# TABLE OF CONTENTS

## Introduction and Setup
- Instrument Overview 1
- Preparation for Use 2
  - Line Voltage 2
  - Line Fuse 2
  - Line Cord 2
  - Ventilation 2
  - Power-Up 2
  - Repackaging for Shipment 3
  - Use in Biomedical Applications 3
  - Warning Regarding Use with Photomultipliers 3
  - Accessories Furnished 3
  - Environmental Conditions 3
  - Symbols 4

## Specifications
- SR560 Low Noise Preamplifier Specifications Chart 5

## Operation and Controls
- Front Panel Operating Summary 7
  - Power 7
  - Source 7
  - Filters 8
  - Gain Mode 9
  - Gain 9
  - Output 9
  - Reset 9
  - Status 9
- Rear Panel Operating Summary 10
  - AC Power Input 10
  - Amplifier Power Output 10
  - Battery Charger 10
  - Blanking Input 11
  - RS-232 Interface 11
- Battery Care and Usage 11
  - Recharging 11
  - Battery Care 11

## Circuit Description
- Differential Low-Noise Front End 13
- Configurable Filters and Gain 13
- Output Stages 13
- Overload Detection 14
- Microprocessor 14
- Battery Charger and Pre-regulators 14
- Power Regulators 15
- Rear Panel Interfaces 15
- Batteries and P.E.M. 15
- Front Panel 16
# TABLE OF CONTENTS

**Calibration and Repair**
- Offset Adjustment 17
- Calibration 17
- Front End Replacement 17
- Battery Replacement 18
- Fuse Replacement 18
- Noise Contours 18
- Input Voltage Noise 19
- Dynamic Reserve 19

**Appendix A**
- Remote Programming A-1
- Introduction A-1
- Commands A-1

**Appendix B**
- Noise Sources and Cures B-1
  - Intrinsic Noise Sources B-1
    - Johnson Noise B-1
    - ‘1/f’ Noise B-1
    - Others B-1
  - Non-Essential Noise Sources B-1
    - Capacitive Coupling B-2
    - Inductive Coupling B-2
    - Resistive Coupling ('Ground Loops') B-3
    - Microphonics B-3
    - Thermocouple Effect B-3

**SR560 - Component List**
- Front Panel Board C-1
- Main Board C-3
- Miscellaneous Parts C-14

**PCB - SR560 Revision F (9/89)**
- D-1

**Schematics**
- E-1 to E-10
INSTRUMENT OVERVIEW

The SR560 architecture is diagrammed above. The instrument provides DC-coupled low-noise amplification of single-ended and true differential input signals at gains of 1 to 50,000. Two configurable R-C filters are provided to selectively condition signals in the frequency range from DC to 1 MHz. The user can choose high dynamic reserve or low noise settings, and can invert the output relative to the input. The SR560 normally operates with a fully floating ground and can be viewed as an "in-line-BNC amplifier" with the amplifier ground isolated from the chassis and the AC power supply. Opto-isolated input blanking control and listen-only RS-232 interface lines are provided for instrument control. Digital noise is eliminated by shutting down the microprocessor's oscillator except during the short time required to alter the instrument's configuration, either through a front-panel pushbutton or through an RS-232 command. Internal sealed lead-acid batteries provide 20 hours of line-
INTRODUCTION AND SETUP

independent operation. Rear panel banana jacks provide access to the internal regulated power supplies (or batteries) for use as a bias source.

PREPARATION FOR USE

**********CAUTION**********

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

Line Voltage

When the AC power cord is connected to the unit and plugged into an AC outlet, the unit automatically switches the amplifier power source from internal battery operation to line operation. The internal batteries are charged as long as AC power is connected.

The SR560 can operate from a 100 V, 120 V, 220 V or 240 V 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 of the unit, is set so that the correct AC input voltage value is visible.

Conversion from one AC input voltage to another requires a change in the fuse holder's LINE VOLTAGE SELECTOR card position and a new fuse. Disconnect the power cord, slide the fuse holder cover to the left and rotate the fuse-pull lever to remove the fuse. Remove the small printed circuit board. Select the operating voltage by orienting the printed circuit board. Press the circuit board firmly into its slot, so the desired voltage is visible. 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 to the unit. For 100 V and 120 V, use a 1 Amp fuse and for 220 V and 240 V, use a 1/2 Amp fuse.

Line Cord

The SR560 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 connects to the accessible metal parts of the instrument except for BNC shields.

To prevent electrical shock, always use a power source outlet that has a properly grounded protective-ground contact.

Ventilation

Always ensure adequate ventilation when operating the SR560. The unit will generate heat while charging dead batteries.

Power-Up

All instrument settings are stored in nonvolatile memory (RAM backed-up) and are retained when the power is turned off. They are not affected by the removal of the line cord. If the power-on self test passes, the unit will return to the settings in effect when the power was last turned off. If an error is detected or if the backup battery is exhausted, the default settings will be used. Additionally, if the RESET key is held down when the power is turned on, the instrument settings will be set to the defaults shown below:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOURCE</td>
<td>Channel A</td>
</tr>
<tr>
<td>COUPLING</td>
<td>DC</td>
</tr>
<tr>
<td>INVERT</td>
<td>OFF</td>
</tr>
</tbody>
</table>
INTRODUCTION AND SETUP

ROLLOFF bypassed
HIGH-PASS 0.03 Hz, +6 dB/oct
LOW-PASS 1 MHz, -6 dB/oct
GAIN MODE High Dynamic Reserve
GAIN 20, calibrated
LISTEN ON
DEVICE ADDRESS As per SW601

Accessories Furnished
- Power cable
- Operating Manual

Environmental Conditions
OPERATING
Temperature: 10°C to 40°C
Relative Humidity: <90% Non-condensing

NON-OPERATING
Temperature: -25°C to +65°C
Relative Humidity: <95% Non-condensing

Warning regarding battery maintenance
Batteries used in this instrument are seal lead acid batteries. With usage and time these batteries can leak. Always use and store this instrument in the feet-down position. To prevent possible damage to the circuitboard, it is recommended that the batteries be periodically inspected for any signs of leakage.

