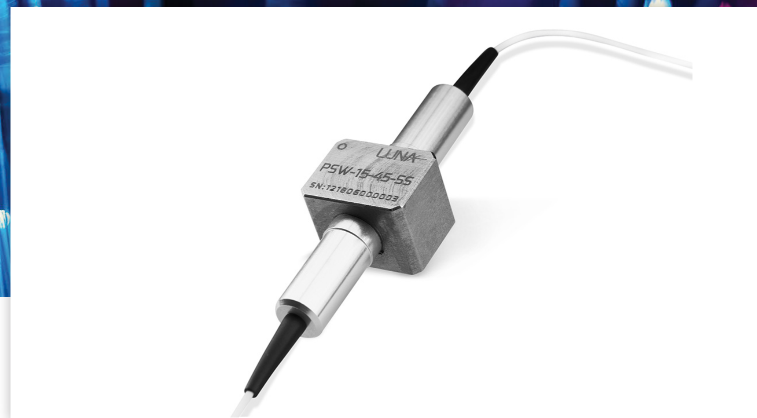


PSW-003

High-Speed Polarization Switch

LUNA's high-speed self-latching polarization switch (PSW) 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.

Block Diagram

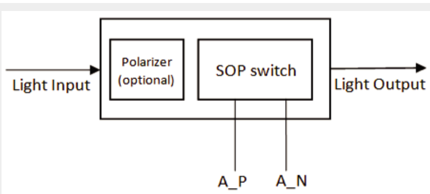


Figure 1 Functional block diagram
Note: Polarizer is standard for PM input devices. SM input devices have no polarizer.

Pin Configurations

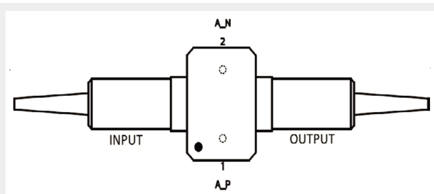


Figure 2 Electrical pin labels (device top view)

Optical Connections

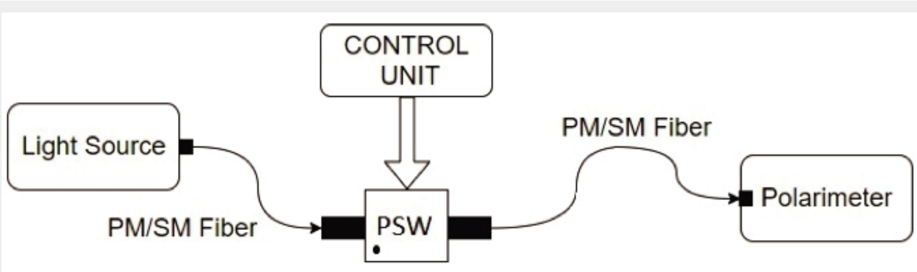


Figure 3 Sample setup - Polarization measurement for switch function verification

KEY FEATURES

- Digitally switched SOP
- Typical Switching Time 45µs
- SOP repeatability 0.1°
- Self-latching
- Zero static power dissipation
- Compact
- Minimal heat generation

APPLICATIONS

- Polarization diversified detectors and sensors
- Polarization sensitive OCT
- Polarization metrology
- Polarization sensitive OTDR or OFDR
- PMD monitoring
- Fiber optic sensing

High-speed solid state optical polarization switch with compact design and low loss

PINOUT

Pin #	Pin Name	I/0 Type	Description
1	A_P	Input	SOP switch positive rotation input
2	A_N	Input	SOP switch negative rotation input

