

Operation Manual

# Laser Shutter

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**SR475**



Stanford Research Systems

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## 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

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## General Information

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The SR475 Laser Shutter is a high performance instrument designed to provide fast, versatile, and reliable mechanical blocking of a free-space laser beam while minimizing vibration and acoustic noise.

### Service

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.

The SR475 Laser Shutter contains small parts and it is recommended that users do not remove the covers. There are no user-serviceable parts inside and reassembling the unit may be difficult.

### Environment

This product is intended for use only in a clean and dry laboratory environment. Operation in other environments may cause damage to the product.

### Laser Safety



#### WARNING

Certain hazards are always present when working with laser radiation. Visible and invisible beams of light have the potential to cause serious bodily injury including blindness or death and to cause significant damage to property. While the SR475 is designed for use with laser systems, **it is fully the users responsibility to ensure that safe operating conditions are maintained and to provide for fail-safe operation whenever an equipment failure could lead to a hazardous situation.**

**Symbols you may Find on SRS Products**

<b>Symbol</b>	<b>Description</b>
	Alternating current
	Caution - risk of electric shock
	Frame or chassis terminal
	Caution - refer to accompanying documents
	Earth (ground) terminal
	Battery
	Fuse
	On (supply)
	Off (supply)

## Notation



### WARNING

The following notation will be used throughout this manual.

A warning means that injury or death is possible if the instructions are not obeyed.



### CAUTION

A caution means that damage to the instrument or other equipment is possible.

Typesetting conventions used in this manual are:

- Remote command names are set as **A**.
- Literal text other than command names is set as **OFF**.

Remote command examples will all be set in monospaced font. In these examples, data sent by the host computer to the SR475 are set as **straight teletype font**, while responses received by the host computer from the SR475 are set as *slanted teletype font*.

## Specifications

### Operation

#### General

Primary function	Block/unblock laser beam
Controller/Driver type	SR470 Series
Clear aperture	0.120" (3 mm) min.
Lifetime	$10^7$ cycles min.

#### Shutter blade

Blade material	BeCu alloy, black oxide finish
Optical power	Low-power laser beams; no absolute specification is established
Bearing type	Sapphire jewel bearing
Blade position	PID controlled; neither open nor closed is preferred
Power-off blade position	Indeterminate
Hold time	Indefinite in either open or closed state.

#### Mounting

Orientation	Any
Mounting holes	8-32 (3), 1/4-20 (1)
Housing material	Anodized aluminum

#### Performance

Laser beam rise/fall time	500 $\mu$ s typ., 1 ms max., in full-speed mode (Depending on beam size/quality)
Open/close time	5 ms full-stop to full-stop, in full-speed mode; User selectable to 10 ms, 20 ms, or 40 ms
Maximum rate	100 Hz, in full-speed mode. (Limited by open/close time).
Insertion delay jitter	10 $\mu$ s rms typ. (Measured at 10 Hz rep rate in full-speed mode.)
Opening/closing bounce	None



**Electrical and Mechanical**

## General

Interface	SRS Shutter interface connector
Weight	0.28 lbs
Dimensions	2.25" W × 1.6" H × 1.0" D
Operating temperature	0 °C to 35 °C, non-condensing
Maximum temperature	90 °C

## Shutter interface

Voltage inputs	+12 VDC, +4.5 VDC
Current draw	1.20 A max. continuous (12 VDC)
	0.25 A max. continuous (4.5 VDC)
Signal lines	Serial TX, Serial RX, logic-level control
Connector type	Mechanically compatible with 6-pin IEEE-1394 cables.
Cable length	10 ft (3 m) max.
Cable shield	Internally connected to housing



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# 1 Getting Started

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This chapter gives you the necessary information to begin using the SR475 Laser Shutter.

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## 1.1 Introduction to the Instrument

The SR475 Laser Shutter is a high performance instrument designed to provide fast, versatile, and reliable mechanical blocking of a free-space laser beam while minimizing vibration and acoustic noise.

The shutter is suitable for low-power beam switching and pulse selection applications. It is also particularly suited to provide additional extinction to optical systems incorporating fast optoelectronic shutters.

### 1.1.1 Overview

The basic function of the SR475 Laser Shutter is to block or unblock a laser beam when commanded to do so.

The shutter head is normally operated in conjunction with a shutter driver or controller that provides power, a serial communications interface, and a control input. Details about this interface are given in §1.7.

### 1.1.2 Design and theory of operation

Mechanical laser shutters have traditionally been electronic descendants of camera shutters, consisting of a solenoid-driven blade (or set of blades) with a return spring. The shutter's open and closed positions are then determined by physical stops that limit the blade travel.

By contrast, the SR475 Laser Shutter does not use physical stops to control the blade position. Instead, the blade position is precisely measured in real time and a digital servo loop is used to hold the blade in the desired location. During a transition between the open and closed states, the shutter blade is guided along a pre-determined trajectory such that it arrives at its final position with zero velocity, without encountering a physical stop.

