PSW-003-M

High Speed Polarization Switch Module

LUNA's high-speed self-latching polarization switch module (PSW-003-M) switches between 2 output states of polarization (SOPs). It can be configured as a polarization rotator, with output states 45° or 90° apart, or as a linear-circular converter. The device can be used for polarization sensitive OCT, polarization sensitive OTDR or OFDR, PMD monitoring, polarization modulation, polarization detection, and polarization metrology. The module version integrates the polarization switch (PSW-003) with a compact driver board that allows the user to control the switch state using TTL logic levels rather than having to build high-current driver circuits.

KEY FEATURES

- Self-latching
- Pulse drive with low power dissipation
- Low power consumption: Power supply +12VDC

  1KHz switch frequency average current: 5.7mA

  1Hz switch frequency average current: 2.1mA
- Compact: 42(L) x 20.5(W) x 17.5(H) mm
- Flexible driving method: quadrature dual-port logic signal

Block Diagram

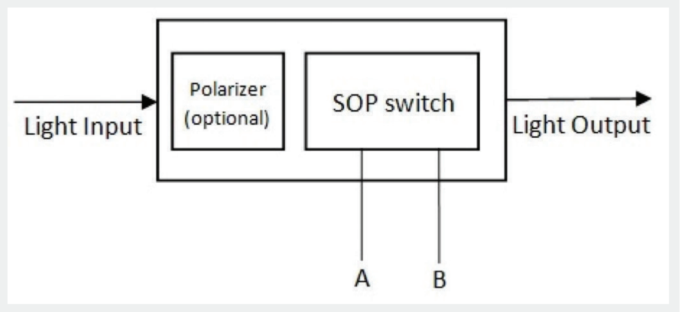


Figure 1: Functional block diagram
Note: Polarizer is optional

Pin Configuration

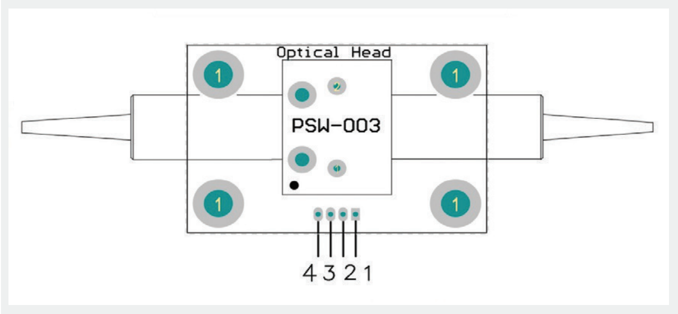


Figure 2: Electrical pin labels (device top view)

High-speed self-latching polarization switch module with two output states of polarizations (SOPs)

OPTICAL CONNECTIONS

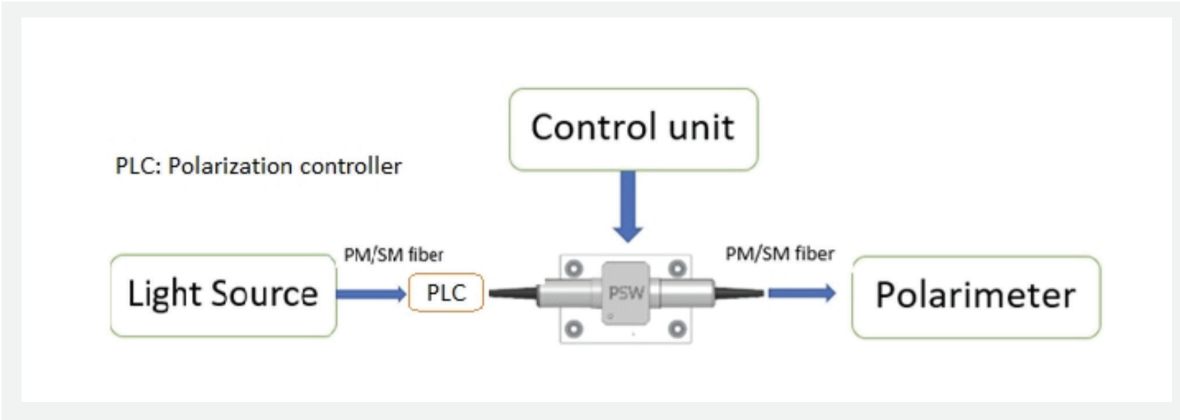


Figure 3 Sample setup - Polarization measurement for switch function verification