FIBER DESCRIPTION

Pigtail fiber options :	
Input Fiber	SM or PM
Output Fiber	SM or PM

POLARIZATION STATE AND ANGLE DEFINITIONS

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

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

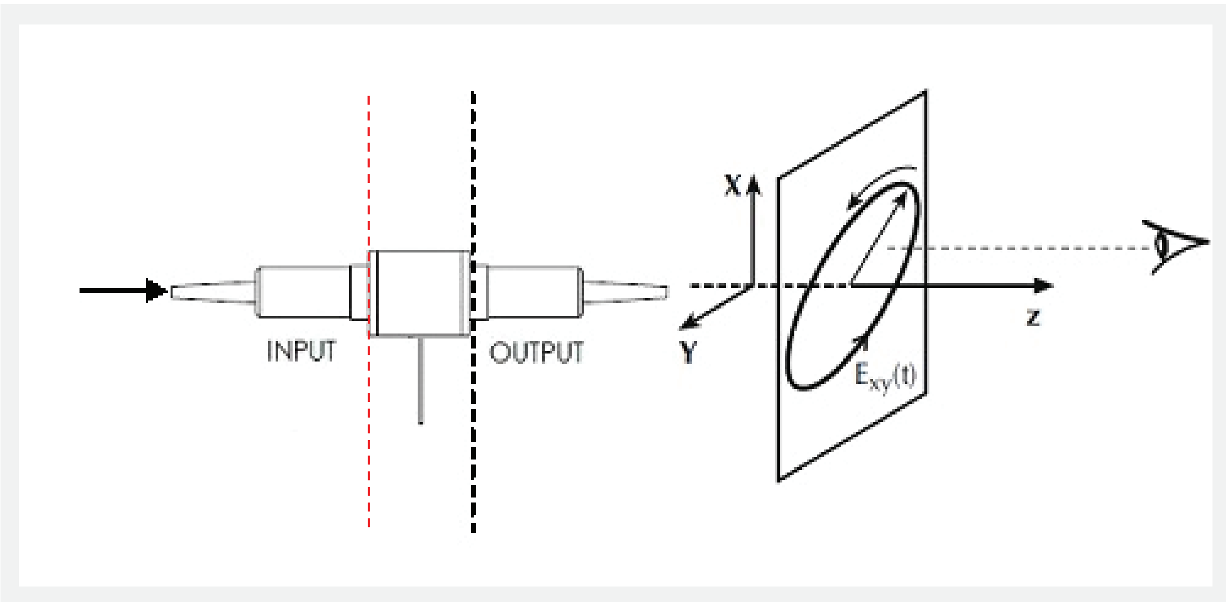
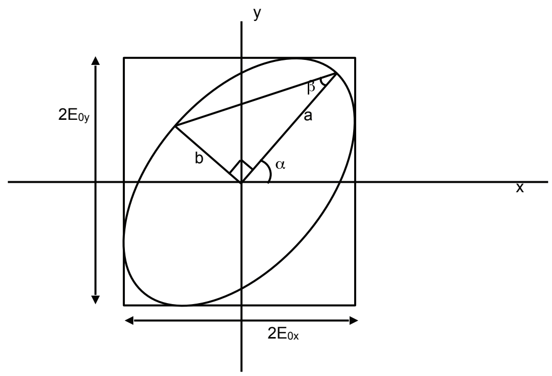


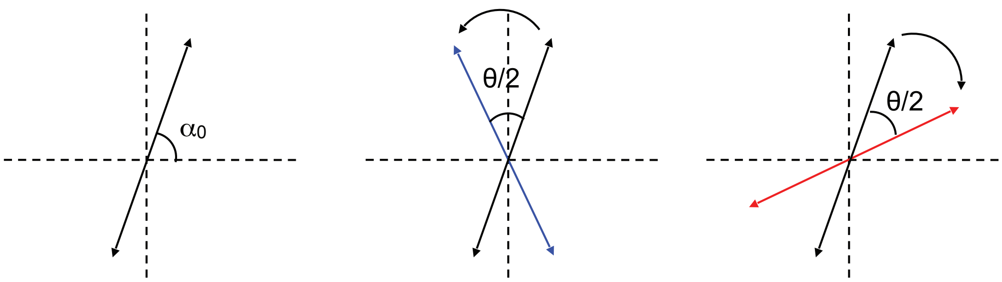
Figure 4 Electrical field is observed against the direction of propagation.

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.



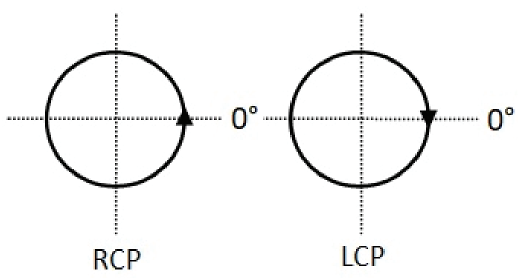
Input SOP
Linear at angle α_0

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.