This design reduces or eliminates many of the less desirable characteristics of conventional solenoid-based mechanical laser shutters. Most importantly, it removes the high impulse that is encountered when a solenoid or a return spring drives a shutter blade into a hard stop. This high impulse is responsible for the bulk of vibration and mechanical noise associated with shutters, but is also a contributing factor in the limited lifetime of such devices.

A typical shutter with a solenoid and return spring necessarily has a defined *normal* state—either open or closed—and expends energy not only to reach but also to hold in the *normal* state. By using an active servo system instead of a solenoid and return spring, the

SR475 does not have a preferred state, and can stay indefinitely in either state without significant power dissipation. Significant power is only used when opening or closing, and the shutter head is rated for continuous duty without duty cycle restrictions.

The SR475 shutter blade is mounted in a sapphire jewel bearing to minimize friction, and is driven as a part of a tightly integrated rotary motor. The motor design, along with the impulse reduction from eliminating physical stops, results in a head lifetime that is orders of magnitude more than is typically found in other laser shutter systems.

The on-board electronics of the SR475 detect the blade position, servo control the blade position, and provide control, communication, and error detection functions. Electrical, over-temperature, and mechanical faults are detected and can be reported over the shutter head's serial interface.

### 1.1.3 Mechanical performance

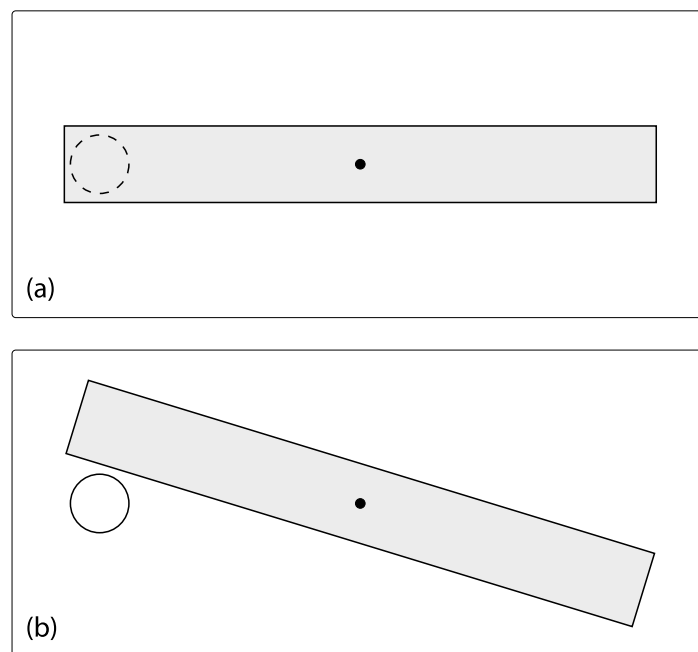


Figure 1.1: Mechanical action of the SR475 shutter head. Part (a) illustrates the shutter head in the *closed* position, where the shutter blade blocks the aperture. Part (b) shows the shutter head in the *open* position, where the shutter blade is clear of the aperture.

The location of the shutter blade in its open and closed positions is illustrated in Fig. 1.1. In the open position the shutter blade is clear of

the laser aperture, and in the closed position the shutter blade fully covers the aperture.

The process of opening or closing the SR475 Laser Shutter consists of guiding the blade along a smooth pre-determined trajectory between the closed and open positions. In what follows we will describe this in more detail. For clarity we will discuss only the case of opening, but the sequence of events applies equally to closing the shutter.

When the shutter is initially closed and it receives a signal to open, it begins moving the shutter blade under servo-loop control along the preprogrammed “opening” trajectory. Once this has begun, the shutter will guide the blade along the entire trajectory—bringing the blade to a full stop at the open position—before carrying out any subsequent instruction to close. In other words, a transition in progress cannot be reversed or aborted (except by disabling the motor).

