FSM-300 or FSM-320 Fast Steering Mirror & FSM-CD300B Controller/Driver

User's Manual

Newport

EU Declaration of Conformity

We declare that the accompanying product, identified with the CE mark, complies with requirements of the Electromagnetic Compatibility Directive, 89/336/EEC and the Low Voltage Directive 73/23/EEC.

Model Number: FSM-300 or FSM-320 & FSM-CD300B

Year CE mark affixed: 2003

Type of Equipment:
Electrical equipment for measurement, control and laboratory use.

Standards Applied:
Compliance was demonstrated to the following standards to the extent applicable:

BS EN61326-1:1997+A1+A2 "Electrical equipment for measurement, control and laboratory use – EMC requirements."

> This equipment meets the CISPR 11 Class A Group 1 radiated and conducted emission limits.
>
> This equipment passed performance criteria B for RF immunity tests per BS EN 61000-4-3.

BS EN 61000-3-2:2001, Harmonic current emissions, Class A.

BS EN 61000-3-3:2002, Voltage fluctuations and flicker.

BS EN 61010-1:1993, A1+A2 "Safety requirements for electrical equipment for measurement, control and laboratory use."

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Warranty

Newport Corporation warrants that this product will be free from defects in material and workmanship and will comply with Newport's published specifications at the time of sale for a period of one year from date of shipment. If found to be defective during the warranty period, then product will either be repaired or replaced at Newport's option.

To exercise this warranty, write or call your local Newport office or representative, or contact Newport headquarters in Irvine, California. You will be given prompt assistance and return instructions. Send the product, freight prepaid, to the indicated service facility. Repairs will be made and the instrument returned freight prepaid. Repaired products are warranted for the remainder of the original warranty period or 90 days, whichever first occurs.

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The above warranties do not apply to products which have been repaired or modified without Newport's written approval, or products subjected to unusual physical, thermal or electrical stress, improper installation, misuse, abuse, accident or negligence in use, storage, transportation or handling. This warranty also does not apply to fuses, batteries, or damage from battery leakage.

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First printing 2003

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1. Safety Precautions

1.1 General Safety Warnings

Observe these general warnings when operating or servicing this system:

- Heed all warnings on the unit and in the operating instructions.
- Do not use this equipment in or near liquids.
- Do not operate this equipment in an explosive atmosphere.
- Only plug the controller/driver unit into a grounded power outlet.
- Route power cords and cables where they are not likely to be damaged.
- Disconnect power before cleaning the controller/driver unit. Do not use liquid or aerosol cleaners.
- Only qualified service personnel should open the case of the controller/driver. There are no user-serviceable components inside unit.
- Dangerous voltages associated with the 100-120 V AC power supply are present inside controller/driver unit. To avoid injury, do not touch exposed connections or components while power is on.
- Do not wear rings or wristwatches when troubleshooting electrical circuits.
- To avoid fire hazard, use only the specified fuse(s) with the correct type number, voltage and current ratings. Only qualified personnel should replace fuses.
- Qualified service personnel should perform a safety check after any service.
- To prevent damage to the equipment, read the instructions in this manual for selection of the proper input voltage.
- If the Fast Steering Mirror is used with lasers, avoid looking into the laser beam, and take precaution not to aim the laser beam at the eyes of others.

1.2 General Cautions

Observe these cautions when operating or servicing this equipment:

- Handle equipment with care, like other delicate electronic equipment.
- To prevent damage to equipment when replacing fuses, locate and correct the problem that caused the fuse to blow before re-applying power.

- Use only specified replacement parts.
- Follow precautions for static-sensitive devices when handling electronic circuits.
- This product should only be powered as described in this manual.
- If this equipment is used in a manner not specified within this manual, the protection provided by the equipment may be impaired.
- Do not position this equipment in a location that would make it difficult to turn off power to the equipment or disconnect the AC power cord.

WARNING

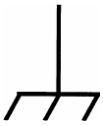
AC power line voltages are present inside the controller/driver unit. To avoid possibility of electrical shock, refer all service to qualified personnel.

WARNING

If the Fast Steering Mirror is used with lasers, avoid looking into the laser beam, and take precaution not to aim the laser at the eyes of others.

CAUTION

Static-sensitive electronic equipment. Wear grounding strap when handling electronic circuit boards and components found inside the controller/driver unit.



FRAME & CHASSIS TERMINAL

This symbol identifies the terminal used for connecting a ground to the chassis. The power cord, properly grounded, will normally ground the chassis.

2. Fast Steering Mirror Technology

Originally conceived for military/aerospace applications such as high-speed target tracking and secure satellite-to-satellite communication, fast steering mirror technology has been developed to the point where it is economically viable for widespread commercial use in dynamic mirror alignment applications. This technology can be used to stabilize laser beams (*Figure 1*), track work pieces for precision laser micro-machining, scan laser beams for real-time confocal microscopy, track optical receivers for laser free-space communication, and increase sharpness in sophisticated imaging systems.

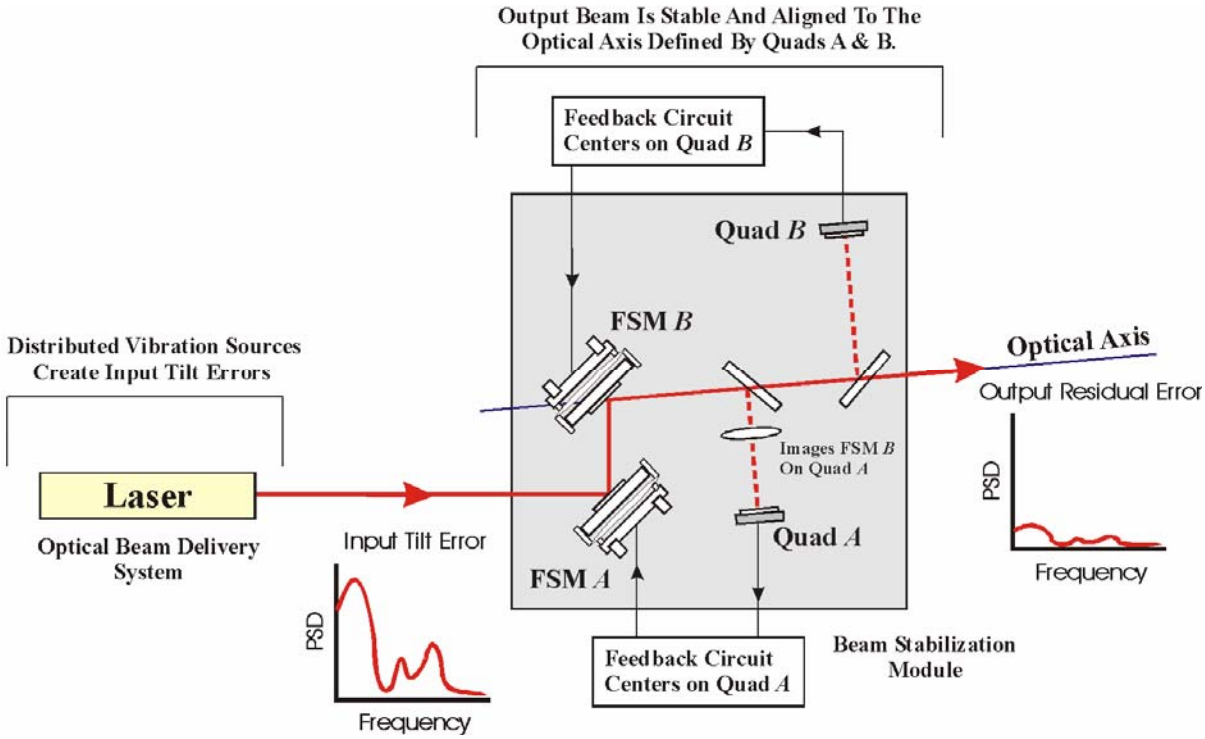


Figure 1: *Two fast steering mirrors used to compensate for input tilt errors.*

A practical fast steering mirror head is shown in *Figure 2*. There are eight basic head components: voice-coil actuators, mirror, mirror carrier, flexure suspension, frame, housing, internal position sensors, and position sensor electronics. These components work with the controller to produce the precision rotation and speed characteristic of these devices.

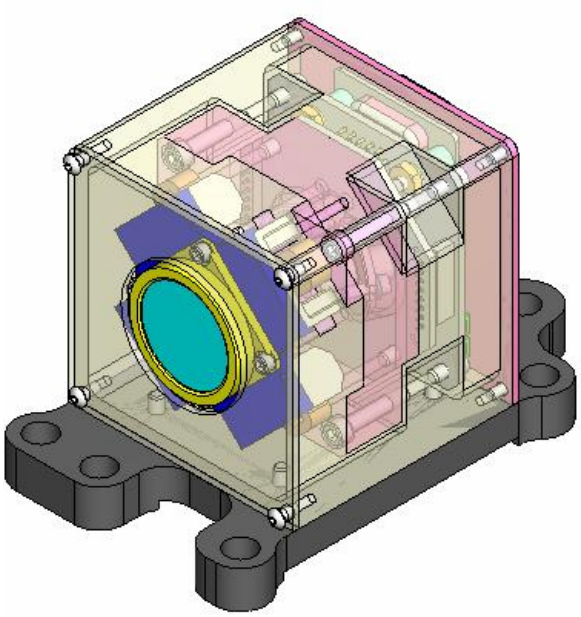


Figure 2: *FSM mirror head showing the eight basic components.*

The voice coil actuators[1] provide the torque necessary to tilt the mirror substrate. Four actuators are mounted behind the mirror, one in each quadrant. Voice coils are connected in pairs along the diameter of the mirror and operate in a push/pull manner, rotating the mirror about the axis that bisects them. Two actuator pairs (four coils) plus a coordinate transformation are used to produce two orthogonal rotations θ_x and θ_y about the ***X*** and ***Y*** axes. The high force generated by four distributed actuators rotates large mirrors more effectively than the one actuator used in galvanometer scanners. The distributed force combined with thick optics enables the FSM mirror head to preserve static and dynamic surface flatness, excellent positional resolution, large angular range and rapid motion. The coil portion of the actuators is placed within the support structure and contacted to a heat sink such that heat produced in the actuator is dissipated far from the mirror surface, thus minimizing thermal distortions.

