Operation and Service Manual

400 MHz Programmable Gain Preamplifier

SR446

Stanford Research Systems

Revision 1.01 • November 18, 2022

Certification

Stanford Research Systems certifies that this product met its published specifications at the time of shipment.

Warranty

This Stanford Research Systems product is warranted against defects in materials and workmanship for a period of one (1) year from the date of shipment.

Service

For warranty service or repair, this product must be returned to a Stanford Research Systems authorized service facility. Contact Stanford Research Systems or an authorized representative before returning this product for repair.

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Printed in the U.S.A. Document Number 9-01766-903

Contents

General Information

Safety and Preparation for Use

WARNING

Dangerous voltages, capable of causing injury or death, are present in this instrument. These voltages can persist for many minutes after AC power is removed. Do not remove the product covers or panels. Do not apply power or operate the product without all covers and panels in place.

AC Line Voltage

The SR446 400 MHz Programmable Gain Preamplifier operates from a 90 V–250 V nominal AC power source having a line frequency of 50 Hz or 60 Hz.

Line Cord

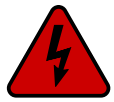
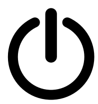
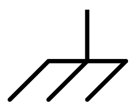
The SR446 400 MHz Programmable Gain Preamplifier has a detachable, three-wire power cord for connection to the power source and to a protective ground. The chassis of the instrument is connected to the outlet ground to protect against electrical shock. Always use an outlet which has a properly connected protective ground.

Service

The SR446 400 MHz Programmable Gain Preamplifier does not have any user serviceable parts inside. Refer service to a qualified technician.

Do not install substitute parts or perform any unauthorized modifications to this instrument. Contact the factory for instructions on how to return the instrument for authorized service and adjustment.

Symbols on the SR446

	**Warning**	Risk of electric shock. Injury or death is possible if the instructions are not obeyed.
	**Caution**	Refer to user manual. Damage to the instrument or other equipment is possible.
	**Power**	Toggle instrument power.
	**Chassis Ground**	

Notation

Typesetting conventions used in this manual, with examples of each.

Use case	Example
Front-panel buttons	[Term]
Front-panel indicators	● AC
Remote command names	*IDN?
Literal text (sent)	`*IDN?`
Literal text (received)	*`Stanford_Research_Systems,SR446,00000001,3.11.2`*

Specifications

All performance specifications after 2 hour warm-up at (23±1)°C ambient, and within 24 hours of automatic offset calibration.

Input	
Input level	±500 mV
AC coup. (−3 dB, with 50 Ω source)	
50 Ω	16 kHz (typ)
500 Ω	3 kHz (typ)
Input impedance	
50 Ω	(50 ± 1) Ω
500 Ω	(500 ± 10) Ω
Clamp levels	±1.5 V
Protection	±4 Vdc
Noise (+40 dB, r.t.i.)	
1 MHz	3.3 nV/$\sqrt{\text{Hz}}$ (typ)
1 Hz to 400 MHz	40 μVrms (typ)
Amplifier	
Gain	1.0 V/V (+0 dB) to 100 V/V (+40 dB)
Accuracy	±0.5 dB @ 1 MHz
Flatness	±0.3 dB, DC to 100 MHz (typ)
Bandwidth (−3 dB)	400 MHz (typ)
Gain stability	±0.1 %/°C (typ)
Offset (r.t.i.)	±1 mV
Offset drift	±0.8 mV/°C (typ)
Outputs	
(specified into 50 Ω load)	
Source impedance	(50±1) Ω
Linear operation	±0.65 V, each channel
Overload detection	±0.8 V (typ)
Limit level	± 0.9 V
Overload recovery	12 ns (typ)
Rise / Fall time	1 ns (typ)
Propagation delay	4.5 ns (typ)
Differential skew	20 ps (typ)
General	
Inputs	1 (BNC)
Outputs	2 (BNC: inverting and non-inverting)
Remote interface	USB type B
Operating temp.	+5 °C to +40 °C, non-condensing
Mains voltage	(85 to 264) Vac, (47 to 63) Hz
Power	15 W (max), 5 W (typ)
Weight	2.3 lb
Dimensions	8.4 × 1.8 × 9.1, inches

Frequency Response

Figure 1 shows the typical frequency response from a 50 Ω source, for each gain setting from +0 dB (bottom curve) to +40 dB (top curve). Some gain peaking is typical between 200 MHz and 400 MHz.