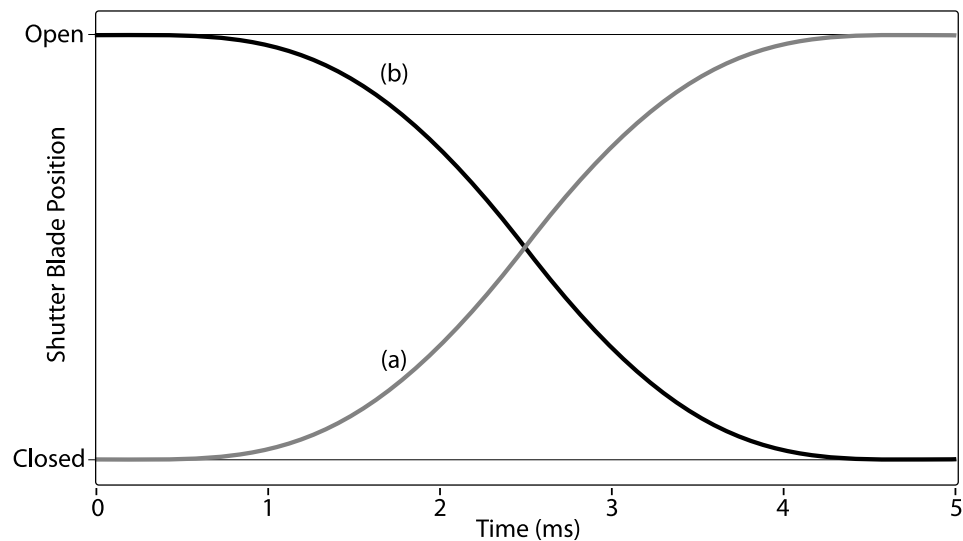


Figure 1.2: Shutter blade trajectory during a transition. Curve (a) illustrates the position of the shutter blade as it moves from the closed to the open position, and curve (b) illustrates the closing trajectory.

Sample trajectories for opening and closing are illustrated in Fig. 1.2. At full speed, each pre-programmed trajectory takes 5 ms to complete. This means that the minimum time to complete a closed-open-closed full cycle is 10 ms, which gives the shutter’s maximum rate of 100 Hz. The minimum exposure time between the midpoint of opening and the midpoint of closing is 5 ms. If full speed is not needed, there are alternate speed modes available that use less power and create less vibration; see §1.6.

### 1.1.4 Power-off and standby states

The SR475 Laser Shutter does not incorporate a return spring and the shutter blade is in an indeterminate position whenever the shutter is powered off or in the *Standby* mode.

The shutter is in the *Standby* mode whenever its +4.5 VDC “logic” power supply is available but the motor is not enabled. In this mode, the logic power supply provides power for serial communications, but the motor is turned off and the shutter blade position is therefore indeterminate.

The SR475 Laser Shutter can be placed into *Standby* with a remote command. It also enters *Standby* mode automatically when certain fault conditions are detected. These conditions include mechanical failure, over temperature, and undervoltage on the +12 VDC power supply for the motor. The SR475 Laser Shutter may be held in *Standby* by turning off its +12 VDC power supply. Once in this mode, the shutter head will remain so until reset.

Note: The +4.5 VDC “logic” power supply is always provided to a shutter while it is connected to a powered-on SRS shutter controller such as the SR470 Shutter Controller or the SR474 Four-Channel Shutter Driver. Placing a shutter drive channel on one of these instruments into the “off” or “sleep” states will put a SR475 Laser Shutter attached to that channel into the *Standby* mode.

### 1.1.5 Power-on state

At turn-on, the SR475 executes a brief mechanical initialization to verify motor function and perform the initial servo-lock of the shutter blade position. This can potentially last several seconds and/or involve minor mechanical bumps in excess of normal operation.

All settings and modes of the SR475 are in volatile memory, and at power-on the instrument always returns to its default state.

The SR475 can be reset by turning off and restoring the +4.5 VDC power supply, through a remote command to reset the shutter head, or by restoring the +12 VDC power supply after it has been turned off.

## 1.2 Mounting

The SR475 Laser Shutter can be mounted and operated in any orientation. 8-32 mounting holes are provided on three sides of the shutter head, and a single 1/4 – 20 mounting hole is provided on the bottom side, as shown in Fig. 1.3.