A flexure suspension system is used to support the mirror carrier that holds the mirror. This system allows free rotation about orthogonal ***X*** and ***Y***-axes while constraining side-to-side motion, rotation about the normal (***Z***) axis and "pogo" motion along the ***Z***-axis. Different types of flexure systems are used for different FSM applications. Some flexure systems are stiff (large spring constant) and offer a relatively stable and repeatable power-off mirror

[1] Historically, voice coils were first used in loudspeakers, from which they derive their name. A linear voice coil consists of a tubular coil of wire situated within the radially oriented magnetic field of a permanent magnet. When current flows through the coil, a force is generated that causes axial (linear) motion. This linear motion is then used to move the mirror.

position. One downside to stiff flexures is the increased current necessary to move the mirror. The FSM series of mirror heads is designed around a small spring constant to keep the current and the consequential heating to a minimum. As expected, the FSM in power-off status is greatly affected by external effects such as gravity and vibrations. This power-off susceptibility must be taken into consideration when designing the mirror into an integrated system. Proper turn-on and turn-off procedures should be followed to ensure that light is only applied to the mirror when it is powered and under the control of either internal or external position feedback.

A position transducer is included in the FSM mirror head to provide position feedback with reference to the support frame. This transducer senses the angle of the mirror carrier and transfers this information to the position sensor electronics board located within the mirror head. This board processes the position information and outputs a differential voltage, A-B. This signal is sent to the FSM-CD300B controller/driver to provide the appropriate feedback current to the voice coils.

Two significant advantages of FSM technology are derived from the flexure suspension:

1. **FSM flexure suspension eliminates bearing surfaces** often used with galvanometer scanners, and eliminates their associated stiction and wear. With bearing surfaces, stiction interrupts the smooth motion of the actuator and limits its accuracy (smallest incremental motion). Wear sets a device lifetime based on the number of commanded cycles. On the other hand, properly designed flexure suspensions have infinite cycle lifetimes.
2. **FSM flexure suspension delivers motion about two axes intersecting at a common pivot point.** When the pivot point is placed at the surface of the mirror, the design is called gimbaled. The advantage is that a mirror-centered optical beam does not experience a change in path length with angular rotation. The FSM is such a gimbaled design. On the other hand, the two galvanometers and two mirrors used in dual-axis galvanometer-based designs make it impossible for the axes to intersect, with no common pivot point and no gimbaled motion. Relay optics can solve the problem by imaging the first galvo mirror onto the second, but at substantially increased complexity and cost. The lack of a common pivot point complicates post-objective and pre-objective scanning applications, requiring a compromised optical design to accommodate the separate rotation axes.

The FSM-300 System comes with a 1" (25.4 mm) diameter, λ/10 Pyrex mirror, which is available with a choice of reflective coatings for different wavelengths. The mirror is bonded to an aluminum carrier, which is user replaceable in the event that wavelength requirements are changed or the mirror surface has been damaged. Two standard mirrors can be specified at the time of order:

- **10D20ER.1: Enhanced Aluminum Coating.** Multi-layer dielectric stack deposited over an aluminum film for improved performance in the visible and enhanced durability of the coating. Average reflectivity is > 93% from 450-700 nm.
- **10D20ER.4: Protected Gold Coating.** Multi-layer dielectric stack deposited over a gold film for excellent reflectivity from the near IR to the far IR. Average reflectivity is > 96% from 650- 1700 nm and > 98% from 1.7-2.0 μm.

The FSM-320 System comes with a 2" (50.8 mm) diameter, λ/2 Fused Silica mirror, which is available with a choice of reflective coatings for different wavelengths. The mirror is bonded to a stainless steel carrier, which is replaceable in the event that wavelength requirements are changed or the mirror surface has been damaged. The enhanced aluminum coating described above comes standard with the FSM-320 system.

3. Typical Specifications

3.1 FSM System

	FSM-300	FSM-320
Number of Axes	2 (tip-tilt)	2 (tip-tilt)
Angular Range from ±10 V	± 26.2 mrad (± 1.5°), mechanical(1)	± 26.2 mrad (± 1.5°), mechanical(1)
Resolution	≤ 1 µrad rms, mechanical(1)	≤ 1 µrad rms, mechanical(1)
Repeatability	≤ 3 µrad rms, mechanical(1)	≤ 3 µrad rms, mechanical(1)
Accuracy From ±26.2 mrad, 20°C(1,2)	≤ 0.262 mrad (0.015°), mechanical(1)	≤ 0.262 mrad (0.015°), mechanical(1)
Linearity From ±26.2 mrad, 20°C(1,2)	≤ 1.0%	≤ 1.0%
Closed-Loop Amplitude Bandwidth(2) (-3 dB)	≥ 800 Hz at 10 mV	≥ 350 Hz at 10 mV
Closed-Loop Phase Bandwidth(2) (60° lag)	≥ 400 Hz	≥ 325 Hz
Response Flatness(2)	Peaking ≤ 3 dB	Peaking ≤ 3 dB
Noise Equivalent Angle (1 Hz to 10 kHz)	≤ 3 µrad rms	≤ 3 µrad rms
Resolution of Local Position Sensor	≤ 0.5 µrad	≤ 0.5 µrad
Quiescent Power at FSM Assembly	≤ 5 W at any angle ± 26.2 mrad	≤ 5 W at any angle ± 26.2 mrad
Operating Temperature Range(2)	0 to 35°C (32 to 95°F)	0 to 35°C (32 to 95°F)
Storage Temperature Range	-20 to 55°C (-4 to 131°F)	-20 to 55°C (-4 to 131°F)
Warm-up Time for Mirror Stability(2) at 20°C	≤ 10 minutes	≤ 10 minutes
Mirror Thermal Drift(2)	≤ 5 µrad/°C, mechanical(1)	≤ 5 µrad/°C, mechanical(1)
Optical Axis Location	1.5 in. (38.1 mm) high, centered left-to-right	1.5 in. (38.1 mm) high, centered left-to-right
Mirror Head Weight with Base	15.3 oz (434 g)	15.3 oz (434 g)
Interconnect Cable Length	9.8 ft (3 m)	9.8 ft (3 m)

3.2 Standard Mirror Options

	FSM-300	FSM-320
Mirror Substrate Material	Pyrex	Fused Silica
Mirror Retaining Mechanism	Mirror bonded to aluminum carrier (user replaceable).	Mirror bonded to stainless steel carrier (replaceable).
Mirror Pivot Point (centered on mirror)	Gimbaled 12.19 mm behind mirror surface	Gimbaled 9.15 mm behind mirror surface
Mirror Diameter	25.4 mm	50.8 mm
Mirror Thickness	6.0 mm	3.0 mm
Mirror Wedge	≤ 5 arc min	≤ 5 arc min
Clear Aperture(3) at 0° angle of incidence	≥ 20.3 mm	≥ 40.6 mm
Clear Aperture(3) at 45° angle of incidence	≥ 14.4 mm	≥ 28.8 mm
Surface Flatness(3) (after coating and bonding)	≤ λ/10 at 632.8 nm over clear aperture	≤ λ/2 at 632.8 nm over clear aperture
Surface Quality(3)	15-5 scratch-dig	40-20 scratch-dig
Reflectivity, Standard Coatings(3)		
ER.1 Coating: Enhanced Aluminum	> 93%, 450-700 nm	> 93%, 450-700 nm
ER.4 Coating: Protected Gold	> 96%, 650- 1700 nm; > 98% from 1.7-2.0 µm	Please contact Newport.
Additional coating options	Please contact Newport.	Please contact Newport.

FOOTNOTES:

1) Optical angular range is equal to twice the mechanical angular range.
2) Measured under position output control. Optical closed-loop performance is also determined by external feedback electronics.
3) Optical parameters apply to central 80% of mirror aperture.

NOTES:

4) Performance data is based upon well-defined, smooth, D-A sine wave inputs. Alternate inputs (square waves, triangle waves, low resolution D-A sine waves) are addressed in section 6.3

3.3 FSM-CD300B Controller/Driver

Command Input and Position Output	Analog, ±10 V = ±26.2 mrad
Peak Operating Power to Mirror	30 W
Continuous Max Operating Power to Mirror	15 W
Thermal Protection	60°C at mirror coil
Operating Temperature(2)	0 to 35°C (32 to 95°F)
Storage Temperature	-20 to 55°C (-4 to 131°F)
Use Location	Indoor use only
Relative humidity	< 95%, non-condensing
Operating altitude	< 3,000 m (10,000 ft)
Power	100-240 Vac ±10%, 47-63 Hz
Current consumption (typical)	0.40 A @ 100 Vac, 0.25 A @ 240 Vac
Fuses	2 ea, “slo-blo” (T), 5 x 20 mm, rated 2.5 A, 250 Vac
Weight	5.5 lbs (2.5 kg)
Case Dimensions (excluding connectors)	3.9” x 9.0” x 10.0” [h x w x d] (100 x 229 x 254 mm)