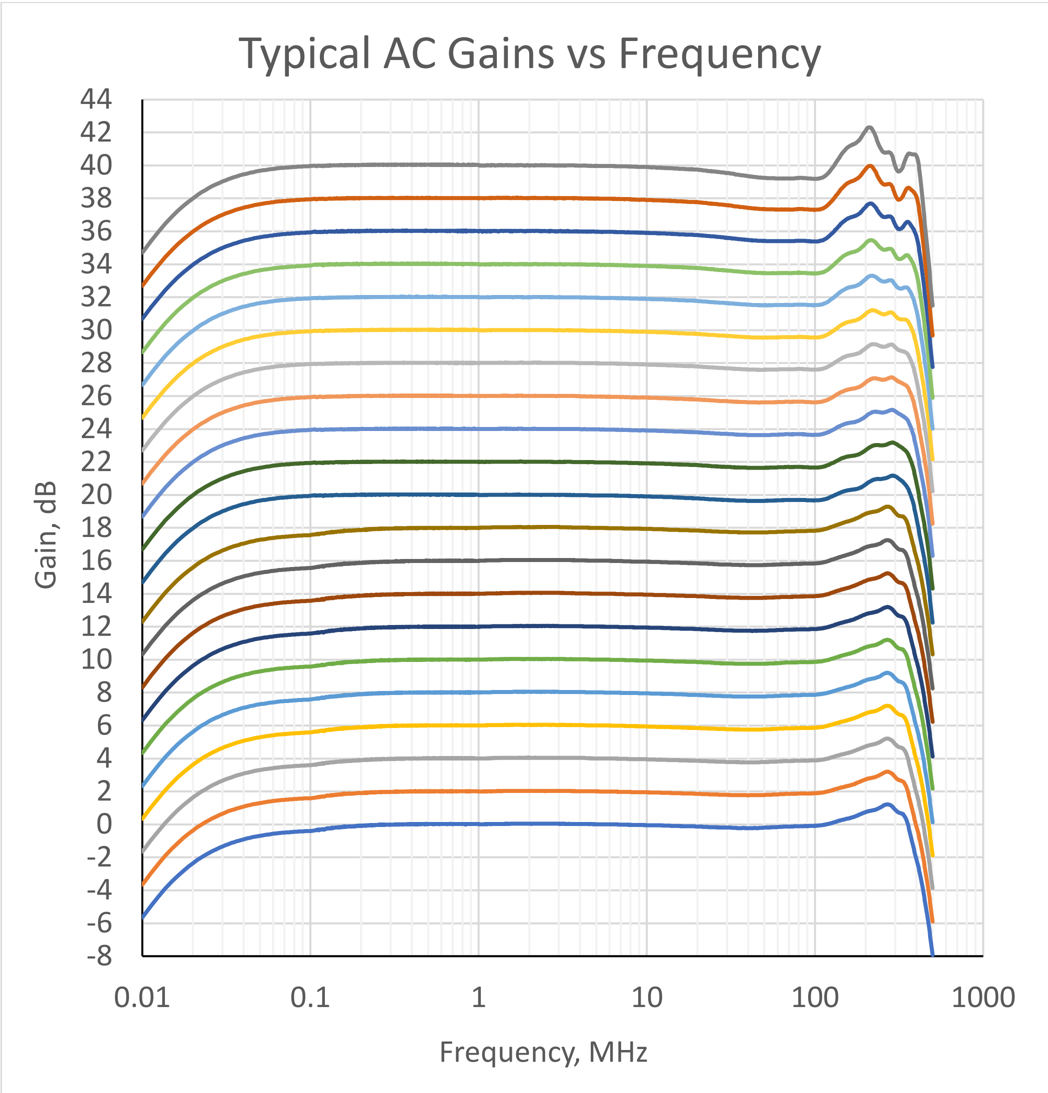


Figure 1: Typical AC gain versus frequency. Measured with AC coupling, 50 Ω input impedance, and full bandwidth. Input signal generated with 50 Ω source impedance, amplitude adjusted for 130 mVpp sinusoidal output signal.

1 Operation

This chapter provides an introduction to the SR446 400 MHz Programmable Gain Preamplifier, and a detailed description of its operation from the front panel.

1.1 Introduction

The SR446 is a single-channel, 400 MHz bandwidth voltage preamplifier with 21 programmable gains from ×1 to ×100 (+0 dB to +40 dB) in 2 dB steps. The amplifier also includes a programmable low-pass filter with four settings: full bandwidth, 200 MHz, 100 MHz, and 20 MHz. The two 50 Ω outputs provide complementary outputs (inverting and non-inverting), and can be used separately or together as a differential output.