PCB PIN DEFINITIONS

Electrical connector on board: Harwin M50-3530442 or equivalent (4-pin, 1.27mm pitch)

Pin #	Pin Name	I/0 Type	Description
1	Power Input	PWR	+12V± 1.0V power supply input
2	GND	PWR	Power and logic ground.
3	Signal Input (A_IN)	I	Drive logic signal input 1 (A) , Input resistance:50KΩ
4	Signal Input (B_IN)	I	Drive logic signal input 2 (B) , Input resistance:50KΩ

ELECTRICAL INPUTS

Parameter	Min.	Typical	Max.	Unit
Power supply voltage	11	12	15	V
Logic level 0 (min=0, typical =0, max=0.4, unit V)	0	5	5.5	V
Logic pin signal pulse width	50	80	1000	μs
Storage temperature	45	25	85	°C

The driver board uses a MOSFET H-bridge to generate the forward and reverse current pulses needed to drive the switch. The logic levels applied to board input pins A_IN and B_IN determine the drive signal applied to the switch. The following table lists, for each logic state combination of A_IN and B_IN, the corresponding driver state and the board outputs applied to the switch (OUT1 appied to positive rotation pin, OUT2 applied to negative rotation pin).

In general, the "coast" state (both pins low) is the default drive condition (switch stays in its current state). To switch to the forward rotation state, pin A_IN would be pulled high for at least 50us before returning to the "coast" state. To switch to the reverse rotation state, pin B_IN would be pulled high for at least 50us before returning to the "coast" state. See Fig. 8 for details on switch dynamics.

H-bridge Control				
Driver State	**A_IN**	**B_IN**	**OUT1**	**OUT2**
Coast; H-bridge disabled to High-Z (sleep entered after 1 ms)	0	0	High-Z	High-Z
Reverse (Current OUT2 -> OUT1)	0	1	L	H
Forward (Current OUT1 -> OUT2)	1	0	H	L
Brake; low-side slow decay	1	1	L	L

POLARIZATION STATE AND ANGLE DEFINITIONS

The following figures describe the possible output SOPs for different configurations of the PSW-003-M.

Electrical field rotation directions and angles shown in real space are defined when observed against the direction of propagation.

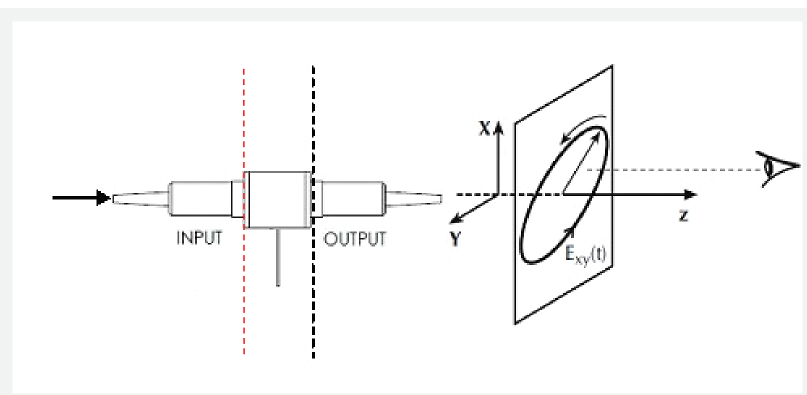
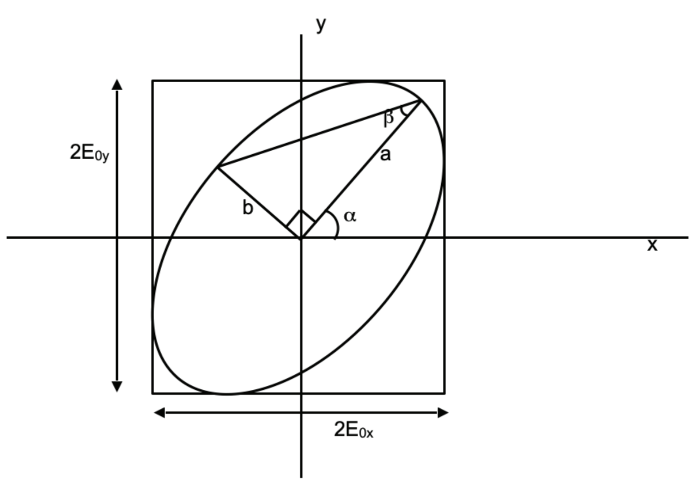


