LSO-SERIES

PD-97812E

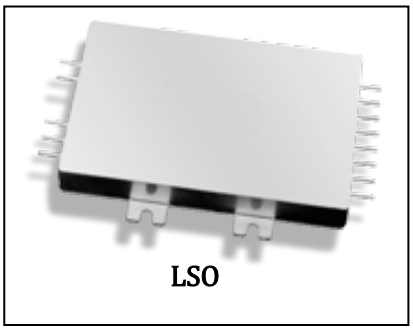
Hybrid – High Reliability
Radiation Hardened DC-DC Converter
28V Input, Single and Dual Output

Features

- 18 to 40V DC Input Range
- Total Dose > 100 kRads(Si)
- SEE Hardened to LET (Heavy Ions) up to 82 MeV·cm²/mg (SEU, SEL, SEGB, SEGR)
- Internal EMI filter; Converter Capable of meeting MIL-STD-461C CE03
- De-rated per MIL-STD-1547, MIL-STD-975 and NASA EEE-INST-002
- Magnetically Coupled Feedback
- Up to 30W Output Power
- Single and Dual Output Models Include 1.5, 1.8, 2.5, 3.3, 5, 12, 15, ±5, ±12 and ±15V
- Remote Sense Compensation for Single Output
- Latch-off Output Overvoltage Protection
- Input Current Telemetry
- Input Undervoltage Lockout with Latching Mode Options
- High Efficiency - to 81%
- 20MΩ @ 100VDC Isolation
- Undervoltage Protection
- Short Circuit and Overload Protection
- Adjustable Output Voltage
- Adjustable External OVP - 115% to 125%
- External Inhibit
- Low Weight, < 125 grams
- 4000000 Hour MTBF (SF)

Product Summary

- **Part number**: LSO2801R5S, LSO2801R8S, LSO2802R5S, LSO2803R3S, LSO2805S, LSO2812S, LSO2815S, LSO2805D, LSO2812D, LSO2815D



LSO

Potential Applications

- Geostationary Earth Orbit Satellites (GEO)
- Deep Space Satellites / Probes
- Communication and Display Systems
- Payload and Experiment Low Voltage Power Supply (LVPS)

Product Validation

Validated according to MIL-PRF-38534 for high-reliability applications

Orderable Part Numbers and DLA SMD Numbers

If a DLA SMD is available as listed in the table below, such model shall be ordered using the DLA SMD number. Otherwise the model shall be ordered using the part number nomenclature

Table 1 Ordering Information

Reference IR Base Model	Orderable Part Number	Lead finish	RHA
LSO2801R5S/CKA	5962-1522401KXA	Solder Dipped	No
LSO2801R5S/CKC	5962-1522401KXC	Gold Plated	No
LSO2801R5S/CKRA	5962R1522401KXA	Solder Dipped	Yes
LSO2801R5S/CKRC	5962R1522401KXC	Gold Plated	Yes
LSO2801R8S/CKA	5962-1522402KXA	Solder Dipped	No
LSO2801R8S/CKC	5962-1522402KXC	Gold Plated	No
LSO2801R8S/CKRA	5962R1522402KXA	Solder Dipped	Yes
LSO2801R8S/CKRC	5962R1522402KXC	Gold Plated	Yes
LSO2802R5S/CKA	5962-1522403KXA	Solder Dipped	No
LSO2802R5S/CKC	5962-1522403KXC	Gold Plated	No
LSO2802R5S/CKRA	5962R1522403KXA	Solder Dipped	Yes
LSO2802R5S/CKRC	5962R1522403KXC	Gold Plated	Yes
LSO2803R3S/CKA	5962-1522404KXA	Solder Dipped	No
LSO2803R3S/CKC	5962-1522404KXC	Gold Plated	No
LSO2803R3S/CKRA	5962R1522404KXA	Solder Dipped	Yes
LSO2803R3S/CKRC	5962R1522404KXC	Gold Plated	Yes
LSO2805D/CKA	5962-1522408KXA	Solder Dipped	No
LSO2805D/CKC	5962-1522408KXC	Gold Plated	No
LSO2805D/CKRA	5962R1522408KXA	Solder Dipped	Yes
LSO2805D/CKRC	5962R1522408KXC	Gold Plated	Yes
LSO2805S/CKA	5962-1522405KXA	Solder Dipped	No
LSO2805S/CKC	5962-1522405KXC	Gold Plated	No
LSO2805S/CKRA	5962R1522405KXA	Solder Dipped	Yes
LSO2805S/CKRC	5962R1522405KXC	Gold Plated	Yes
LSO2812D/CKA	5962-1522409KXA	Solder Dipped	No
LSO2812D/CKC	5962-1522409KXC	Gold Plated	No
LSO2812D/CKRA	5962R1522409KXA	Solder Dipped	Yes
LSO2812D/CKRC	5962R1522409KXC	Gold Plated	Yes
LSO2812S/CKA	5962-1522406KXA	Solder Dipped	No
LSO2812S/CKC	5962-1522406KXC	Gold Plated	No
LSO2812S/CKRA	5962R1522406KXA	Solder Dipped	Yes
LSO2812S/CKRC	5962R1522406KXC	Gold Plated	Yes