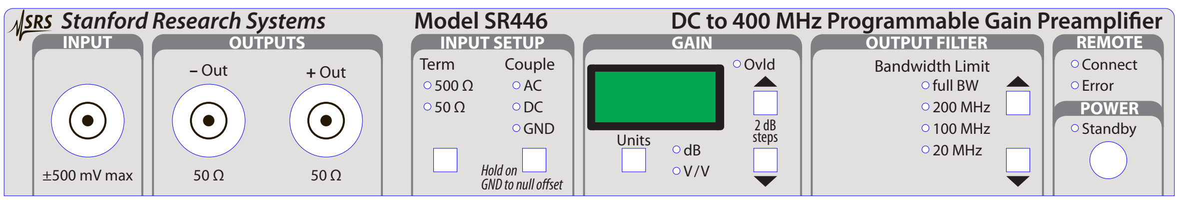


Figure 1.1: The front panel of the SR446.

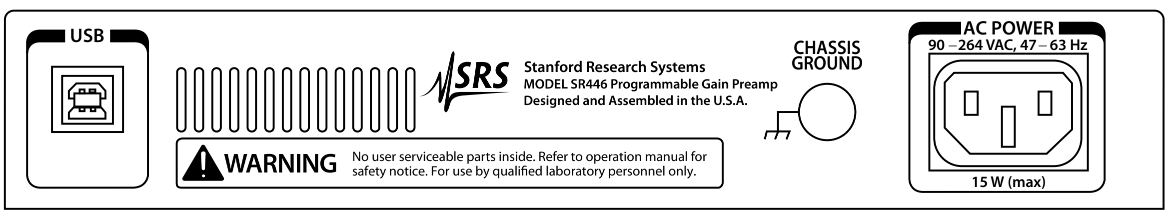


Figure 1.2: The rear panel of the SR446.

The front panel user interface (see Figure 1.1) displays the complete state of the instrument. All configuration settings can be performed either through the front panel directly, or remotely through the USB interface located on the rear panel (see Figure 1.2). A connect indicator shows when the remote USB interface is connected and ready for communication. An error indicator illuminates if any remote command errors have occurred, and will remain lit until the STAT? query is executed. The power standby indicator shows that the AC main power is connected and the SR446 is ready to be turned on.

1.2 Using the SR446

The SR446 400 MHz Programmable Gain Preamplifier can be configured easily by using the 7 front-panel buttons. Settings are stored in non-volatile memory and restored upon power-up.

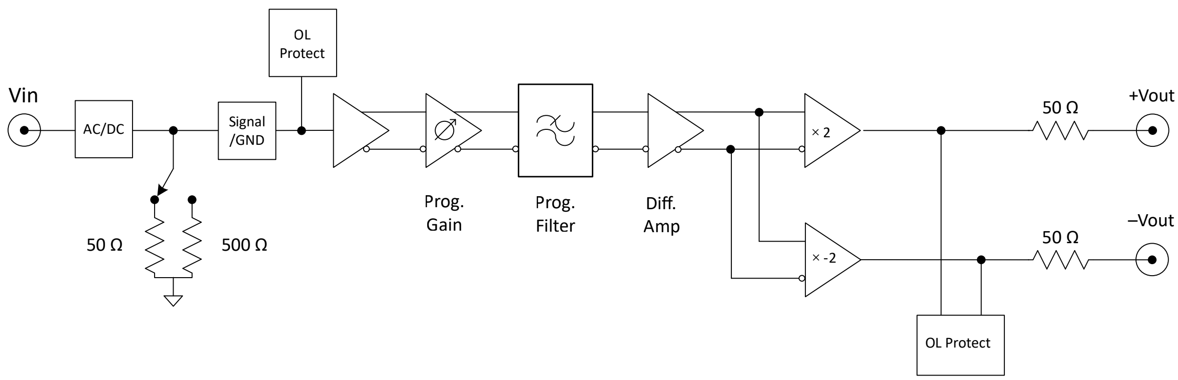


Figure 1.3: SR446 block diagram.

1.2.1 Input

Operation of the SR446 is described by the simplified block diagram (Figure 1.3). Input coupling is either ● DC, ● AC, or ● GND, and is selected by pressing the [Couple] button. AC coupling is through a 100 nF capacitor, giving a 16 kHz −3 dB corner frequency when driven by a 50 Ω source, AC coupled, with Term set to 50 Ω. See the ICPL remote command (§2.3.5, pg 18).