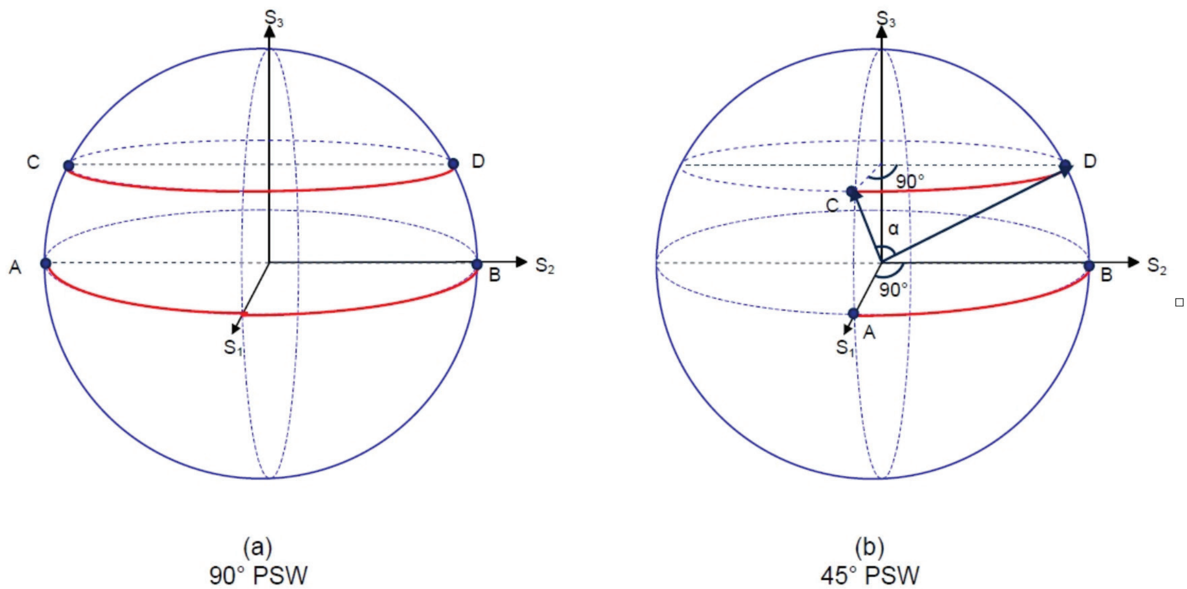


Figure 6 Examples of PSW-003 rotator switch output SOP representations on the Poincaré Sphere.

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 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 is a half (1/2) circle or quarter circle (1/4 circle), respectively, along the latitude line on which the input polarization state falls. Figure 6a 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.

Figure 6b shows a similar example for a 45° PSW-003. 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 Figure 6b, 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-003s 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 rotator switch therefore creates a polarization transformation on the equator of the Poincaré sphere. A 90° PM PSW-003 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.

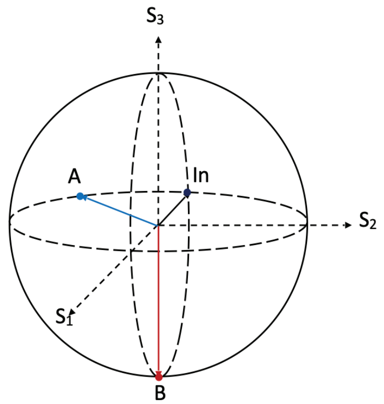


Figure 7 Output SOP representation on Poincaré Sphere for linear to circular converter switch

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.

SPECIFICATIONS

Specifications apply at ambient temperature T = 25°C and at center wavelength, unless otherwise noted. Unless otherwise noted, electrical parameters are given for a polarization switch driven with an H-Bridge circuit with the specified bias voltages applied to the switch.