3.4 Bode Plots

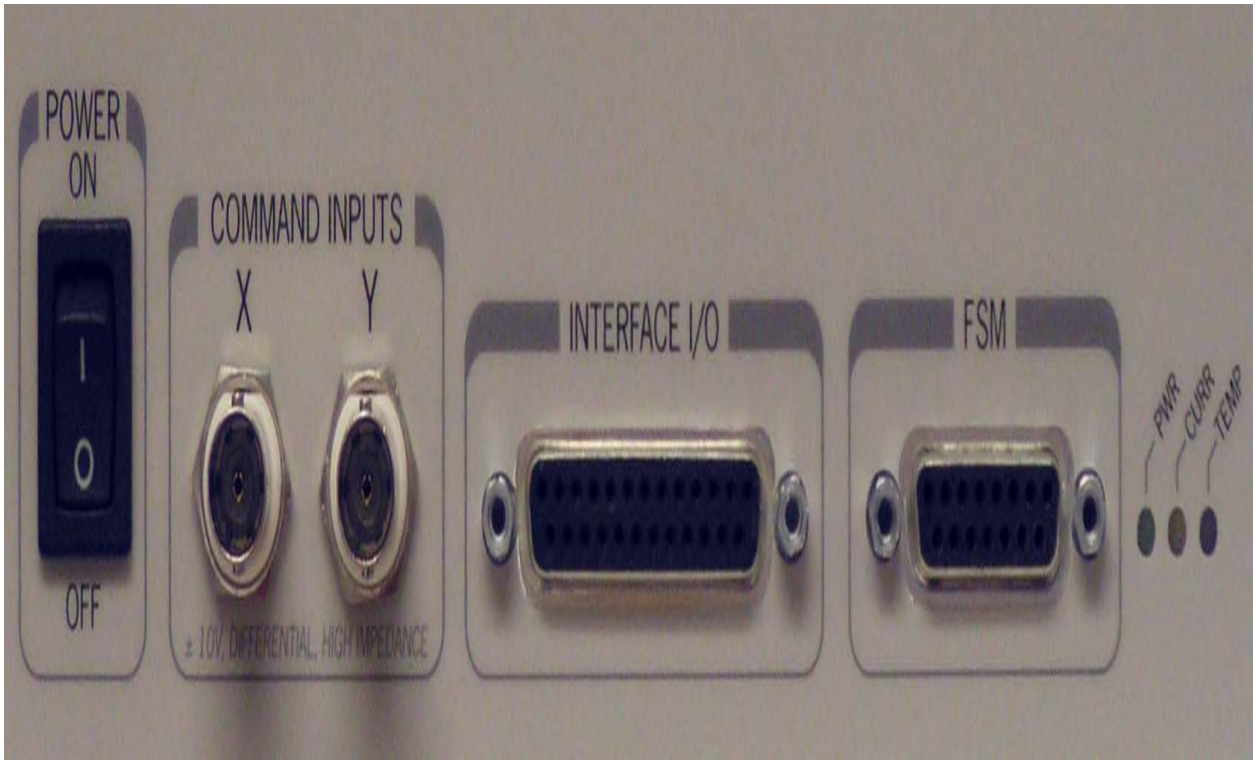


Figure 3: *Typical gain response Bode plot for small-angle excitation. Amplitude 0.262 mrad.*

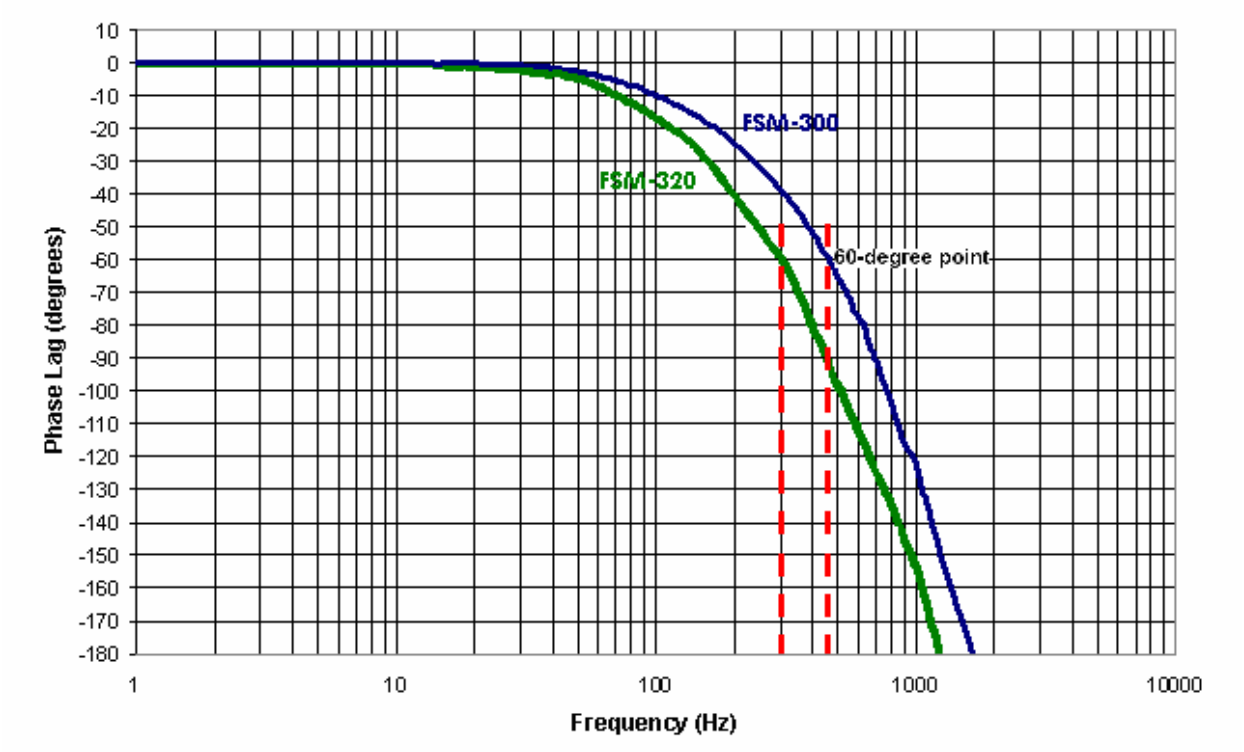


Figure 4: *Typical phase angle Bode plot for small-angle angle excitation.*
Amplitude 0.262 mrad.

3.5 Safe Operating Area

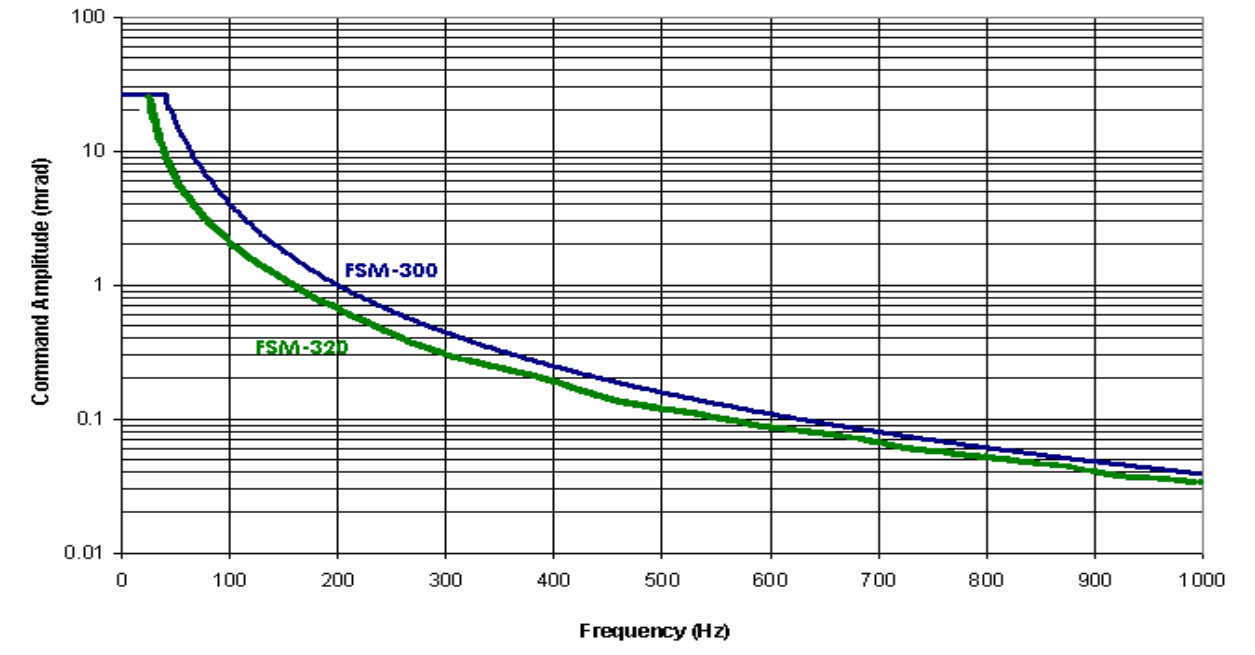


Figure 5: *Typical shut-down curve as a function of amplitude and frequency at 20ºC. Continuous operation is "safe" below the line. Derate for higher ambient temperatures.*

FSM operation is limited to an envelope of mirror deflection amplitude versus frequency. For the FSM-300, amplitude is mechanically limited to 26 mrad up to 40 Hz. Above 40 Hz, long-term, continuous operation is limited by the allowed thermal loading of the drive coils. The latter is approximately proportional to signal amplitude times frequency squared. This means that above 40 Hz, the maximum allowed amplitude is inversely proportional to the square of frequency. For the FSM-320, amplitude is mechanically limited to 26 mrad up to 30 Hz.

If the coils reach a temperature warning threshold, as measured by thermistors, a yellow warning light labeled CURR comes on; however, the system continues to operate as before. If the coils reach an upper temperature shut-off threshold, a red warning light labeled TEMP comes on, and the mirror reverts to the unpowered state. Upon cooling of the coils, the red light will go off, and the system will automatically resume normal operation.

If the yellow warning light comes on during normal, continuous operation, consider decreasing the drive signal frequency and/or amplitude to prevent overheating of the drive coils and avoid a possible thermal shutdown.