Following the AC coupling stage, the input impedance is switched between ● 50 Ω or ● 500 Ω by pressing the [Term] button. The 500 Ω setting can be used to provide a higher transimpedance gain for charge and current sources—such as photomultiplier tubes—that may be useful when the amplifier is located close to the signal source. Although the input has protection circuitry against electrostatic discharge, users must avoid applying continuous input signals beyond ±4 V to avoid damaging the amplifier front-end components. The 50 Ω impedance setting is intended to terminate 50 Ω coaxial cable such as RG-58. See the INPZ command (§2.3.5, pg 18).

The amplifier performs best when both outputs are terminated into 50 Ω loads. Do not leave unterminated cables connected to the outputs, as this can lead to oscillation of the amplifier. The overload indicator shows if any output signal is over the limits or beyond the linear operating range of the instrument. See the OVLD? query command (§2.3.9, pg 20).

The SR446 can reject a DC bias voltage on the input, as well as unwanted low frequency signals, by using the AC coupling mode. The cutoff frequency is around 16 kHz when set to 50 Ω termination and driven by a 50 Ω source. When the input coupling is set to GND, the amplifier front-end circuitry is disconnected from the input BNC and internally shorted to ground. Note that the input loading at the BNC is not changed when configured to GND.

1.2.2 Gain

Gain of the SR446 is displayed in either ● dB or ● V/V units, selected by the [Units] button. See the UNIT command (§2.3.6, pg 18).

Gain can be adjusted from +0 dB (×1) to +40 dB (×100) in 2 dB steps, by pressing the GAIN ▲ or ▼. See the GAIN command (§2.3.6, pg 18).

1.2.3 Output filter

The full bandwidth (−3 dB) of the SR446 is 400 MHz. In many situations, users may wish to reduce the output bandwidth. This can be helpful to block unwanted high-frequency components of an amplified input signal, as well as to reduce the overall output noise for low-bandwidth applications.

The output filter provides three reduced output bandwidth settings, ● 200 MHz, ● 100 MHz, and ● 20 MHz in addition to the full bandwidth ● full BW setting. The filter setting is selected by pressing OUTPUT FILTER ▲ or ▼ buttons. See the BNDW command (§2.3.7, pg 19).

1.3 Special operations

1.3.1 Offset calibration

The SR446 has an automatic offset calibration feature that will trim the input offset voltage to within ±1 mV of zero after operation. To trim the DC offset:

1. Ensure the unit has been on for at least 30 minutes to warm up.
2. Disconnect cables from the input and both output ports.
3. Select input grounded by pressing the [Couple] button until ● GND is illuminated.
4. With the ● GND indicator illuminated, press and hold the [Couple] button until the display shows cAL .
5. Release the [Couple] button.

The display will show a countdown while each gain configuration is separately trimmed and recorded to non-volatile memory. When the procedure has completed, the display will briefly show End . See the OCAL command (§2.3.8, pg 19).

1.3.2 Factory reset

Restoring the factory default settings of the SR446 will erase all user settings and return the instrument to the *RST configuration. Additionally, any trim data from offset calibration (see section 1.3.1, above) is erased and returned to the original factory calibration. See the FRST command (§2.3.8, pg 19).

To initiate a factory reset from the front panel:

1. Turn off the unit.
2. Press and hold the [Couple] button, and then press the [POWER] button while continuing to hold [Couple] depressed.
3. The display will show rSt
4. After about 5 seconds, the unit will return to normal operation.

2 Remote Operation

This chapter describes operation of the SR446 400 MHz Programmable Gain Preamplifier via the remote interface.

2.1 List of Commands by Subject

Interface

Input

Gain

Filter

Utility

Status

2.2 Introduction

Remote operation of the SR446 400 MHz Programmable Gain Preamplifier is through a simple command language documented in this chapter. Both set and query forms of most commands are supported, allowing the user complete control of the unit from a remote computer through USB.

Where applicable, the corresponding front-panel interface to each command is also indicated. Most instrument settings are retained in non-volatile memory. Upon power-on, these settings are restored to their values before the power was turned off. Where appropriate, the default value for parameters is listed in **`boldface`** in the command descriptions.

2.2.1 Interface Configuration

The USB interface is implemented as a serial port emulator, with fixed data rate of 115,200 baud, 8 data bits, 1 stop bit, no parity, and no flow control.

The ● Connect indicator illuminates whenever a USB connection is active. The ● Error indicator illuminates after a remote command error, and can be cleared by the STAT? query.

2.2.2 Buffers

The SR446 stores incoming bytes from the remote interfaces in separate 500-byte input buffers. Characters accumulate in the input buffer until a command terminator (the ⟨CR⟩ byte) is received, at which point the message is parsed and queued for execution. Query responses from the SR446 are buffered an a 500-byte output queue.