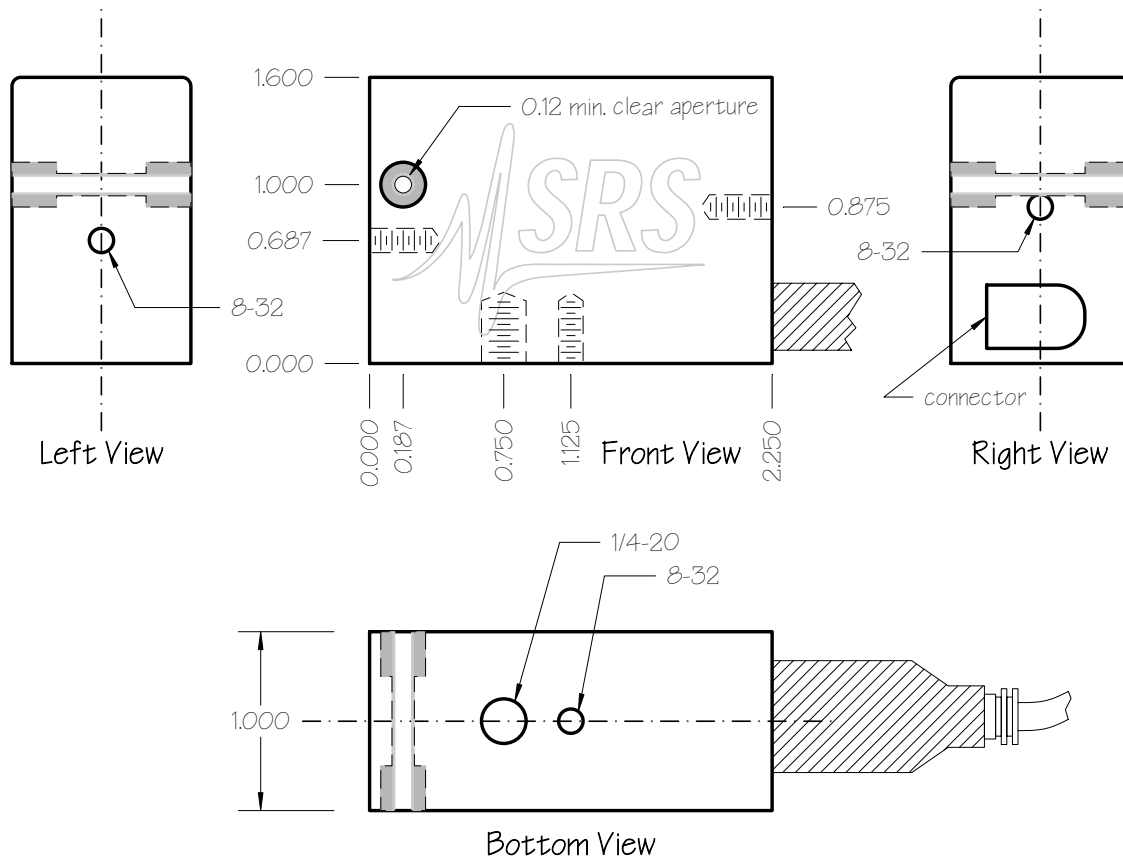


Figure 1.3: Physical dimensions and mounting of the SR475.

Orientation may be chosen for convenient routing of the shutter cable, for aligning to the appropriate beam height above an optical table, or for pulsing one of two closely separated laser beams.

### 1.2.1 Vibration considerations

The SR475 Laser Shutter should be firmly mounted to a solid surface. Using long and/or narrow mounting posts will increase the apparent vibration induced by the shutter.

For optimal results, use short, large-diameter mounting posts or other sturdy optomechanical hardware to mount the SR475 Laser Shutter to an appropriate surface. Attaching the shutter head directly to a heavy, damped optical table will minimize its vibrational effects.



### 1.2.2 Thermal considerations

Like most mechanical shutters, the performance of the SR475 Laser Shutter is fundamentally limited by its ability to dissipate heat. The shutter incorporates a motor that can get hot when run continuously (or nearly so), particularly in full-speed mode.

The case of the SR475 may get warm but should not become too hot to touch under normal operating conditions. Solidly mounting the shutter head to metal surfaces can assist heat sinking and help the shutter head to run at a comfortable temperature, particularly in a warm laboratory environment.

An internal thermal sensor will trip off if the shutter head overheats. In this case, the head will declare a fault and go to the *Standby* state.

### 1.2.3 Grounding considerations

For reliable operation of a SR475 Laser Shutter, it is essential that the shield of the shutter cable is properly grounded.

Inside the shutter head, there is an electrical connection between its chassis (case) and the shield of the cable. If the chassis of the shutter head is electrically connected to earth ground, for example by way of attachment to a grounded optical table, then the shield will be grounded as well.

SRS shutter controllers, such as the SR470 Shutter Controller and the SR474 Four-Channel Shutter Driver, provide optional internal grounding of the shutter cable shield. If a shutter case is properly grounded and thereby providing a suitable ground to the cable shield, it may be desirable to disconnect the shield-ground connection within the controller; consult that instrument's operation manual for details.

Apart from the cable shield, the shutter cable uses a separate "signal ground" as one of the power supply lines. This ground is normally isolated from the shutter case and cable shield. Under certain circumstances it may be desirable (for the control of ground loops, for example) to establish an electrical connection between the signal ground and the cable shield. To do so, unplug the SR475 and jumper across location J11 on the circuit board. To access the circuit board, you will need to temporarily remove the outer case, which is held on by four screws.

## 1.3 Optical alignment

The SR475 Laser Shutter is designed for easy alignment with a 0.120" (3 mm) minimum clear aperture. The laser beam may enter the

shutter head from either side, but there is less potential for leakage of indirect scattered light if the beam enters from the side marked “Front” in Fig. 1.3.

SRS shutter controllers incorporate an “Align” mode that chops the shutter open and closed at a rate of 1 Hz to assist with manual alignment. A similar chopping function is also directly built into the shutter head firmware, and can be enabled over the remote interface.

The rise and fall time of a laser beam chopped by the SR475 are application dependent, determined by the size and profile of the laser beam. A narrower beam will blink on and off quickly compared to a broader beam, since the blade edge will take less time to transit a smaller beam. Similarly, the insertion delay, i.e., the time between initiating an open-closed transition and when the laser beam is actually switched, depends upon the beam profile and its location in the clear aperture. In general, the insertion delay will be different for opening and closing.