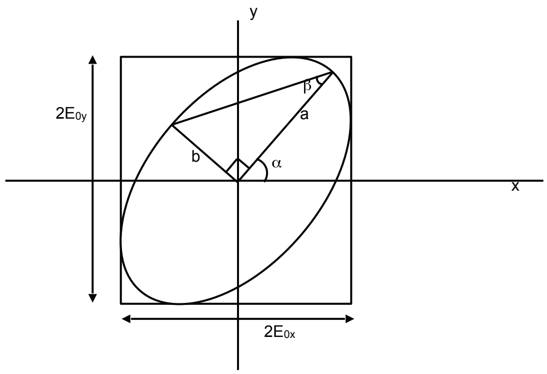
Figure 4 Electrical field is observed against the direction of propagation.

Input SOPs are defined at the plane marked by the red vertical dotted line at the input end of the PSW frame, after the input pigtail. Output SOPs are defined at the plane marked by the black vertical dotted line at the output end of the PSW frame, before the output pigtail.



(a) Polarization ellipse for a generalized elliptical SOP

α is the azimuth angle and β is the ellipticity angle of the polarization ellipse.



(a) Polarization ellipse for a generalized elliptical SOP

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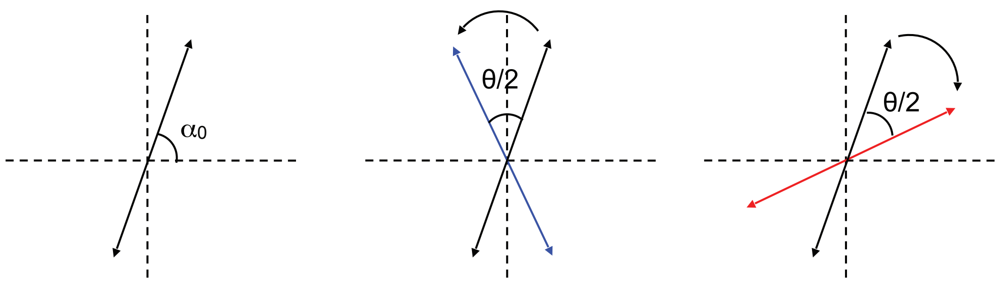


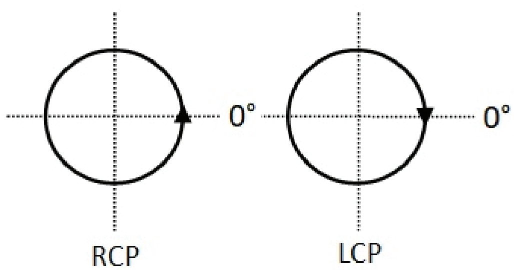
Input SOP
Linear at angle α_0

Positive output SOP (blue) is
rotated counterclockwise by θ/2

Negative output SOP (red) is
rotated clockwise by θ/2

(b) Polarization Rotator Switch - Linear SOP rotation example:

A linear input SOP at an arbitrary angle α_0 experiences a positive (counterclockwise) or negative (clockwise) rotation of θ/2 due to the action of the switch. The azimuth angle difference between the two output SOPs is the nominal switch angle θ, where θ=45° or 90°, depending on the switch.