If the input buffer overflows, then bit 0 (unknown command) is typically set in the STAT? register, the buffer is cleared, and the instrument continues to process new commands.

2.3 Commands

This section provides syntax and descriptions for remote commands.

2.3.1 Command Syntax

The four letter mnemonic (shown in CAPS) in each command sequence specifies the command. The command mnemonic is optionally followed by one parameter.

Many commands may take either *set* or *query* form, depending on whether the ? character follows the mnemonic. Set only commands are listed without the ?, query only commands show the ? after the mnemonic, and optionally query commands are marked with a (?).

Parameters in {} are required to set a value, and must be omitted for queries.

Do not send ( ) or {} as part of the command.

Each command must be separately terminated with the ⟨CR⟩ character.[1] Null commands and duplicate whitespaces (including the ⟨LF⟩ character) are ignored. Execution of the command does not begin until the command terminator is received.

2.3.2 Notation

Symbol	Definition
i	Unsigned decimal integer
(?)	Required for queries; illegal for set commands
{*var*}	Required parameter for set commands; illegal for queries

2.3.3 Examples

Each command is provided with a simple example illustrating its usage. In these examples all data sent by the host computer to the SR446 are set in `upright teletype` font, while responses received by the host computer from the SR446 are set in *`slanted teletype`* font.

The usage examples vary with respect to set/query, optional parameters, and token formats. They are not exhaustive, and are intended to provide a convenient starting point for user programming.

[1] The SR446 does not support compound (";") command formats.

2.3.4 Interface Commands

These commands can be used to identify the connected instrument and reset it to a known configuration.

---

*IDN?

Identify

Query the SR446 identification string.

Example:
```
»*IDN?
 Stanford_Research_Systems,SR446,00000001,3.11.2
```

---

*RST

Reset

Reset the SR446 to its default configuration.

This is equivalent to the following command sequence:
```
»ICPL 0
»INPZ 1
»UNIT 0
»GAIN 0
»BNDW 0
```

Example:
```
»*RST
```

2.3.5 Input Commands

The two input commands provide remote program control corresponding to the front-panel INPUT SETUP section (§1.2.1).

ICPL(?) {*i*}

Input Coupling

Sets (or queries) the input coupling mode.

i = **0** (**DC**), 1 (AC), or 2 (GND).

Example: »`ICPL 1`

INPZ(?) {*i*}

Input Impedance

Sets (or queries) the input impedance.

i = 0 (500 Ω), or **1** (**50 Ω**).

Example: »`INPZ?`
1

2.3.6 Gain Commands

The two gain commands provide remote program control corresponding to the front-panel GAIN section (§1.2.2).

UNIT(?) {*i*}

Display Units

Sets (or queries) the gain display units.

i = **0** (**dB**), or 1 (V/V).

Example: »`UNIT?`
0

GAIN(?) {*i*}

Gain

Sets (or queries) the amplifier gain.

i = **0** (**0 dB**), 1 (+2 dB), 2 (+4 dB), …, 20 (+40 dB).

Example: »`GAIN 12` Sets the gain to +24 dB

2.3.7 Filter Command

The filter command provides remote program control corresponding to the front-panel OUTPUT FILTER section (§1.2.3).

BNDW(?) {*i*}

Output Filter

Sets (or queries) the output filter bandwidth.

i = 0 (**full BW**), 1 (200 MHz), 2 (100 MHz), or 3 (20 MHz).

Example: »BNDW?
1 indicates the SR446 is set to 200 MHz

2.3.8 Utility Commands

The utility commands provide remote program control corresponding to the front-panel special operations described in §1.3.

OCAL(?)

Offset Calibration

Initiates the offset calibration, or queries the offset status.

The calibration sequence requires about 18 s to complete. OCAL? queries will return *i* = 0 (idle), 1 (started by OCAL), 2 (started from front panel), 3 (calibration in progress), 4 (calibration failed), or 5 (calibration completed).

Note that while OCAL is in progress, the SR446 will only respond to remote OCAL? queries–all other commands and queries will be ignored.

Example: »OCAL?
3 indicates calibration in progress

FRST

Factory Reset

Initiates a factory reset.

The FRST command restores the SR446 to its factory configuration. This will erase any results from OCAL calibrations performed by the user, restore the factory offset calibration, and then restore the instrument configuration to *RST.

Example: »FRST

2.3.9 Status Commands

OVLD? **Overload**

Query the overload detection.

The OVLD? query returns 1 whenever the amplifier outputs are overloaded. This follows the front-panel ● Ovld indicator.

Example: »`OVLD?`
0 amplifier is not overloaded

STAT? **Status Flags**

Query status flags.