Absolute Maximum Ratings		
Parameter	**Rating**	**Unit**
Optics		
Optical input power	300	mW
Electronics		
Power dissipation	1	W
Peak drive current I_{peak}[1]	150	mA
Pulse width 2		
At bias voltage 10V	130	µs
At bias voltage 5V	550	µs
At bias voltage 3.3V	1000	µs

NOTES:

1. Maximum allowed instantaneous current during a drive pulse.
2. The pulse width at which the maximum instantaneous current may reach 150 mA. Exceeding this value may cause higher than normal device heating or damage the switches.

Physical Operating Conditions			
Parameter	**Min.**	**Max.**	**Unit**
Operating Temperature	0	50	°C
Storage Temperature	-40	85	°C

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		dB
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]				
At bias voltage 10V	40	45	50	µs
At bias voltage 5V	70	80	100	µs
At bias voltage 3.3V	90	120	150	µs
Optical Power Handling			300	mW

NOTES: Values are referenced without connectors:

1. The specified wavelength ranges are center wavelength (λc)±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. Rotation angle temperature dependence is the same for 1310 and 1550nm PSWs.
5. Time interval between drive signal pulse leading edge and completion of SOP transition (t_5 and t_7 in Figure 9) at room temperature (~23°C) using an H-bridge driver circuit.

Electrical Characteristics (Dynamic)	Values				
Parameter	Min.	Typical	Max.	Unit	Note/Comments
Drive Signal Pulse Width1 (T_{PW} in Figure 8, t_1 or t_3 in Figure 9)					Pulse width required to switch and latch the SOP
At bias voltage 10V	50		130	μs	
At bias voltage 5V	110		550	μs	
At bias voltage 3.3V	170		1000	μs	
Drive Signal Pulse Interval				μs	Time between consecutive pulses
Peak Pulsed Drive Current2 (I_{peak})					See Figure 8.
At bias voltage 10V	65		150	mA	
At bias voltage 5V	60		150	mA	
At bias voltage 3.3V	55		110	mA	
Self-latching Current		0		mA	No current required to maintain SOP after latching.

NOTES:

1. A drive signal pulse width shorter than $T_{PW\text{-}MIN}$ may not fully switch the SOP. A drive signal pulse width longer than $T_{PW\text{-}MAX}$ will result in a peak drive current higher than the specified maximum I_{peak} value.
2. Typical pulsed-current waveform is shown in Figure 8. At each listed bias voltage in this table, $I_{peak\ MIN}$ corresponds to $T_{PW\ MIN}$ and $I_{peak\ MAX}$ corresponds to $T_{PW\ MAX}$. For bias voltages 10V and 5V, peak instantaneous current can exceed maximum values if pulse width exceeds the specified maximum value.