Repackaging for Shipment
The original packing materials should be saved for reshipment of the SR560. If the original packing materials are not available, wrap the instrument in polyethylene sheeting or equivalent and place in a strong box, cushioning it on all sides by at least three inches of high-density foam or other filler material.

Warning Regarding Use with Photomultipliers
The front-end amplifier of this instrument is easily damaged if a photomultiplier is used improperly with the amplifier. When left completely unterminated, a cable connected to a PMT can charge to several hundred volts in a relatively short time. If this cable is connected to the inputs of the SR560, the stored charge may damage the front-end FETs. To avoid this problem, provide a leakage path of about 100 kΩ to ground inside the base of the PMT to prevent charge accumulation.

Use in Biomedical Applications
Under certain conditions, the SR560 may prove to be unsafe for applications involving human subjects. Incorrect grounding, component failure, and excessive common-mode input voltages are examples of conditions in which the instrument may expose the subject to large input currents. Therefore, Stanford Research Systems does not recommend the SR560 for such applications.
Symbols you may find on SRS products.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Symbol 1" /></td>
<td>Alternating current</td>
</tr>
<tr>
<td><img src="image2.png" alt="Symbol 2" /></td>
<td>Caution - risk of electric shock</td>
</tr>
<tr>
<td><img src="image3.png" alt="Symbol 3" /></td>
<td>Frame or chassis terminal</td>
</tr>
<tr>
<td><img src="image4.png" alt="Symbol 4" /></td>
<td>Caution - refer to accompanying documents</td>
</tr>
<tr>
<td><img src="image5.png" alt="Symbol 5" /></td>
<td>Earth (ground) terminal</td>
</tr>
<tr>
<td><img src="image6.png" alt="Symbol 6" /></td>
<td>Battery</td>
</tr>
<tr>
<td><img src="image7.png" alt="Symbol 7" /></td>
<td>Fuse</td>
</tr>
<tr>
<td><img src="image8.png" alt="Symbol 8" /></td>
<td>On (supply)</td>
</tr>
<tr>
<td><img src="image9.png" alt="Symbol 9" /></td>
<td>Off (supply)</td>
</tr>
</tbody>
</table>
### SR560 LOW-NOISE PREAMPLIFIER SPECIFICATIONS CHART

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inputs</strong></td>
<td>Single-ended or true differential</td>
</tr>
<tr>
<td><strong>Impedance</strong></td>
<td>100 MΩ + 25 pF, DC-coupled</td>
</tr>
<tr>
<td><strong>Maximum Inputs</strong></td>
<td>1 VDC before overload; 3 V peak to peak max AC coupled; protected to 100 VDC</td>
</tr>
<tr>
<td><strong>Maximum Output</strong></td>
<td>10 Vpp</td>
</tr>
<tr>
<td><strong>Noise</strong></td>
<td>&lt;4 nV/√Hz at 1 kHz</td>
</tr>
<tr>
<td><strong>CMRR</strong></td>
<td>&gt;90 dB to 1 kHz, decreasing by 6 dB / octave (20 dB / decade) above 1 kHz</td>
</tr>
<tr>
<td><strong>Gain</strong></td>
<td>1 to 50,000 in 1-2-5 sequence vernier gain in 0.5% steps</td>
</tr>
</tbody>
</table>
| **Frequency Response**  | Gains up to 1000  
±0.5 dB to 1 MHz  
±0.3 dB to 300 kHz |
| **Gain Stability**      | 200 ppm /°C |
| **DC Drift**            | 5 µV/°C referred to input (DC coupled) |
| **Filters**             | 0.03 Hz to 1 MHz, 10% typical accuracy |
| **Distortion**          | 0.01% typical |
| **Power**               | 100, 120, 220, 240 VAC (50/60 Hz), 60 Watts Max  
Internal Batteries: 3 x 12 V, 1.9 Ah sealed lead-acid (rechargeable)  
±12 VDC in / out through rear panel banana jacks. |
| **Battery Life**        | 20 hours nominal  
250-1000 charge / discharge cycles |
| **Charge Time**         | 4 hours to 80% of capacity |
| **Mechanical**          | 1/2 Rack-Mount width, 3 1/2" height, weight 15 lbs. |
| **Dimensions**          | 14-7/8" x 8-1/8" x 3-1/2" |
| **Warranty**            | 1 year parts and labor on materials and workmanship |
FRONT PANEL OPERATING SUMMARY

The operation of the SR560 Low-Noise Preamplifier has been designed to be as simple as possible. The effect of each keypress on the front panel is reflected in the change of a nearby LED. The front panel LED’s will remain lighted at all times unless dip switch SW601 (accessible through the bottom cover of the unit) positions 3 and 4 are placed in the "off" position. All front panel functions can be controlled through the rear-panel RS-232 interface.

Power

The SR560 is turned on by depressing the POWER switch. When disconnected from AC power, the unit will operate for approximately 20 hours on internal sealed lead-acid batteries. Up to 200 mA of unregulated battery power is available at the rear panel banana jacks as long as the power switch is in the ON position. Battery life will be reduced when the unit is providing external power through the rear panel jacks. When operating on batteries, the front panel “BATT” indicator will be lighted. As the batteries near exhaustion, this indicator will change from green to red, indicating that the unit should be connected to AC power to charge the batteries.

When connected to an AC power source, amplifier power is derived from regulated line power, and the internal batteries are automatically charged. When operating on AC power, the front panel "LINE" indicator is on to indicate the source of amplifier power. Charging status is indicated on the rear panel by the "CHARGE" and "MAINTAIN" LED indicators.