While it may be desirable to gently focus a laser beam through the shutter aperture to reduce the apparent open/close time, it should be noted that this speed increase comes as a tradeoff with increased sensitivity to insertion delay jitter.

## 1.4 Optical power capacity

The SR475 uses a thin BeCu alloy shutter blade with a black oxide finish and is intended for use in “low-power” laser beam applications.

The maximum power handling capability of a laser shutter depends on wavelength, duty cycle, and many other environmental factors. SRS does not establish optical power ratings for laser shutters; please contact SRS if you would like to request sample shutter blades to evaluate for your application.

## 1.5 Operating environment

The SR475 Laser Shutter is designed for operation in a clean and dry laboratory environment.

### 1.5.1 Dust

Both the bearing and the position detection system within the shutter head are susceptible to impairment in a dusty environment. This can potentially result in a fault condition, when either the blade is unable to move to the commanded position, or when the readout system is unable to verify that the blade is in the correct position.

Always operate the SR475 with its outer cover in place to minimize the potential for dust to collect inside the shutter head.

If dust contamination inside the shutter is suspected, the outer cover can be unscrewed and dust can be *gently* blown out. Use only low-velocity air to remove dust from the shutter head, for example a handheld hair dryer with the heat turned off.

 **CAUTION**

Never expose the SR475 Laser Shutter to compressed air or other compressed gas dusters, since they could easily damage the shutter mechanism.

 **CAUTION**

Never touch or attempt to clean the shutter blade.

### 1.5.2 Magnetic field

The SR475 uses a magnetic mechanism and may not operate properly in the presence of a strong external magnetic field.

### 1.5.3 Temperature

The SR475 is designed for operation in a 0°C to 35°C laboratory environment.

The internal thermal sensor will trip if the shutter head exceeds a temperature of approximately 60°C, as measured on the circuit board. In this case, the head will declare a fault and go to the *Standby* state. See also §1.2.2.

The absolute maximum storage temperature of the shutter head is 90°C. Above this temperature permanent damage will result.

### 1.5.4 Vacuum

The SR475 is not designed for use in a vacuum environment. It relies on convection cooling and would overheat quickly unless active external cooling were applied.

Also note that adhesives used in construction of the SR475 are not considered vacuum compatible.

### 1.5.5 Oxygen-rich environments

Because of the adhesives used in construction, the SR475 is not suitable for use in oxygen-enriched, pure oxygen, or other similar environments.

## 1.6 Alternate speed modes

The SR475 Laser Shutter is by default configured to operate in *full-speed mode*, where the opening/closing time is fixed at 5 ms between full-stop to full-stop. During this 5 ms, the shutter is guided along a pre-determined trajectory between the two states, as discussed in §1.1.3.

Three alternate modes of operation are provided, each of which guides the shutter along the same trajectory but at a slower rate. This leads to a significant reduction in power usage and physical impulse. These slower modes can be used in many applications where absolute speed is not as crucial as minimizing vibration.

Mode	Transition time	Max Rate
0	5 ms	100 Hz
1	10 ms	50 Hz
2	20 ms	25 Hz
3	40 ms	12.5 Hz

Table 1.1: Shutter alternate speed modes

Mode 0 is the full-speed mode, and modes 1–3 are alternate modes. The alternate modes can be selected using the remote interface; please see §2.4 for more information.

## 1.7 Shutter interface connector

The SR475 Laser Shutter is normally operated through a SR470 Series Laser Shutter driver (such as the SR470 Shutter Controller or the SR474 Four-Channel Shutter Driver) that provides power and external interfaces. Users may also wish to directly interface the SR475 to their own systems without the use of additional hardware.

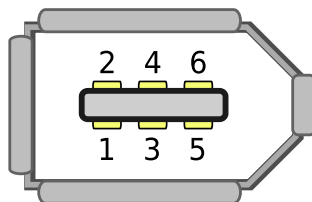


Figure 1.4: Shutter connector pinout, as seen looking into the connector.

Connector Pin	Description
1	+12 VDC in (motor power supply)
2	Signal ground / power return
3	+4.5 VDC in (logic power supply)
4	Control signal in (logic level)
5	RX (Serial input)
6	TX (Serial output)

Table 1.2: Shutter connector pinouts

The pinout for the connector is shown in Fig. 1.4 and the signal names are shown in Table 1.2.

The shield of the shutter connector is connected to the case of the shutter head. Please see §1.2.3 about grounding considerations for more information.

### 1.7.1 Direct interfacing



#### CAUTION

*The SR475 has limited or no internal protection against reverse polarity, missing supply, or overvoltage on the power supply pins. The misapplication of power may cause circuit damage. For most applications, SRS recommends using the SR475 together with an SR470 Series Laser Shutter driver such as the SR470 Shutter Controller or the SR474 Four-Channel Shutter Driver.*

The connector is mechanically compatible with 6-pin IEEE-1394 cables. Clean, well-regulated supply voltages of +4.5,+12 VDC must be provided at the shutter head following the pin-out specified in

Table 1.2. Ground must be provided on pin 2, with chassis ground on the shield.