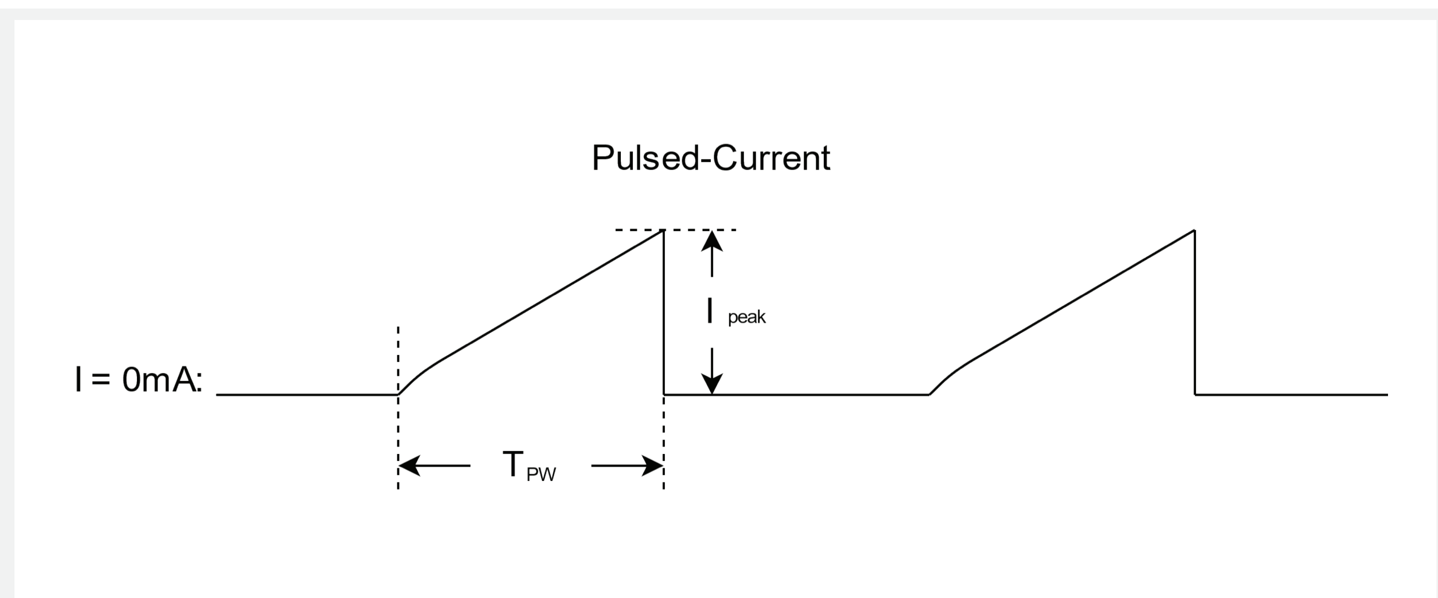


Figure 8 Typical pulsed-current waveform for pulse widths in the specified range

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**
Drive Pulse (positive) Signal Width				t_1
	50		130	For bias 10V
	110		550	For bias 5V
	170		1000	For bias 3.3V
Drive Pulse Signal Width	40			t_1
Drive Pulse (negative) Signal Width				t_3
SOP Switch Delay Time				t_4, t_6
	20	25	30	For bias 10V
	30	35	40	For bias 5V
	40	45	50	For bias 3.3V
SOP Switch Time				t_5, t_7
	40	45	50	For bias 10V
	70	80	100	For bias 5V
	90	120	150	For bias 3.3V