(c) Right and Left Circular SOP electrical field rotation directions

Figure 5 Polarization state and rotation directions, observed against the direction of propagation. For a generalized polarization state, the electrical field vector traces out an ellipse with azimuth angle α and ellipticity angle β. For a linear or elliptical input polarization state with azimuth angle α, a rotator switch with nominal rotation angle θ rotates the azimuth by ±θ/2, such that the angle between the two output SOPs is θ. Circular input SOPs are unaffected by the action of a rotator switch.

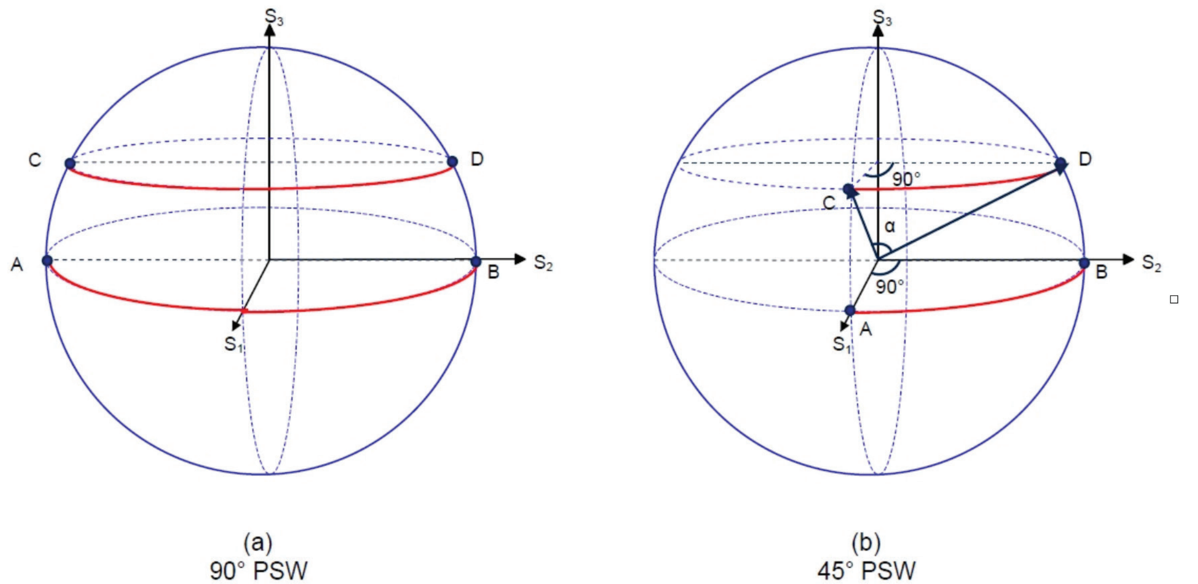


Figure 6 Examples of PSW-003-M rotator switch output SOP representations on the Poincaré Sphere.
The sphere diagram for each switch shows the relative positions of output SOPs for 2 cases of input polarizations:
Case 1: linear input SOP -> output states A and B Case 2: elliptical input SOP -> output states C and D

A PSW-003-M rotator switch transforms the SOP of an input optical signal along the equi-ellipticity contours that are represented by latitude lines on the Poincaré sphere. The SOP rotation between the two output states of a 90° or a 45° PSW-003-M is a half (1/2) circle or quarter circle (1/4 circle), respectively, along the latitude line on which the input polarization state falls.

a) shows the two output SOPs of a 90° PSW resulting from different input polarization states. In the first case, the input SOP is linear (on the equator); the two output SOPs will be 180° apart on the circle defined by the equator (points A and B in the diagram). In the second case, the input SOP is elliptical; the two output SOPs (points C and D) will be 180° apart on a smaller circle corresponding to the latitude line on which the input SOP falls. If the input polarization state is circular (north or south poles of the sphere), the latitude circle collapses to a point, so the output SOP will still be circular. b) shows a similar example for a 45° PSW-003-M. In this case, points A and B and points C and D are 90° from each other on their respective circles.

