytic, 16V, 20%, Rad
C 126	2200U	Capacitor, Electrolytic, 16V, 20%, Rad
C 127	.22U	Capacitor, Stacked Metal Film
C 128	.22U	Capacitor, Stacked Metal Film
C 129	1.0U	Capacitor, Stacked Metal Film
C 131	1.0U	Capacitor, Stacked Metal Film
C 132	1.0U	Capacitor, Stacked Metal Film
C 133	.01U	Capacitor, Stacked Metal Film
C 134	.01U	Capacitor, Stacked Metal Film
C 136	10P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 137	10P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 145	24P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 146	24P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 147	10P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 148	47P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 201	7.5P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 202	150P	Capacitor, Polystyrene, 50V, 5%, Ax
C 203	.0015U	Capacitor, Stacked Metal Film
C 204	.015U	Capacitor, Stacked Metal Film
C 205	.15U	Capacitor, Stacked Metal Film
C 206	1.0U	Capacitor, Stacked Metal Film
C 207	.47U	Capacitor, Stacked Metal Film
C 208	10P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 209	150P	Capacitor, Polystyrene, 50V, 5%, Ax
C 210	.0015U	Capacitor, Stacked Metal Film
C 211	.015U	Capacitor, Stacked Metal Film
C 212	.15U	Capacitor, Stacked Metal Film
C 213	1.0U	Capacitor, Stacked Metal Film
C 214	.47U	Capacitor, Stacked Metal Film
C 215	1.0U	Capacitor, Stacked Metal Film
C 216	.1U	Capacitor, Stacked Metal Film
C 217	10U	Capacitor, Electrolytic, 16V, 20%, Rad
C 218	10U	Capacitor, Electrolytic, 16V, 20%, Rad
C 230	.15U	Capacitor, Stacked Metal Film
C 301	1.0U	Capacitor, Stacked Metal Film
C 302	10P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 303	24P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 304	560P	Capacitor, Polystyrene, 50V, 5%, Ax
C 305	10U	Capacitor, Electrolytic, 16V, 20%, Rad
C 306	1.0U	Capacitor, Stacked Metal Film
C 307	.001U	Capacitor, Stacked Metal Film
C 308	.33U	Capacitor, Stacked Metal Film
C 310	22P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 311	22P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 312	47P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 313	47P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 314	.1U	Capacitor, Stacked Metal Film
C 315	10U	Capacitor, Electrolytic, 16V, 20%, Rad
C 317	1.0U	Capacitor, Stacked Metal Film
C 318	.001U	Capacitor, Stacked Metal Film
C 319	.33U	Capacitor, Stacked Metal Film
C 320	.001U	Capacitor, Stacked Metal Film
C 321	10P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 322	10P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 323	47U	Capacitor, Electrolytic, 25V, 20%, Rad
C 324	47U	Capacitor, Electrolytic, 25V, 20%, Rad
C 325	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 326	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 327	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 328	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 329	47U	Capacitor, Electrolytic, 16V, 20%, Rad
C 330	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 331	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 332	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 333	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 334	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 335	470P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 336	470P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 337	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 338	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 401	1.0U	Capacitor, Stacked Metal Film
C 402	.01U	Capacitor, Stacked Metal Film
C 403	.01U	Capacitor, Stacked Metal Film
C 404	1.0U	Capacitor, Stacked Metal Film
C 405	1.0U	Capacitor, Stacked Metal Film
C 406	.01U	Capacitor, Stacked Metal Film
C 407	.01U	Capacitor, Stacked Metal Film
C 408	10P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 409	.1U	Capacitor, Stacked Metal Film
C 410	.1U	Capacitor, Stacked Metal Film
C 411	.1U	Capacitor, Stacked Metal Film
C 412	.1U	Capacitor, Stacked Metal Film
C 413	.001U	Capacitor, Stacked Metal Film
C 414	.033U	Capacitor, Stacked Metal Film
C 415	10U	Capacitor, Mylar/Poly, 50V, 5%, Rad
C 416	.1U	Capacitor, Stacked Metal Film
C 417	1.0U	Capacitor, Stacked Metal Film
C 418	.01U	Capacitor, Stacked Metal Film
C 419	.01U	Capacitor, Stacked Metal Film
C 420	.001U	Capacitor, Stacked Metal Film
C 421	33P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 422	33P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 501	330P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 502	.01U	Capacitor, Polystyrene, 50V, 5%, Rad
C 503	220P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 504	100P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 505	22P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 506	.047U	Capacitor, Stacked Metal Film
C 507	.047U	Capacitor, Stacked Metal Film
C 508	.047U	Capacitor, Stacked Metal Film
C 509	.047U	Capacitor, Stacked Metal Film
C 510	.047U	Capacitor, Stacked Metal Film
C 511	.047U	Capacitor, Stacked Metal Film
C 512	.047U	Capacitor, Stacked Metal Film
C 513	.047U	Capacitor, Stacked Metal Film
C 514	.001U	Capacitor, Stacked Metal Film
C 515	.001U	Capacitor, Stacked Metal Film

C 516	.001U	Capacitor, Stacked Metal Film
C 517	100P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 518	.1U	Capacitor, Stacked Metal Film
C 519	.001U	Capacitor, Stacked Metal Film
C 520	.01U	Capacitor, Stacked Metal Film
C 521	.01U	Capacitor, Stacked Metal Film
C 523	.01U	Capacitor, Stacked Metal Film
C 525	.01U	Capacitor, Stacked Metal Film
C 526	.1U	Capacitor, Ceramic Disc, 50V, 20%, Z5U
C 527	.1U	Capacitor, Ceramic Disc, 50V, 20%, Z5U
C 701	220P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 702	220P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 703	1.0U	Capacitor, Electrolytic, 50V, 20%, Rad
C 704	1.0U	Capacitor, Electrolytic, 50V, 20%, Rad
C 705	.01U	Capacitor, Stacked Metal Film
C 706	.01U	Capacitor, Stacked Metal Film
C 707	.01U	Capacitor, Stacked Metal Film
C 708	.01U	Capacitor, Stacked Metal Film
C 709	.01U	Capacitor, Stacked Metal Film
C 710	.01U	Capacitor, Stacked Metal Film
C 711	.01U	Capacitor, Stacked Metal Film
C 712	.01U	Capacitor, Stacked Metal Film
C 801	330P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 802	330P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 803	330P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 804	.01U	Capacitor, Stacked Metal Film
C 805	.01U	Capacitor, Stacked Metal Film
C 806	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 807	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 808	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 809	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 901	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 902	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 903	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 904	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 905	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 906	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 907	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 908	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 909	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 910	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 911	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 912	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 913	47U	Capacitor, Electrolytic, 25V, 20%, Rad
C 914	47U	Capacitor, Electrolytic, 25V, 20%, Rad
C 915	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 916	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 917	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 918	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 919	47U	Capacitor, Electrolytic, 25V, 20%, Rad
C 920	47U	Capacitor, Electrolytic, 25V, 20%, Rad
C 923	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 924	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 925	2500U	Capacitor, Electrolytic, 50V, 20%, Ax
C 926	2500U	Capacitor, Electrolytic, 50V, 20%, Ax
C 927	1.0U	Capacitor, Tantalum, 50V, 20%, Rad
C 928	1.0U	Capacitor, Tantalum, 50V, 20%, Rad
C 929	100U	Capacitor, Electrolytic, 25V, 20%, Rad
C 930	100U	Capacitor, Electrolytic, 25V, 20%, Rad
C 931	100U	Capacitor, Electrolytic, 25V, 20%, Rad
C 932	100U	Capacitor, Electrolytic, 25V, 20%, Rad
C 933	1.0U	Capacitor, Tantalum, 50V, 20%, Rad
C 934	1.0U	Capacitor, Tantalum, 50V, 20%, Rad
C 935	7200U	Cap, Electro. 25V 10% Ax, Mallory TCX
C 936	.1U	Capacitor, Stacked Metal Film
C 937	.1U	Capacitor, Stacked Metal Film
C 938	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C 939	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
CN801	9 PIN D	Connector, D-Sub, Right Angle PC, Female
CN802	RS232 F PC	Connector, D-Sub, Right Angle PC, Female
CN803	IEEE488 PC	Connector, IEEE488, Reverse, PC Mount
CY1	4M	Crystal
D 101	1N4148	Diode
D 102	1N4148	Diode
D 103	1N4148	Diode
D 104	1N4148	Diode
D 105	1N4148	Diode
D 106	1N4148	Diode
D 201	1N4148	Diode
D 202	1N4148	Diode
D 203	1N4148	Diode
D 204	1N4148	Diode
D 301	1N4148	Diode
D 302	1N4148	Diode
D 303	1N4148	Diode
D 401	1N4148	Diode
D 402	1N4148	Diode
D 403	1N4148	Diode
D 404	1N4148	Diode
D 501	1N4148	Diode
D 502	1N4148	Diode
D 701	1N747A	Diode
D 702	1N4148	Diode
D 703	1N4148	Diode
D 901	1N4007	Diode
D 902	1N4007	Diode
D 903	1N4007	Diode
D 904	1N4007	Diode
FU1	.5ASLO-BLO	Fuse
P 101	20	Trim Pot, PC Mount, In-Line Leads
P 102	20K	Pot, Multi-Turn Trim
P 103	20K	Pot, Multi-Turn Trim
P 104	50K	Pot, Multi-Turn Trim
P 105	5K	Pot, Multi-Turn Trim
P 401	10K	Pot, Multi-Turn Trim
P 402	10K	Pot, Multi-Turn Trim
P 403	10K	Pot, Multi-Turn Trim
P 404	10K	Pot, Multi-Turn Trim
P 501	100	Trim Pot, PC Mount, In-Line Leads
P 502	100	Trim Pot, PC Mount, In-Line Leads
PC1	SR500	Printed Circuit Board
Q 101	2N6485	Transistor, TO-71 Package
Q 102	2N6485	Transistor, TO-71 Package
Q 103	MPSA18	Transistor, TO-92 Package
Q 201	2N4249	Transistor, TO-92 Package
Q 202	2N5210	Transistor, TO-92 Package
Q 502	2N5210	Transistor, TO-92 Package
Q 701	2N5210	Transistor, TO-92 Package
Q 702	2N5210	Transistor, TO-92 Package
Q 703	2N5210	Transistor, TO-92 Package
R 101	100M	Resistor, Carbon Film, 1/4W, 5%
R 102	100M	Resistor, Carbon Film, 1/4W, 5%
R 103	10	Resistor, Carbon Film, 1/4W, 5%
R 104	100	Resistor, Carbon Film, 1/4W, 5%
R 105	100	Resistor, Carbon Film, 1/4W, 5%
R 108	1.00K	Resistor, Metal Film, 1/8W, 1%
R 109	6.81K	Resistor, Metal Film, 1/8W, 1%
R 110	6.81K	Resistor, Metal Film, 1/8W, 1%
R 111	1.00K	Resistor, Metal Film, 1/8W, 1%
R 112	1.00K	Resistor, Metal Film, 1/8W, 1%
R 113	110	Resistor, Metal Film, 1/8W, 1%

R 114	110	Resistor, Metal Film, 1/8W, 1%
R 115	2.2	Resistor, Carbon Film, 1/4W, 5%
R 116	6.04K	Resistor, Metal Film, 1/8W, 1%
R 117	9.09K	Resistor, Metal Film, 1/8W, 1%
R 118	1.00K	Resistor, Metal Film, 1/8W, 1%
R 119	499	Resistor, Metal Film, 1/8W, 1%
R 120	301	Resistor, Metal Film, 1/8W, 1%
R 121	100	Resistor, Metal Film, 1/8W, 1%
R 122	100	Resistor, Metal Film, 1/8W, 1%
R 126	9.09K	Resistor, Metal Film, 1/8W, 1%
R 127	1.00K	Resistor, Metal Film, 1/8W, 1%
R 128	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 130	470K	Resistor, Carbon Film, 1/4W, 5%
R 132	470K	Resistor, Carbon Film, 1/4W, 5%
R 133	30.1K	Resistor, Metal Film, 1/8W, 1%
R 134	30.1K	Resistor, Metal Film, 1/8W, 1%
R 135	1.00M	Resistor, Metal Film, 1/8W, 1%
R 138	20	Resistor, Carbon Film, 1/4W, 5%
R 139	20	Resistor, Carbon Film, 1/4W, 5%
R 140	13.0K	Resistor, Metal Film, 1/8W, 1%
R 141	280	Resistor, Metal Film, 1/8W, 1%
R 142	22.6K	Resistor, Metal Film, 1/8W, 1%
R 143	13.0K	Resistor, Metal Film, 1/8W, 1%
R 144	16.9K	Resistor, Metal Film, 1/8W, 1%
R 145	16.9K	Resistor, Metal Film, 1/8W, 1%
R 146	499	Resistor, Metal Film, 1/8W, 1%
R 147	301	Resistor, Metal Film, 1/8W, 1%
R 148	100	Resistor, Metal Film, 1/8W, 1%
R 149	100	Resistor, Metal Film, 1/8W, 1%
R 150	30.1K	Resistor, Metal Film, 1/8W, 1%
R 151	634	Resistor, Metal Film, 1/8W, 1%
R 152	54.9K	Resistor, Metal Film, 1/8W, 1%
R 153	3.01K	Resistor, Metal Film, 1/8W, 1%
R 154	3.83K	Resistor, Metal Film, 1/8W, 1%
R 155	9.53K	Resistor, Metal Film, 1/8W, 1%
R 156	499	Resistor, Metal Film, 1/8W, 1%
R 157	301	Resistor, Metal Film, 1/8W, 1%
R 158	100	Resistor, Metal Film, 1/8W, 1%
R 159	100	Resistor, Metal Film, 1/8W, 1%
R 160	100M	Resistor, Carbon Film, 1/4W, 5%
R 161	750	Resistor, Metal Film, 1/8W, 1%
R 162	4.99K	Resistor, Metal Film, 1/8W, 1%
R 163	10M	Resistor, Carbon Film, 1/4W, 5%
R 165	909	Resistor, Metal Film, 1/8W, 1%
R 166	100	Resistor, Metal Film, 1/8W, 1%
R 167	909	Resistor, Metal Film, 1/8W, 1%
R 168	100	Resistor, Metal Film, 1/8W, 1%
R 169	1.24K	Resistor, Metal Film, 1/8W, 1%
R 170	107	Resistor, Metal Film, 1/8W, 1%
R 171	33.2	Resistor, Metal Film, 1/8W, 1%
R 172	10M	Resistor, Carbon Film, 1/4W, 5%
R 173	499	Resistor, Metal Film, 1/8W, 1%
R 174	301	Resistor, Metal Film, 1/8W, 1%
R 175	200	Resistor, Metal Film, 1/8W, 1%
R 176	9.53K	Resistor, Metal Film, 1/8W, 1%
R 177	1.00K	Resistor, Metal Film, 1/8W, 1%
R 178	10M	Resistor, Carbon Film, 1/4W, 5%
R 201	1.50K	Resistor, Metal Film, 1/8W, 1%
R 202	5.11K	Resistor, Metal Film, 1/8W, 1%
R 203	10.0K	Resistor, Metal Film, 1/8W, 1%
R 204	10.0K	Resistor, Metal Film, 1/8W, 1%
R 205	15.0K	Resistor, Metal Film, 1/8W, 1%
R 206	10.0K	Resistor, Metal Film, 1/8W, 1%
R 207	1.50K	Resistor, Metal Film, 1/8W, 1%
R 208	1.00K	Resistor, Metal Film, 1/8W, 1%
R 209	13.0K	Resistor, Metal Film, 1/8W, 1%
R 210	100M	Resistor, Carbon Film, 1/4W, 5%
R 211	10.0K	Resistor, Metal Film, 1/8W, 1%
R 212	1.50K	Resistor, Metal Film, 1/8W, 1%
R 213	1.00K	Resistor, Metal Film, 1/8W, 1%
R 214	13.0K	Resistor, Metal Film, 1/8W, 1%
R 215	100M	Resistor, Carbon Film, 1/4W, 5%
R 216	100K	Resistor, Carbon Film, 1/4W, 5%
R 217	100K	Resistor, Carbon Film, 1/4W, 5%
R 218	10M	Resistor, Carbon Film, 1/4W, 5%
R 219	100K	Resistor, Carbon Film, 1/4W, 5%
R 220	3.48K	Resistor, Metal Film, 1/8W, 1%
R 221	120K	Resistor, Carbon Film, 1/4W, 5%
R 222	62K	Resistor, Carbon Film, 1/4W, 5%
R 223	120K	Resistor, Carbon Film, 1/4W, 5%
R 224	6.8K	Resistor, Carbon Film, 1/4W, 5%
R 225	3.0K	Resistor, Carbon Film, 1/4W, 5%
R 226	6.8K	Resistor, Carbon Film, 1/4W, 5%
R 227	3.0K	Resistor, Carbon Film, 1/4W, 5%
R 228	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 229	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 301	10K	Resistor, Carbon Film, 1/4W, 5%
R 302	10.0K	Resistor, Metal Film, 1/8W, 1%
R 303	10.0K	Resistor, Metal Film, 1/8W, 1%
R 304	2.0K	Resistor, Carbon Film, 1/4W, 5%
R 305	100K	Resistor, Carbon Film, 1/4W, 5%
R 306	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 307	13K	Resistor, Carbon Film, 1/4W, 5%
R 308	499	Resistor, Metal Film, 1/8W, 1%
R 309	330K	Resistor, Carbon Film, 1/4W, 5%
R 310	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 311	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 312	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 313	10K	Resistor, Carbon Film, 1/4W, 5%
R 314	300K	Resistor, Carbon Film, 1/4W, 5%
R 315	680K	Resistor, Carbon Film, 1/4W, 5%
R 316	680K	Resistor, Carbon Film, 1/4W, 5%
R 317	6.2K	Resistor, Carbon Film, 1/4W, 5%
R 318	10.0K	Resistor, Metal Film, 1/8W, 1%
R 319	10K	Resistor, Carbon Film, 1/4W, 5%
R 320	10K	Resistor, Carbon Film, 1/4W, 5%
R 321	100K	Resistor, Carbon Film, 1/4W, 5%
R 322	249K	Resistor, Metal Film, 1/8W, 1%
R 323	6.81K	Resistor, Metal Film, 1/8W, 1%
R 324	6.81K	Resistor, Metal Film, 1/8W, 1%
R 325	2.80K	Resistor, Metal Film, 1/8W, 1%
R 326	13.0K	Resistor, Metal Film, 1/8W, 1%
R 327	2.10K	Resistor, Metal Film, 1/8W, 1%
R 328	1.8K	Resistor, Carbon Film, 1/4W, 5%
R 329	51K	Resistor, Carbon Film, 1/4W, 5%
R 330	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 332	2.49K	Resistor, Metal Film, 1/8W, 1%
R 333	1.8K	Resistor, Carbon Film, 1/4W, 5%
R 334	6.49K	Resistor, Metal Film, 1/8W, 1%
R 335	51K	Resistor, Carbon Film, 1/4W, 5%
R 336	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 337	10M	Resistor, Carbon Film, 1/4W, 5%
R 338	10	Resistor, Carbon Film, 1/4W, 5%
R 339	100K	Resistor, Carbon Film, 1/4W, 5%
R 340	100K	Resistor, Carbon Film, 1/4W, 5%
R 341	1.2M	Resistor, Carbon Film, 1/4W, 5%
R 342	330K	Resistor, Carbon Film, 1/4W, 5%
R 343	2.0M	Resistor, Carbon Film, 1/4W, 5%
R 344	300K	Resistor, Carbon Film, 1/4W, 5%
R 345	1.0M	Resistor, Carbon Film, 1/4W, 5%
R 346	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 347	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 348	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 349	300K	Resistor, Carbon Film, 1/4W, 5%