Reference IR Base Model	Orderable Part Number	Lead finish	RHA
LSO2815D/CKA	5962-1522410KXA	Solder Dipped	No

Description and Circuit Description

Reference IR Base Model	Orderable Part Number	Lead finish	RHA
LSO2815D/CKC	5962-1522410KXC	Gold Plated	No
LSO2815D/CKRA	5962R1522410KXA	Solder Dipped	Yes
LSO2815D/CKRC	5962R1522410KXC	Gold Plated	Yes
LSO2815S/CKA	5962-1522407KXA	Solder Dipped	No
LSO2815S/CKC	5962-1522407KXC	Gold Plated	No
LSO2815S/CKRA	5962R1522407KXA	Solder Dipped	Yes
LSO2815S/CKRC	5962R1522407KXC	Gold Plated	Yes

Description and Circuit Description

Description

The LSO Series of DC-DC converters are high reliability devices designed for hostile radiation hardened environments. The design is based on the heritage-rich LS Series with enhanced functional performance and an inclusion of an output overvoltage protection. The LSO Series provide up to 30 watts output power, small size, low weight, integrated EMI filtering and a high tolerance to environmental stresses such as radiation, temperature extremes, mechanical shock, and vibration. All components are fully de-rated to meet the requirements of MIL-STD-1547, MIL-STD-975 and NASA EEE-INST-002. Extensive documentation including, thermal analysis, stress analysis and reliability predictions are available.

The LSO Series of converters incorporate a fixed frequency single forward topology with magnetic feedback and an internal EMI filter. These converters are capable of meeting the conducted emissions requirements of MIL-STD-461C without any additional components. All models include an external inhibit port and have an adjustable output voltage. The converters are overload, short circuit and output over-voltage protected. They are enclosed in a hermetic 3.5" x 2.5" x 0.475" H steel package and weigh less than 125 grams. The package utilizes rugged ceramic feed-through copper core pins and is sealed using parallel seam welding.

Manufactured in a facility fully qualified to MIL-PRF-38534, these converters are fabricated utilizing DLA Land and Maritime qualified processes. For available screening options, refer to device screening table in the data sheet.

Variations in electrical specifications and screening to meet custom requirements can be accommodated.

Circuit Description

The LSO Series converters utilize a single-ended forward topology with resonant reset. The nominal switching frequency is 500kHz. Electrical isolation and tight output regulation are achieved through the use of a magnetically coupled feedback. Voltage feed-forward with duty factor limiting provides high line rejection.

An internal EMI filter allows the converter to meet the conducted emissions requirements of MIL-STD-461C on the input power leads.

Functional Notes

Input Current Telemetry: The LSO Series single and dual output models also feature an input current telemetry with a magnitude of 0 to 3.3V full scale. The voltage signal at this pin (Pin 7) with respect to Output Return (Pin 12) is equal to 1.5 times the input current (Vin TLM (V) =1.5 *Input Current (A)+/-0.1V).