Source

There are two input connectors located in the SOURCE section of the front panel. The pushbutton located between them selects either single-ended (A or B) or differential (A-B) inputs.

The A and B inputs are voltage inputs with 100 MΩ, 25 pF input impedance. Their connector shields are completely isolated from chassis ground, but can be made
common with chassis ground by connecting the "AMP GROUND" and "CHASSIS GROUND" banana jacks on the rear panel of the SR560. When connected to AC power, the chassis of the unit is always connected to the grounding conductor of the AC power cord. The inputs are protected to 100 VDC but the DC input should never exceed 10 Vp. The maximum DC input before overload is 1 V peak.

The COUPLING pushbutton selects the method of connecting the A and B inputs to the amplifier. The inputs can be AC (0.03 Hz - 3 dB) or DC-coupled, or the inputs to the amplifier can be internally grounded with the A and B input BNC’s left floating. This feature makes for simple offset nulling, particularly useful when operating the amplifier DC-coupled at high gains. Please refer to CALIBRATION AND REPAIR -- OFFSET ADJUSTMENT for information on the offset nulling procedure.

NOTE: When the coupling is set to AC, a 0.03 Hz cutoff high-pass filter is always engaged. All high-pass filter modes can still be selected while AC-coupled, but the 0.03 Hz filter will always be in, even if the filters are set to DC. Because one of the two filter sections is always used as a high pass when AC coupling is selected, low-pass filters are only available with a 6 dB / octave rolloff.

The INVERT pushbutton allows the user to invert the output of the instrument with respect to the input when operating with single-ended or differential inputs. The INVERT LED displays the output sense relative to the input for all SOURCE settings.

Filters

The SR560 contains two identical 1st-order R-C filters whose cutoff frequencies and topology (high-pass or low-pass) are controlled from the front panel. The maximum bandwidth of the instrument is 1 MHz. The filters in the FILTER CUTOFFS section can be configured in the following six ways:

i. high-pass filter at +12 dB / octave
ii. high-pass filter at +6 dB / octave
iii. high-pass filter at +6 dB / octave, and low-pass filter at -6 dB / octave (band-pass)
iv. low-pass filter at -6 dB / octave
v. low-pass filter at -12 dB / octave
vi. no filters in the signal path

The filter settings are controlled by the ROLLOFF, HIGH-PASS and LOW-PASS pushbuttons. Each time the ROLLOFF pushbutton is pressed the instrument configures the two R-C filters to conform to the progression shown above. The four ROLLOFF LED’s give a visual indication of the current filter configuration. For the HIGH-PASS filter the left pushbutton serves to decrease its cutoff frequency. The two pushbuttons for the LOW-PASS filter function in an analogous manner.

When the FILTER CUTOFFS section is configured solely as high-pass or low-pass (i, ii, iv and v ), the cutoff frequency is illuminated by one of sixteen LED’s in the range from 0.03 Hz to 1 MHz, and the slope of the rolloff is shown by one of the four ROLLOFF LED’s. When the filter section is configured as band-pass (iii), the cutoff frequencies are illuminated by two LED’s. The frequency setting on the left marks the cutoff for the high-pass filter, and the setting on the right is the cutoff for the low-pass filter. The two 6 dB / oct ROLLOFF LED’s are also illuminated. In this case the two cutoffs can be set to the same frequency to provide a narrow bandpass. When both filters are removed from the signal path (vi) all rolloff and cutoff frequency LED’s are extinguished from the FILTER CUTOFFS section and the DC LED is on.

NOTE: High pass filters are not available for the four highest frequency settings. See the note under Source: Coupling for
OPERATION AND CONTROLS

information on using filters with the amplifier in AC coupled mode.

Gain Mode

The allocation of gain throughout the instrument is set using the GAIN MODE pushbutton. The Gain Mode is displayed by two indicator LED's: HIGH DYNAMIC RESERVE and LOW NOISE. For a given gain setting, a HIGH DYNAMIC RESERVE allocates the SR560's gain toward the output stages after the filters. This prevents signals, which are attenuated by the filters from overloading the amplifier. The LOW NOISE setting allocates gain toward the front-end in order to quickly "lift" low-level (nV range) signals above the instrument's noise floor.

Gain

The instrument's gain is increased or decreased using the GAIN pushbuttons. Gain settings from 1 to 50,000 are available and are displayed as the product of a factor 1, 2 or 5 and a multiplier (none (i.e. 1), 10, 100, 1,000 or 10,000). In addition to these fifteen fixed gain settings, the user may specify arbitrary gains through the UNCAL feature. To set an uncalibrated or arbitrary gain the user must press both Gain buttons simultaneously, lighting the UNCAL LED. In this mode by pressing the Gain Up or Gain Down pushbuttons, the user may reduce the calibrated gain in roughly 1% increments from 100% down to 0% of the selected gain. In contrast to other front-panel functions, when in UNCAL the instrument's key-repeat rate will start slowly and increase to a limit as long as either Gain button is depressed. Simultaneously pressing both Gain buttons once again will restore the unit to the previously calibrated gain setting, and turn off the UNCAL LED.

Output

The outputs of the instrument are located within the OUTPUT section of the front panel. Two insulated BNCs are provided: a 600Ω output and a 50Ω output. The amplifier normally drives high impedance loads and the instrument's gain is calibrated for high impedance loads. When driving a 600Ω load via the 600Ω output (or a 50Ω load via the 50Ω output) the gain of the amplifier is reduced by two. The shields of all the front-panel BNC's are connected together and form the amplifier's floating ground.

Reset

The OVLD LED indicates a signal overload. This condition can occur when a signal is too large or the dynamic reserve is too low. Reducing the gain, reducing the input signal and/or switching to the HIGH DYNAMIC RESERVE setting should remedy this condition. If an overload occurs with filter settings of long time constants, the RESET pushbutton will speed the SR560's recovery from overload.