4. Unpacking the FSM

4.1 Packing List

Included with each FSM System are the following items:

- FSM-300 or FSM-320 Mirror Head
- FSM-CD300B controller/driver
- FSM-CD300B controller/driver interconnect cable, 3 m
- Allen wrench for protective cover of Mirror Head
- Instruction manual

4.2 Freeing the Mirror Head

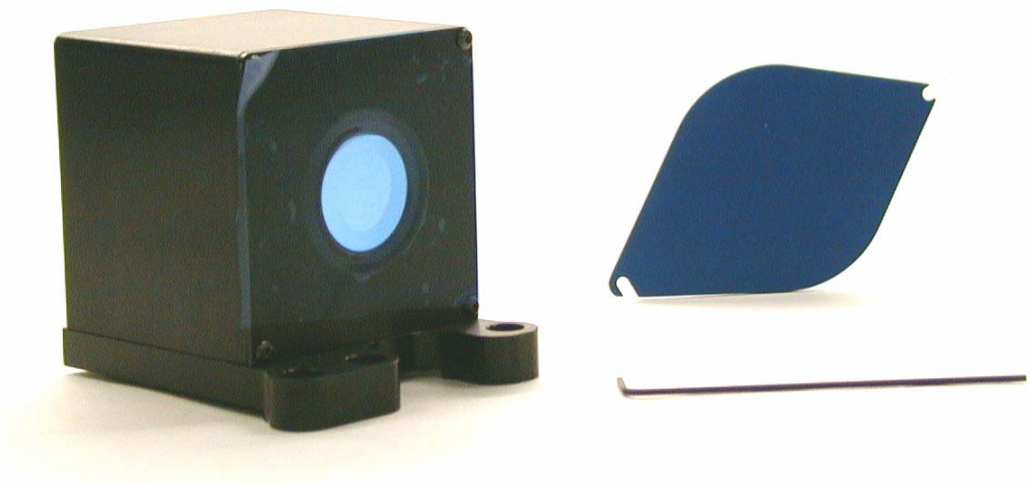


Figure 6: *Protective lens tape and metal cover for mirror.*

For shipment, the FSM mirror is secured by adhesive lens tape plus an oval, hinged metal cover, as illustrated in Figure 6. To free the mirror, loosen the two diagonally opposed retaining screws so that the protective cover can be pivoted for easy removal. The appropriate Allen wrench is supplied with the mirror head. Once the cover is removed, gently pull off the lens tape. Store the lens tape inside a clean polyethylene bag for possible later use.

4.3 Storing and Shipping the Mirror Head

When the mirror head is not in use, replace the oval protective cover so that it covers and protects the mirror. If you ever have to ship the mirror head, also reposition the lens tape.

4.4 Replacing the Mirror

The FSM is designed so that the user can replace the mirror assembly in the event that the original mirror has been damaged or different spectral characteristics are required. FSM mirrors bonded to a metal carrier are available from Newport as subassemblies. Hex wrenches are required tools for mirror removal and reinstallation. The FSM-300 requires 0.050" hex wrenches. The FSM-320 requires 1/16" and 5/64" hex wrenches. Use of Loctite 222 thread locker on mounting screws is recommended.

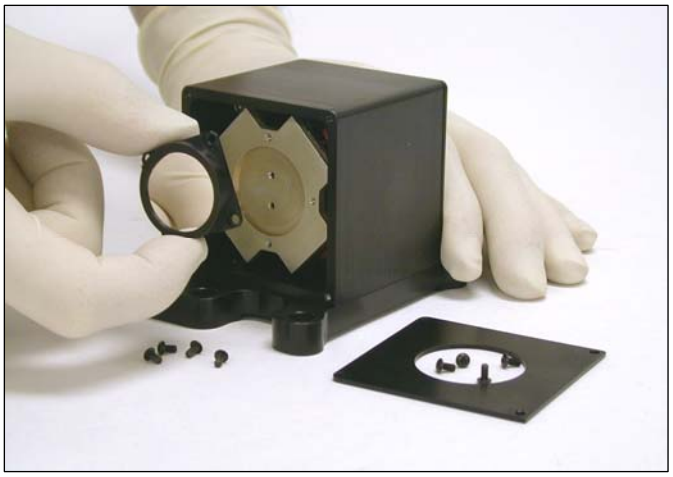


Figure 7: *Replacement of FSM-300 mirror carrier.*

To remove the mirror carrier, first remove the front protective cover plate. To do so, remove the four retaining socket head cap screws using the appropriate hex wrench. Then remove the mirror carrier. To do so, remove the four retaining socket head cap screws using the appropriate hex wrench. Reverse the process to install the new mirror carrier. Application of Loctite 222 thread locker to each of the mounting screws is recommended.

CAUTION

The mirror surface is extremely delicate. Wear latex gloves to minimize the possibility of fingerprints. Be extremely careful not to scratch the mirror surface with the wrench or cap screws.

5. System Components

5.1 FSM Mirror Head Assembly

Envelope and Mounting Interface

The FSM head assembly conforms to both 1-inch and 25 mm on-center hole patterns and is configured for mounting at 0° and 45° angles on a standard optical table or breadboard. The optical axis height is 1.50" when mounted. The FSM-300 and FSM-320 head dimensions and mechanical interface are shown in *Figure 9 and Figure 10*.

Rotation Axes

The ***X*** and ***Y*** rotation axes are shown in *Figure 8*. Note that X rotation is about the X-axis. The definition of these axes should be considered in the mechanical layout and the coordinate frame definitions in the optical layout. The polarity of the mirror rotation complies with the "right hand rule," i.e., positive voltage applied at the command input creates positive (clockwise) rotation as viewed looking along the axis. If an external quad cell or lateral effect detector is used as the angle sensor, the sensor axes of the detector must be aligned to the rotation axes of the FSM mirror head.

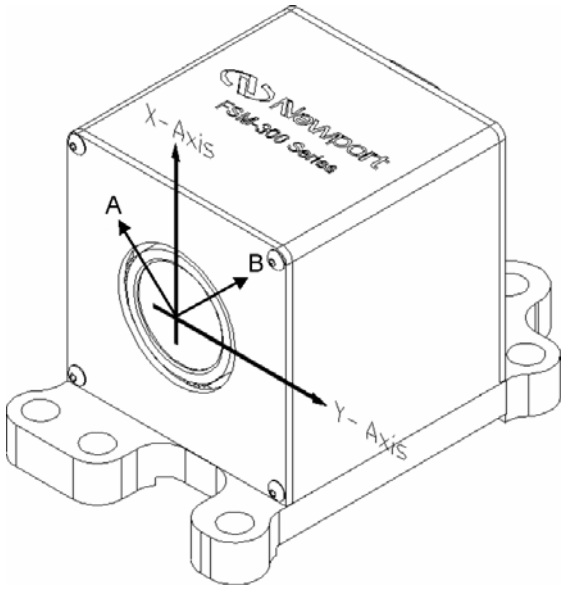


Figure 8: *X and Y axes corresponding to FSM input commands and position outputs.*