Note that standard IEEE-1394 cables are crossover cables that reverse the signals of pins (3,5) and of (4,6) at the two ends.

#### 1.7.1.1 Serial communication

If the user intends to directly wire the SR475 independent of an SRS shutter controller, an external signal level converter may be needed to translate between the logic-level signals of the SR475 serial interface and (for example) the voltages and “negative” polarity of an RS-232 interface.

The SR475 serial interface accepts logic-level input (3.3 VDC, 5 VDC tolerant) signals on the RX pin and transmits signals at 3.3 VDC on the TX pin. The protocol is fixed at 19200 baud, with 8 data bits, 1 stop bit, no parity, and no flow control. The polarity of both signals is such that the start bit and logical “0” are at ground potential, while the logical “1” is at +3.3 VDC.

#### 1.7.1.2 Control signal

The control signal input is the principal input to the SR475. If directly interfacing to the SR475, this pin accepts a logic-level input (3.3 VDC, 5 VDC tolerant) signal that dictates which state the shutter is commanded to be in at any given moment.

A high signal commands the shutter to the open state, and a low signal commands the shutter to the closed state. When a change in the input signal is detected, the shutter will immediately begin a transition to the new state if a transition is not already in progress. A pending state change request will be executed only after completion of the transition.

To ensure reliable operation, control pulses to the SR475 should be at least 200  $\mu$ s in duration.

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## 2 Remote Operation

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This chapter describes operating the SR475 over its serial interface.

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## 2.1 Index of Commands

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### Motion control

@	2-5	Open
A	2-5	Close
B	2-5	Toggle state
J	2-5	Toggle alignment mode
0	2-6	Select speed mode 0
1	2-6	Select speed mode 1
2	2-6	Select speed mode 2
3	2-6	Select speed mode 3

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### Control mode commands

E	2-6	Serial control lockout
F	2-7	Logic-level control lockout
G	2-7	Flexible (default) control mode

---

### Communication control commands

L	2-7	Enable assertive mode
M	2-7	Disable assertive mode

---

### Utility commands

C	2-8	Reset
K	2-8	Standby
O	2-8	Assert fault

---

### Shutter queries

S	2-8	State
R	2-9	Rate
T	2-9	Temperature
W	2-9	Error Word
X	2-10	Model Number
Y	2-10	Serial Number
Z	2-10	Status Word



## 2.2 Introduction

When the SR475 is operated through an SRS shutter controller such as the SR470 Shutter Controller or the SR474 Four-Channel Shutter Driver, that instrument normally signals the shutter head to open or close through the shutter head's logic-level control input.

The SR475 also supports serial communication and may be remotely programmed via this interface.

Any host computer interfaced to the SR475 through a shutter controller may use that instrument to relay (pass through) serial commands to the shutter head. This allows the SR475 to be controlled remotely through the controller's interfaces, which may include Ethernet, RS-232, and/or GPIB.

The SR475 can also be operated as a stand-alone device without an SRS controller. See §1.7.1.1 for details.

### 2.2.1 Control modes

By default, the SR475 state follows the value given by its logic-level control input (§1.7.1.2), but also accepts commands over the serial interface.

Executing any remote command that changes the position of the shutter blade will force the shutter into *logic level lockout mode*, where it will no longer respond to the logic-level control signal. Note that SRS shutter controllers, such as the SR470 Shutter Controller and the SR474 Four-Channel Shutter Driver, normally control the state of the shutter through the logic-level input, but cannot do so when that interface is locked out. Hence, care should be exercised when directly commanding the shutter state over the serial interface.

Logic level and remote interface control of the blade position can be separately enabled or disabled through the remote interface.

Also keep in mind that settings and modes of the SR475 only exist in volatile memory, and at power-on the instrument always returns to its default state.

### 2.2.2 Timing considerations

While it is possible to open and close the SR475 Laser Shutter through direct commands over its serial interface, these operations are executed with significantly lower timing precision than control through the logic-level input. Whenever timing is important, serial control of the shutter position should be avoided.

## 2.3 Commands

This section provides syntax and operational descriptions for remote commands.

### 2.3.1 Command syntax

Communication with the SR475 uses ASCII characters. All commands are one character long and are case sensitive.

Commands are executed when the command character is received without waiting for additional data or confirmation. No command terminator should be used. While this style of execution is referred to as “immediate,” remote commands are not executed with precision timing (§2.2.2).

The command buffer is limited to 16 bytes. If the buffer overflows, a bit will be set in the error word, and the last command will be discarded.

Query commands, which are commands that request a return of data, will return exactly seven bytes of data, of which the last byte is <LF> (ASCII 10). Numbers are formatted as signed integers, where the leading character is ‘-’ for negative numbers or ‘ ’ (ASCII 32) for positive numbers.