Status

The ACT LED indicates communications activity over the SR560's optoisolated RS-232 port. Please refer to Appendix A: Remote Programming for further details on programming the instrument via RS-232.

The BLANK LED indicates the optoisolated BLANKING input (on the rear panel of the SR560) is active. The SR560 responds to a blanking input by internally grounding the amplifier signal path after the front end and before the first filter stage.
REAR PANEL OPERATING SUMMARY

The SR560 rear panel is pictured in Figure 3. Various interface and power connectors are provided, along with fuses and charger status LEDs.

AC Power Input

The power entry module contains the receptacle for the AC line cord and fuse. The line fuse should be a 1 A slow-blow for 100/120 VAC operation, or a 1/2 A slow-blow for 220/240 VAC operation.

Amplifier Power Output

The -12 V, +12 V, and AMP GROUND banana jacks provide external DC power up to 200 mA for use as a bias source referenced to the amplifier's floating power supplies.

The CHASSIS GROUND banana jack is provided to allow the amplifier's ground to be referenced to the chassis. If the unit is connected to an AC power source via a three prong grounding plug, the chassis ground is connected to the AC line ground conductor.

Battery Charger

The two 3 A slow-blow fuses protect the battery supply and charging circuitry. If these fuses are blown, battery power will be unavailable, and charging of the batteries will not be possible.

When both the positive and negative supply batteries are dead, the red "CHARGE" LED will be on brightly, and the batteries will be charging at a fast rate. When the batteries approach a fully charged condition, the charging current will be reduced to complete the charge and maintain the batteries. Because the batteries charge at different rates, the indicators on the rear panel can reflect the charge status of the positive and negative batteries independently. When one set of batteries switches to the "MAINTAIN" mode, the red "CHARGE" LED will be reduced to half brightness, and the yellow "MAINTAIN" LED will turn on at half brightness. When both batteries switch to "MAINTAIN", the red "CHARGE" LED will
turn off and the yellow "MAINTAIN" LED will be on full brightness.

Blanking Input

The blanking input accepts a TTL-level signal and grounds the amplifier signal path after the front end for as long as the input is held high. The response time of the blanking input is typically "on" 5 µs after the rising edge and "off" 10 µs after the falling edge.

RS-232 Interface

The RS-232 interface connector allows listen-only communication with the SR560 at 9600 baud, DCE. Communication parameters should be set to 8 bits, no parity, 2 stop bits. Data sent must be delimited by <CR> <LF>. All front panel functions excluding power and blanking, are available over the RS-232 interface. For more information on programming and commands, see Appendix A: Remote Programming.

Battery Care

WARNING: As with all rechargeable batteries, for safety reasons the chemical recombination processes within the cells require that the batteries be allowed to vent non-corrosive gases to the atmosphere. Always use the batteries in an area with adequate ventilation.

As with all instruments powered by rechargeable batteries, the user must take some precautions to ensure long battery life. Understanding and following the precautions outlined below will result in a long operating life for the batteries in the SR560.

The SR560's internal lead-acid batteries will have a variable service life directly affected by THE NUMBER OF DISCHARGE CYCLES, DEPTH OF DISCHARGE AND AMBIENT TEMPERATURE. The user should follow these simple guidelines below to ensure longest battery life.
OPERATION AND CONTROLS

• AVOID DEEP DISCHARGE
Recharge the batteries after each use. The two-step fast-charge / trickle-charge operation of the SR560 allows the charger to be left on indefinitely. ALWAYS recharge the batteries immediately after the BATT indicator LED on the SR560 turns red. Built-in protection circuitry in the unit removes the batteries from the load once a dead-battery condition is detected. Avoiding deep discharge will provide the longest battery life - upwards of 1,000 charge / discharge cycles.

• AVOID TEMPERATURE EXTREMES
When using battery power, operate the SR560 at or near room temperature. Operating at lower temperatures will reduce the capacity of the batteries. As well, more time will be required to recharge the batteries to their rated capacity. Higher temperatures accelerate the rate of reactions within the cell, reducing cell life.

• KEEP THE BATTERIES COOL
When not in use, the SR560 should be stored in a cool, dry place with the batteries fully charged. This reduces the self-discharge of the batteries and ensures that the unit will be ready for use when called upon. A SR560 in storage should be "topped off" every three months with an overnight charge to maintain its batteries in peak condition.

Warning regarding battery maintenance
Batteries used in this instrument are seal lead acid batteries. With usage and time these batteries can leak. Always use and store this instrument in the feet-down position. To prevent possible damage to the circuitboard, it is recommended that the batteries be periodically inspected for any signs of leakage.
DIFFERENTIAL LOW-NOISE FRONT END

Two high-impedance inputs A and B allow the instrument to operate in either single-ended or true differential modes. Relays K103 and K104 allow the inputs A and B to be individually grounded, while K101 selects AC or DC coupling. Inversion of the inputs is provided by relay K105. The input capacitances and R101 and R102 establish the front end's input impedance at 25 pF and 100 MΩ.

U106 is an NPD5564 low-noise matched FET pair, which, along with U102 and U103 form the first differential amplifier stage. U102 compares the currents in the drain loads of U106, and U103 maintains the sum of those currents at a fixed level by varying the total current in both FETs. C109 provides open-loop compensation for U102, and front-end gain is nominally established by the sum of R118 and R112 over the sum of R114 and R128. K102 is a gain switching relay which selects a front end gain of 2 or 10. In the gain of 2 position, gain to the next stage becomes 1 when R116 divides with the input attenuator to the next stage. For a gain of 10, relay K102 shorts the top of R115 and R128 together, essentially eliminating them from the gain loop. P103 allows adjustment of front-end offset, and P104 allows for offset compensation when in the low gain configuration. P102 allows adjustment of the front-end common-mode rejection ratio, along with P101, which adjusts the CMRR in the low gain configuration.