Short Circuit and Overload Protection: Output current is limited under any load fault condition to approximately 125% of rated. An overload condition causes the converter output voltage to drop below nominal. The converter will resume normal operation when the load current is reduced below the current limit point. This protects the converter from both overload and short circuit conditions. The current limit point exhibits a slightly negative temperature coefficient to reduce the possibility of thermal runaway.

Input Undervoltage Lockout (UVLO) and Undervoltage Release (UVR): The converter is designed to be protected against an under-voltage condition. The converter will be in a non-functional (UVLO) mode when the input voltage is approximately 15.5V or less. The converter will turn on when the input voltage rises to 15.5V to 17.9V (defined as UVR threshold) and will provide a regulated output as the input voltage reaches 18V.

Functional Notes and Design Methodology

Should the input voltage drop below 16.5V to 14.5V (defined as UVLO threshold), the converter will turn off and remains off so long as the input voltage remains under the UVLO threshold. The converter will resume a normal operation when the input line rises above the UVR threshold. However, the converter can be configured to remain in a latch-up mode if desired

To take advantage of the latch-up feature, the U/V Latch Pin (Pin 5) should be shorted (with less than 100 Ohms) to the Inhibit Return Pin (Pin 4). Note that in this mode the converter will latch off if an under-voltage condition lasts more than 1milli-sec. The converter is reset by a shorted Enable Input pin command followed by an open Enable Input pin command.

Output Overvoltage Protection: The converter also features an output over-voltage protection. One OVP circuitry for each output for the dual output models. In an event the voltage output exceeds a preset voltage threshold of approximately 120 +/- 5% of nominal voltage output, the converter will turn off. The input power to the converter or the signal at the Inhibit pin must be recycled (connecting and removing the Inhibit pin to/from Inhibit Return pin) to turn on the converter. This event is possible only if the converter shuts off due to a false triggering. The OVP threshold voltage can also be reset to within 115% to 125% of nominal output voltage with two external resistors. Refer to the Application Notes section of the data sheet on page 24.

Inhibit (On/Off Command): An external inhibit port is provided to control converter operation. The converter's operation is inhibited when this pin is pulled low. It is intended to be driven by an open collector logic device. The pin may be left open for normal operation and has a nominal open circuit voltage of 4V with respect to the inhibit return (Pin 4).

Output Voltage Adjustment: The output voltage of all models can be adjusted greater or less than the nominal output voltage using a single external resistor. Refer to the Application Notes section of the data sheet on page 21.

Design Methodology

The LSO Series was developed using a proven conservative design methodology derived from other space level designs that includes selection of established reliability components and fully de-rating to the requirements of MIL-STD-1547, MIL-PRF-975 and NASA EEE-INST-002 except for the CDR type ceramic capacitors, a capacitor with 50V rating is used for in-circuit voltage stress of less than 10V. A magnetic feedback circuit is utilized instead of opto couplers to minimize temperature, aging and radiation sensitivity. PSPICE was used extensively to predict and optimize circuit performance for both beginning and end-of-life. Thorough design analyses include stress, thermal, and reliability (MTBF).

Table of contents

1 Specification and Electrical Performance

1.1 Maximum and Operating Table

Table 2 Absolute Maximum Rating and Recommended Operating Conditions

Absolute Maximum Rating		Recommended Operating Conditions	
Input voltage	-0.5V_{DC} to +60V_{DC}	Input voltage range [1]	+18V_{DC} to +40V_{DC}
Output power	Internally limited	Output power	0 to Max. Rated
Lead Temperature	+300°C for 10 seconds	Operating Temperature	-55°C to +85°C
Operating Temperature	-55°C to +125°C (Note 13)	Storage Temperature	-55°C to +70°C
Storage Temperature	-55°C to +135°C		