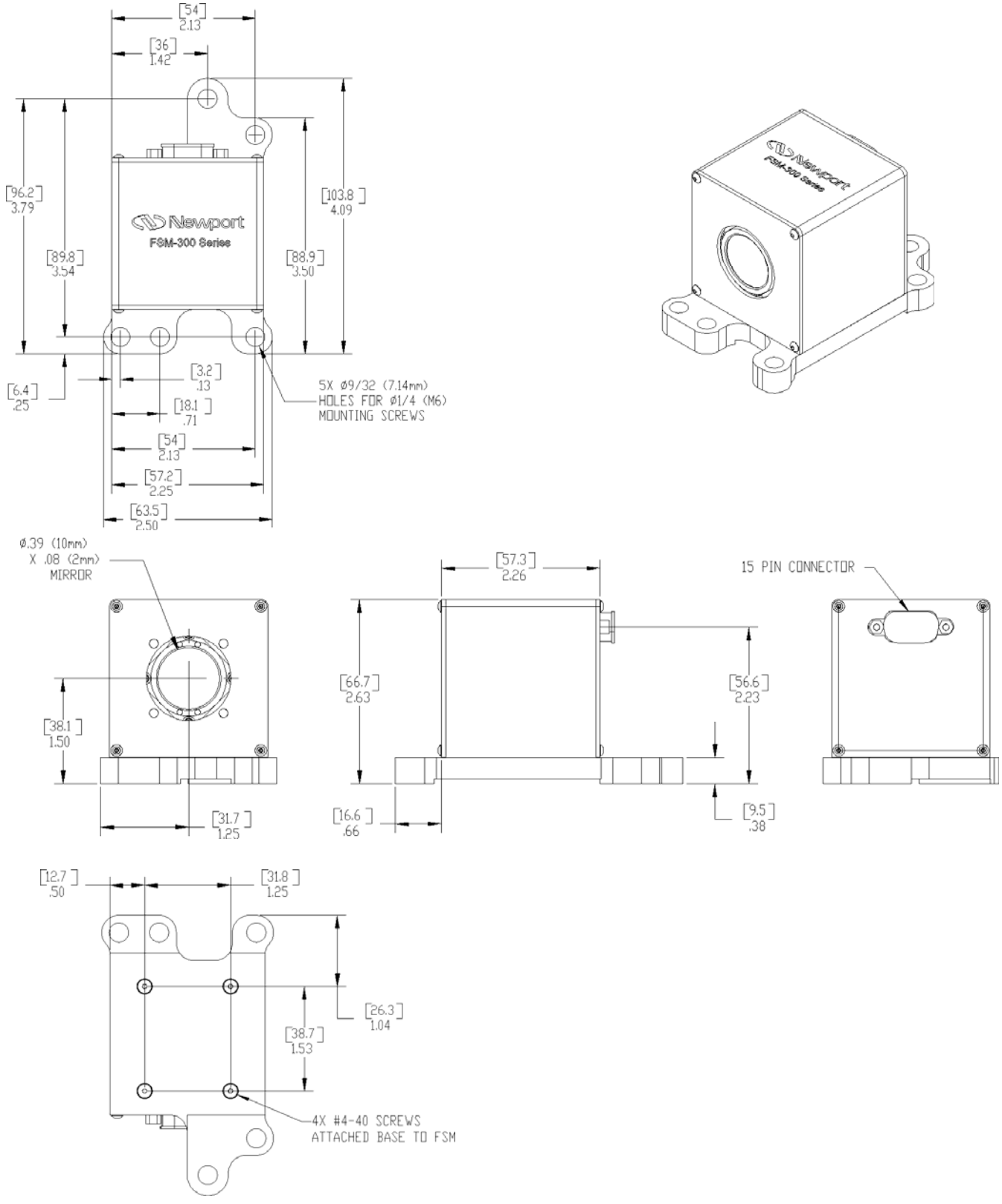


Figure 9: *Detailed Drawing of FSM-300 Mirror Head Housing.*

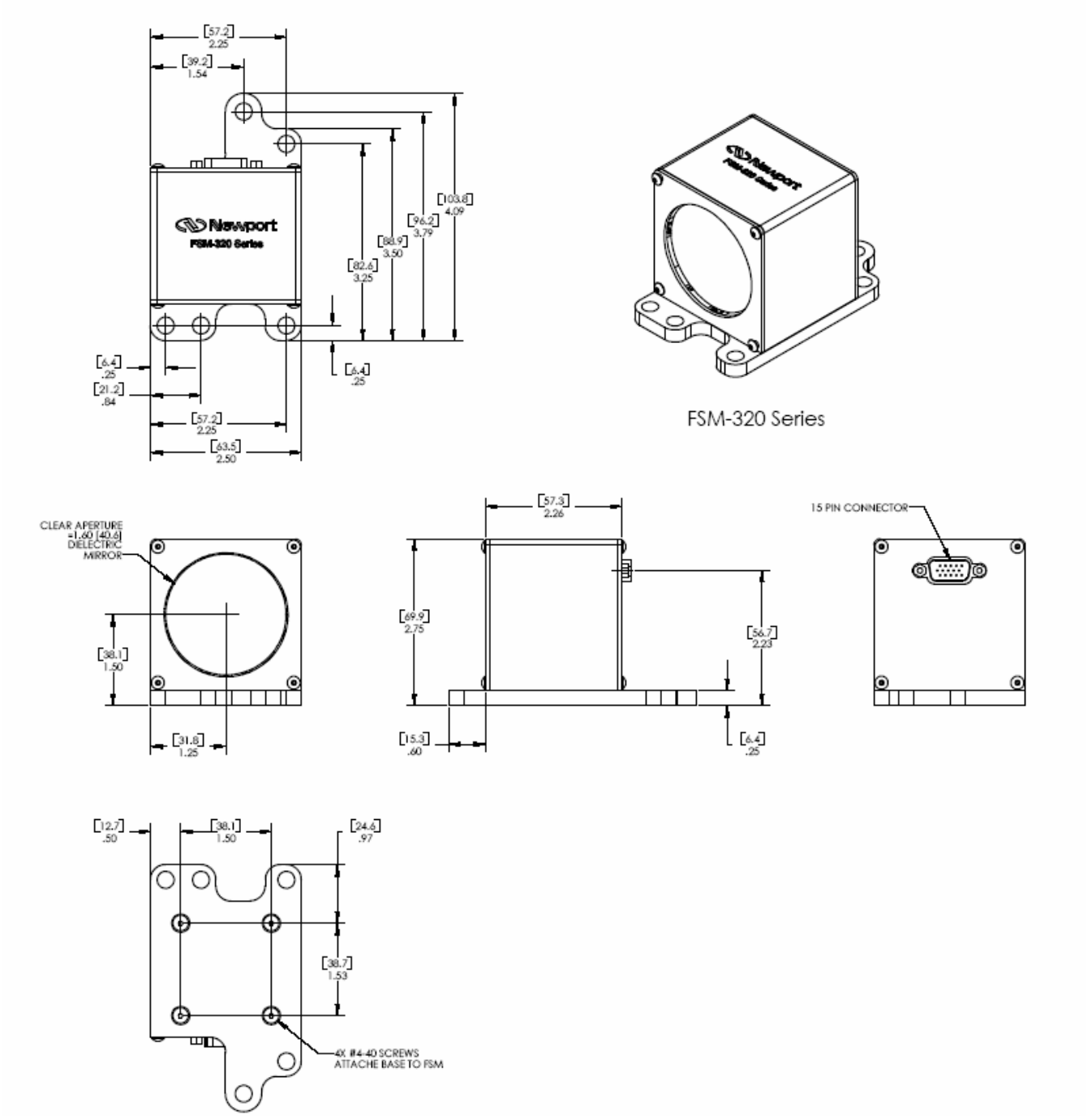


Figure 10: *Detailed Drawing of FSM-320 Mirror Head Housing.*

5.2 FSM-CD300B Controller/Driver

The FSM-CD300B controller/driver establishes the feedback interface between the angle position sensors and the drivers providing current to the voice coils that tip and tilt the mirror assembly. It also provides an interface between the user and mirror, allowing control voltages to be applied and mirror positions to be ascertained.

The FSM-CD300B is equipped with a universal power supply that handles 100-240 V, 50/60 Hz. A standard power cord interface (IEC 950) facilitates power plugs that are suitable for most European, North American, and Pacific Rim Countries.

Figure 11. *Removal of Fuse Block.*

A fuse block is located above the power connector and utilizes two 5 x 20 mm slow-blow glass fuses rated 2.5 A, 250 Vac. To remove the fuse block, first unplug the power cord, compress the two plastic tabs on the right and left sides of the fuse block, and pull out the fuse block. No tools are needed. When reinserting the fuse block, make sure that the alignment tab is at the bottom.

WARNING

Dangerous voltages are present inside the FSM-CD300B controller/ driver when connected to AC line power. To avoid the possibility of electrical shock, always unplug the unit from AC line power when checking or changing fuses.

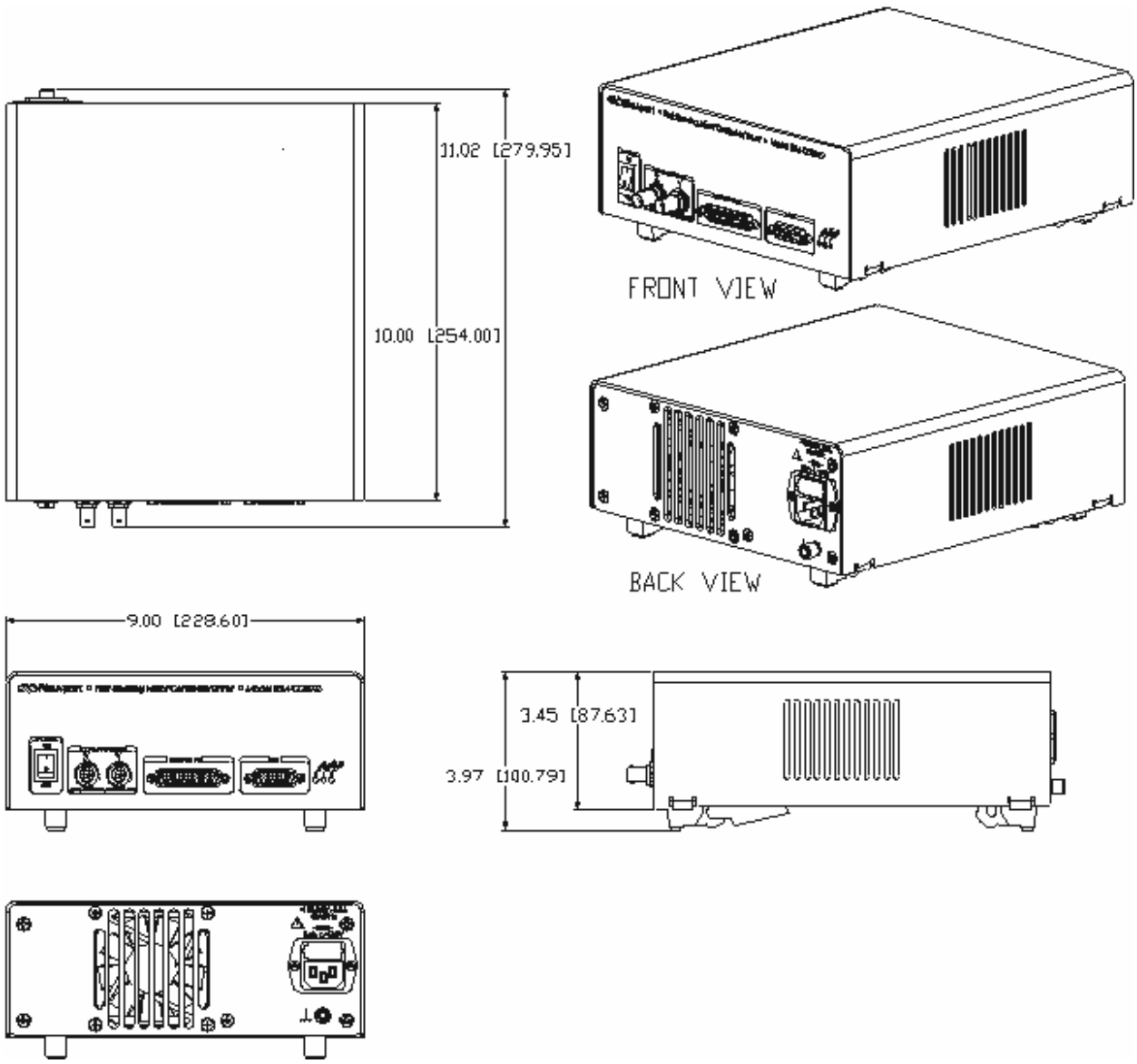


Figure 12: *Dimensioned exterior drawings of FSM-CD300B controller/driver.*

5.3 FSM Electronics

The FSM electronics are housed in two locations:

1. The FSM Mirror Head containing the voice coil actuators, the angle position sensors and the position sensor electronics.

2. The FSM-CD300B Controller/Driver containing the control circuits (PIDs, calibration factors), current drivers, power supply, user interface and interlocks.

The mirror head is connected to the controller/driver by a 3-meter long, 15-pin cable. The controller has a universal power supply that can be plugged

directly into most wall outlets. The appropriate power cord for the destination country should be included with your controller. If the correct cord is not present please contact your local Newport representative for assistance.