In the second gain stage, U105 is configured with a fixed gain of 10. By switching the input attenuation of this stage with DG444 U101, the overall gain of this stage can be computer selected as 2, 5, or 10. C111 provides high frequency compensation for U105. The output of this stage passes through all three sections of U104, a CMOS multiplexer that serves as the blanking control. The three parallel switches provide a low "on" resistance to select either the output of the second stage amplifier or ground as the input to the next stage, the first filter section.

CONFIGURABLE FILTERS AND GAIN

The two filter stages in the SR560 each consist of 16 R-C filters which can be configured as either high pass or low pass by a relay. In the following description, part references in parentheses refer to filter two. Relay K201, (K301) selects either the high-pass or low-pass configuration for all of the sixteen filters. The output of one R-C section is selected by multiplexer U202 or U203, (U301 or U302) and passed on to non-inverting buffer U202, (U303).

Approximately 80 pF input capacitance of the multiplexers is included in the calculation of the R-C time constants of the filters. The four highest frequency stages are not available as high-pass filters because of unacceptable attenuation of the signal that occurs when the filter capacitance forms a divider with the input capacitance of the multiplexers.

DG444 U205D, (U401A) is used to bypass the filter sections entirely and U101D, (U304D) is used to "reset" the filter stages by discharging them through R228, (R329).

U201, (U305) is the third, (fourth) gain stage with a fixed gain of 5. The input attenuator U205, (U304) allows setting the gain of these stages to 1, 2, or 5 under computer control.

OUTPUT STAGES

The fifth gain stage consists of op-amp U402 which is configured as a non-inverting amplifier with a gain of 5. U401 is a DG444 that again serves to switch the input attenuation of this stage for overall gains of 1, 2, or 5. Additionally, output offset
adjustment is provided by this stage. U405B, half of an AD7528 dual 8-bit DAC is used to provide a ±5 volt offset voltage at the non-inverting input of U402. The front panel offset control also sums at this junction, and provides an offset voltage of ±5 V that is buffered by U407D.

Following amplifier U402 is the other half of the 8-bit DAC U405A, which along with op-amp U404 forms a digital gain vernier. This vernier is used in calibration to compensate for gain variances that occur with configuration changes such as input coupling and filter settings. This DAC also provides the front panel "uncal" gain vernier function.

The sixth and final gain stage consists of U403 and output buffer U406, configured for a gain of 5 and with input attenuator U409 to select overall gains of 1, 2, or 5. The LM6321, (U406) provides the output drive capability for both the 600Ω and 50Ω outputs.

OVERLOAD DETECTION

The overload detector constantly monitors the front-end output, filter 1 output, U402 (after the second filter) output, and final stage output for excessive signal levels. Comparator U408 compares both positive and negative signal excursions against a 5 volt reference and lights the front panel overload indicator if any levels are excessive.

MICROPROCESSOR

The system processor U503 is a CMOS Z80 processor running at 4 MHz. The system clock consists of Schmitt trigger U506A and an R-C network. The oscillator is designed so that latch U508A can shut down the clock oscillator completely, thereby disabling all digital circuits in the amplifier so that no digital noise will be present. The processor and clock only run when a front panel key is pressed and instrument settings are to be changed, or while there is activity on the RS-232 port.

The SR560 uses a 16 K x 8 CMOS EPROM, (U504) containing system firmware and calibration bytes, along with a 2 K x 8 CMOS RAM, (U505) which is battery backed-up at all times to retain instrument settings.

U507 generates port strobes for system IO, and U510 provides a buffered data bus. The buffered data bus is active only during IO instructions to keep digital noise in the amplifier to a minimum while the processor is running.

U601 through U606 are control latches providing the 48 DC control lines that configure all of the instrument's hardware. U607 is an input buffer and takes data from the front panel and RS-232, as well as providing a processor input indicating line operation and address from SW601 for ganged RS-232 operation. SW601 additionally controls power to the front panel LED's through positions 3 and 4.

BATTERY CHARGER AND PRE-REGULATORS

The 17 volt AC line transformer provides unregulated power for both amplifier operation and battery charging. Diode bridge D706 and filter capacitors C706 and C707 generate unregulated DC that is pre-regulated to ±12 VDC by U706 and U707 to take the place of the batteries when the instrument is operating on AC line power. Relay U705 switches the amplifier from battery to pre-regulated AC whenever the AC line cord is plugged in.

Diode bridge D710 and C709 and C710 provide unregulated DC to charge the batteries. U701 and U702 operates as "AC" regulators, limiting peak battery charging voltage. As there are two positive batteries and one negative battery, U701 is a LM350
CIRCUIT DESCRIPTION

A regulator that provides twice the current of the LM317 negative battery regulator.

Charging is controlled by changing the set voltage of the regulators based on battery charge status. Flip-flop U703 determines whether the charge regulators will be set to 15.5 volts for a quick charge or 13.8 volts for a trickle or "maintain" charge by grounding the bottom of P701 and P702. C712 and R704 insure that the charger always powers up in the "quick" charge mode. P701 and P702 are provided to adjust the open circuit trickle charge voltage to 13.8 volts. D701 and D703 are blocking diodes for the charging circuits while not charging, and D707 and D708 are clamps to guard against battery polarity reversal.

Comparators U708 and U709 are LP365 micropower comparators that monitor the battery voltage. A resistive divider chain sets the four trip points for each comparator. D709 provides a stable 2.5 volt reference against which levels are compared. For each battery, three level indications are provided, and are decoded by multiplexer U704. The "trip" level is 14.5 volts. The trip outputs control the state of U703 and switch the battery charge voltage settings. The "low" level is 11.3 volts and activates the front panel low battery indicator. R730 provides some level hysteresis for the low battery indication to prevent oscillation around the trip point. The "dead" level is 10.7 volts and is used to disconnect the load from the batteries before they are damaged by an excessively deep discharge. Q701 and Q703 are power MOSFET switches used to disconnect battery power from the amplifier. Dead level hysteresis is provided by R724. R731 and D711 provide un-interrupted battery power to the system RAM so that stored instrument settings are retained when the power is switched off.