R 350	6.2K	Resistor, Carbon Film, 1/4W, 5%
R 351	10.0K	Resistor, Metal Film, 1/8W, 1%
R 352	100K	Resistor, Carbon Film, 1/4W, 5%
R 353	10K	Resistor, Carbon Film, 1/4W, 5%
R 354	75.0K	Resistor, Metal Film, 1/8W, 1%
R 355	4.53K	Resistor, Metal Film, 1/8W, 1%
R 356	2.26K	Resistor, Metal Film, 1/8W, 1%
R 357	2.80K	Resistor, Metal Film, 1/8W, 1%
R 358	10K	Resistor, Carbon Film, 1/4W, 5%
R 359	2.0K	Resistor, Carbon Film, 1/4W, 5%
R 360	100K	Resistor, Carbon Film, 1/4W, 5%
R 361	5.1K	Resistor, Carbon Film, 1/4W, 5%
R 362	32.4K	Resistor, Metal Film, 1/8W, 1%
R 363	1.10K	Resistor, Metal Film, 1/8W, 1%
R 364	100K	Resistor, Carbon Film, 1/4W, 5%
R 365	2.0K	Resistor, Carbon Film, 1/4W, 5%
R 366	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 367	130K	Resistor, Metal Film, 1/8W, 1%
R 368	16.2K	Resistor, Metal Film, 1/8W, 1%
R 369	1.00K	Resistor, Metal Film, 1/8W, 1%
R 370	1.00K	Resistor, Metal Film, 1/8W, 1%
R 371	10	Resistor, Carbon Film, 1/4W, 5%
R 372	1.1M	Resistor, Carbon Film, 1/4W, 5%
R 373	100M	Resistor, Carbon Film, 1/4W, 5%
R 374	100M	Resistor, Carbon Film, 1/4W, 5%
R 375	100M	Resistor, Carbon Film, 1/4W, 5%
R 376	100M	Resistor, Carbon Film, 1/4W, 5%
R 377	4.53K	Resistor, Metal Film, 1/8W, 1%
R 378	2.0K	Resistor, Carbon Film, 1/4W, 5%
R 401	1.000K	Resistor, Metal Film, 1/8W, 0.1%
R 402	1.000K	Resistor, Metal Film, 1/8W, 0.1%
R 403	5.1M	Resistor, Carbon Film, 1/4W, 5%
R 404	1.000K	Resistor, Metal Film, 1/8W, 0.1%
R 405	1.000K	Resistor, Metal Film, 1/8W, 0.1%
R 406	499	Resistor, Metal Film, 1/8W, 1%
R 407	1.00K	Resistor, Metal Film, 1/8W, 1%
R 408	1.00M	Resistor, Metal Film, 1/8W, 1%
R 409	1.0M	Resistor, Carbon Film, 1/4W, 5%
R 410	1.000K	Resistor, Metal Film, 1/8W, 0.1%
R 411	499	Resistor, Metal Film, 1/8W, 1%
R 412	1.000K	Resistor, Metal Film, 1/8W, 0.1%
R 413	75.0K	Resistor, Metal Film, 1/8W, 1%
R 414	47	Resistor, Carbon Film, 1/4W, 5%
R 415	100K	Resistor, Metal Film, 1/8W, 1%
R 417	10K	Resistor, Carbon Film, 1/4W, 5%
R 418	1.10K	Resistor, Metal Film, 1/8W, 1%
R 419	30.1K	Resistor, Metal Film, 1/8W, 1%
R 420	348K	Resistor, Metal Film, 1/8W, 1%
R 421	150K	Resistor, Metal Film, 1/8W, 1%
R 422	37.4K	Resistor, Metal Film, 1/8W, 1%
R 423	9.76K	Resistor, Metal Film, 1/8W, 1%
R 424	2.49K	Resistor, Metal Film, 1/8W, 1%
R 425	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 426	2.0K	Resistor, Carbon Film, 1/4W, 5%
R 427	1.00M	Resistor, Metal Film, 1/8W, 1%
R 428	1.00M	Resistor, Metal Film, 1/8W, 1%
R 429	110K	Resistor, Metal Film, 1/8W, 1%
R 430	10.2K	Resistor, Metal Film, 1/8W, 1%
R 431	100K	Resistor, Carbon Film, 1/4W, 5%
R 432	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 433	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 501	1.0M	Resistor, Carbon Film, 1/4W, 5%
R 502	1.0M	Resistor, Carbon Film, 1/4W, 5%
R 503	1.0M	Resistor, Carbon Film, 1/4W, 5%
R 504	1.0M	Resistor, Carbon Film, 1/4W, 5%
R 505	10K	Resistor, Carbon Film, 1/4W, 5%
R 506	10K	Resistor, Carbon Film, 1/4W, 5%
R 507	10K	Resistor, Carbon Film, 1/4W, 5%
R 508	10K	Resistor, Carbon Film, 1/4W, 5%
R 509	10.00K	Resistor, Metal Film, 1/8W, 0.1%
R 510	20.00K	Resistor, Metal Film, 1/8W, 0.1%
R 511	10.00K	Resistor, Metal Film, 1/8W, 0.1%
R 512	20.00K	Resistor, Metal Film, 1/8W, 0.1%
R 513	200K	Resistor, Metal Film, 1/8W, 1%
R 514	806K	Resistor, Metal Film, 1/8W, 1%
R 515	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 516	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 518	10K	Resistor, Carbon Film, 1/4W, 5%
R 519	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 520	51	Resistor, Carbon Film, 1/4W, 5%
R 521	51	Resistor, Carbon Film, 1/4W, 5%
R 522	10.00K	Resistor, Metal Film, 1/8W, 0.1%
R 523	10.00K	Resistor, Metal Film, 1/8W, 0.1%
R 524	39K	Resistor, Carbon Film, 1/4W, 5%
R 525	22K	Resistor, Carbon Film, 1/4W, 5%
R 526	100K	Resistor, Carbon Film, 1/4W, 5%
R 527	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 528	10K	Resistor, Carbon Film, 1/4W, 5%
R 529	220	Resistor, Carbon Film, 1/4W, 5%
R 530	9.09K	Resistor, Metal Film, 1/8W, 1%
R 531	1.00K	Resistor, Metal Film, 1/8W, 1%
R 532	100K	Resistor, Carbon Film, 1/4W, 5%
R 533	100K	Resistor, Carbon Film, 1/4W, 5%
R 534	10K	Resistor, Carbon Film, 1/4W, 5%
R 535	220	Resistor, Carbon Film, 1/4W, 5%
R 536	10K	Resistor, Carbon Film, 1/4W, 5%
R 537	220	Resistor, Carbon Film, 1/4W, 5%
R 538	10K	Resistor, Carbon Film, 1/4W, 5%
R 539	220	Resistor, Carbon Film, 1/4W, 5%
R 540	10K	Resistor, Carbon Film, 1/4W, 5%
R 541	220	Resistor, Carbon Film, 1/4W, 5%
R 542	10K	Resistor, Carbon Film, 1/4W, 5%
R 543	10K	Resistor, Carbon Film, 1/4W, 5%
R 544	15K	Resistor, Carbon Film, 1/4W, 5%
R 545	10K	Resistor, Carbon Film, 1/4W, 5%
R 546	10K	Resistor, Carbon Film, 1/4W, 5%
R 547	15K	Resistor, Carbon Film, 1/4W, 5%
R 548	200K	Resistor, Carbon Film, 1/4W, 5%
R 549	100K	Resistor, Carbon Film, 1/4W, 5%
R 701	100	Resistor, Carbon Film, 1/4W, 5%
R 702	4.7K	Resistor, Carbon Film, 1/4W, 5%
R 703	1.5K	Resistor, Carbon Film, 1/4W, 5%
R 705	1.0K	Resistor, Carbon Film, 1/4W, 5%
R 706	10K	Resistor, Carbon Film, 1/4W, 5%
R 707	10K	Resistor, Carbon Film, 1/4W, 5%
R 708	300K	Resistor, Carbon Film, 1/4W, 5%
R 709	10K	Resistor, Carbon Film, 1/4W, 5%
R 710	100K	Resistor, Carbon Film, 1/4W, 5%
R 711	10K	Resistor, Carbon Film, 1/4W, 5%
R 801	10K	Resistor, Carbon Film, 1/4W, 5%
R 802	10K	Resistor, Carbon Film, 1/4W, 5%
R 803	3.3K	Resistor, Carbon Film, 1/4W, 5%
R 901	10	Resistor, Carbon Comp, 1/2W, 5%
R 902	10	Resistor, Carbon Comp, 1/2W, 5%
R 903	240	Resistor, Carbon Film, 1/4W, 5%
R 904	1.2K	Resistor, Carbon Film, 1/4W, 5%
R 905	1.2K	Resistor, Carbon Film, 1/4W, 5%
R 906	240	Resistor, Carbon Film, 1/4W, 5%
R 907	10	Resistor, Carbon Comp, 1/2W, 5%
R 908	10	Resistor, Carbon Comp, 1/2W, 5%
R 909	200	Resistor, Carbon Film, 1/4W, 5%
R 910	3.0K	Resistor, Carbon Film, 1/4W, 5%
R 911	3.0K	Resistor, Carbon Film, 1/4W, 5%
R 912	200	Resistor, Carbon Film, 1/4W, 5%