Please note that the rotation angle with respect to the S3 axis is generally not the same as the solid angle with respect to the origin of the sphere unless the rotation is on the equator (S3 = 0). In b) both sets of output states (points A and B and points C and D) are rotated 90° from each other with respect to the S3 axis; however, the solid angle between points C and D with respect to the origin of the sphere is not 90°. Instead, it is some angle α, whose value depends on the S3 coordinate of the input SOP.

PM input PSW-003-Ms typically have an input polarizer aligned to the slow axis of the PM fiber. The polarizer constrains the SOP of the light entering the rotator to a known linear state. A PSW-003-M rotator switch therefore creates a polarization transformation on the equator of the Poincaré sphere. A 90° PM PSW-003-M switches the output polarization state between alignment with the slow (positive rotation) and fast (negative rotation) axes of the output PM fiber. A 45° PM PSW switches the state of its output light between slow-axis aligned (positive rotation) and 45° from the slow axis (negative rotation) at the point where it launches into the output PM fiber.

For a linear to circular converter switch with PM input fiber and slow-axis aligned polarizer, the input SOP is fixed at linear vertical polarization (LVP) by the polarizer. The optics are aligned such that the positive output state is linear and the negative output state is LCP.

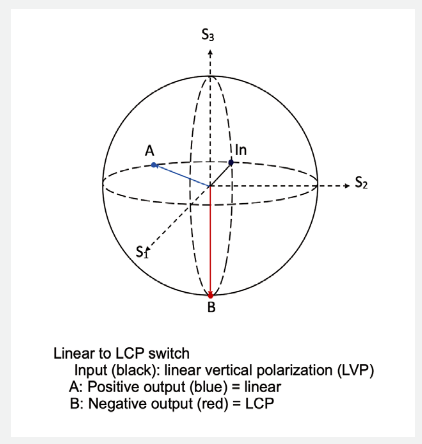


Figure 7 Output SOP representation on Poincaré Sphere for linear to circular converter switch

SPECIFICATIONS

Specifications apply to ambient temperature T = 25°C and at center wavelength, unless otherwise noted. Unless otherwise noted, electrical parameters are given for a PSW-003-M using +12VDC power supply voltage and nominal logic levels (0 and 3.3V) for the signal input pins.

Absolute Maximum Ratings			
Parameter	**Min.**	**Max.**	**Unit**
Optics			
Optical input power		300	mW
Electronics			
Power supply voltage (DC)	11	13	V
Quiescent current		2.0	mA
Operating current (Alternating switching frequency 8KHz)		45	mA
Maximum transient current (<1µ)		160	mA
Pulse width Storage temperature		-40	
At power supply voltage 12V	50	1000	µs
Operating temperature	0	50	°C
Storage temperature	-40	85	°C
Physical and Environmental	SM or PM		

NOTE:

Rotator switches can have SM or PM pigtails. Linear to circular switches typically have PM input and SM output.

TIMING CHARACTERISTICS

Power supply is 12V (unless otherwise noted) - (All values in µs)

Timing Parameter Labels and Definitions	Values				
Definitions	**Min.**	**Typical**	**Max.**	**Timing Symbol**	**Test Conditions**
Drive Pulse Signal Width. t_1 is for positive signal, t_3 is for negative signal.	50 80	80 100	1000 1000	t_1, t_3	$20 < t_2 < 500$ $t_2 > 500$
Drive Pulse Signal Interval	20	50	1000	t_2	
SOP Switch Delay Time	20	25	N/A	t_4, t_6	
SOP Switch Time	40	45	50	t_5, t_7	