POWER REGULATORS

The +5 V and +10 V supplies are produced with three-terminal regulators U801 and U802, respectively. The -10 V supply is constructed of op-amp U803 and Q801, a N-channel MOSFET as the pass element. The +10 V supply serves as the reference for the -10 V supply through divider R807 and R806.

The power output banana jacks on the rear panel (J801 and J803) are connected to the pre-regulated voltages after the power switch and before the regulators. This output can provide up to 200 mA of power for use as an external bias source, etc. Under some conditions, these jacks may be used to supply the unit with external DC power.

U506D and U506B generate the TTL level input to the processor to indicate when the unit is operating on the AC line.

Capacitors C801 through C821 are logic supply bypass capacitors distributed throughout the printed circuit board.

REAR PANEL INTERFACES

Two optically isolated rear panel interfaces are provided on the SR560. The blanking input accepts a TTL-level signal and grounds the amplifier signal path after the front end for as long as the input is held high. The response time of the blanking input is typically "on" 5 µs after the rising edge and "off" 10 µs after the falling edge. The RS-232 interface allows calibration and control of the instrument at 9600 baud. Data in and out on the connector are tied together, echoing data back to the sender. Hardware handshaking lines CTS, DSR, and CD are tied to DTR. Refer to Appendix A-1 for information on remote programming of the SR560.
BATTERIES AND P.E.M.

The batteries used in the SR560 are of sealed lead-acid construction. There are three 12 V, 1.9 amp-hour batteries, two of which serve as the positive power supply, and one of which serves as the negative power supply. Powering the SR560 alone, battery life should be greater than 20 hours. The batteries should last for more than 1000 charge / discharge cycles, provided the guidelines under the Usage section are followed. Two 3A, fast blow fuses on the rear panel protect the battery supplies and amplifier against excessive currents.

The power entry module (P.E.M.) contains the AC line fuse, RFI filter, and voltage selection card. To change the operating voltage of the unit, the voltage selector printed circuit card must be pulled out and reinserted into the P.E.M. with the desired operating voltage visible.

FRONT PANEL

The front panel contains the keypad pushbuttons, LED indicators and serial shift registers. The front panel pushbuttons are decoded in a 3 x 4 matrix fashion. The front panel LEDs are controlled by shift registers U1 through U5, which allow the 5 eight-bit control bytes to be serially shifted-in one bit at a time. The red overload LED is controlled directly from the output of the overload comparator.

The battery LED is a dual-color LED that is green when the unit is operating on battery power, and turns red when the low_batt signal is asserted.

The front panel output offset pot P1 is also mounted on the front panel printed circuit board.
OFFSET ADJUSTMENT

The SR560’s front-panel offset adjustment provides an easy way for the user to null the amplifier’s DC offset. Use the COUPLING pushbutton to light the GND LED. Now, regardless of the SOURCE setting, the input to the amplifier is grounded internally. Insert a small screwdriver through the front-panel OFFSET hole and adjust the offset potentiometer until the DC offset of the amplifier (e.g. as viewed on a DVM) is zero. Finally, return to the desired coupling.

CALIBRATION

There are four pots, which are used to calibrate the instrument. The pots adjust the front-end CMRR (Common Mode Rejection Ratio) and offset. These pots are located close to the front of the instrument, and may be accessed by removing the bottom cover.

These pots should be adjusted to optimize the CMRR or null the offset when the front-end FET is replaced. Two of the pots adjust the CMRR and offset when the front-end gain is x10, and two adjust the CMRR and offset when the front-end gain is x2. The x10 gain pots must be set first, followed by the x2 gain pots.

First, the front panel offset pot must be set to zero:

- Adjust front panel Offset pot to read 0 VDC on pin 14, U407.

Next adjust the offset and CMRR for the case where the front-end gain is x10. View the amplifier output on a scope and perform the following adjustments:

- Couple = GND, Gain = 5 k, LOW NOISE: adjust P103 to null DC and output.

Now use a function generator as the source of a common mode signal:

- Apply 1 kHz 1 Vpp sine to both the A and B inputs.
- Couple = DC, source = A - B: adjust P102 to null sine wave output.

Now adjust the offset and CMRR for the case where the front-end gain is x2. View the amplifier output on a scope and perform the following adjustments:

- Couple = GND (remove signal from A and B inputs), Gain = 5 k, HIGH DR: adjust P104 to null DC and output.
- Apply 1 kHz 1 Vpp sine to both the A and B inputs.
- Couple = DC, source = A - B: adjust P101 to null sine wave output.

NOTE: In the above procedures, the gain of the front-end (x10 or x2) is determined by the selection of LOW NOISE or HIGH DYNAMIC RESERVE.

FRONT END REPLACEMENT

The most commonly damaged component is the front-end FET (U106, National Semiconductor Corp. P/N NPD5564). It is located in an 8-pin DIP socket behind the relays near the input BNCs. If the instrument exhibits a constant overload, excessive drift or noise, or large input bias currents, it is likely that this component has been damaged.

When replacing the FET, be certain that all eight pins are inserted into the socket, and observe the orientation of pin #1. After replacement adjust the CMRR and offset per the calibration procedure. More severely damaged front-ends may require replacement of op-amp, U102.
CALIBRATION AND REPAIR

BATTERY REPLACEMENT

After three to five years or about 1000 charge/discharge cycles, the sealed lead-acid batteries degrade. When the battery operation time shortens, or if the unit stays very warm for more than a day after it is plugged into the line, the batteries may require replacement.

The three batteries are a standard size which are available from several different distributors. All are 12 VDC with a charge capacity of about 2.0 Amp-hours, and measure 7.02" X 1.33" X 2.38". Two of the batteries are wired in parallel to provide the high current required for the positive supply. When replacing the batteries, take care to observe the polarities!