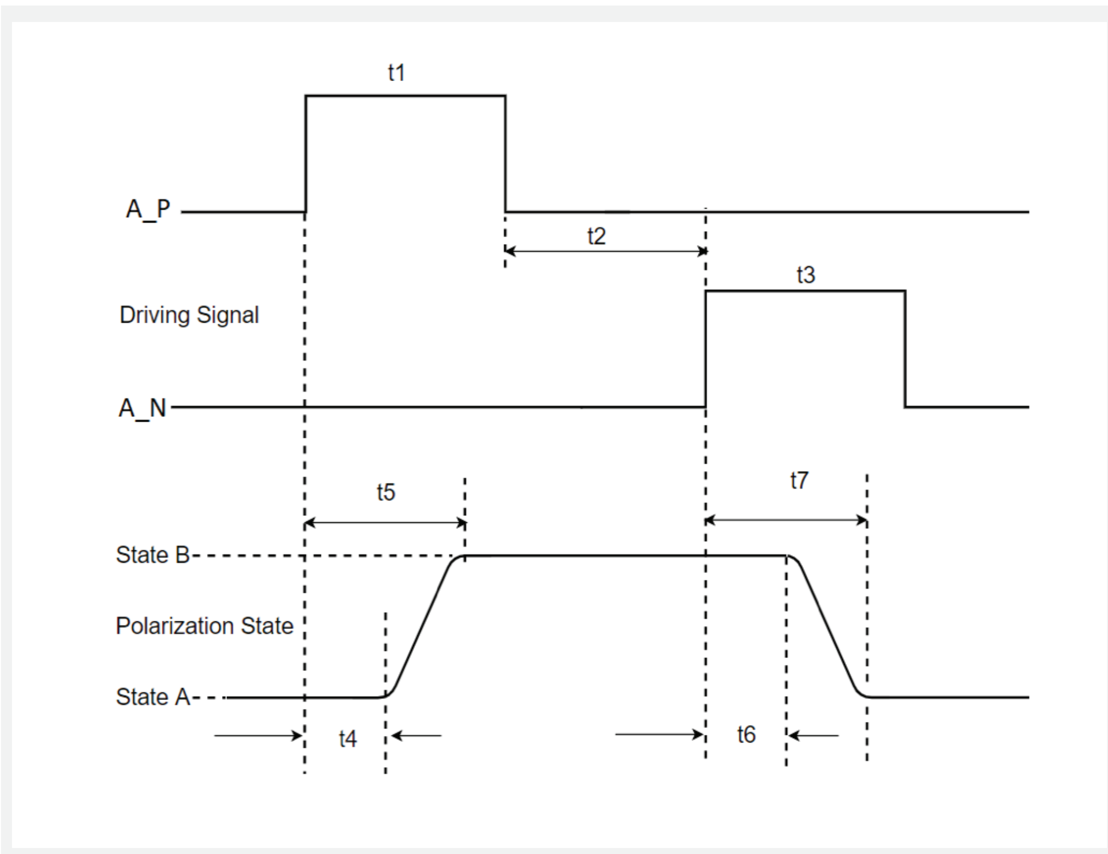


Figure 9 Polarization response to drive signal

THERMOGENESIS

This section describes the heating effects that can be expected due to operation of the PSW-003. 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, using an H-bridge driver circuit with bias voltage 10V.
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 set to 50μs.

PRINCIPLE OF OPERATION

The PSW-003 is an electrically controlled, self-latching polarization switch that switches between two output states of polarization. The relationship between 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 as shown in Figure 5 and Figure 6. 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 $+\theta/2$ (counterclockwise when looking into the beam) or $-\theta/2$ (clockwise when looking into the beam) 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 an 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 positive output state is aligned to the slow axis of the output fiber. The negative output is aligned to the fast axis for a 90° switch, or to 45° from the slow axis for a 45° switch. These switches have 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 circular (LCP), as shown in Figure 7.

APPLICATION INFORMATION

The polarization of light can be rotated by switching the direction of the driver current. The PSW-003 is designed to use pulsed drive currents. Because the switch is self-latching, the output polarization state is maintained after being rotated by a current pulse. Do not use DC current to drive the PSW-003, as this can result in excessive heating and possible switch damage. The driver current should meet the requirements listed in the Electrical Characteristics (Dynamic) section of the specifications.

Figure 10 shows the equivalent circuit of a polarization switch.

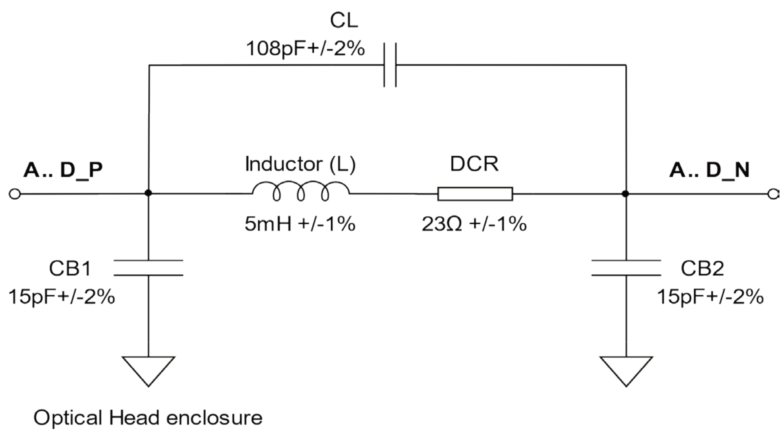


Figure 10 Polarization switch equivalent circuit

The A_P label refers to the positive switch drive pin A_P; A_N refers to the negative switch drive pin A_N. C_L is the parasitic capacitance between the positive and negative drive pins of a switch, while CB_1 and CB_2 are the parasitic capacitances between the positive drive pin (A_P) or negative drive pin (A_N) and ground, respectively.
The core components in an equivalent circuit of a switch (Figure 10) are a 5mH ideal inductor in series with a 23Ω±1% DC resistor (DCR). The inductive reactance of the circuit varies for different switching rates. The inductive reactance of the circuit can be estimated according to Equation 1,