Aside from communication errors, commands may fail due to either syntax or execution errors. Not all such failures will generate a fault. As an example, if the shutter is initially open, a command to open the shutter will simply be ignored.

All commands (ASCII characters) that are not in the command list are reserved for future use and/or factory use. Commands that are not in the list may produce unpredictable results and should be avoided.

Errors and changes in shutter status can be detected by requesting the status word and error word, with commands W and Z.

#### 2.3.1.1 Examples

Commands may be given with a simple example illustrating their usage. In these examples, commands sent by the host computer to the SR475 are set as *straight teletype font*, while responses received from the host computer from the SR475 are set as *slanted teletype font*.

These examples are not exhaustive, but are intended to provide a convenient starting point for user programming.

## 2.4 Command List

### 2.4.1 Shutter motion control commands

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@	<p>Open</p> <p>Moves the shutter blade from the closed state to open state.</p> <p>When executed, this places the shutter into logic level lockout mode. (See description of command F.)</p> <p>The command to open the shutter will be ignored unless (1) the shutter is in the closed position, and (2) serial control of the blade position has not been disabled with command E.</p>
A	<p>Close</p> <p>Moves the shutter blade from the open state to closed state.</p> <p>When executed, this places the shutter into logic level lockout mode. (See description of command F.)</p> <p>The command to close the shutter will be ignored unless (1) the shutter is in the open position, and (2) serial control of the blade position has not been disabled with command E.</p>
B	<p>Toggle state</p> <p>Moves the shutter from the Open state to Closed state or vice versa, depending on the initial state.</p> <p>When executed, this places the shutter into logic level lockout mode. (See description of command F.)</p> <p>The command to toggle the shutter state will be ignored unless (1) the shutter is in the open or closed position, and (2) serial control of the blade position has not been disabled with command E.</p>
J	<p>Toggle alignment mode</p> <p>Enable alignment mode if it is presently disabled. Disable alignment mode if it is presently enabled.</p> <p>In alignment mode, the shutter continuously opens and closes at fixed rate of approximately 2 Hz. This mode can be helpful for optical alignment of the shutter head; see §1.3.</p> <p>When executed, this places the shutter into logic level lockout mode. (See description of command F.)</p> <p>This command will be ignored unless (1) The shutter is either in the open or closed position or already in alignment mode, and (2) serial</p>

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control of the blade position has not been disabled with command E.

- 0 Select speed mode 0  
Select full-speed mode for the shutter head. This is the default setting. The transition speed (and corresponding mechanical vibration) can be changed using mode commands 0, 1, 2, and 3. See also §1.6. The alternate speed modes are as follows:

Mode	Transition time	Max Rate
0	5 ms	100 Hz
1	10 ms	50 Hz
2	20 ms	25 Hz
3	40 ms	12.5 Hz

- 1 Select speed mode 1  
Select alternate speed mode 1 for the shutter head, so that it moves at one-half of full speed between open and closed.

- 2 Select speed mode 2  
Select alternate speed mode 2 for the shutter head, so that it moves at one-quarter of full speed between open and closed.

- 3 Select speed mode 3  
Select alternate speed mode 3 for the shutter head, so that it moves at one-eighth of full speed between open and closed.

#### 2.4.2 Shutter control mode commands

- E Serial control lockout  
Disable remote (serial command) control of shutter blade position. Commands that do not change the blade position are not affected.  
When this mode is selected, the blade position can only be controlled through the shutter head's logic-level control input. Serial control can be re-established through commands F, G, or through a hard reset with command C or by removing power (§1.1.5).

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F	<p>Logic-level control lockout</p> <p>Disable logic-level control of shutter blade position.</p> <p>When this mode is selected, the blade position can only be controlled through the remote (serial) interface. Logic-level control can be re-established through commands E, G, or a hard reset with command C or by removing power (§1.1.5).</p>
G	<p>Flexible (default) control mode</p> <p>Serial control lockout and logic-level control lockout are both disabled, and either may control the shutter blade position.</p> <p>This is the default control mode, and is always selected after the shutter head is reset.</p>

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### 2.4.3 Communication control commands

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L	<p>Enable assertive mode</p> <p>Places the shutter in assertive communication mode.</p> <p>Under normal operation, the shutter head will never initiate communication over its serial interface; it will only respond to queries.</p> <p>When assertive mode is enabled, the shutter head will actively request communication—by issuing a Serial Break character—if a “fatal” fault occurs. The fatal faults are those that will trip the shutter into the standby state: temperature, 12 V, position, and motor failures. A fatal fault can also be simulated by issuing command O.</p> <p>While this mode is enabled, all queries that request data are ignored. This mode is disabled by either issuing command M or by a hard reset, either with command C or by removing power (§1.1.5).</p>
M	<p>Disable assertive mode</p> <p>Disable assertive communication mode.</p> <p>If assertive mode is currently enabled, this command will turn it off and restore the ability to communicate normally with the shutter head.</p>