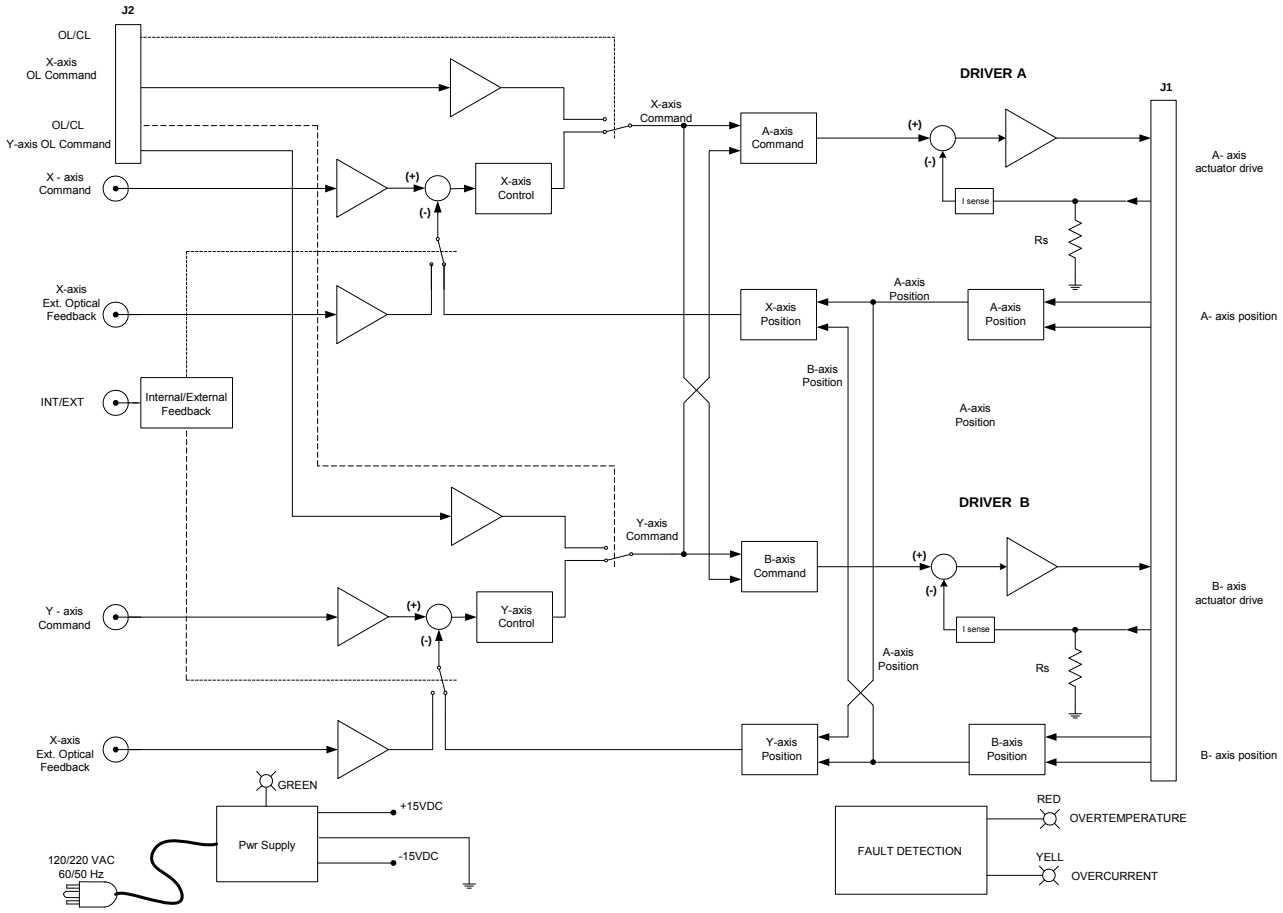


Figure 13: *Functional Block diagram of FSM-CD300B controller/driver.*

5.4 FSM-CD300B Controller/Driver Cable Pin Connections

The electrical connection between the mirror head and the controller/driver is via a 15-pin D-connector terminated cable. This cable attaches between the connector located on the back of the mirror head and the connector labeled "FSM" on the front of the FSM-CD300B controller/driver. The position sensors and voice coils are located on ***A*** and ***B*** axes (at 45° to the ***X*** and ***Y*** axes). A coordinate transform is done in the controller/driver to produce ***X*** and ***Y*** axis rotations.

Pin Controller	Pin FSM Head	Name	Type Controller	Description
1	**6**	+15VA	DC power	FSM positive 15V power
2	**11**	-15VA	DC power	FSM negative 15V power
3	**2**	B-	Analog input	B axis position sensor negative (±10V)
4	**8**	B_RTN	Analog output	B axis actuator drive return
5	**13**	B_OUT	Analog output	B axis actuator drive output
6	**4**	A-	Analog input	A axis position sensor negative (±10V)
7	**10**	A_RTN	Analog output	A axis actuator drive return
8	**15**	A_OUT	Analog output	A axis actuator drive output
9	**1**	GND	Analog ground	FSM ground reference and power return
10	**7**	B+	Analog input	B axis position sensor positive (±10V)
11	**12**	B_TEMP_RTN	Analog ground	B axis temperature sensor return (Analog Ground)
12	**3**	B_TEMP	Analog input	B axis temperature sensor signal
13	**9**	A+	Analog input	A axis position sensor positive (±10V)
14	**14**	A_TEMP_RTN	Analog ground	A axis temperature sensor return (Analog Ground)
15	**5**	A_TEMP	Analog input	A axis temperature sensor signal

Table 1. *FSM pinout descriptions of 15-pin interface cable.*

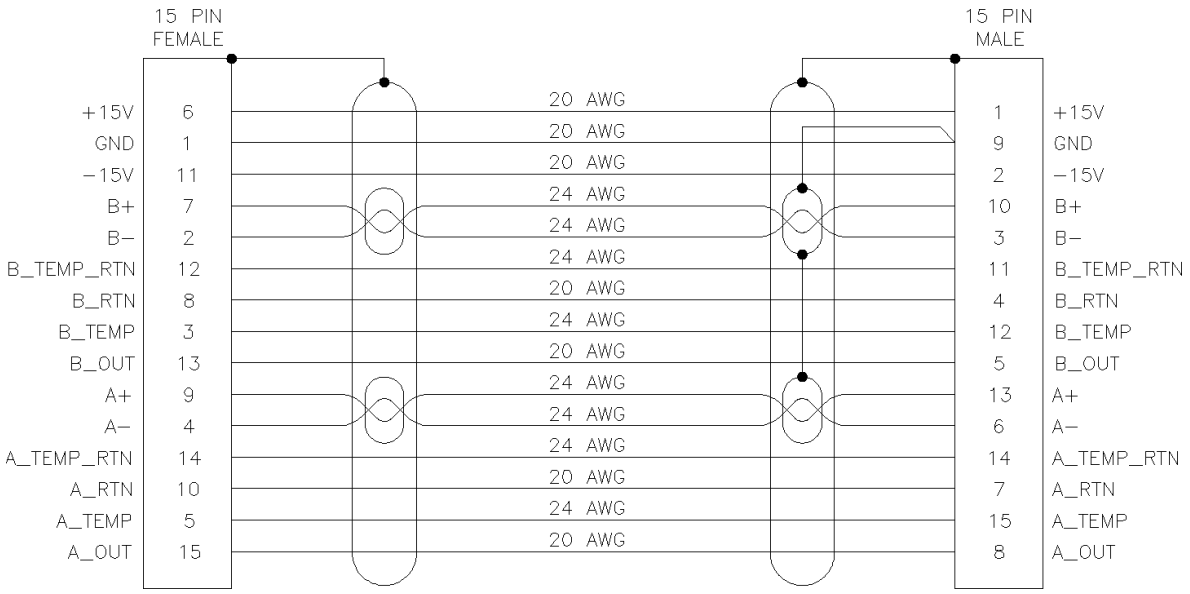


Figure 14: *FSM pinout diagram of 15-pin interface cable.*

5.5 Interface I/O Pin Connections

A 25-pin D-connector on the front of the FSM-CD300B controller/driver provides access to key diagnostic and control parameters from the control board.

Pin	Name	Type	Description
1	Y_CMD(+)	Analog Input	Y-Axis Command Signal, ±10V differential
2	Y_CMD(-)	Analog Input	Y-Axis Command Signal, ±10V differential
3	X_CMD(+)	Analog Input	X-Axis Command Signal, ±10V differential
4	X_CMD(-)	Analog Input	X-Axis Command Signal, ±10V differential
5	Y_ERR	Analog Output	Y-Axis Error Voltage Output
6	GND	Ground	Ground
7	X_ERR	Analog Output	X-Axis Error Voltage Output
8	GND	Ground	Ground
9	Y_OL_SW	Digital Input	Y-Axis Open Loop Selector Switch Input (0V = closed loop; 5V, 5 mA = open loop)
10	X_OL_SW	Digital Input	X-Axis Open Loop Selector Switch Input (0V = closed loop; 5V, 5 mA = open loop)
11	Y_EXTFB(+)	Analog Input	Y-Axis External Feedback Input, ±10V differential
12	Y_EXTFB(-)	Analog Input	Y-Axis External Feedback Input, ±10V differential
13	NC	No Connection	No Connection
14	NC	No Connection	No Connection
15	X_EXTFB(+)	Analog Input	X-Axis External Feedback Input, ±10V differential
16	X_EXTFB(-)	Analog Input	X-Axis External Feedback Input, ±10V differential
17	INT/EXT_SW	Digital Input	External Feedback Selector Switch Input (0V = internal; 5V, 5 mA = external)
18	Y_POS_OUT	Analog Output	Y-Axis Position Output
19	GND	Ground	Ground
20	X_POS_OUT	Analog Output	X-Axis Position Output
21	GND	Ground	Ground
22	Y_OL_CMD	Analog Input	Y-Axis Open-Loop Command Voltage, ±10V, Single-Ended
23	GND	Ground	Ground
24	X_OL_CMD	Analog Input	X-Axis Open-Loop Command Voltage, ±10V, Single-Ended
25	GND	Ground	Ground

Table 2: *Front Panel Interface I/O Connector Pinout.*

6. System Operation

Figure 15: *FSM-CD300B controller/driver.*

6.1 Installation Location & Ventilation

The FSM-CD300B controller/driver is designed for indoor operation in an ambient temperature of 0 to 35°C (32 to 95°F). Component cooling is provided by a fan, which aspirates air through slots in both sides of the unit and ejects air through the back. To assure adequate airflow, provide a minimum clearance of 25 mm (1") on both sides of the unit and 2" (50 mm) in back of the unit. Also, adequate spacing behind the fan provides quieter operation.

6.2 Electrical Connections

The FSM mirror head is interfaced to the FSM-CD300B controller/driver by the system's 15-pin connector cable. The controller/driver is powered from an AC wall outlet. It is equipped with a universal power supply that accommodates 100-240 Vac, 50/60 Hz. No switch or fuse needs to be changed when going from 100 to 120 or 240 Vac power.

Prior to applying AC power, verify that the protective cover and protective packing material have been removed from the FSM mirror head.