$$X_L = 2\pi f L + DCR \qquad \text{Equation 1}$$

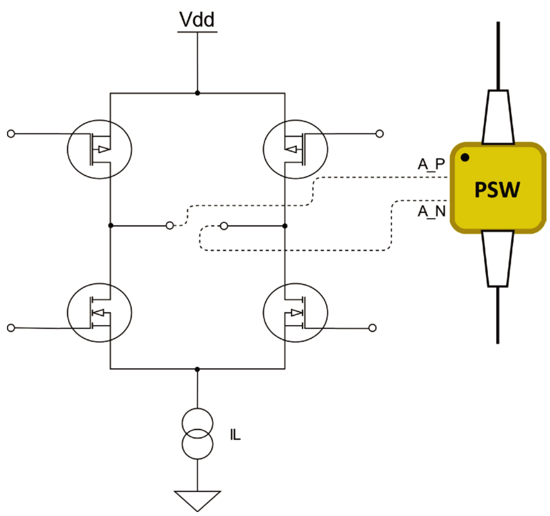


Figure 11 Diagram of a MOSFET H-bridge being used to drive one polarization switch

where X_L is the inductive reactance, f is the equivalent frequency, L is the ideal inductance and DCR is the DC resistance. For example, a driving signal with switch pulse width 50μs and 50% duty cycle would have frequency 10kHz. The overall reactance of the circuit is determined by the AC term 2πfL rather than the DC term DCR, so the driving voltage should be higher than DCR × 100mA to improve switching speed. Note that if the control pulse width exceeds the maximum specified value and the drive current is not limited, the power dissipation could exceed the absolute rate limit of 1W and damage the device. It is therefore necessary for the driver circuit to be current limited.

A driver circuit can be implemented using different approaches, such as an H-bridge, BTL amplifier, electronic analog switch, etc. The key is to provide a suitable driving current. In general, we recommend designing the driver with a MOSFET H-bridge. Figure 11 shows a typical H bridge used to drive a switch.

A_P and A_N are the drive pins for the switch. The current limit (IL) in Figure 11 could be implemented by using either a constant current source (CCS) or a current limiting (iLIM) solution such as a current chop in a motor driving chip. The purpose of IL is to set a maximum limit on the amount of current passing through the circuit so as to protect it from overdriving (and consequent overheating).

Most H-bridge driving ICs are suitable to drive the PSW-003. In particular, well-defined motor driver ICs with current chopping functions such as the Texas Instruments (TI) DRV8833 are good choices. Figure 12 demonstrates a driving solution using a DRV8833 chip to drive a PSW-003 with the current limitation function or protection.