R 913	10	Resistor, Carbon Comp, 1/2W, 5%
R 914	10	Resistor, Carbon Comp, 1/2W, 5%
RN401	10KX8	Resistor Network, DIP, 1/4W,2%,8 ind
RN801	9X100K	Resistor Network SIP 1/4W 2% Common
RN802	9X100K	Resistor Network SIP 1/4W 2% Common
SO701	40	Socket, DIP
SO702	28	Socket, DIP
SW1	SPSTX8	Switch, DIP
SW2	SPSTX8	Switch, DIP
SW601	4PDT	Switch, Rocker, PCB Mount
SW602	DPDT	Switch, Rocker, PCB Mount
T 1	241-7-2200	Transformer
U 101	XR5533A	Integrated Circuit
U 102	XR5533A	Integrated Circuit
U 103	DG211	Integrated Circuit
U 104	MC78L15	Integrated Circuit
U 105	MC79L15	Integrated Circuit
U 106	DG211	Integrated Circuit
U 107	XR5532A	Integrated Circuit
U 108	DG211	Integrated Circuit
U 109	LF353	Integrated Circuit
U 110	DG211	Integrated Circuit
U 111	LF357	Integrated Circuit
U 112	DG211	Integrated Circuit
U 113	LF357	Integrated Circuit
U 114	DG211	Integrated Circuit
U 115	LF357	Integrated Circuit
U 117	LF353	Integrated Circuit
U 118	XR5532A	Integrated Circuit
U 201	LF347	Integrated Circuit
U 202	LM13600	Integrated Circuit
U 203	CD4052	Integrated Circuit
U 204	CD4052	Integrated Circuit
U 205	DG211	Integrated Circuit
U 206	74HC139	Integrated Circuit
U 207	74HC139	Integrated Circuit
U 208	LF347	Integrated Circuit
U 301	LF353	Integrated Circuit
U 303	DG211	Integrated Circuit
U 304	LM311	Integrated Circuit
U 305	CD4538	Integrated Circuit
U 306	CD4046	Integrated Circuit
U 307	LM13600	Integrated Circuit
U 308	CA3140E	Integrated Circuit
U 309	LM13600	Integrated Circuit
U 310	DG211	Integrated Circuit
U 311	DG211	Integrated Circuit
U 312	DG211	Integrated Circuit
U 313	74HC74	Integrated Circuit
U 314	LM311	Integrated Circuit
U 315	LM311	Integrated Circuit
U 316	CD4046	Integrated Circuit
U 317	LM13600	Integrated Circuit
U 318	DG211	Integrated Circuit
U 319	CA3140E	Integrated Circuit
U 320	DG211	Integrated Circuit
U 321	CA3140E	Integrated Circuit
U 322	LM13600	Integrated Circuit
U 323	LM13600	Integrated Circuit
U 324	LM311	Integrated Circuit
U 325	LF412	Integrated Circuit
U 326	CD4018	Integrated Circuit
U 327	DG211	Integrated Circuit
U 328	LM311	Integrated Circuit
U 329	LM311	Integrated Circuit
U 401	DG211	Integrated Circuit
U 402	LF412	Integrated Circuit
U 403	LF411	Integrated Circuit
U 404	LT1007	Integrated Circuit
U 405	CD4066	Integrated Circuit
U 406	AD534	Integrated Circuit
U 407	LF411	Integrated Circuit
U 408	LT1007	Integrated Circuit
U 409	LF411	Integrated Circuit
U 410	ICL7650	Integrated Circuit
U 411	51A05	Integrated Circuit
U 412	51A05	Integrated Circuit
U 413	51A05	Integrated Circuit
U 414	51A05	Integrated Circuit
U 415	51A05	Integrated Circuit
U 416	ICL7650	Integrated Circuit
U 417	51A05	Integrated Circuit
U 418	DG211	Integrated Circuit
U 419	LF411	Integrated Circuit
U 420	CA3081	Integrated Circuit
U 421	74C74	Integrated Circuit
U 501	LF347	Integrated Circuit
U 502	AD7524	Integrated Circuit
U 503	74HC374	Integrated Circuit
U 504	DG528	Integrated Circuit
U 505	AD7542JN	Integrated Circuit
U 506	AD7524	Integrated Circuit
U 507	DG528	Integrated Circuit
U 508	LF347	Integrated Circuit
U 509	DG211	Integrated Circuit
U 510	DG211	Integrated Circuit
U 511	LF347	Integrated Circuit
U 512	LF347	Integrated Circuit
U 513	LF347	Integrated Circuit
U 514	LM311	Integrated Circuit
U 515	LF347	Integrated Circuit
U 516	DG211	Integrated Circuit
U 517	LH0071	Integrated Circuit
U 701	Z80A-CPU	Integrated Circuit
U 702	27128-250	Integrated Circuit
U 703	HM6116LP	Integrated Circuit
U 704	UPD8253-5	Integrated Circuit
U 705	74HC138	Integrated Circuit
U 706	74HC138	Integrated Circuit
U 707	74HC138	Integrated Circuit
U 708	74HC157	Integrated Circuit
U 709	74HC74	Integrated Circuit
U 710	74HC32	Integrated Circuit
U 711	74HCU04	Integrated Circuit
U 712	74HC4040	Integrated Circuit
U 713	74HC74	Integrated Circuit
U 714	74HC175	Integrated Circuit
U 715	74HC175	Integrated Circuit
U 716	74HC244	Integrated Circuit
U 717	74HC374	Integrated Circuit
U 718	74HC14	Integrated Circuit
U 719	74HC374	Integrated Circuit
U 720	74HC374	Integrated Circuit
U 721	74HC374	Integrated Circuit
U 722	74HC32	Integrated Circuit
U 801	UPD8251A	Integrated Circuit
U 802	MC68488	Integrated Circuit
U 803	74HC244	Integrated Circuit
U 804	74HC244	Integrated Circuit
U 805	74HC74	Integrated Circuit
U 806	MC1488	Integrated Circuit
U 807	MC1489	Integrated Circuit

U 808	DS75160A	Integrated Circuit
U 809	MC78L12	Integrated Circuit
U 810	MC79L12	Integrated Circuit
U 811	DS75161A	Integrated Circuit
U 901	LM317	Integrated Circuit
U 902	LM337	Integrated Circuit
U 903	LM340T-15	Integrated Circuit
U 904	LM340T-15	Integrated Circuit
U 905	LM340T-15	Integrated Circuit
U 906	LM320T-15	Integrated Circuit
U 907	LM320T-15	Integrated Circuit
U 908	LM320T-15	Integrated Circuit
U 909	MC7805K	Integrated Circuit
U 910	MC78L05	Integrated Circuit
U 911	LM317L	Integrated Circuit
U 912	LM337L	Integrated Circuit
Z 0	Heat Sinks	
Z 0	POWERBLOCK	Power Entry Hardware
Z 0	TIE ANCHOR	Hardware, Misc.
Z 0	TRANSCOVER	Power Entry Hardware
Z 0	MICA	Insulators
Z 0	3/8"	Lugs
Z 0	4-40 KEP	Nut, Kep
Z 0	4-40 MINI	Nut, Mini
Z 0	6-32 KEP	Nut, Kep
Z 0	6-20X5/8P	Screw, Sheet Metal
Z 0	M/F 3/16"	Standoff
Z 0	M/F 5/16"	Standoff
Z 0	36154	Termination
Z 0	4"	Tie
Z 0	1/16"	Tubing
Z 0	1/8"	Tubing
Z 0	3/16"	Tubing

Z 0	#6	Washer
Z 0	4-40 NYLON	Washer, nylon
Z 0	10-1/8"#18	Wire #18
Z 0	12" #24	Wire #24
Z 0	3" #18	Wire #18
Z 0	5-5/8" #18	Wire #18
Z 0	6-1/2" #24	Wire #24
Z 0	7-5/8" #18	Wire #18
Z 0	8-1/2" #24	Wire #24
Z 0	GROMMET2	Grommet
Z 0	6-32X3/8PP	Screw, Panhead Phillips
Z 0	6-32X11/8P	Screw, Panhead Phillips
Z 0	4-40X1/4PP	Screw, Panhead Phillips
Z 0	6-32X3/8FPH	Screw, Flathead Phillips
Z 0	4-40X3/8PF	Screw, Flathead Phillips
Z 0	10-32X3/8PF	Screw, Flathead Phillips
Z 0	6-32X1/4PP	Screw, Panhead Phillips
Z 0	6-32X3/8TR P	Screw, Truss Phillips
Z 0	17" #22 BLAC	Wire #22
Z 0	17" #22 WHIT	Wire #22
Z 0	17" #22 RED	Wire #22
Z 0	17" #22 GREE	Wire #22
Z 0	BNC	Connector, BNC, Panel Mount
Z 0	20 PIN ELH	Connector, Male
Z 0	TO-3	Socket, DIP
Z 0	USA	Line Cord
Z 0	SR510-13	Bracket
Z 0	SR510-8	Bracket
Z 0	SR500-15	Fabricated Part
Z 0	SR510-12	Rear Panel
Z 0	SR510 R CNR	Fabricated Part

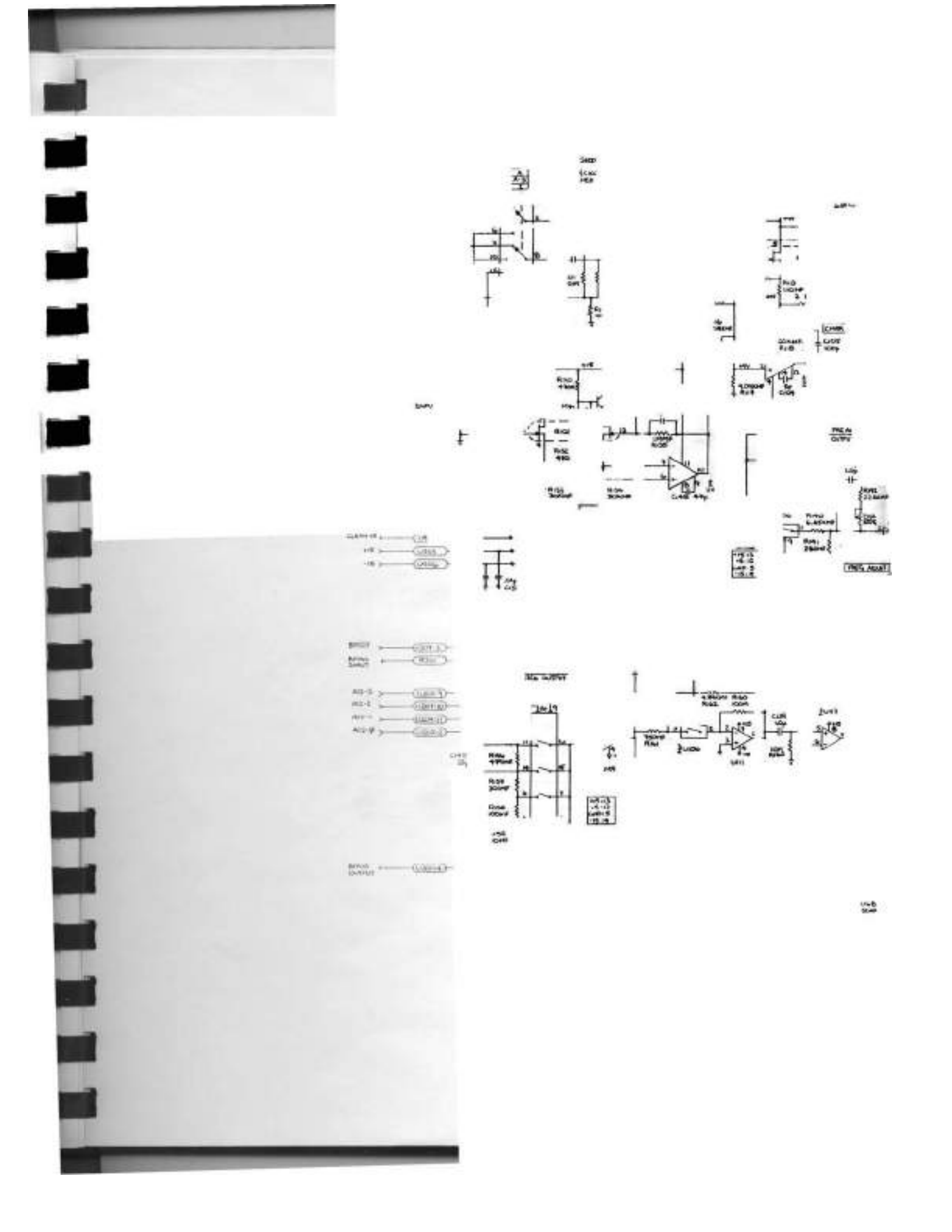
Front Panel Part List

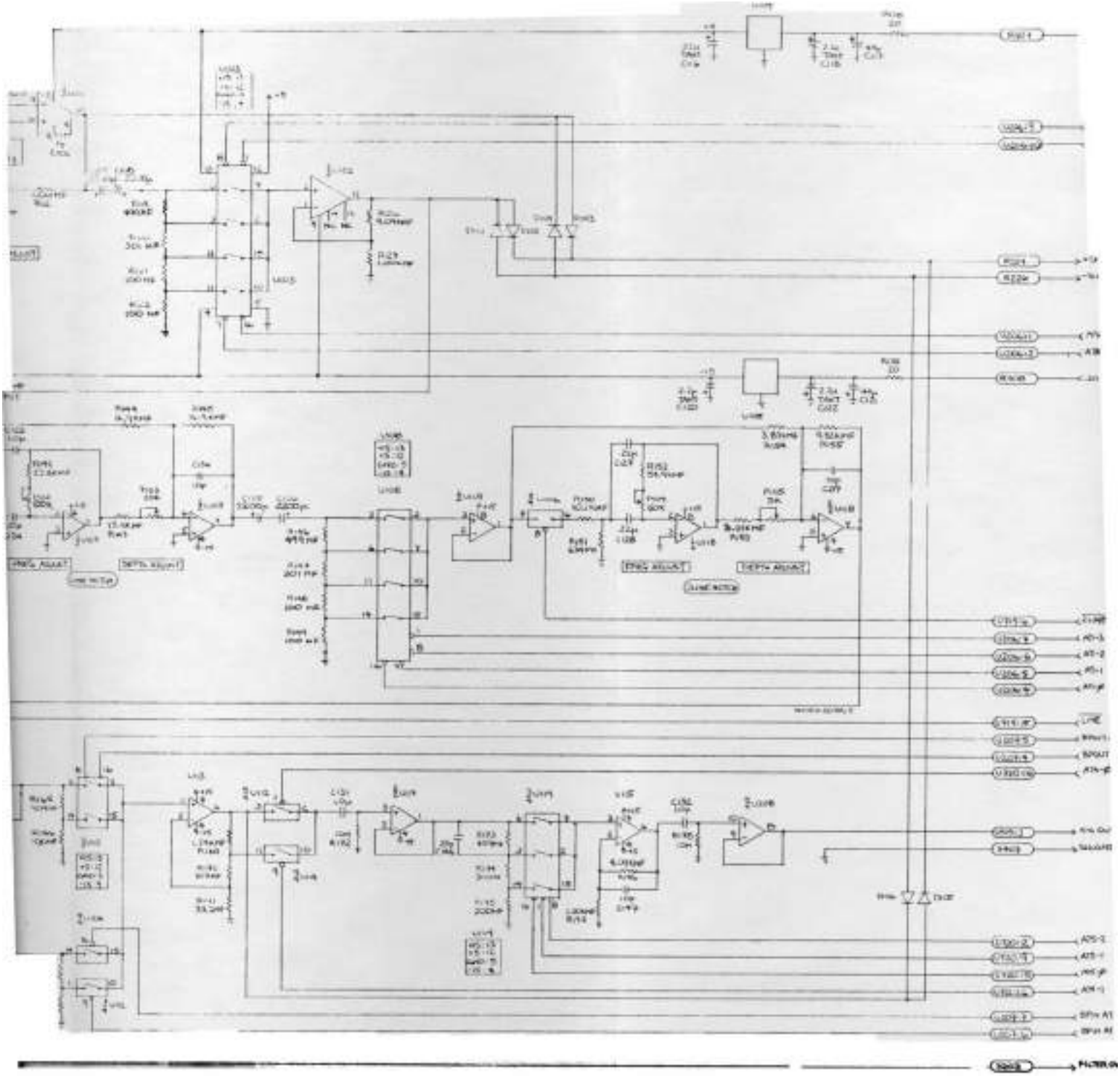
REF#	VALUE	DESCRIPTION
C 601	68P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 602	68P	Capacitor, Ceramic Disc, 50V, 10%, SL
C 603	.01U	Capacitor, Stacked Metal Film
C 604	.01U	Capacitor, Stacked Metal Film
C 605	.1U	Capacitor, Stacked Metal Film
C 606	.1U	Capacitor, Stacked Metal Film
C 607	.1U	Capacitor, Ceramic Disc, 50V, 20%, Z5U
D 601	1N4148	Diode
D 602	1N4148	Diode
D 603	1N4148	Diode
D 604	1N4148	Diode
DS601	HLMP-0504	LED, Rectangular
DS602	HLMP-0504	LED, Rectangular
DS603	HLMP-0504	LED, Rectangular
DS604	HLMP-0504	LED, Rectangular
DS605	HLMP-0504	LED, Rectangular
DS606	HLMP-0504	LED, Rectangular
DS607	HLMP-0504	LED, Rectangular
DS608	HLMP-0504	LED, Rectangular
DS609	HLMP-0504	LED, Rectangular
DS610	HLMP-0504	LED, Rectangular
DS611	HLMP-0504	LED, Rectangular
DS612	HLMP-0504	LED, Rectangular
DS613	HLMP-0504	LED, Rectangular
DS614	HLMP-0504	LED, Rectangular
DS615	HLMP-0504	LED, Rectangular
DS616	HLMP-0504	LED, Rectangular
DS617	HLMP-0504	LED, Rectangular
DS618	HLMP-0504	LED, Rectangular
DS619	HLMP-0504	LED, Rectangular
DS620	HLMP-0504	LED, Rectangular
DS621	HLMP-0504	LED, Rectangular
DS622	HLMP-0504	LED, Rectangular
DS623	HLMP-0504	LED, Rectangular
DS624	HLMP-0504	LED, Rectangular
DS625	HLMP-0504	LED, Rectangular
DS626	HLMP-0504	LED, Rectangular
DS627	HLMP-0504	LED, Rectangular
DS628	HLMP-0504	LED, Rectangular
DS629	HLMP-0504	LED, Rectangular
DS630	HLMP-0504	LED, Rectangular
DS631	HLMP-0504	LED, Rectangular
DS632	HLMP-0504	LED, Rectangular
DS633	HLMP-0504	LED, Rectangular
DS634	HLMP-0504	LED, Rectangular
DS635	HLMP-0504	LED, Rectangular
DS636	HLMP-0504	LED, Rectangular
DS637	HLMP-0504	LED, Rectangular
DS638	HLMP-0301	LED, Rectangular
DS639	HLMP-0301	LED, Rectangular
DS640	HLMP-0301	LED, Rectangular
DS641	HLMP-0504	LED, Rectangular
DS642	HLMP-0504	LED, Rectangular
DS643	HLMP-0504	LED, Rectangular
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DS654	HLMP-0504	LED, Rectangular
DS655	HLMP-0504	LED, Rectangular
DS656	HLMP-0504	LED, Rectangular
DS657	HLMP-0504	LED, Rectangular
DS658	HLMP-0504	LED, Rectangular
DS659	HLMP-0504	LED, Rectangular
DS660	HLMP-0504	LED, Rectangular
DS661	HLMP-0504	LED, Rectangular
DS662	HLMP-0504	LED, Rectangular
LD1	FE0206	LCD Display
LD2	FE0206	LCD Display
M 1	-10/0/10	Analog Meter
PB601	D6-01-01	Switch, Momentary Push Button
PB602	D6-01-01	Switch, Momentary Push Button
PB603	D6-01-01	Switch, Momentary Push Button
PB604	D6-01-01	Switch, Momentary Push Button
PB605	D6-01-01	Switch, Momentary Push Button
PB606	D6-01-01	Switch, Momentary Push Button
PB607	D6-01-01	Switch, Momentary Push Button
PB608	D6-01-01	Switch, Momentary Push Button
PB609	D6-01-01	Switch, Momentary Push Button
PB610	D6-01-01	Switch, Momentary Push Button
PB611	D6-01-01	Switch, Momentary Push Button
PB612	D6-01-01	Switch, Momentary Push Button
PB613	D6-01-01	Switch, Momentary Push Button
PB614	D6-01-01	Switch, Momentary Push Button
PB615	D6-01-01	Switch, Momentary Push Button
PB616	D6-01-01	Switch, Momentary Push Button
PB617	D6-01-01	Switch, Momentary Push Button
PB618	D6-01-01	Switch, Momentary Push Button
PB619	D6-01-01	Switch, Momentary Push Button
PB620	D6-01-01	Switch, Momentary Push Button
PB621	D6-01-01	Switch, Momentary Push Button
PB622	D6-01-01	Switch, Momentary Push Button
PB623	D6-01-01	Switch, Momentary Push Button
PB624	D6-01-01	Switch, Momentary Push Button
PB625	D6-01-01	Switch, Momentary Push Button
PC1	SR511	Printed Circuit Board
R 601	10K	Resistor, Carbon Film, 1/4W, 5%
R 602	10K	Resistor, Carbon Film, 1/4W, 5%
RN601	7X22K	Resistor Network SIP 1/4W 2% Common
RN602	9X150	Resistor Network SIP 1/4W 2% Common
RN603	9X150	Resistor Network SIP 1/4W 2% Common
RN604	5X150	Resistor Network SIP 1/4W 2% Common
U 601	ICM7211AM	Integrated Circuit
U 602	ICM7211AM	Integrated Circuit
U 603	74HC244	Integrated Circuit
U 604	74HC374	Integrated Circuit
U 605	CD4030	Integrated Circuit
U 606	CD4030	Integrated Circuit
U 607	74LS164	Integrated Circuit
U 608	74LS164	Integrated Circuit
U 609	74LS164	Integrated Circuit
U 610	74LS164	Integrated Circuit
U 611	74LS164	Integrated Circuit
U 612	74LS164	Integrated Circuit
U 613	74LS164	Integrated Circuit
U 614	74LS164	Integrated Circuit
Z 0	4-40 HEX	Nut, Hex
Z 0	4-40 MINI	Nut, Mini
Z 0	5/16" #4	Spacer
Z 0	#4	Washer
Z 0	#4 SPLIT	Washer, Split
Z 0	4-40 NYLON	Washer, nylon
Z 0	CLEAR	Window