Prior to applying AC power, connect the system's15-pin connector cable to the FSM mirror head and FSM-CD300B controller/driver. If you later need to remove the 15-pin connector cable, first remove AC power. Connecting and disconnecting the 15-pin connector cable in the absence of power will avoid making or breaking powered signal connections.

Once connected to the mirror head and to the wall outlet, the FSM-CD300B controller/driver may be turned on using the POWER switch located on the left side of the front panel (see *Figure 17*).

Figure 16: *15-pin interface cable from controller to mirror head.*

6.3 Command Inputs

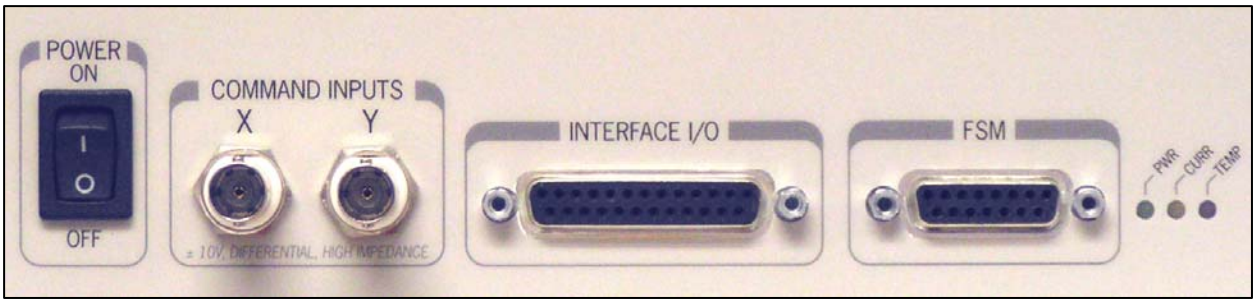


Figure 17. *Front panel I/O connections.*

Control voltages called "Command Inputs" are used to direct the mirror to specified angular positions around two orthogonal axes. These voltages are normally applied to the two BNC connectors labeled COMMAND INPUTS X and Y on the front panel, but can also be applied to the 25-pin INTERFACE I/O connector on the front panel. Please see *Figure 17*. Scaling is set so that ±10V DC offsets correspond to the full-scale motion of ±1.5° (±26 mrad) mechanical angular range on each axis. A command voltage of zero will bring the mirror to the powered-on null position for that axis. The X and Y inputs are differential. Neither lead of the BNC connector is grounded.

Certain FSM system output results (overshoot, settling time and point-to-point travel path) are dependant upon the input waveform, amplitude and frequency of the signal. Due to the many possibilities, customers are encouraged to experiment with their particular drive signal parameters when

optimizing their application. As a practical guide, a well-defined, smooth sinewave input will generate the best output results.

Self-heating of the mirror drive coils is proportional to command signal amplitude and to the square of frequency. Consult *Figure 5* in the specification section of this manual for the Safe Operating Area before driving your FSM system near its frequency versus amplitude maxima. The gain and phase response as a function of frequency for typical FSM systems are shown in *Figures 3 & 4*.

6.4 Position Outputs

If confirmation of mirror position is desired, the position angle sensors can be monitored at the Position Output pins (pins 18 and 20) of the 25-pin INTERFACE I/O connector on the front panel. A full-scale deflection of ±1.5º on either axis corresponds to a ±10 V output swing. Zero volts output corresponds to a powered-on null, or 0º.

6.5 Fault Indication

Two LED fault indicator lights on the front panel, labeled CURR and TEMP, are used to indicate overheating of the drive coils, as measured separately by thermistors for the X and Y axes.

- **The yellow CURR** warning indicator light comes when the temperature of the drive coils has reached a warning threshold as a result of applying too high an RMS drive current. In the event that the yellow light comes on during continuous system operation, decrease the amplitude and/or frequency of the drive signal.
- **The red TEMP** shut-off light comes on when thermistors have reached the shut-off temperature threshold, above which the over-temperature condition would damage the coils. While the red light is on, the mirror will be in the unpowered state. Upon cooling of the coils, the red light will go off, and the system will automatically resume normal operation. In the event that the red warning light comes on during continuous system operation, decrease the amplitude and/or frequency of the drive signal. Also check for possible inverse polarity of an External Feedback signal.

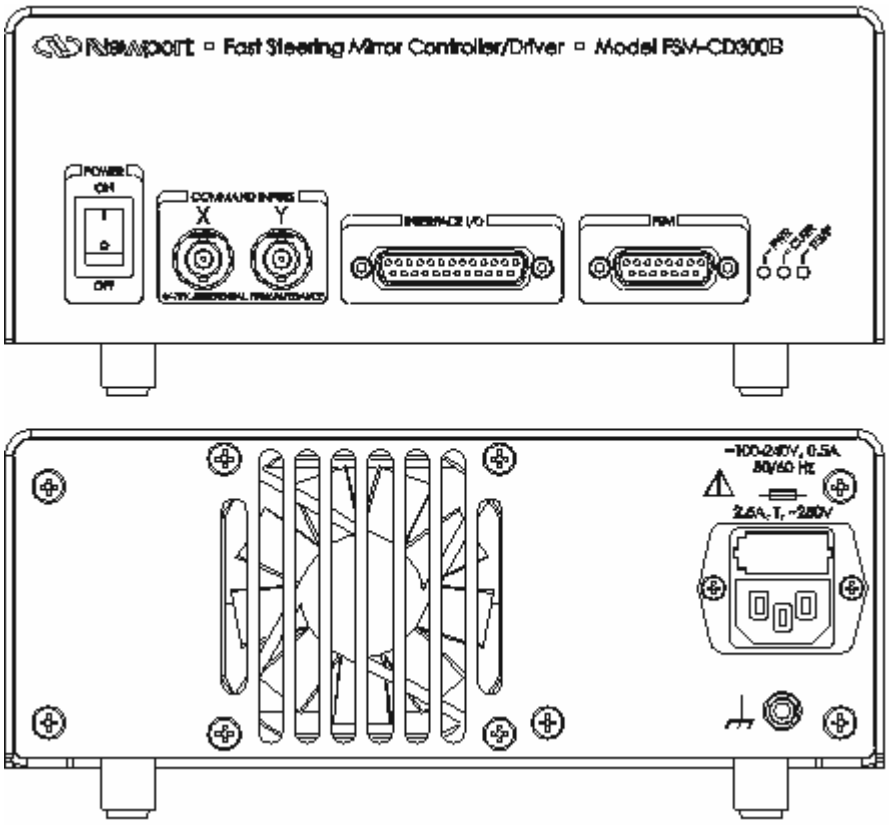


Figure 18: *Model FSM-CD300B controller/driver front and rear panels*

6.6 External Sensor Feedback Control Mode

The Model FSM-CD300B controller/driver can be used in an External Sensor Feedback Control mode with position feedback from an external sensor, such as a quad cell or lateral effect cell. This allows the FSM to lock a laser beam onto a target such as the center of a quad cell. The default alternative is the Internal Control mode, which utilizes a quad cell sensor built into the mirror head and feeds the error signal back to the controller/driver via the system's 15-pin, 3-foot interface cable.

A beam stabilization system with external position feedback sensing is shown in *Figure 19*. To switch system operation to External Feedback Control from the Internal Control, a high TTL-level signal must be applied to the INT/EXT selector switch (Pin 17) of the 25-pin INTERFACE I/O connector. External Feedback inputs can then be applied to Pins 11, 12, 15 and 16. Returning the signal on Pin 17 to a low state will switch the FSM back to Internal Control.

In the illustration in *Figure 19*, a Logic Unit (supplied by the user) provides the TTL-level signal for locking the FSM onto the quad cells. The sum of the outputs from the quad cell determines whether sufficient light is on the detector. If light is sufficient, the Logic Unit switches the FSM's to External Feedback Control and cancels out the tilt errors. If light is insufficient, the

Logic Unit keeps the FSM's on Internal Control and flags an error to the operator.

The external feedback signals should be scaled so that ±10V yields ±26 mrad of mechanical rotation. Care needs to be taken to align the external sensors so that **X** and **Y** rotation axes of the FSM correspond to the correct **X** and **Y** outputs of the quad / lateral effect cell amplifier.

Reference position voltages can be applied to the Command Inputs so that if the INT/EXT selector switch voltage input returns to Internal Control mode, the FSM will move to a defined position. Otherwise the mirror will return to the powered-on null position.

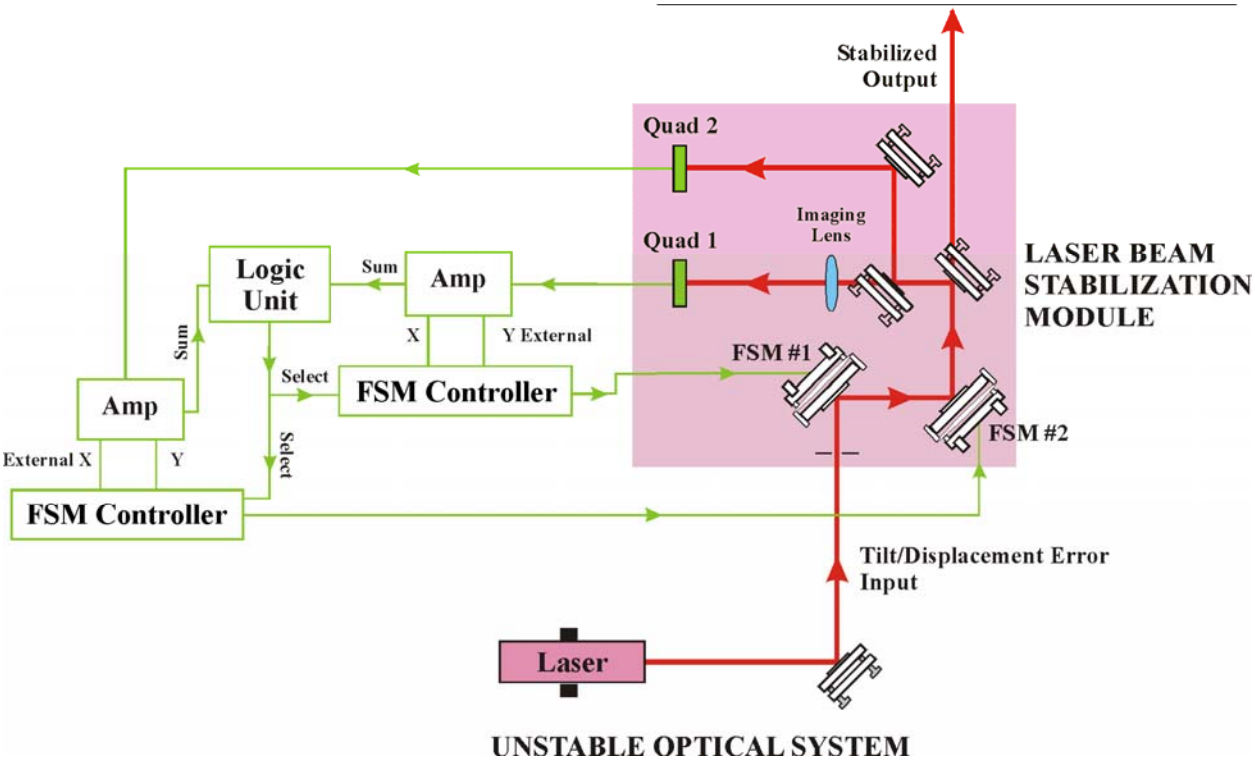


Figure 19: *FSM configured with external feedback sensor for laser beam stabilization.*