STAT? returns a binary-weighted integer, with bit definitions:

Weight	Bit	Flag
1	0	unknown command
2	1	invalid parameter
4	2	failed to execute command
8	3	front-panel hardware failure
16	4	analog board hardware failure
32	5	non-volatile memory error
64	6	factory calibration invalid
128	7	user calibration invalid
256	8	unable to set parameter
512	9	unable to configure system
1024	10	invalid serial number
2048	11	watchdog timer expired and disabled
4096	12	ADC autocalibration for +Out failed
8192	13	ADC autocalibration for −Out failed
16384	14	DC calibration failed
32768	15	reserved
65536	16	+Out output overload
131072	17	−Out output overload

Bits remain latched to 1 until read by STAT?

Example: »`ABCD`

»`STAT?`
1 indicates unknown command ("ABCD")

»`STAT?`
0 bits cleared after previous STAT? query

3 Performance Verification

This chapter describes the equipment and procedures to verify the SR446 is performing within specification.

3.1 Preliminary

Users may verify the amplifier offset (with respect to input) and/or the AC gain accuracy (at 1 MHz). All equipment should be powered on and warmed up for at least 2 hours prior to performing verification measurements. The SR446 should be in a (23±1)°C ambient indoor environment, and the automatic offset calibration procedure (see § 1.3.1) should be performed within 24 hours prior to verification.

Gather the following instruments and accessories:

1. Digital voltmeter, with better than 100 μV accuracy and resolution (for amplifier offset verification)
2. Banana-to-BNC adaptor to connect BNC coax cable to voltmeter
3. SR865A 4 MHz DSP Lock-in Amplifier (for AC gain verification)
4. Several 1 m (approximate) RG58 coax cables with BNC connectors
5. BNC Tee adaptor
6. BNC 50 Ω terminator

3.2 DC offset

Input offset is measured at +40 dB gain with the input grounded. It is important to terminate the cable connection from the SR446 to the voltmeter with a 50 Ω terminator to avoid possible amplifier oscillation.

The steps to verify the amplifier offset are:

1. Select input grounded by pressing the [Couple] button until ● GND is illuminated.
2. Press the GAIN ▲ button repeatedly until the display shows 40 dB (or 100 V/V).
3. Ensure the output filter is set to ● full BW by pressing the OUTPUT FILTER ▲ button.
4. Connect a BNC coax cable to the +Out connector on the SR446 front panel.

5. Connect the BNC Tee adaptor to the other end of the cable, and connect the 50 Ω terminator to the Tee. Connect the male end of the Tee to the banana-to-BNC adaptor
6. Plug the banana-to-BNC adaptor into the digital voltmeter, and note the DC volts on a scale showing at least 100 μV resolution. Since the gain is +40 dB, the actual offset reference to input will be this reading divided by 100. Record this offset r.t.i. as the +Out offset.
7. Move the BNC cable from the +Out connector to the −Out connector on the SR446, and repeat the measurement. Record this offset r.t.i. as the −Out offset.

3.3 AC gain

Gain accuracy is measured at 1 MHz, for each output, and at three gain setting of the SR446. For specified accuracy, coupling should be DC and input impedance 50 Ω.

To configure the SR865A to verify the amplifier AC gain accuracy:

1. Both the SR865A and the SR446 should be powered on and warmed up.
2. Connect a 50 Ω terminator to the BNC tee, and connect the tee to the "A" input of the SR865A.
3. Reset the SR865A by pressing the [Save Recall] button. Then touch the [Recall default] tile at the upper-left of the screen, and touch [Confirm].
4. Press the [Config] button, and then touch the on/off tiles to disable graphs for X, Y, and Θ. Leave "Data 3" set to R, and graph On. Touch [close].
5. Press the [Screen Layout] button twice, so the display is showing large numeric displays for X, Y, R, and Θ, and the bottom half of the display has a strip chart for R.
6. Push the INPUT RANGE down button twice, to select 100 mV.
7. Push the FILTER [Slope] button three times, to select 24 dB. Then press and hold the [Slope] button to select Advanced.
8. Near the top left of the display, touch the gray Fint tile to bring up the control window for setting internal frequency. Enter 1 MHz.
9. Near the top right of the display, touch the gray Ampl tile to set the sine out amplitude. Enter 2 mV.

10. Connect a BNC cable from the SINE OUT + connector, to the terminated BNC tee at the ”A” input.
11. Press the [Auto Scale] button to increase resolution on the display. Then slowly adjust the AMPLITUDE knob until the R display value shows as close to 1.00 mV as possible (must be between 0.990 mV and 1.010 mV).