FUSE REPLACEMENT

There are three fuses on the back panel of the instrument. The fuse located inside the power entry module will blow if the unit draws excessive line current. Replace this fuse with the value indicated for your line voltage.

The other two fuses are in-line with the batteries. These fuses will blow if the rear panel ±12 VDC supplies are shorted, or if the unit sources or draws excessive current to or from the batteries.

NOISE CONTOURS

The noise contours (shown upper right) plot the noise figure as a function of source impedance and frequency. Noise Figure (NF) is defined as:

\[ NF = 20 \log \left( \frac{\text{Output noise} \times \text{Gain}}{\text{Source Thermal Noise}} \right) \]

A low noise figure means that the output noise is dominated by the thermal (Johnson) noise of the source. A high noise figure indicates that the amplifier's output noise is dominated by the amplifier's own noise, which is much larger than the thermal noise of the source.

The NF gets worse for low source resistances because the source's thermal noise gets very small, while the amplifier's input voltage noise stays relatively constant.

The NF gets worse for low frequencies and low source resistances because the amplifier's "1/f" noise is large relative to the thermal noise of the source.

The NF gets worse for large source impedances and high frequencies because the signal is attenuated (hence the gain reduced) by the shunting capacitance of the input.

Under no circumstances will adding source resistance reduce the amplifier's output noise! While this does improve the NF, it does so by making the source so noisy that the amplifier is quiet in comparison.
CALIBRATION AND REPAIR

INPUT VOLTAGE NOISE

The amplifier's input voltage noise approximates that of a 1000Ω resistor (about 4 nV/√Hz). For source impedances below 1000Ω, the output noise will be dominated by the amplifier's input voltage noise. A typical amplifier has an input voltage noise vs. frequency as shown in the figure below. Notice that the voltage noise rises at lower frequencies ("1/f" noise).

DYNAMIC RESERVE

The dynamic reserve of the amplifier is a measure of how large a signal can be present at the input to the amplifier without causing an overload condition.

The definition of dynamic reserve is:

- DR (dB) = 20 log (Vin(f) w/o overload / Vin for full scale)

A full-scale output voltage is 10 Vpp. Signals at the output (or at any stage) which exceed 10 Vpp cause an overload. The dynamic reserve is greater than 0 dB only when the filters are used to remove unwanted signals.

The dynamic reserve is a function of frequency and depends on the amplifier configuration (gain, filters and dynamic reserve setting). The figure below shows the dynamic reserve (and maximum input signal without overload) for a SR560 set to a gain of 1000, the high pass filter set to 1 kHz and the low pass filter set to 10 kHz (for a bandpass from 1 kHz to 10 kHz). The dynamic reserve characteristic is shown for both "High Dynamic Reserve" and "Low Noise" gain modes.

There are several features to note. In the bandpass region between 1 and 10 kHz the dynamic reserve is 0 dB. The dynamic reserve is 3 dB at the filter frequencies of 1 and 10 kHz. The dynamic reserve rises by 6 dB/oct (or 20 dB per decade) as the signal moves away from the pole frequency, since each RC filter attenuates the signal. If a faster roll-off for interfering signals were required, a 12 dB/octave HP or LP filter could be used.

The HIGH DR characteristic offers 16 dB more DR at low frequencies and 26 dB more at high frequencies. The high frequency DR is limited only by the maximum 3 Vpp limit of the input stage.

The maximum DR in the low noise mode is 36 dB. Since there is no gain between the HP and LP filters in the Low Noise gain mode, the DR is the same at very high frequencies and very low frequencies.

The input reference voltage noise for the High DR gain mode is about 10 nV/√Hz, compared to 4 nV/√Hz in the Low Noise gain mode. The table (middle of next page) summarizes the input referenced noise and maximum dynamic reserve for all gains.
### Dynamic Reserve vs. Frequency

![Dynamic Reserve vs. Frequency](image)

<table>
<thead>
<tr>
<th>Gain</th>
<th>Input Noise (nV/√Hz)</th>
<th>Maximum DR (dB 0)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>60</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>40</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>25</td>
<td>6</td>
</tr>
<tr>
<td>10, LN</td>
<td>13</td>
<td>6</td>
</tr>
<tr>
<td>10, HDR</td>
<td>25</td>
<td>14</td>
</tr>
<tr>
<td>20, LN</td>
<td>11</td>
<td>6</td>
</tr>
<tr>
<td>20, HDR</td>
<td>25</td>
<td>20</td>
</tr>
<tr>
<td>50, LN</td>
<td>10</td>
<td>14</td>
</tr>
<tr>
<td>50, HDR</td>
<td>25</td>
<td>28</td>
</tr>
<tr>
<td>100, LN</td>
<td>4</td>
<td>14</td>
</tr>
<tr>
<td>100, HDR</td>
<td>20</td>
<td>34</td>
</tr>
<tr>
<td>200, LN</td>
<td>4</td>
<td>20</td>
</tr>
<tr>
<td>200, HDR</td>
<td>18</td>
<td>40</td>
</tr>
<tr>
<td>500, LN</td>
<td>4</td>
<td>28</td>
</tr>
<tr>
<td>500, HDR</td>
<td>15</td>
<td>48</td>
</tr>
<tr>
<td>1000, LN</td>
<td>4</td>
<td>34</td>
</tr>
<tr>
<td>1000, HDR</td>
<td>15</td>
<td>54</td>
</tr>
</tbody>
</table>

Gain | Input Noise (nV/√Hz) | Maximum DR (dB 0) |
--- |-----------------------|-------------------|
2000, LN | 4                   | 40               |
2000, HDR | 10                  | 52               |
5000, LN | 4                   | 48               |
5000, MDR | 8                  | 54               |
10000 | 4                   | 54               |
20000 | 4                   | 52               |
50000 | 4                   | 54               |
APPENDIX A

REMOTE PROGRAMMING

Introduction

The SR560 is equipped with a standard DB-25 RS-232C connector on the rear panel for remote control of all instrument functions. The interface is configured as listen-only, 9600 baud DCE, 8-bit, no parity, 2 stop bits, and is optically isolated to prevent any noise or grounding problems.