6.7 Open Loop Control Mode

The Model FSM-CD300B controller/driver can be used in Open Loop mode, which does not make use of External or Internal feedback signals. The Open Loop mode is selected by applying a high TTL-level signal X_OL_SW selector switch for X (Pin 9) and/or Y_OL_SW selector switch for Y (Pin 10). The Open Loop command signals are applied to the X_OL_CMD input for X (Pin 22) and/or Y_OL_CMD input for Y (Pin 24). These input are single-ended. Ground pins are adjacent on Pins 23 and 25.

The Open Loop mode allow users to develop their own control systems. In this mode, the FSM-CD300B controller/driver is only used as an amplifier/driver, which converts voltage signals to current to drive the coils.

6.8 Maintenance & Service

Clanging sounds from the mirror head are normal when the unit is first turned on, when a high step function is applied, or when the mirror is unpowered and is shaken by hand. Such sounds are normal and occur when the mirror hits its hard stops. They are not a sign of malfunction.

The FSM system does not require periodic maintenance or calibration. There is no reason for a user to ever open the FSM-CD300B Controller/Driver unit. Opening the unit would break a label and void the warranty. The only reason for a user to open the FSM Mirror Head would be to replace the mirror. Any repairs, if necessary, are to be done by Newport Corporation.

To clean the FSM-CD300B Controller/Driver unit, first unplug the unit. Then wipe the exterior using a damp, soft cloth. Do not use solvents or detergents.

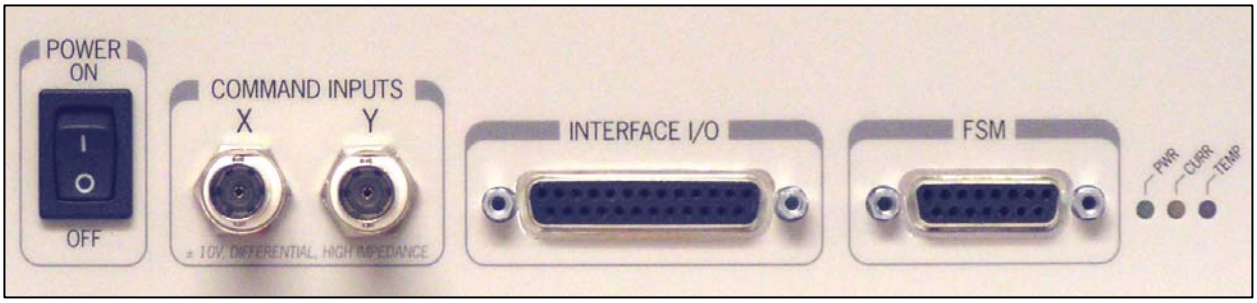
The best way to maintain cleanliness of the mirror is to protect it from dirt in the first place. If the Mirror Head Assembly is to be stored, always install the protective metal cover, as described in the section "Unpacking the FSM." Also, store the Mirror Head Assembly in a hermetically sealed zipped bag.

The mirror surface is delicate and scratches easily. A qualified optics professional should do any mirror cleaning. To remove loose dust, gently blow across the optical surface using a can of optical-grade compressed air. You may also gently brush the surface with a clean, optical-grade dust brush.

In case of heavy contamination that would interfere with the operation of the FSM system, a qualified optics professional may remove the front cover and attempt to use some of the techniques described in the section "Care & Cleaning of Optics" in Newport's product catalog, the *Newport Resource*. In case of any mechanical contact with the optical surface, some scratches are unavoidable.

7. Appendices

7.1 Appendix A – Troubleshooting the FSM System



Problem	Possible Cause & Solution
Mirror does not respond to command inputs. Green PWR indicator light is off.	Controller does not receive power. Assure that power plug is live, that power switch is ON, and that fuses (located above power connector) are good.
Mirror does not respond to command inputs. Green PWR indicator light is on.	+5V is applied to the INT/EXT selector switch input (Pin 17), causing the system to expect External Feedback inputs (Pins 11, 2, 15, 16). Or +5V is applied to Open Loop selector switch inputs (Pins 9 or 10), causing the system to expect Open Loop inputs (Pins 22, 24). Remove the +5V source or supply control voltages on the required pins.
Yellow CURR indicator LED is on. The drive signals to the mirror are clipped.	The attempt is made to apply to much RMS current to the FSM drive coils, which would create a potential over-temperature condition. Decrease amplitude and/or frequency of drive signal.
Red TEMP indicator LED is on. Mirror does not respond at all.	Thermistors have detected an over-temperature condition of the drive coils because these are being driven too hard. Decrease amplitude and/or frequency of drive signal. Also check for possible inverse polarity of an External feedback signal. System will automatically resume normal operation once coils have cooled.
Mirror moves in opposite direction of intended.	Polarity is reversed at X and Y Command Inputs or X and Y External Feedback Inputs. To remedy, reverse your electrical connections, since the above four inputs are differential without a fixed ground.

7.2 Appendix B – Abbreviations

FSM	Fast Steering Mirror
D-A	Digital to Analog
IR	Infrared
NIR	Near Infrared

7.3 Technical Support

North America & Asia

Newport Technical Support Department

1791 Deere Ave.
Irvine, CA 92606, USA
Tel: (949) 863-3144, (800) 222-6440
Fax: (949) 253-1680
Email: tech@newport.com

Europe

Newport / Micro-Controle S.A.
11 rue du Bois Sauvage
91055 Evry Cedex, France
Tel: 01-60-91-68-68
Fax: 01-60-91-68-69
Email: france@newport-fr.com

Technical Support Information

When calling Newport Technical Support with a technical issue or problem, please be prepared to provide the following information:

- Your contact information.
- System serial number or original order number.
- Description of problem.
- Environment in which the system is used.
- State of the system right before the problem.
- Can you identify anything that may have caused the problem?
- Can the system continue to operate, or is it non-operational?
- Frequency and repeatability of problem.

7.4 Service & Returns

North America & Asia

Newport Service & Returns Department

1791 Deere Ave.
Irvine, CA 92606, USA
Tel: (949) 253-1694, (800) 222-6440 ext. 31694
Fax: (949) 253-1479
Email: istd.service@newport.com

Europe

Newport/Micro-Controle S.A.

11 rue du Bois Sauvage
91055 Evry Cedex, France
Tel: 01-60-91-68-68
Fax: 01-60-91-68-69
Email: france@newport-fr.com

Service & RMA Information

The user should not attempt any maintenance or service of the FSM Fast Steering Mirror System beyond the procedures outlined in this manual. Any problem that cannot be resolved should be referred to Newport's Service & Returns Department, and any failed product should be returned to that department for service. A Return Materials Authorization (RMA) number must be obtained in advance and should be stated on the outside of the shipping box. To obtain an RMA number, please fill out and fax back the *Return Material Authorization Request* form included at the end of this manual.

Packaging for Returns

Any FSM Fast Steering Mirror Head or FSM-CD300B Controller/Driver being returned under an RMA must be securely packaged for shipment. The RMA number must be stated on the outside of the shipping box. If possible, reuse the original factory packaging. The mirror must be secured for shipment. Please contact Newport's Service & Returns Department if you no longer have the original shipping restraints for the mirror.

7.5 Appendix C – Return Material Authorization Request

Newport Corporation, Returns Department, 1791 Deere Avenue, Irvine, CA 92606
Tel: 800-222-6440 *FAX: 949-253-1479*
Email: rma.service@newport.com *Web: www.newport.com*

Newport RMA #: **R** **(assigned by Newport Corporation)**
Name: _____ Date: _____
Telephone #: _____ Fax: _____
Email: _____
Company Name: _____
Ship to Address Line 1: _____
Ship to Address Line 2: _____
Ship to City: _____
Ship to Country: _____ State: _____ Zip Code: _____

☐YES ☐NO **If Warranty Repair or Replace, complete this section:**
_____ Date of your original purchase.
C _____ Original Newport sales Order number (begins with C).
_____ Your Original Purchase Order number.
☐YES ☐NO Has this product been used?
☐YES ☐NO Would you like a refurbished replacement if available?
☐YES ☐NO Is this product being returned for Credit only?
Credit only is not an option for Newport Warehousing Divisions.
☐YES ☐NO **If Non-Warranty Repair or Replace, complete this section:**
_____ **Purchase Order number** (approval required before invoicing)
☐YES ☐NO Detector Calibration (will include functional check of power meter)
☐YES ☐NO Power Meter Calibration
What Company name should be on the Calibration Certification? _____
☐YES ☐NO Would you like to be quoted a refurbished replacement if available?

PRODUCTS BEING RETURNED (LIST VALID NEWPORT PART NUMBERS)

Part Number	Description	S/N	Qty	Declared value
				$
				$
				$
				$
				$
		Totals		$

Reason for Return and detailed explanation of problem:

_____
_____
_____
_____