Now that the lock-in is prepared, disconnect the BNC cable from the BNC Tee at the ”A” input of the SR865A, and connect that to the INPUT connector of the SR446. Connect a second BNC cable from the −Out connector on the SR446 and connect the other end to the BNC Tee on the SR865A.

Set the SR446 to 50 Ω, DC, dB, and full BW.

The following steps are repeated to measure the gain at 0 dB, 20 dB, and 40 dB:

1. Set the SR446 gain to the desired gain (0 dB, 20 dB, or 40 dB).
2. Pres the [Auto Scale] button on the SR865A, and wait at least 1 second.
3. Record the value of R, along with the gain setting.

Now disconnect the BNC cable from the −Out connector and connect it to the +Out connector. Repeat the measurements for all 3 gains.

gain	−Out	+Out	Spec
+0 dB			0.944 mV to 1.059 mV
+20 dB			9.44 mV to 10.59 mV
+40 dB			94.4 mV to 105.9 mV

Appendix A Gain Calibration

This chapter describes the equipment and procedures to trim the overall gain of the SR446.

A.1 Preliminary

All equipment should be powered on and warmed up for at least 2 hours prior to performing calibration. The SR446 should be in a temperature-stable ambient indoor environment, and the offset calibration procedure (see § 1.3.1) should be performed within 24 hours prior to gain calibration.

WARNING Adjusting the gain calibration requires removing the protective cover from the amplifier while power is applied. This should only be performed by a qualified technician.

Gather the following instruments and accessories:

1. SR865A 4 MHz DSP Lock-in Amplifier
2. Two 1 m (approximate) long RG58 coax cables with BNC connectors
3. BNC Tee adaptor
4. BNC 50 Ω terminator

A.2 AC gain

The gain steps of the SR446 are controlled by variable-gain amplifier U302, and cannot be trimmed. However, the overall gain for the inverting output, and separately the non-inverting output, can be trimmed by adjusting internal trimmers R412 and R512 respectively (see Figure A.1). The procedure described here adjusts the gain at +20 dB, and at 1 MHz.

To configure the SR865A to calibrate the amplifier AC gain:

1. Both the SR865A and the SR446 should be powered on and warmed up, ideally for at least 2 hours.
2. Connect a 50 Ω terminator to the BNC tee, and connect the tee to the ”A” input of the SR865A.
3. Reset the SR865A by pressing the [Save Recall] button. Then touch the [Recall default] tile at the upper-left of the screen, and touch [Confirm].

4. Press the [Config] button, and then touch the on/off tiles to disable graphs for X, Y, and Θ. Leave "Data 3" set to R, and graph On. Touch [close].

5. Press the [Screen Layout] button twice, so the display is showing large numeric displays for X, Y, R, and Θ, and the bottom half of the display has a strip chart for R.

6. Push the INPUT RANGE down button twice, to select 100 mV.

7. Push the FILTER [Slope] button three times, to select 24 dB. Then press and hold the [Slope] button to select Advanced.

8. Near the top left of the display, touch the gray Fint tile to bring up the control window for setting internal frequency. Enter 1 MHz.

9. Near the top right of the display, touch the gray Ampl tile to set the sine out amplitude. Enter 20 mV.

10. Connect a BNC cable from the SINE OUT + connector, to the terminated BNC tee at the "A" input.

11. Press the [Auto Scale] button to increase resolution on the display. Then slowly adjust the AMPLITUDE knob until the "R" display value shows as close to 10.00 mV as possible (must be between 9.90 mV and 10.10 mV). Make a note of the final value displayed as R.