Up to four SR560 amplifiers can be connected in parallel to the same RS-232 interface. Units sharing the same interface must have a unique address as set on dip switch SW601, accessible through the bottom cover of the unit. To set an instrument to one of the four available addresses, adjust positions one and two of dip switch SW601 as follows:

<table>
<thead>
<tr>
<th>SW601 Position</th>
<th>Address of Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pos. 1 Pos. 2</td>
<td></td>
</tr>
<tr>
<td>OFF OFF</td>
<td>UNIT 0</td>
</tr>
<tr>
<td>OFF ON</td>
<td>UNIT 1</td>
</tr>
<tr>
<td>ON OFF</td>
<td>UNIT 2</td>
</tr>
<tr>
<td>ON ON</td>
<td>UNIT 3</td>
</tr>
</tbody>
</table>

Commands

The following commands are obeyed by all SR560’s that are addressed to listen. The LALL, LISN, and UNLS commands are always obeyed and control the address status of the SR560. Commands must end with a carriage return and line feed <CR><LF>.

- **BLINK i** Operates amplifier blanking.  
  \( i = 0 \) = not blanked, \( i = 1 \) = blanked

- **CPLGi** Sets input coupling.  
  \( i = 0 \) = ground, \( i = 1 \) = DC, \( i = 2 \) = AC

- **DYNR i** Sets dynamic reserve.  
  \( i = 0 \) = low noise, \( i = 1 \) = high DR,  
  \( i = 2 \) = calibration gains (defaults)

- **FLTM i** Sets filter mode.  
  \( i = 0 \) = bypass,
  \( i = 1 \) = 6 dB low pass,  
  \( i = 2 \) = 12 dB low pass,  
  \( i = 3 \) = 6 dB high pass,  
  \( i = 4 \) = 12 dB highpass,  
  \( i = 5 \) = bandpass

- **GAIN i** Sets the gain.  
  \( i = 0 – 14 = 1, 2, 5, ... 50 \) k gain

- **HFRQi** Sets highpass filter frequency.  
  \( i = 0 – 11 \) sets frequency = 0.03 Hz to 10 kHz

- **INVT i** Sets the signal invert sense.  
  \( i = 0 \) = non-inverted,  
  \( i = 1 \) = inverted

- **LALL** Listen all. Makes all attached SR560’s listeners.

- **LISN i** Listen command. Makes SR560 with address \( i = (0,1,2,3) \) a listener.

- **LFRQi** Sets lowpass filter frequency.  
  \( i = 0 – 15 \) sets frequency = 0.03 Hz to 1 MHz

- **ROLD** Resets overload for \( \frac{1}{2} \) second.

- **SRCE i** Sets the input source.  
  \( i = 0 \) = A, \( i = 1 \) = A-B, \( i = 2 \) = B

- **UCAL i** Sets the vernier gain status.  
  \( i = 0 \) = cal’d gain,  
  \( i = 1 \) = vernier gain

- **UCGN i** Sets the vernier gain to \( i \) %.  
  \( i = 0 \) to 100

- **UNLS** Unlisten. Unaddresses all attached SR560’s.

- ***RST** Reset. Recalls default settings.
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,

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

where $k$ = Boltzmann’s constant, $1.38 \times 10^{-23}$ 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 $\Delta f$ in Hz. For a 1 M$\Omega$ resistor:

$$\langle V^2 \rangle^{1/2} = 0.13\mu V/\sqrt{Hz}$$

To obtain the rms noise voltage that you would see across this 1M$\Omega$ resistor, we multiply 0.3 $\mu V/\sqrt{Hz}$ 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 a rms Johnson noise of:

$$\langle V^2 \rangle^{1/2} = 0.13\mu V/\sqrt{Hz} \times (10^6 \text{ Hz})^{1/2} = 130 \mu V$$

‘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,

$$\langle V^2 \rangle = AR^2I^2 \Delta f/f$$

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

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

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](image)

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 $C_{\text{stray}}$ may be very small, the coupled in noise may still be larger than a weak experimental signal.

\[
I = C_{\text{stray}} \frac{dV}{dt} = jwC_{\text{stray}} V_{\text{noise}}
\]

Where a reasonable approximation to $C_{\text{stray}}$ can be made by treating it as parallel plate capacitor. Here, $w$ is the radian frequency of the noise source (perhaps $2 \pi \times 60$ Hz), $V_{\text{noise}}$ is the noise voltage source amplitude (perhaps 120 VAC). For an area of $A = (0.01 \text{ m})^2$ and a distance of $d = 0.1 \text{ m}$, the ‘capacitor’ will have a value of 0.009 pF and the resulting noise current will be 400 pA. 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) Remove or turn off the interfering noise source.

2) Measure voltages with low impedance sources and measure currents with high impedance sources to reduce the effect of $I_{\text{stray}}$.

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

**Inductive Noise Coupling**

**Inductive Coupling**

Here noise couples to the experiment via a magnetic field:

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, $(\text{emf} = \frac{d\Phi_B}{dt})$. This is like a transformer, with the experiment-detector loop as the secondary winding.

Cures for inductively coupled noise include:

1) Remove or turn 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 hookups.

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

4) Measure currents, not voltages, from high impedance experiments.
Resistive Coupling (or ‘Ground Loops’)

Currents through common connections can give rise to noise voltages. 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.

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) Ground everything to the same physical point.

2) Use a heavier ground bus to reduce the potential drop along the ground bus.

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

Microphones

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

Microphones

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

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.