Z0	1-3/4"#24B	Wire #24
Z0	1-3/4"#24R	Wire #24
Z0	12" #24	Wire #24
Z0	4" #24	Wire #24
Z0	5" #24	Wire #24
Z0	6-1/2" #24	Wire #24
Z0	9" #26 X20	Wire #26
Z0	6-32X3/8FPH	Screw, Flathead Phillips
Z0	6-32X3/8OVAL	Screw, Oval Head Phillips
Z0	321017	Termination
Z0	4-40X3/8PF	Screw, Flathead Phillips
Z0	INS	Connector, BNC, Panel Mount
Z0	20 PIN DIF	Connector, Female
Z0	20 PIN IDP	Connector, Male
Z0	SR500-16	Bracket
Z0	SR500-22	Bracket
Z0	SR510	Front Panel
Z0	SR510	Casting
Z0	BEZEL	Extrusion
Z0	SR510 F CN	Fabricated Part

Internal Oscillator Parts List

REF#	VALUE	DESCRIPTION
C1	.1U	Capacitor, Ceramic Disc, 50V, 20%, Z5U
C2	.1U	Capacitor, Ceramic Disc, 50V, 20%, Z5U
C3	4.7U	Capacitor, Tantalum, 35V, 20%, Rad
C4	.047U	Capacitor, Stacked Metal Film
C5	390P	Capacitor, Silver Mica, 250V, 5%, DM15
C6	4.7U	Capacitor, Tantalum, 35V, 20%, Rad
C7	390P	Capacitor, Ceramic Disc, 50V, 10%, SL
C8	100U	Capacitor, Electrolytic, 25V, 20%, Rad
C9	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
C10	100U	Capacitor, Electrolytic, 25V, 20%, Rad
C11	2.2U	Capacitor, Tantalum, 35V, 20%, Rad
P1	10K	Pot, Multi-Turn, Side Adjust
P2	100K	Trim Pot, PC Mount, In-Line Leads
P3	10K	Pot, Multi-Turn, Side Adjust
PC1	SR501	Printed Circuit Board
R1	4.7K	Resistor, Carbon Film, 1/4W, 5%
R2	47K	Resistor, Carbon Film, 1/4W, 5%
R3	698	Resistor, Metal Film, 1/8W, 1%
R4	41.2K	Resistor, Metal Film, 1/8W, 1%
R5	4.22K	Resistor, Metal Film, 1/8W, 1%
R6	42.2K	Resistor, Metal Film, 1/8W, 1%
R7	4.22K	Resistor, Metal Film, 1/8W, 1%
R8	698	Resistor, Metal Film, 1/8W, 1%
R9	39K	Resistor, Carbon Film, 1/4W, 5%
R10	4.22K	Resistor, Metal Film, 1/8W, 1%
R11	1.0M	Resistor, Carbon Film, 1/4W, 5%
R12	15K	Resistor, Carbon Film, 1/4W, 5%
R13	30K	Resistor, Carbon Film, 1/4W, 5%
R14	10K	Resistor, Carbon Film, 1/4W, 5%
R15	1.0M	Resistor, Carbon Film, 1/4W, 5%
R16	4.7K	Resistor, Carbon Film, 1/4W, 5%
R17	82K	Resistor, Carbon Film, 1/4W, 5%
R18	10K	Resistor, Carbon Film, 1/4W, 5%
R19	10K	Resistor, Carbon Film, 1/4W, 5%
R20	4.99K	Resistor, Metal Film, 1/8W, 1%
R21	4.99K	Resistor, Metal Film, 1/8W, 1%
R22	1.0M	Resistor, Carbon Film, 1/4W, 5%
R23	1.0M	Resistor, Carbon Film, 1/4W, 5%
R24	100	Resistor, Carbon Film, 1/4W, 5%
R25	100	Resistor, Carbon Film, 1/4W, 5%
SW1	DPDT	Switch, Toggle Right Angle PCB Mount
SW2	DPDT	Switch, Toggle Right Angle PCB Mount
U1	LF347	Integrated Circuit
U2	ICL8038	Integrated Circuit
U3	MC78L15	Integrated Circuit
U4	MC79L15	Integrated Circuit
Z0	1/4X1/16	Washer
Z0	2-1/4" #24	Wire #24
Z0	8-1/2" #24	Wire #24

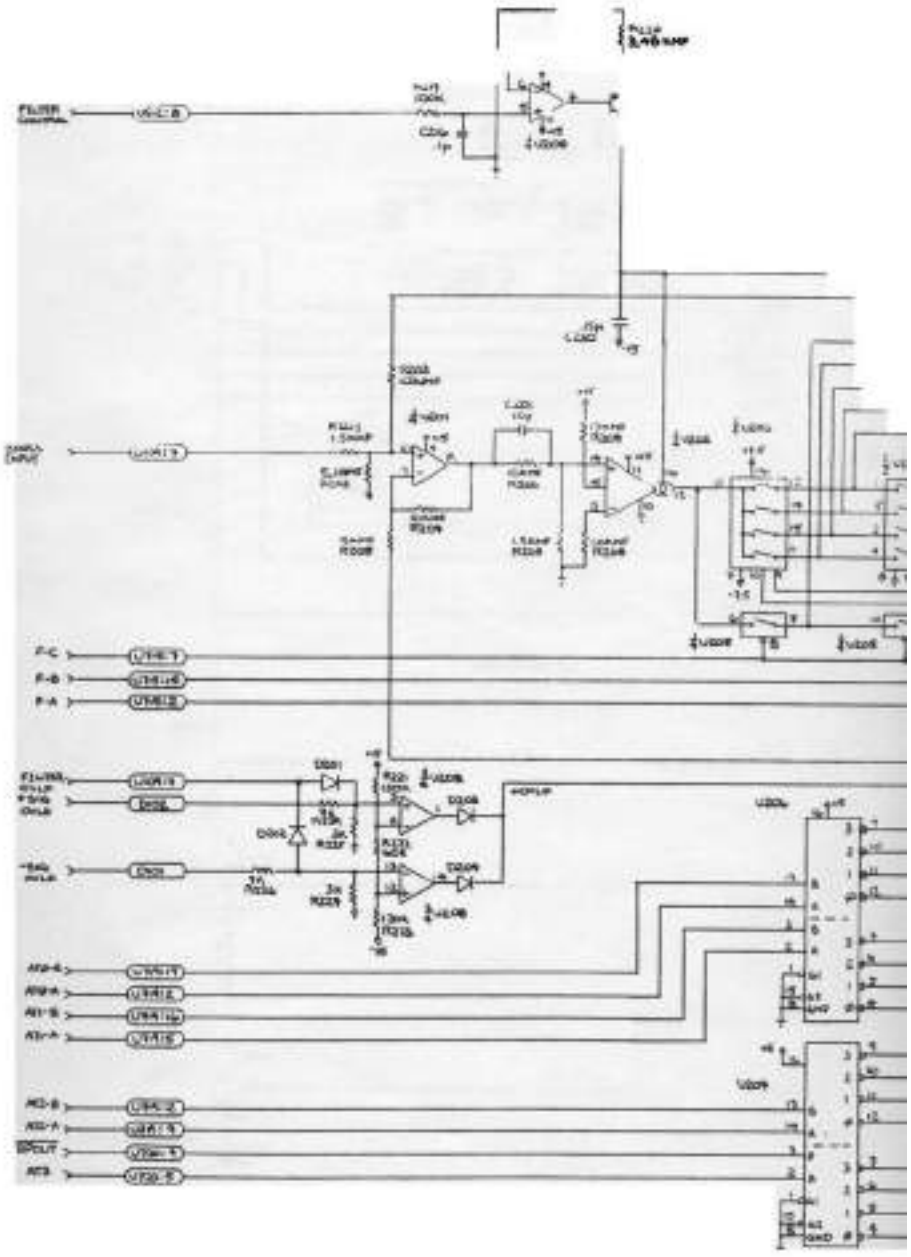


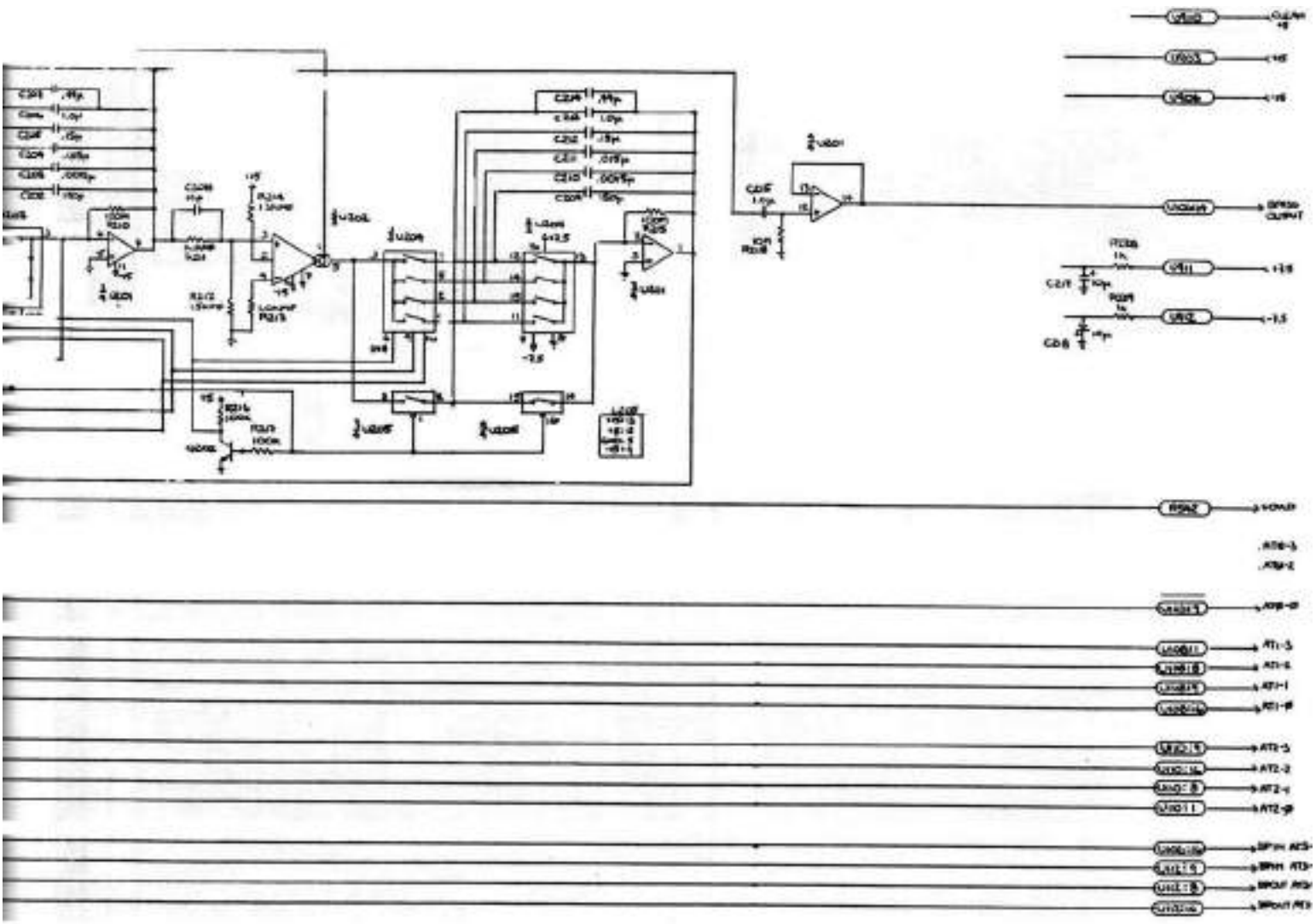


U101	MM5455	U111	LF356
U102	MM5455	U112	3524
U103	DAC-21	U113	LF347
U104	4066B	U114	3524
U105	4066B	U115	LF324
U106	DAC-21	U116	REMOVED
U107	MM5452	U117	LF353
U108	[illegible]	U118	4066B
U109	LF 13[illegible]52		
U110	3524		