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#### 2.4.4 Utility commands

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C	<p>Reset</p> <p>Performs a hard reboot of the shutter head. Upon restart the head will initialize and attempt to move the blade to the state indicated by the logic-level control input. The full startup sequence may take up to one second.</p>
K	<p>Standby</p> <p>Turns off the shutter motor and places the shutter head in the standby state, as described in §1.1.4. The shutter blade position becomes indeterminate. Once this mode is entered, the blade position will remain indeterminate and unpowered until a hard reset, either with command C or by removing power (§1.1.5).</p>
O	<p>Assert fault</p> <p>This command simulates a “fatal” fault which will trip the shutter to the standby mode. This function is provided as a utility for reliability testing.</p>

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#### 2.4.5 Shutter queries

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S	<p>State</p> <p>Query the current position of the shutter blade. The returned value may indicate that the shutter is open, closed, or indeterminate. The shutter is said to be in an indeterminate position (i.e., not open or closed) while in transit between open and closed, or when powered off in standby mode (§1.1.4).</p> <table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>Result</th> <th>Meaning</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>Open</td> </tr> <tr> <td>0</td> <td>Closed</td> </tr> <tr> <td>-1</td> <td>Indeterminate</td> </tr> </tbody> </table>	Result	Meaning	1	Open	0	Closed	-1	Indeterminate
Result	Meaning								
1	Open								
0	Closed								
-1	Indeterminate								

*Example:* S

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The returned value of 1 indicates that the shutter is presently open.

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R	<p>Rate</p> <p>Query the maximum rate of the shutter head.</p> <p>The returned value indicates the maximum rep rate of the shutter head, in Hz, rounded down to the nearest integer. The rate depends on the speed mode that is selected; see §1.6.</p> <p><i>Example:</i> R 100 The shutter has a maximum rate of 100 Hz.</p> <p><i>Example:</i> R 12 This value is returned when the shutter is in alternate speed mode, which has a maximum rate of 12.5 Hz.</p>
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T	<p>Temperature</p> <p>Query the shutter temperature.</p> <p>The returned value is the approximate temperature as measured at the printed circuit board in the shutter head, in °C.</p> <p><i>Example:</i> T 42 The shutter is at an approximate temperature of 42 °C.</p>
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W	<p>Error Word</p> <p>Query the shutter head error word.</p> <p>The error word is a 15-bit value that is returned as an unsigned integer. This query also clears the four communications error bits.</p>
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Bit	Meaning
0	Serial buffer overflow
1	Serial syntax error
2	Serial communications error
3	Serial Timeout
4	(Reserved)
5	Temperature fault
6	12 V fault
7	Motor fault
8	Firmware fault
9	Position fault
10-15	(Reserved)

Bits 5, 6, 7, and 9 correspond to “fatal” faults that will trip the shutter to the standby state. Of the fatal faults, only the first one that is

detected will be recorded in the error word.

*Example:* W  
64  
The returned value of 64 indicates a problem with the 12 VDC shutter power supply.

X Model Number  
Query the shutter head model. Returns the 7 character ASCII identifier “ SR475(LF)”.

*Example:* X  
SR475

Y Serial Number  
Query the shutter head serial number.

*Example:* Y  
1234  
The returned value indicates that the shutter head serial number is 1234.

Z Status Word  
Query the shutter head status word, a 15-bit value that is returned as an unsigned integer. It can be used to verify the current modes and settings of the shutter head.

Bit	Meaning
0	Shutter OK
1	Motor Enabled
2	Direction
3	In transit
4	Logic-level lockout
5	Serial lockout
6	Alignment mode
7,8	(Reserved)
9	Assertive mode
10	(Reserved)
11	Locked
12	Mode0 (Lo bit of mode number)
13	Mode1 (Hi bit of mode number)
14,15	(Reserved)

Bit 0, *Shutter OK* indicates that the shutter head is working properly.

Bit 1, *Motor Enabled* is 1 when the shutter motor is enabled.



Bit 2, *Direction* is 1 when the shutter is currently commanded to the open state, and 0 when commanded to the closed state. (This bit is only meaningful when the motor is enabled.)

Bit 3, *In transit* is 1 when the shutter blade is between the open and closed positions. (This bit is only meaningful when the motor is enabled.)

Bit 4, *Logic-level lockout* is 1 when the logic-level control input is disabled.

Bit 5, *Serial lockout* is 1 when the serial control of the blade position is disabled.

Bit 6, *Alignment mode* is 1 when the shutter head is in alignment mode. (This bit is only meaningful when the motor is enabled.)

Bit 11, *Locked* is 1 when the shutter blade is servo locked to the correct position.

Bits 12 and 13, *Mode number* give a number from 0 to 3 that indicates which of the alternate speed modes is presently selected.