Optical Characteristics				
Parameter	**Min.**	**Typical**	**Max.**	**Unit**
Operation Wavelength[1]				
C band	1520	1550	1580	nm
O band	1280	1310	1340	nm
Insertion Loss			0.5	dB
State Dependent Loss (ΔIL over 2 SOPs at fixed wavelength)			0.05	dB
Wavelength Dependent Loss (ΔIL over all wavelengths at fixed SOP)			0.1	dB
Return Loss			-55	dB
SOP Repeatability (on Poincaré Sphere)[2]		±0.1		deg
SOP Rotation Angle (center wavelength and 25°C)		45±0.5 or 90±1		deg
SOP Rotation Angle[3] (all wavelengths and temperatures)		45 or 90±5		deg
Rotation Angle Wavelength Dependence[4]				
For 45° 1550nm PSW		-0.065		deg/nm
For 90° 1550nm PSW		-0.13		deg/nm
For 45° 1310nm PSW		-0.085		deg/nm
For 90° 1310nm PSW		-0.17		deg/nm
Rotation Angle Temperature Dependence[4]				
For 45° PSW		-0.07		deg/ °C
For 90° PSW		-0.14		deg/ °C
SOP Switching Time[5]	40	45	50	μs
Optical Power Handling			300	mw

NOTES: Values are referenced without connectors

1. The specified wavelength range is center wavelength (λ_c)±30nm. The switch rotation angles are closest to ideal values at center wavelength and room temperature.
2. Relative angles on the Poincaré sphere are twice the electrical field rotation angles in real space. The SOP repeatability is measured on the Poincaré sphere under a fixed measurement condition (static wavelength, temperature, and input polarization, with no fiber movement).
   SOP rotation angles, including wavelength and temperature dependence, are specified in real space.
3. Over all wavelengths and temperatures in the operational ranges.
4. Wavelength and temperature dependence of the relative angle between output SOPs, in real space. A negative sign denotes that the angle decreases with increasing wavelength or temperature.
5. Rise/fall time ($t_5 - t_4$), see Figure 8.

LUNA

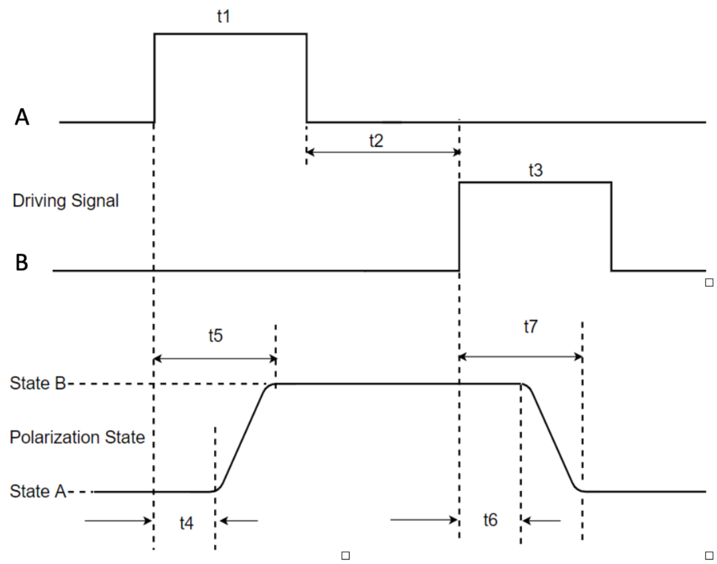


Figure 8 Polarization response to drive signal

THERMOGENESIS

This section describes the heating effects that can be expected due to operation of the PSW-003-M. The operational temperature elevation refers to the amount the device temperature can be expected to rise (relative to ambient temperature) due to device operation. It is dependent on the drive conditions used for switching and the switching frequency.

Internal temperature elevation (relative to ambient temperature)	Operational Temperature Elevation			
Drive Conditions[1]	**Min.**	**Typical**	**Max.**	**Unit**
Worst Case[2]		5		°C

NOTES:

1. Data in this table was measured at room temperature ambient, with power supply voltage 12V.
2. Worst Case: The largest operational temperature increase occurs when the PSW is switched back and forth continuously at a high frequency. In this case, the drive pulse width and interval between pulses were both equal to 50μs.