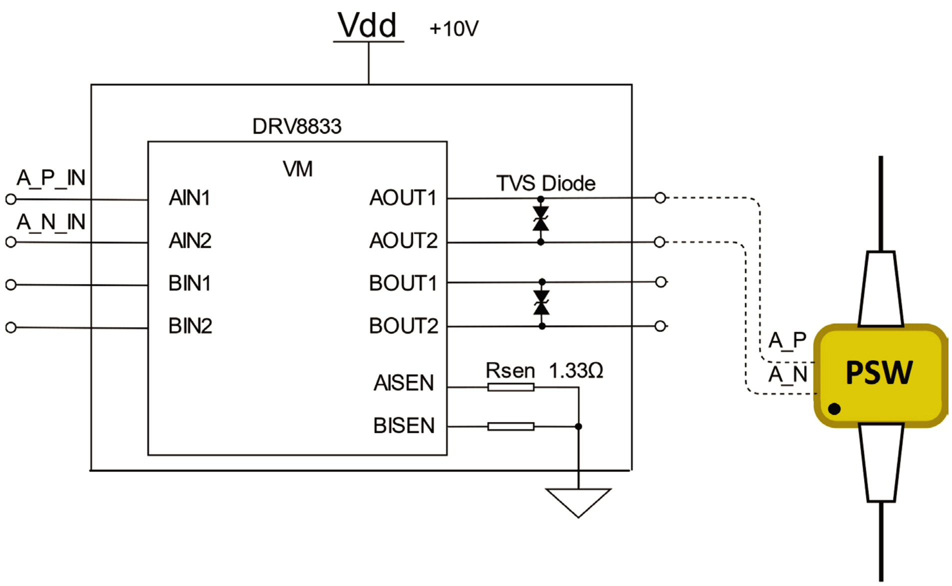


Figure 12 PSW-003 driver circuit example using a DRV8833 chip

Each DRV8833 has 2 full H-bridges, so it can drive two polarization switches. The voltage input Vdd for device power supply pin VM should be no higher than +10V. The current rating of the power supply for VM should be larger than 150mA × 150%. The maximum current passing through the switch is limited by current sensors (R_{sen}) that connect with AISEN/BISEN, where AISEN and BISEN are the bridge A and B current sensor pins, respectively. R_{sen} denotes the 1.33Ω current sensing resistors for the 150mA current chopping or limitation. The current limit can be calculated using Equation 2. We suggest using 1.33Ω/1206 (3216 Metric) resistors as R_{sen} and the maximum current allowance should be 150mA.

$$IC = \frac{0.2V}{R_{sen}} \qquad \text{Equation 2}$$

Additionally, TVS diodes connected in parallel can be used to reduce the induced voltage pulse peak during polarization state switching, thus reducing the switching noise of a circuit. Most TVS diodes with breakdown-voltage +1.2*VM would be suitable for this application. Ensure that the PSW-003's metal case is grounded by the mounting screws, thereby helping to reduce the switching noise.

DIMENSIONS

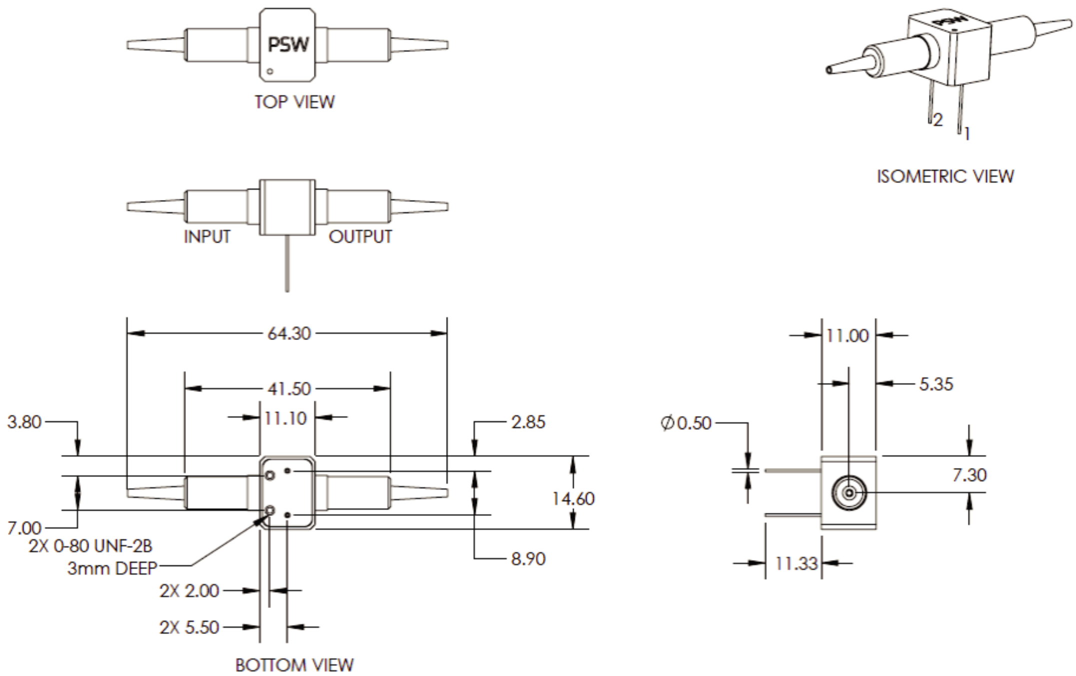


Figure 13 Mechanical drawing and dimensions (in mm)

ORDERING INFORMATION

Catalog #	Wavelength	SOP Rotation	Fiber Type	Input Polarizer	Pigtail Length	Connector Type
PSW-003	□□	□□	□□	□	□	□□
	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 Input) P – Input polarizer (slow axis)	1.0 – 1.0 m	FC/APC

Notes:

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

REVISION HISTORY

Revision	Date	Note
1.0	6/15/2022	Original document
1.1	9/06/2022	Configuration options modified

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