SEARLE MEDICAL SYSTEMS	SIGNAL AMPLIFIER			
DRAWN 9-24-84	SIZE	FSCM NO.	DWG. NO. SR 500 - 1	REV. B
ISSUED	SCALE	JCW	SHEET 1	

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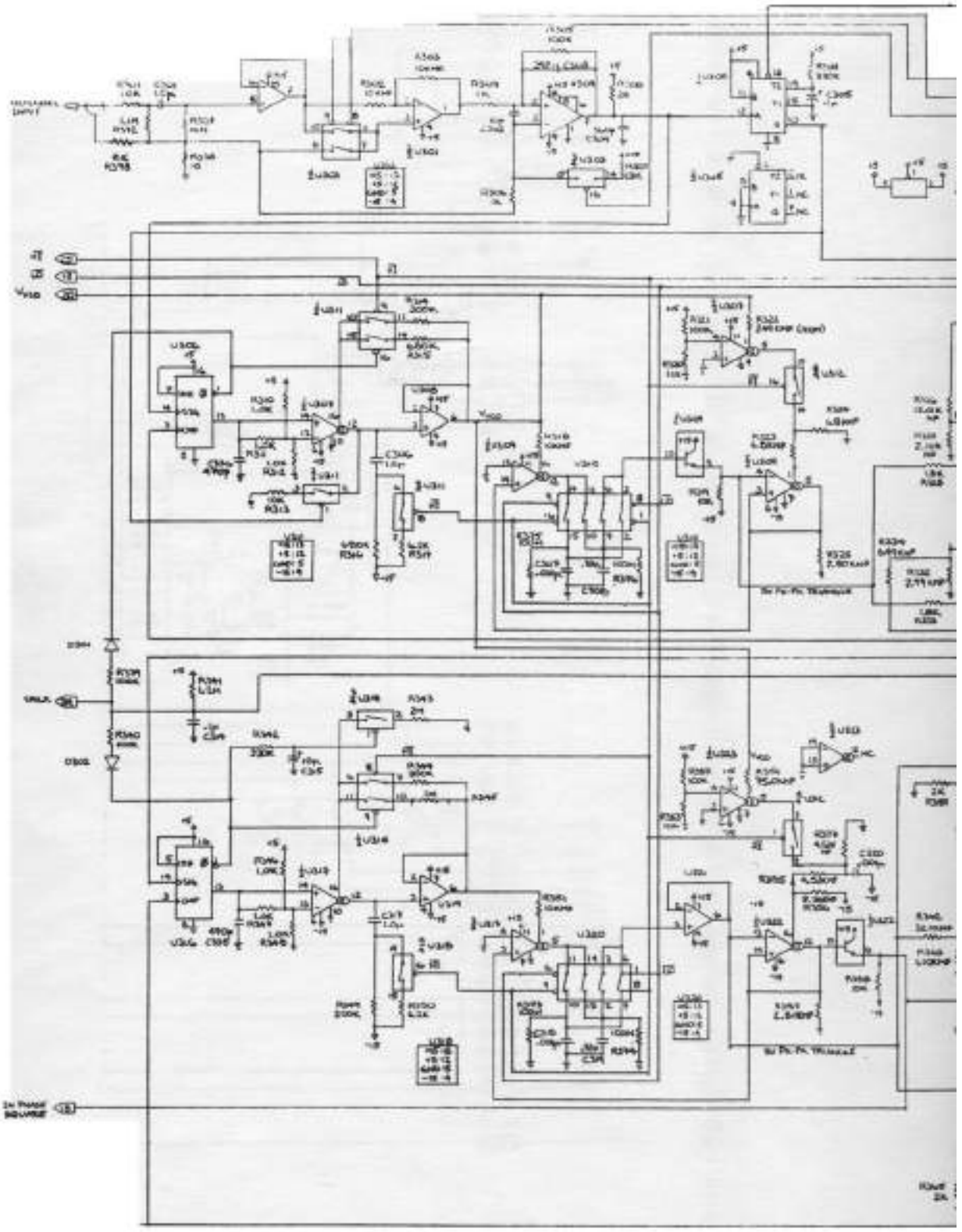


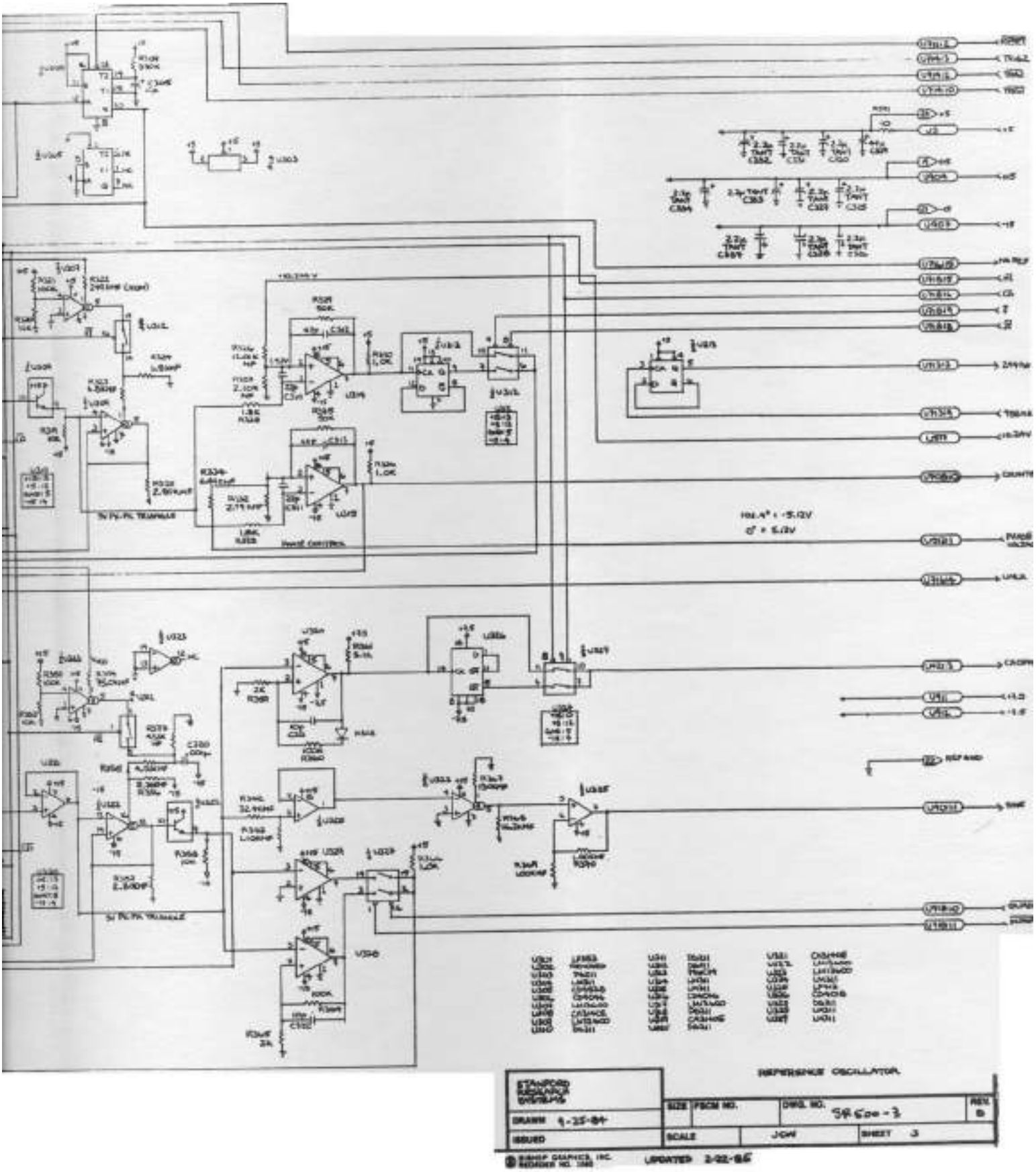


U201	LF344
U202	LM360CD
U203	CD4066BJ
U204	CD4066BJ
U205	DN331
U206	74HC08
U207	74HC04
U208	LF344

STANFORD RESEARCH SYSTEMS	SWITCHED FILTER		
DRAWN 4-25-84	SIZE	FSCM NO.	DWG. NO. SR540-2 REV. B
ISSUED	SCALE	JCW	SHEET 2

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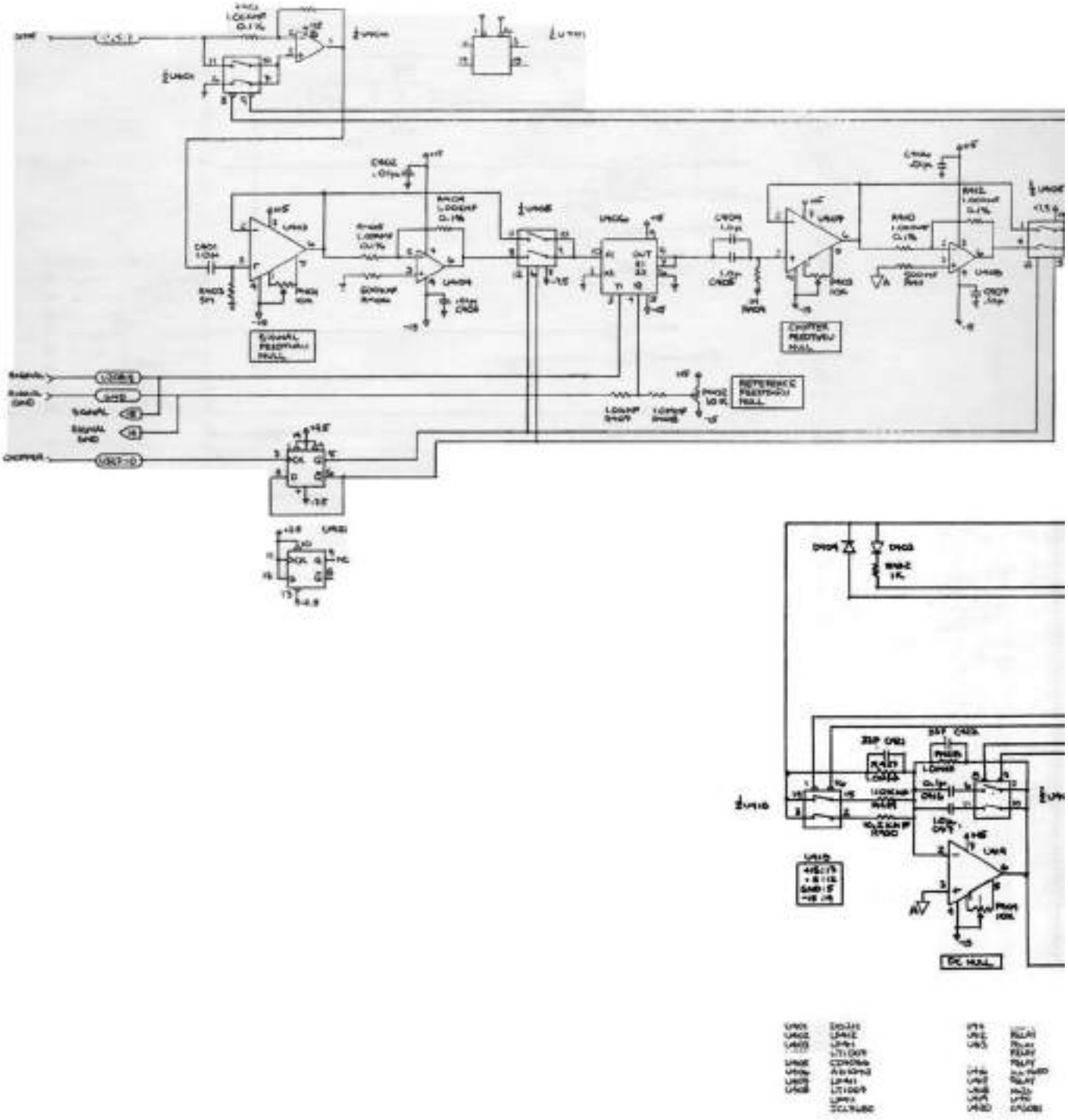


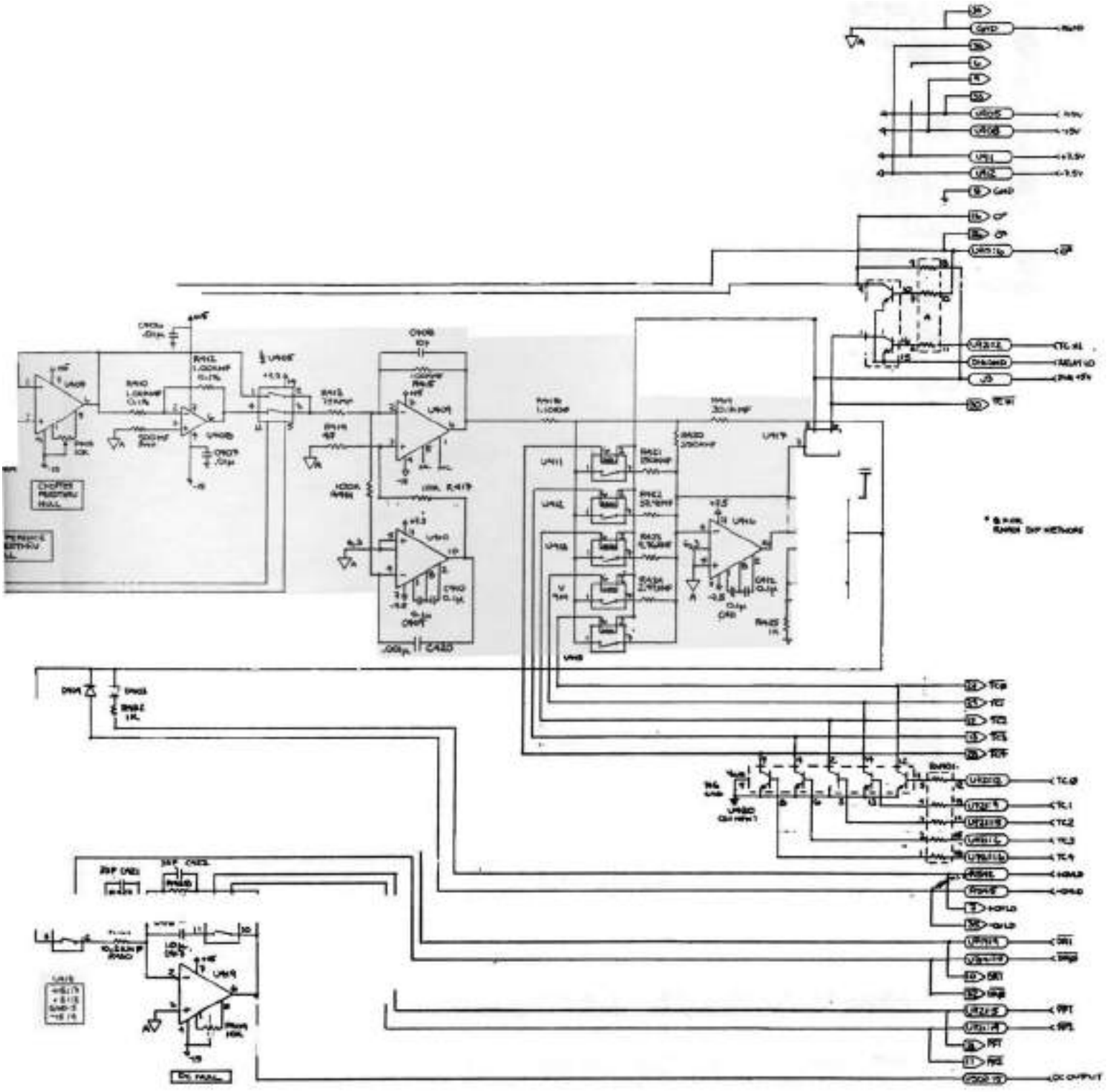


U301	LF353	U311	74LS21	U321	CD4044B
U302	MAX232	U312	74AS11	U322	LM13600
U303	74AS11	U313	74HC04	U323	LM301
U304	LM301	U314	LM301	U324	LF412
U305	CD4053B	U315	LM301	U325	CD4016B
U306	CD4016B	U316	CD4049B	U326	74LS21
U307	LM13600	U317	74LS00	U327	LM301
U308	CD4016B	U318	74S11	U328	LM301
U309	74S11	U319	CD4044B		
U310	74S11	U320	74S11		