PRINCIPLE OF OPERATION

The PSW-003-M is an electrically controlled, self-latching polarization switch that switches between two output states of polarization. The relationship of the two output states depends on the configuration of the polarization switch; it can be configured as a rotator or as a linear to circular converter.

If configured as a rotator, the switch rotates the major axis of the polarization ellipse of the input light by a specified angle without changing the ellipticity. If the light entering the PSW is linear or elliptical, it will be rotated. If it is circular, it will be unaffected by the switch. The output SOP (at the output side of the PSW frame before the output pigtail) is rotated by either +θ/2 or –θ/2 from the input SOP (at the input side of the PSW frame after the input pigtail), such that the relative angle θ between the two output polarizations is either 45° or 90°.

Rotator switches can have either SM or PM pigtails. The birefringence of SM fiber can cause polarization rotation, so the absolute SOPs measured at the end of a SM output pigtail are generally different from the SOPs at the edge of the frame; however, the angular relationship between the SOPs remains the same.

For PM pigtailed rotator switches, the fibers are aligned such that for a linear input aligned to the slow axis of the input fiber, the two output states will be aligned to the slow and fast axes of the output PM fiber for a 90° switch, or to the slow axis and 45° from the slow axis for a 45° switch. These switches are configured with an input polarizer to improve the PER of the axis-aligned output states.

Linear to circular converter switches generally have PM input and SM output pigtails, with an input polarizer aligned to the slow axis of the input fiber to ensure a linear input state. One of the output states is linear, and the other is left circular (LCP).

Figure 9 shows the timing of the PSW-003'M's polarization response to the drive signals,

Traces 1 and 2 are drive signals A_IN and B_IN, respectively. Trace 3 is the power detected by a photodetector measuring the power out of an in-line polarizer placed after the output of the PSW.