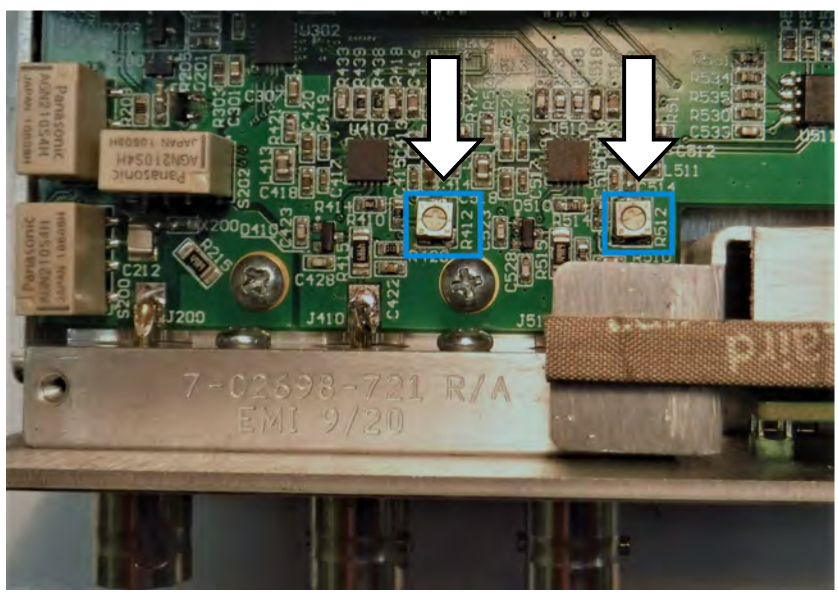


Figure A.1: Location of R412 and R512, near the front of the SR446 circuit board.

Now that the lock-in is prepared, disconnect the BNC cable from the BNC Tee at the "A" input of the SR865A, and connect that to the INPUT connector of the SR446.

Set the SR446 to ● 50 Ω, ● DC, ● dB, and ● full BW.

1. Set the SR446 gain to 20 dB.
2. Connect a BNC cable to the −Out connector on the SR446 and connect the other end to the BNC Tee on the SR865A.
3. Press the [Auto Scale] button on the SR865A, and wait at least 1 second.
4. Remove the top cover from the SR446, by removing the black screws from the left and right sides of the cover. Depending on the build date of the SR446, there may be one additional screw in the top part of the cover, or there may be one silver-colored screw on the bottom of the amplifier. *Do not remove any of the black screws from the underside of the SR446.*
5. With a narrow flat screwdriver, carefully adjust R412 until the "R" display on the SR865A shows between 99 mV and 101 mV. If possible, trim as close to 10× the value noted earlier, when adjusting the SR865A amplitude.
6. Move the BNC cable from the −Out connector to the +Out connector.
7. This time, adjust R512 to bring the R display to 10× the noted value.
8. Replace the SR446 cover and re-install the screws. Ensure the adhesive foam shield gasket is oriented towards the front of the amplifier.

Appendix B Circuit Description

This appendix describes the circuitry of the SR446.

B.1 Analog board

Input signals are received through BNC connector J200. Relay S200 selects AC or DC coupling by shunting the input signal past 0.1 μF input coupling capacitor C212. Input termination of 50 Ω or 500 Ω is selected by relay S202, while the overall amplifier input grounding is provided by relay S201. Diodes D200, D201, and D202 provide input protection with minimal capacitive loading of the input.

JFET Q200 is as a unity-gain buffer to provide a low-impedance copy of the input signal to the following gain stage. Amplifiers U200A and U200B together with Q201 bias the JFET and servo the operating point for low DC input offset voltage.

Programmable gain and filter are provided by U302, an LMH6518 digitally controlled variable gain amplifier. U302 also converts the signal from single-ended to differential.

Two identical output drivers are driven by U410 (inverting output) and U510 (non-inverting output), a THS3217 differential-to-single-ended amplifier with its internal output power stage configured for inverting gain of $\times -2$. Gain trim potentiometers R412 (R512) allow tuning of the overall average gain, and should not require adjustment by the user. Output overload detection is provided by comparators U411 and U511.

The analog board is controlled through J600 by the digital board.

B.2 Bridge board

The bridge board is a small printed circuit board, fastened to the RF shield wall separating analog and digital boards, and providing filtered interconnection between the two main circuits of the SR446.

B.3 Digital board

All configuration settings of the SR446 are performed by U10, an NXP Kinetis K10 microcontroller. The microcontroller uses an SPI serial port to configure the analog board for gain, filter selection, and relay configuration. An SPI port is also used to communicate with the front panel display board at J14. Remote communications are provided through U11, an FT230XQ-R FTDI USB-to-RS232 adaptor chip.

The line-powered AC to DC power supply provides DC power to the digital board through J100. This powers the primary side of shielded transformer T100. T100 is chopped by U100, an LM5030 push-pull controller, to provide the DC voltages for the amplifier. The chopping frequency is dithered by the microcontroller through the PWR_SYNC, and is enabled from standby with the POWER_EN signal. U101 provides ”always on” +3.3 VDC to power the on/standby circuitry for the front-panel power button.

B.4 Front panel board

The front panel display board powers the 3-digit seven segment LED display for gain, as well as discrete LED indicators and the user button inputs. Displays are all driven statically through shift register daisy-chain U9, U6, U4, U7, and U8. Button inputs are latched by parallel-loading shift register U11.

The power/standby button is debounced by Schmitt trigger U10 and latched by flip-flop U5, all of which are powered by the VAO +3.3V ”always on” power supply.

Schematic Diagrams