STANFORD RESEARCH SYSTEMS	REFERENCE OSCILLATOR			
DRAWN 9-25-84	SIZE B	FSCM NO.	DWG. NO. SR600-3	REV. D
ISSUED	SCALE	JOH	SHEET 3	

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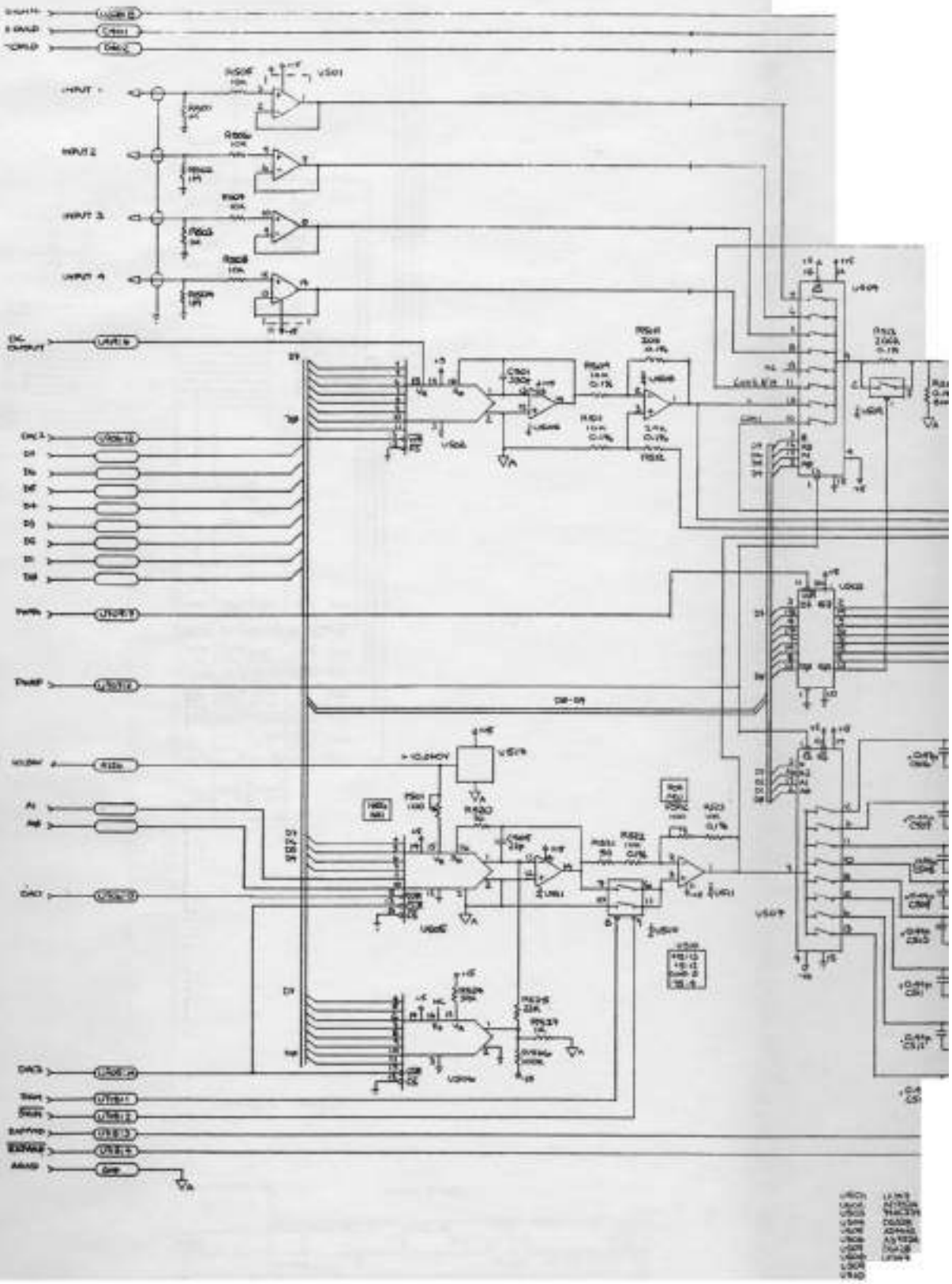