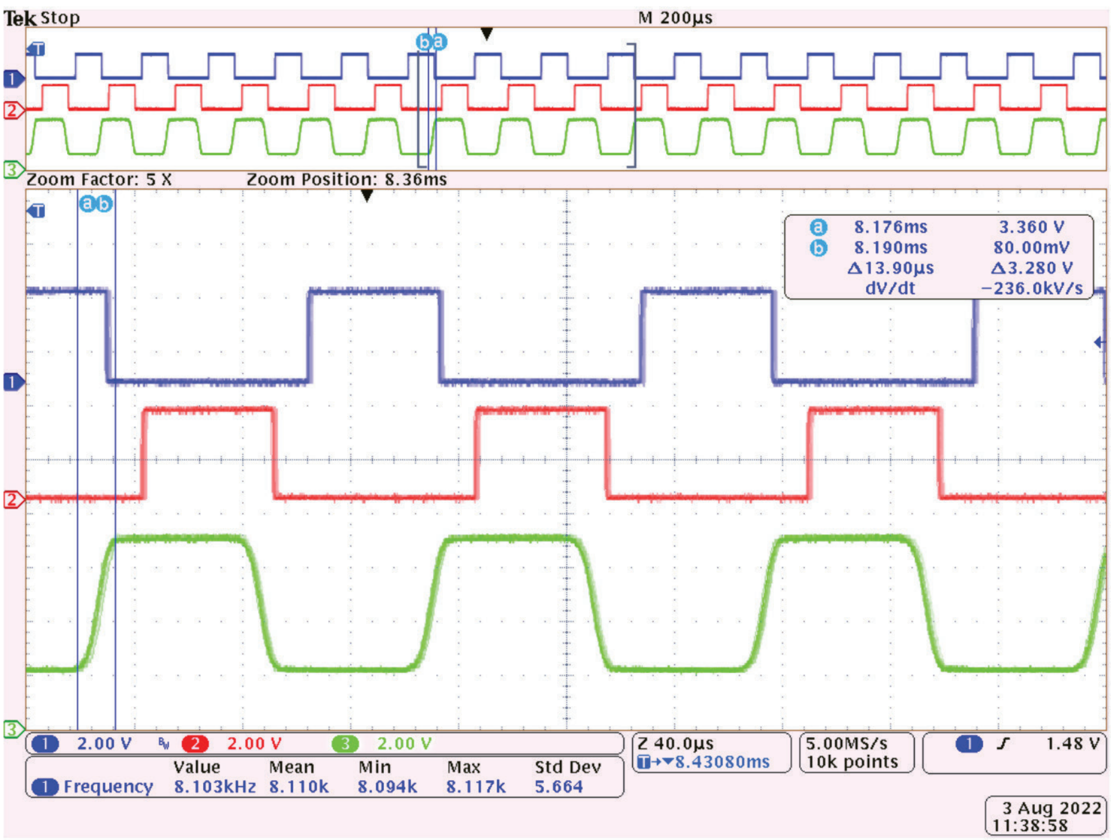


Figure 9 Driving signal, optical polarization states switched by a PSW-003-M tested by an oscilloscope.

DIMENSIONS

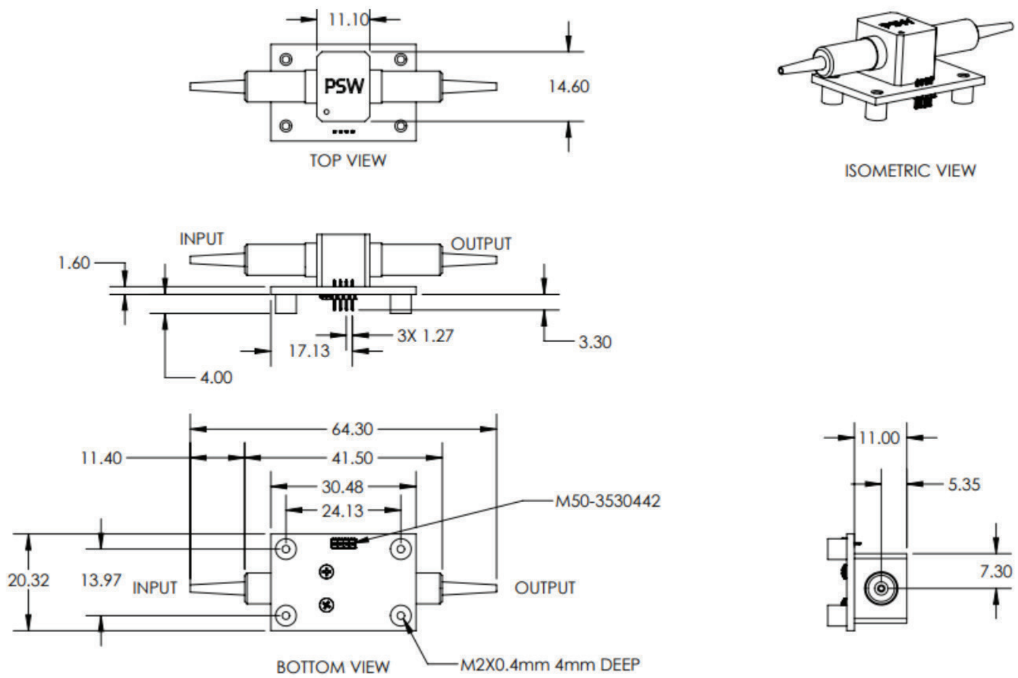


Figure 10 Mechanical drawing and dimensions (in mm)

ORDERING INFORMATION

Catalog #	Wavelength	SOP Rotation	Fiber Type	Input Polarizer	Pigtail Length	Connector Type
PSW-003-M	□□	□□	□□	□	□	□□
	15 – 1550 nm 13 – 1310 nm[1]	90 = 90° 45 = 45° LCL = linear to LCP	SS – SM to SM PP – PM to PM PS = PM to SM	(For PM PSW) 0 – No polarizer P – Input polarizer (slow axis)	1.0 – 1.0 m Specify	NC – no connector FC/APC Specify

Notes:

1. Contact Luna innovations to confirm the part number before quoting

REVISION HISTORY

Revision	Date	Note
1.0	8/15/2022	Original document
1.1	9/08/2022	Configuration options modified

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