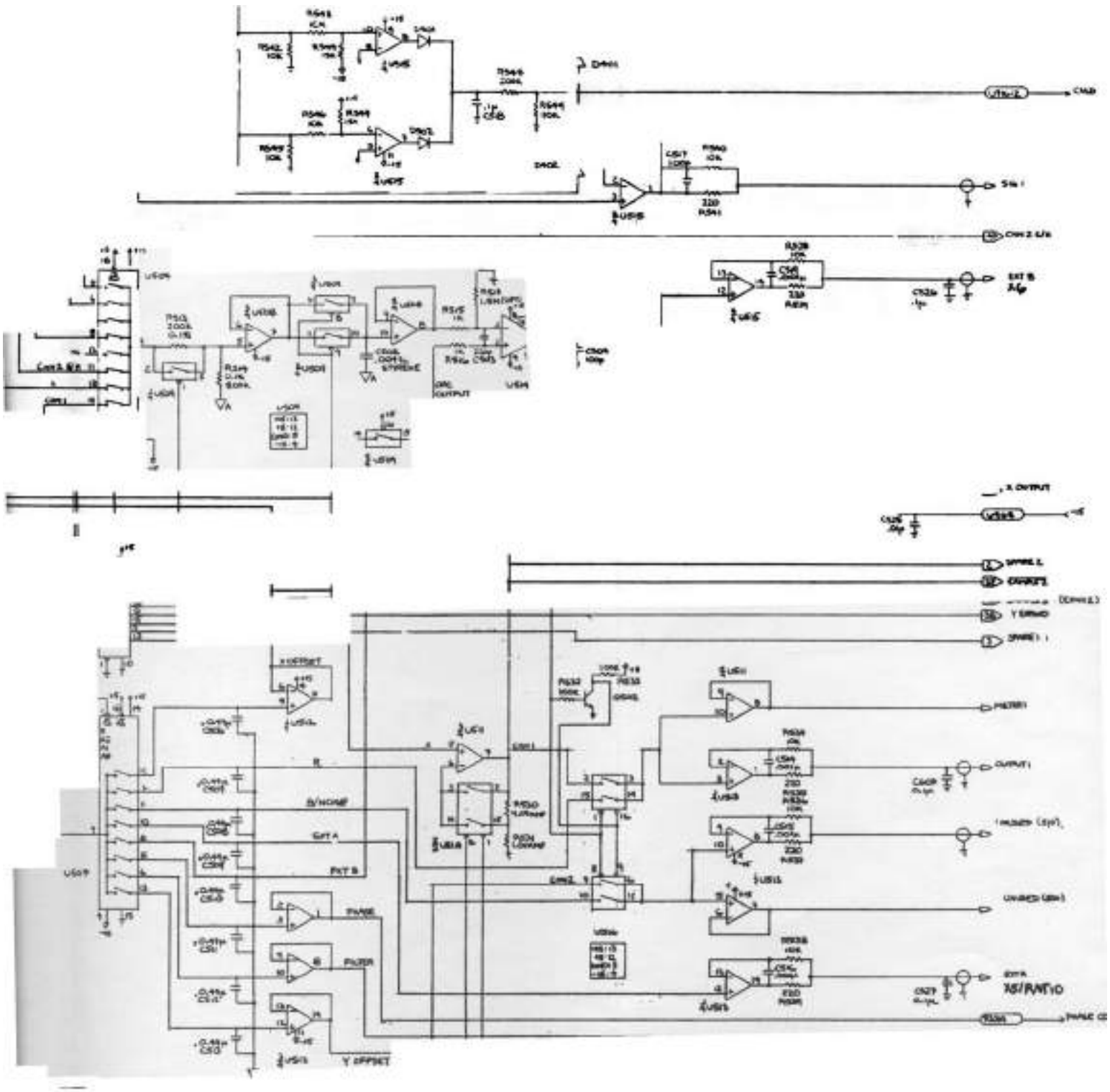


DRAWN 9-24-84	SIZE	FSCM NO.	DWG. NO. 58,500-4
ISSUED	SCALE	JCW	SHEET 4

DEMODULATOR / LOW PASS AMP

UPDATED 2-23-85

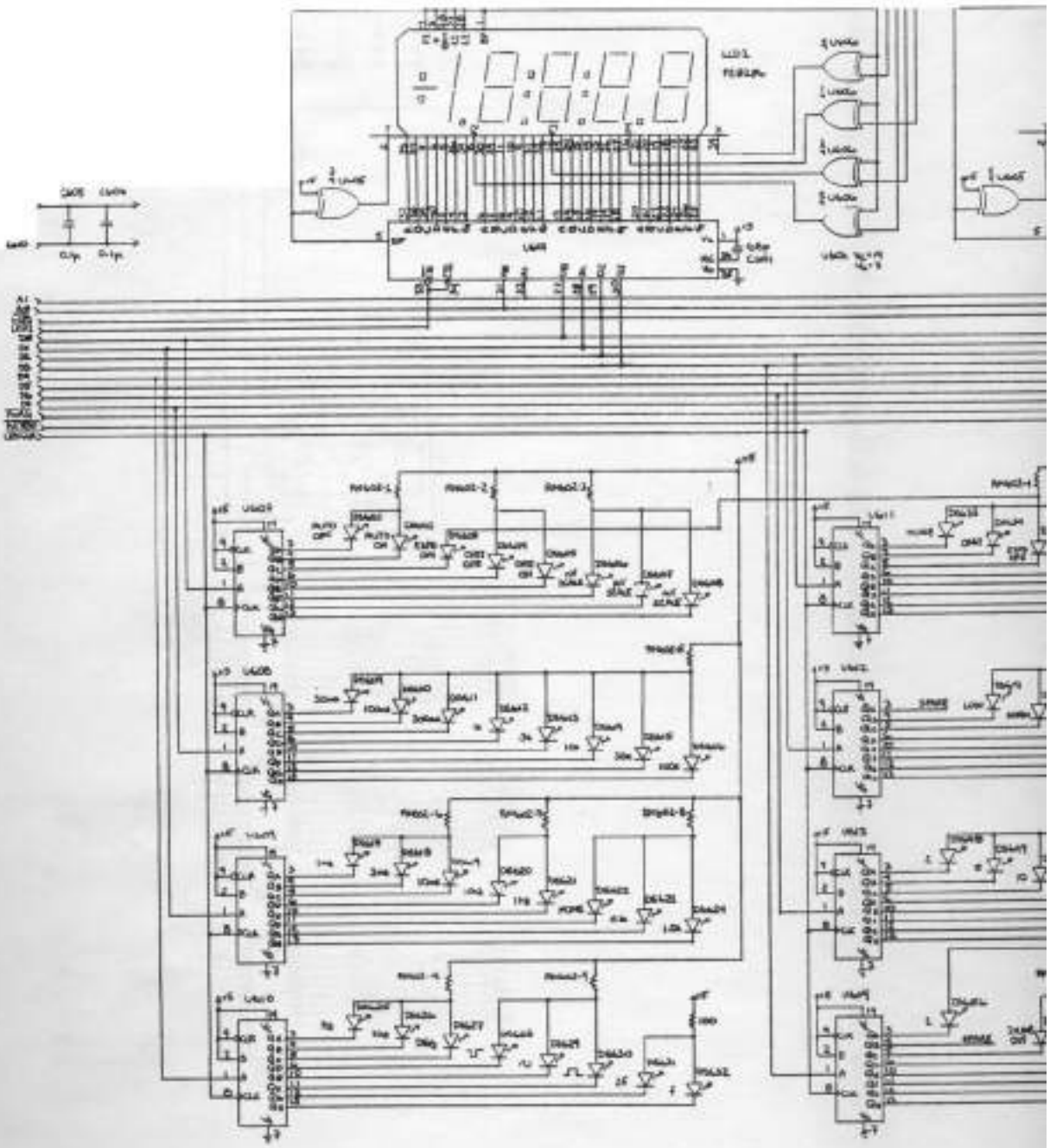


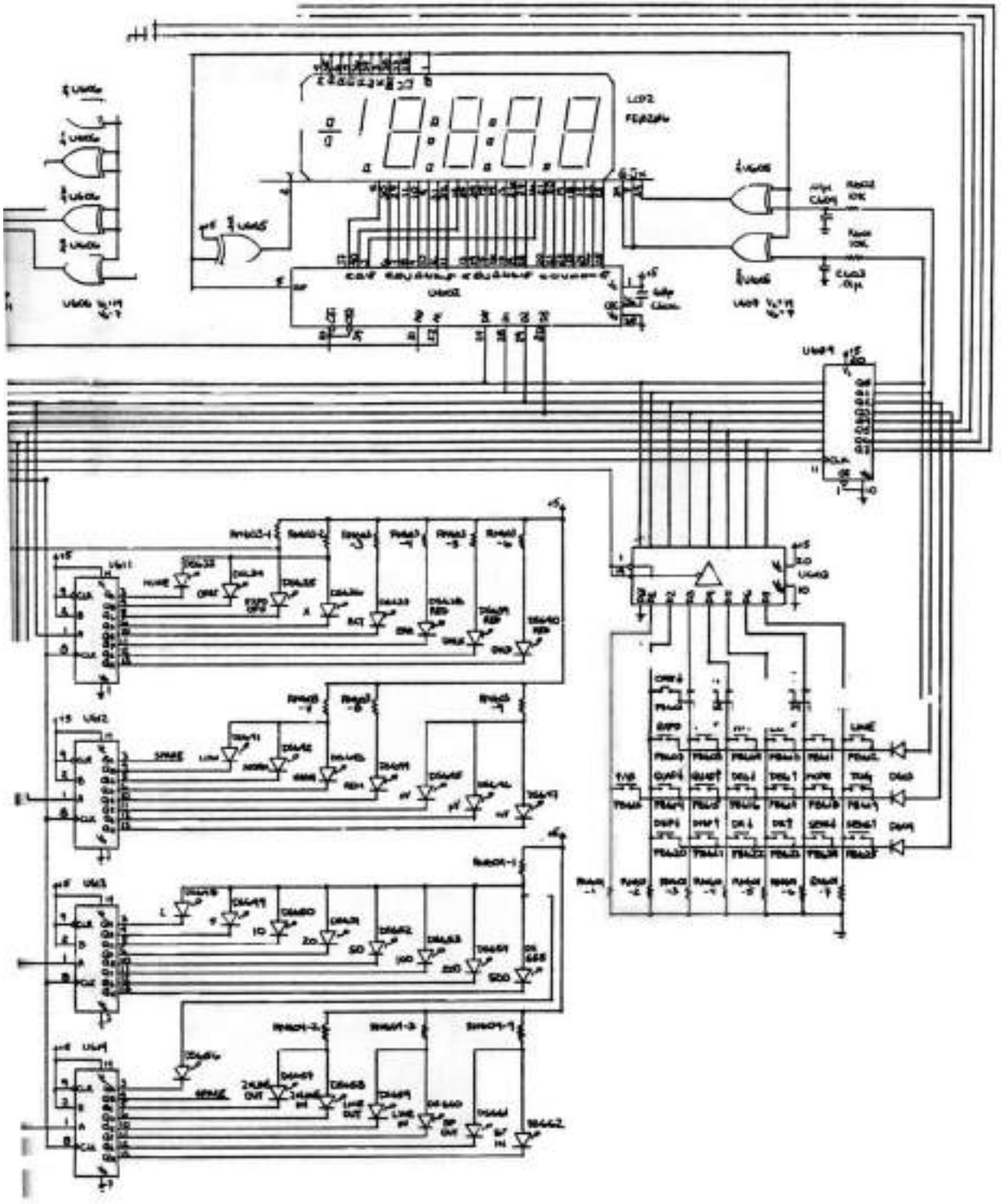


STANFORD RESEARCH SYSTEMS	DC OUTPUTS		
DRAWN 9-26-84	SIZE B	FSCM NO.	DWG. NO. SR500-5
ISSUED	SCALE	JCW	SHEET 5

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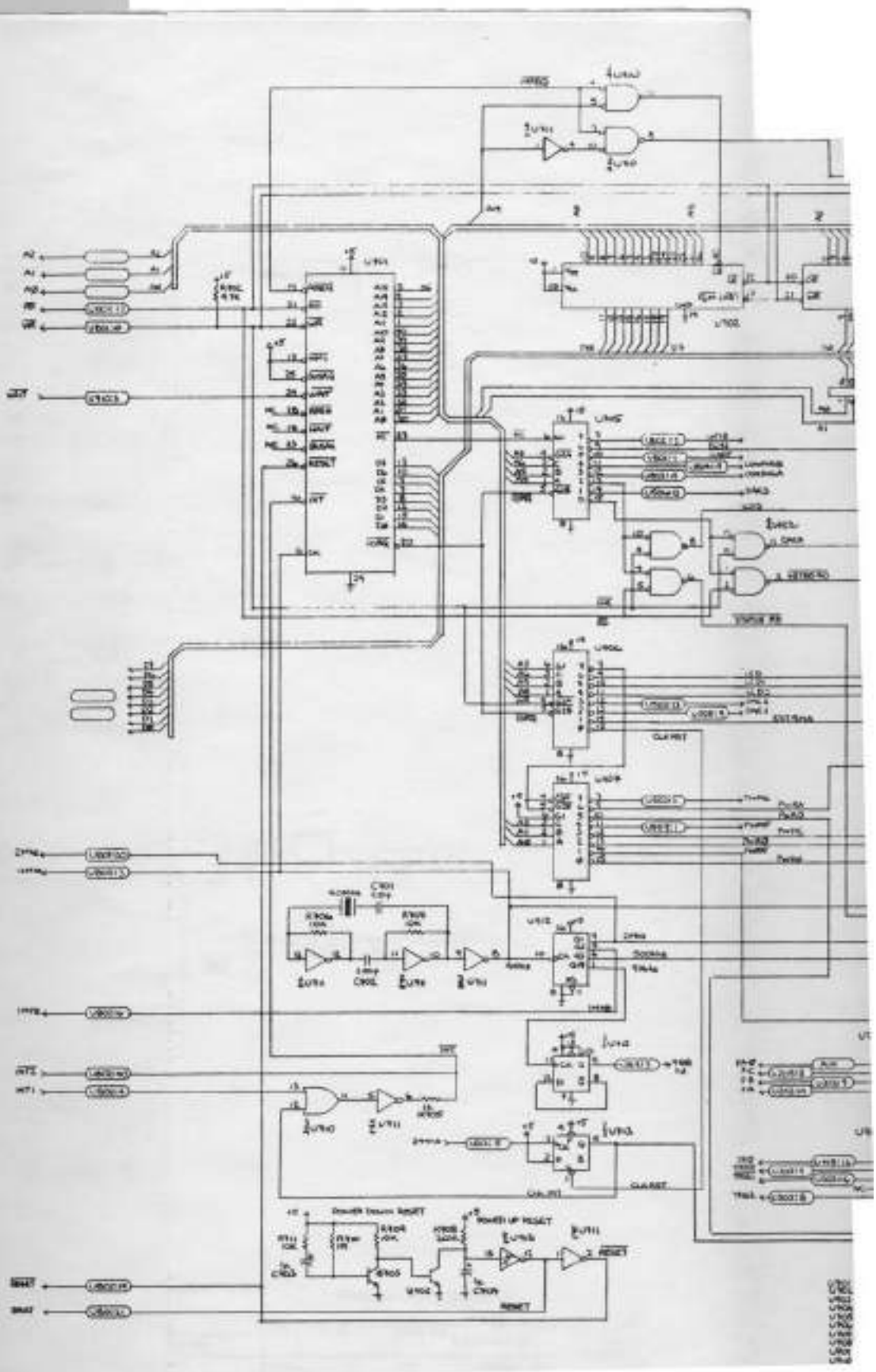


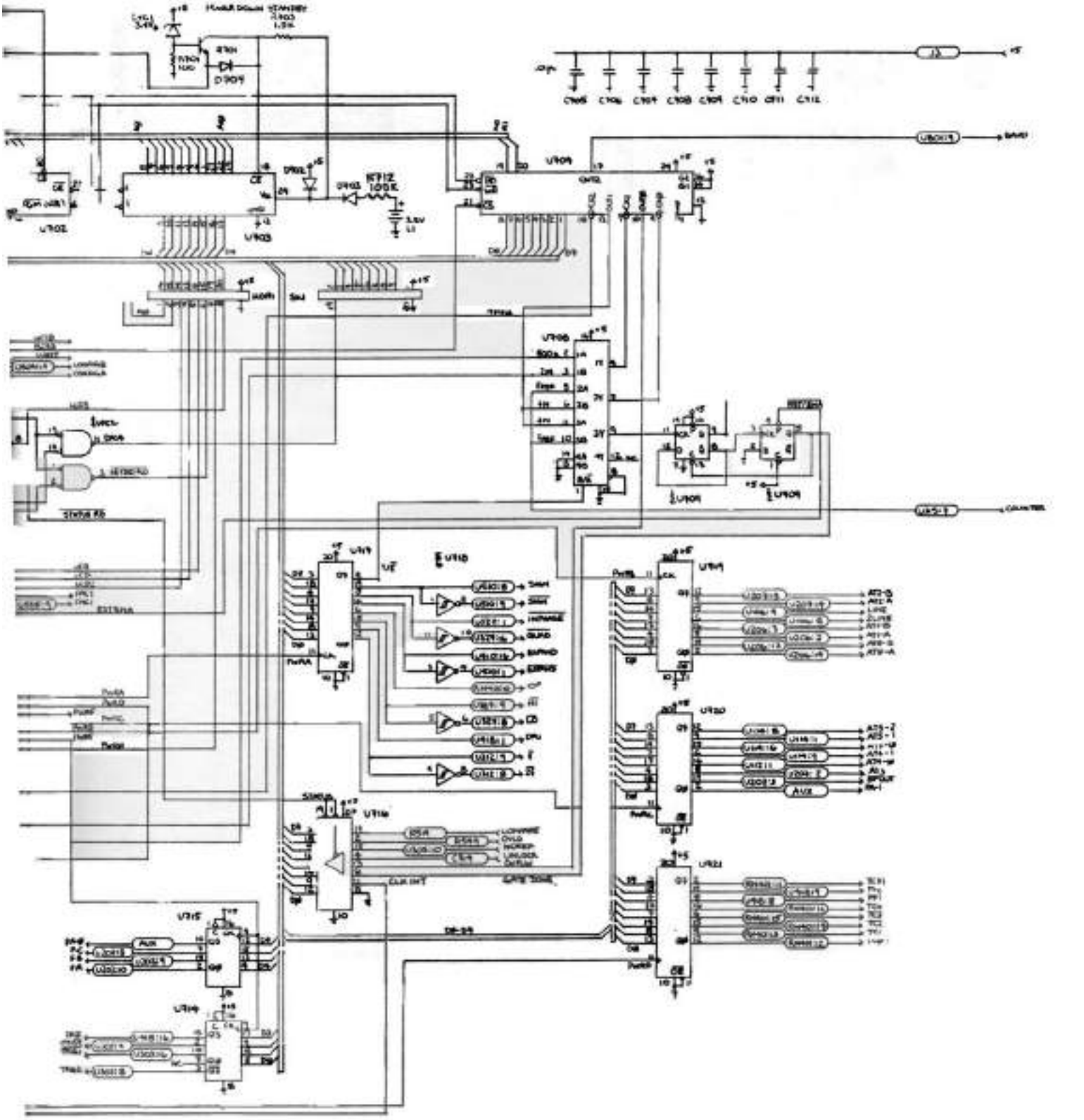
U601 74HC221AMISPL
U602 74HC221AMISPL
U603 74HC299N
U604 74HC157N
U605 CD4030
U606 CD4030

U607-U614 74HC164

STANFORD SYSTEMS SYSTEMS	FRONT PANEL		
DRAWN 8-22-84	SIZE	FSCM NO.	DWG. NO. SR510-6 REV B
ISSUED	SCALE		SHEET 6

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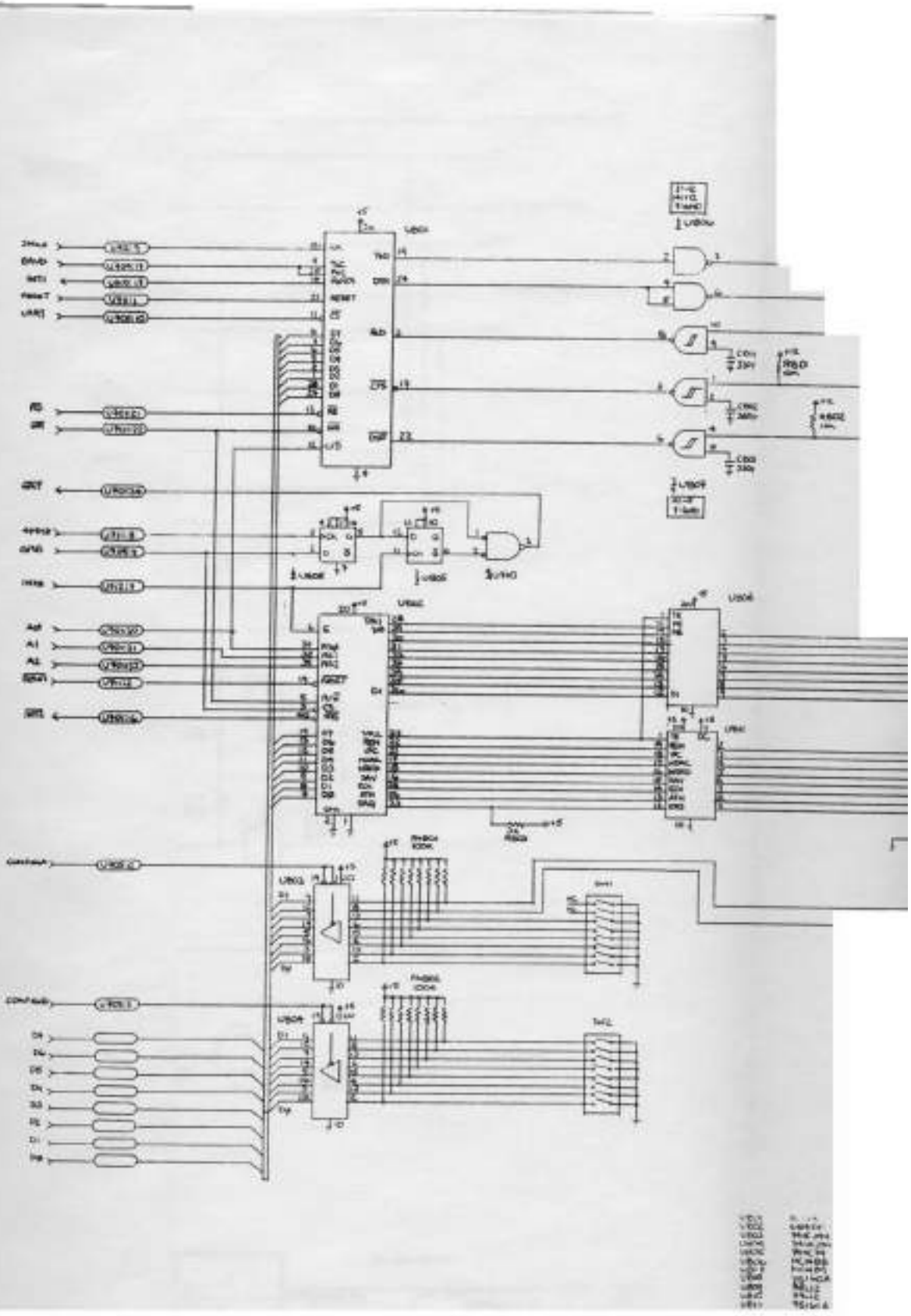


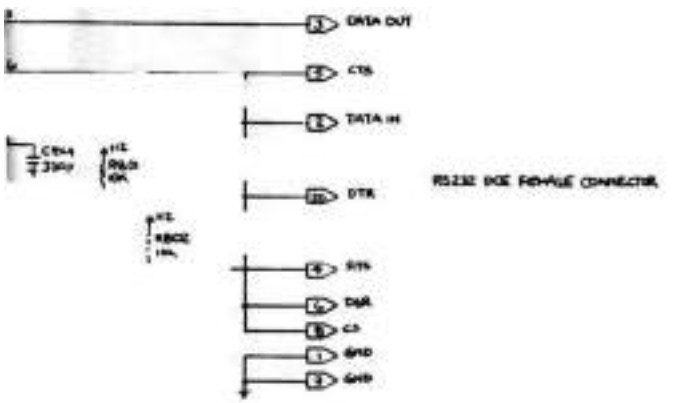
U701	3904	U711	74HC109	U731	74HC374
U702	2716	U712	74HCT04	U732	74HC32
U703	6116LP	U713	74HC74		
U704	8255	U714	74HC00		
U705	74HC138	U715	74HC157		
U706	74HC138	U716	74HC244		
U707	74HC139	U717	74HC374		
U708	74HC157	U718	74HC14		
U709	74HC74	U719	74HC374		
U710	74HC32	U720	74HC374		

STERNWOOD ENGINEERING SEATTLE		MICROPROCESSOR CONTROL	
DRAWN 9-26-84	SIZE	FSCM NO.	DWG. NO. SR500-7 REV. B
ISSUED	SCALE	NEW	SHEET 7

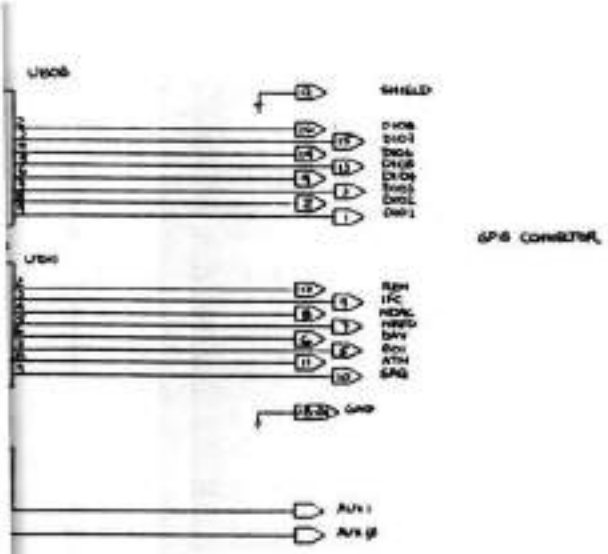
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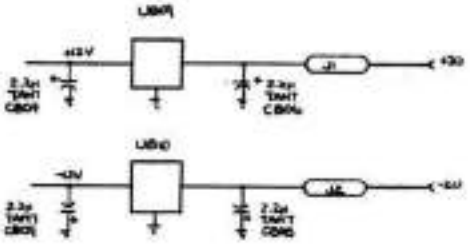
UPDATED 5-22-85





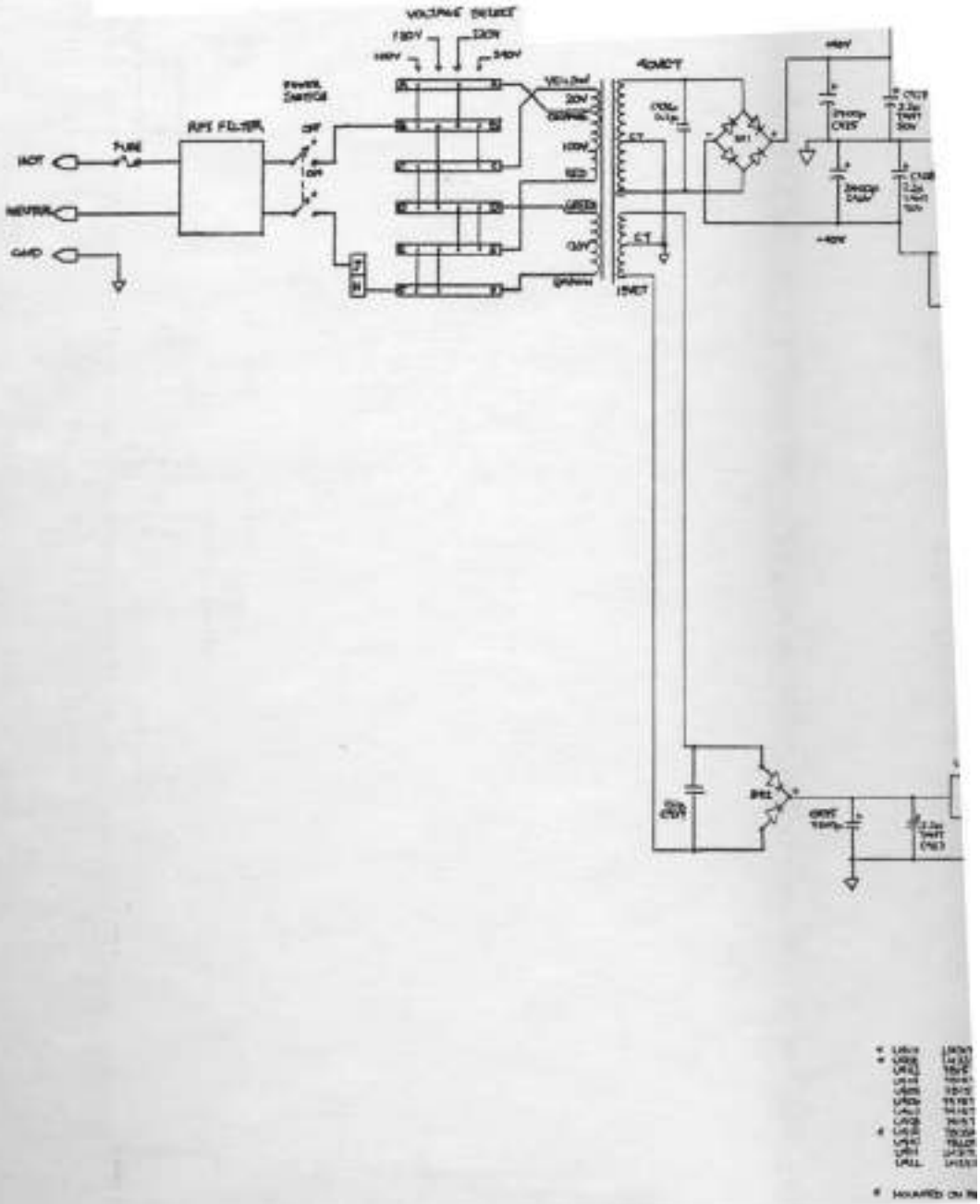


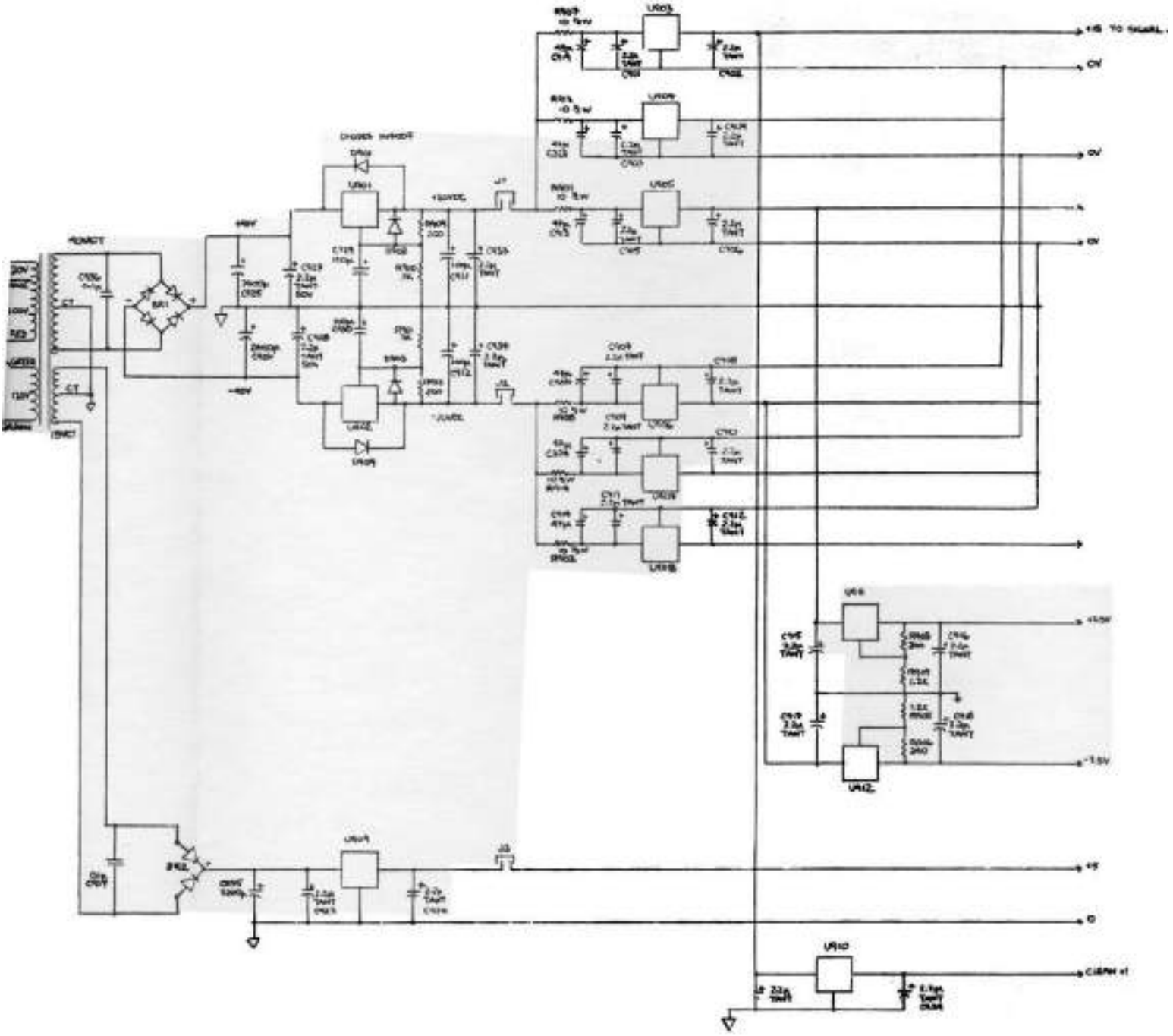




STANFORD RESEARCH SYSTEMS	COMMUNICATIONS INTERFACE		
DRAWN 1-26-94	SIZE	FSCM NO.	DWG. NO. SR500-B REV. B
ISSUED	SCALE	JCW	SHEET 8

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VOLTAGE SELECT
HOT
NEUTRAL
GND
RFI FILTER
+40V



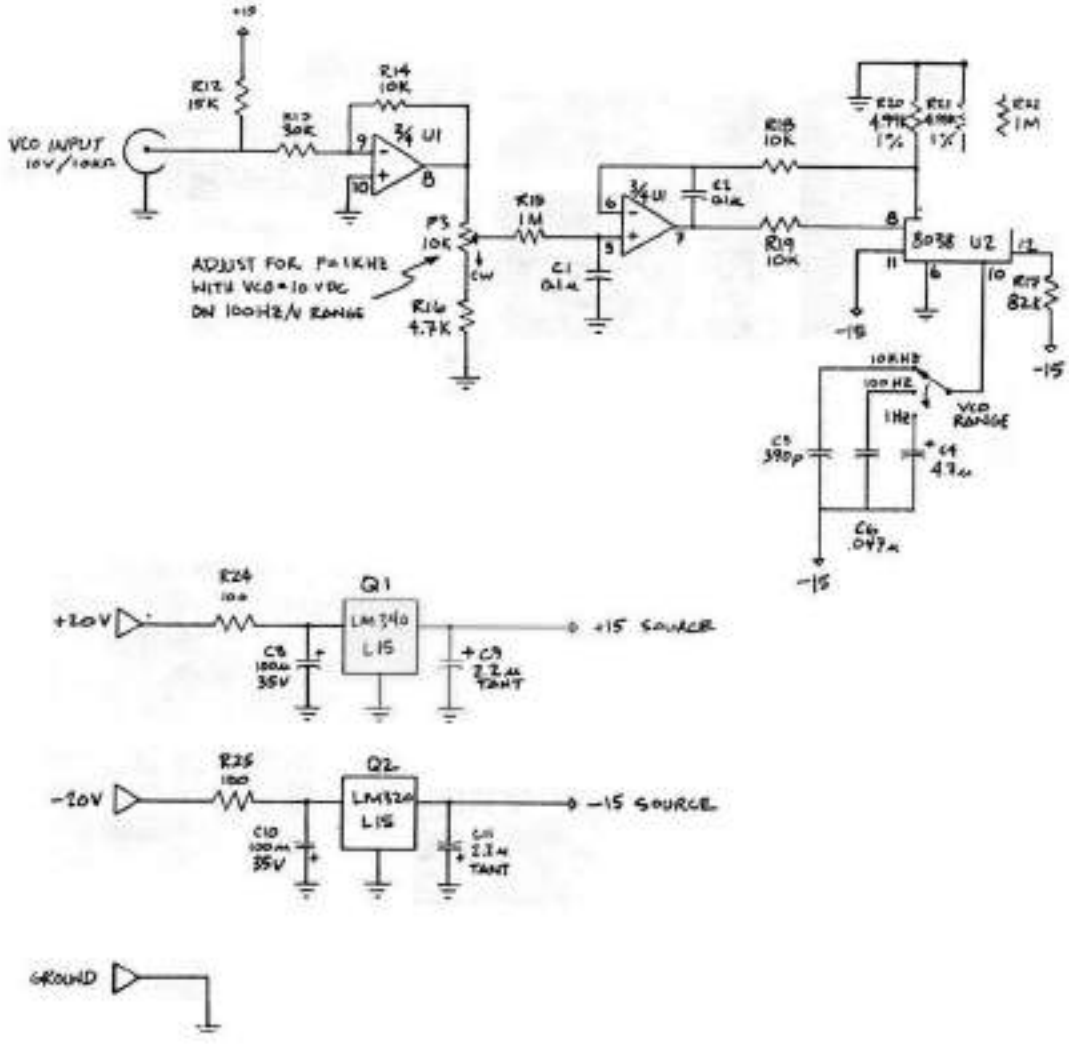
* VR01	LM317K
* VR02	LM337K
VR03	7815T
VR04	7915T
VR05	7815T
VR06	7915T
VR07	7815T
VR08	7915T
* VR09	7805K
VR10	7905K
VR11	LM317LZ
VR12	LM337LZ

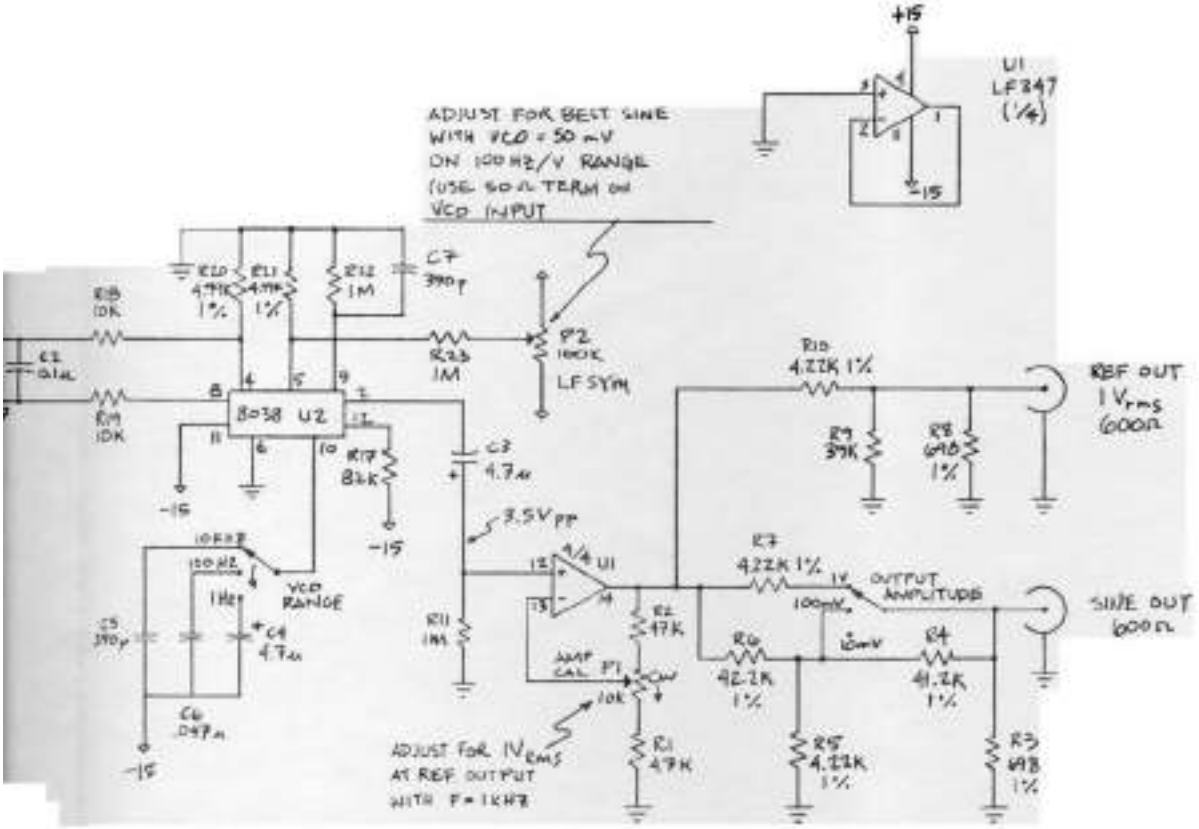
* MOUNTED ON HEAT SINK

STANFORD RESEARCH SYSTEMS		POWER SUPPLY	
DRAWN 1-10-84	SIZE	FSCM NO.	DWG. NO. SR500
ISSUED	SCALE		SH

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MODIFIED DEC 9, 1985 REV. C


+15
R12 15K
R13 50K
R14 10K
VCO INPUT 10V/10KΩ
3/4 U1
9
10
8
P3 10K
CW
ADJUST FOR F=1KHZ WITH VCO=10 VDC ON 100HZ/V RANGE
R16 4.7K
R15 1M
C1 0.1μ
6
5
7
3/4 U1
C2 0.1μ
R18 10K
R19 10K
R20 4.99K 1%
R21 4.99K 1%
R22 1M
8038 U2
11
6
10
12
R17 82K
-15
10KHZ
100HZ
1HZ
VCO RANGE
C5 390P
C4 4.7μ
C6 .047μ
R24 10Ω
Q1
LM340 L15
+20V
+15 SOURCE
C8 100μ 35V
+C9 2.2μ TANT
R25 10Ω
Q2
LM320 L15
-20V
-15 SOURCE
C10 100μ 35V
C11 2.2μ TANT
GROUND



STANFORD RESEARCH SYSTEMS	INTERNAL REFERENCE OSCILLATOR			
DRAWN AWR	SIZE	FSCM NO.	DWG. NO. SR500-17	REV B
ISSUED JRN	SCALE	Aug-26-1985	SHEET	

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