1.2 Electrical Performance Characteristics

Table 3 Electrical Characteristics

Parameter	Group A Subgroups	Conditions -55°C ≤ TC ≤ +85°C V_{IN} = 28V DC ± 5%, CL = 0 unless otherwise specified	Limits			Unit
			Min	Nom	Max	
Input voltage (V_{IN})			18	28	40	V
Output Voltage (V_{OUT})		I_{OUT} = 100% rated load Note 4				V
LSO2801R5S	1		1.47	1.50	1.53	
LSO2801R8S	1		1.77	1.80	1.83	
LSO2802R5S	1		2.47	2.50	2.53	
LSO2803R3S	1		3.27	3.30	3.33	
LSO2805S	1		4.95	5.00	5.05	
LSO2812S	1		11.88	12.0	12.12	
LSO2815S	1		14.85	15.0	15.15	
LSO2805D	1		±4.95	±5.00	±5.05	
LSO2812D			±11.88	±12.0	±12.12	
LSO2815D			±14.85	±15.0	±15.15	
LSO2801R5S	2,3		1.43		1.57	
LSO2801R8S	2,3		1.73		1.87	
LSO2802R5S	2,3		2.43		2.57	
LSO2803R3S	2.3		3.23		3.37	
LSO2805S	2,3		4.90		5.10	
LSO2812S	2,3		11.75		12.24	
LSO2815S	2,3		14.70		15.30	
LSO2805D	2,3		±4.90		±5.10	
LSO2812D			±11.78		±12.24	
LSO2815D			±14.70		±15.30	

[1] Meets MIL-STD-1547, MIL-STD-975 and NASA EEE-INST-002
up to the input voltage at 38.6V.

Specification and Electrical Performance

Parameter	Group A Subgroups	Conditions -55°C ≤ TC ≤ +85°C V_{IN} = 28V DC ± 5%, CL = 0 unless otherwise specified	Limits			Unit
			Min	Nom	Max	
For Notes to Electrical Performance Characteristics, refer to page 12						
Output power (P_{OUT})						
LSO2801R5S	1,2,3	V_{IN} = 18, 28, 40 Volts, Note 2	1		12	W
LSO2801R8S			1		14.4	
LSO2802R5S			1		20	
LSO2803R3S			1		25	
All Others			1		30	
Output current (I_{OUT})						
LSO2801R5S	1,2,3	VI_N = 18, 28, 40 Volts, Note 2	0		8.0	A
LSO2801R8S			0		8.0	
LSO2802R5S			0		8.0	
LSO2803R3S			0		7.57	
LSO2805S			0		6.0	
LSO2812S			0		2.5	
LSO2815S			0		2.0	
LSO2805D		Either Output, Note 3	0		4.8	
LSO2812D		Either Output, Note 3	0		2.3	
LSO2815D		Either Output, Note 3	0		1.6	
Line regulation (VR_{LINE}) All Single and Dual Output Models	1,2,3	V_{IN} = 18, 28, 40 Volts I_{OUT} = 0, 50%, 100% rated, Note 4	-0.5		-0.5	%
Load regulation (VR_{LOAD}) All Single Output Models	1,2,3	V_{IN} = 18, 28, 40 Volts I_{OUT} = 0, 50%, 100% rated, Note 4	-1.0		1.0	%
Total regulation (Line and Load)	1,2,3	V_{IN} = 18 to 40 Volts Min load to full load Dual model is measured from +Output to -Output, Note 13	-1.0		1.0	%
Cross regulation (VR_{CROSS})						
LSO2805D	1,2,3	V_{IN} = 18, 28, 40 Volts Duals only, Note 5	-5.0		5.0	%
LSO2812D			-3.0		3.0	
LSO2815D			-3.0		3.0	
For Notes to Electrical Performance Characteristics, refer to page 12						
Input current, no load (I_{IN})	1,2,3	I_{OUT} = 0, Pin 3 open	0 0		60 60	mA

Parameter	Group A Subgroups	Conditions -55°C ≤ TC ≤ +85°C V_{IN} = 28V DC ± 5%, CL = 0 unless otherwise specified	Limits			Unit
			Min	Nom	Max	
LSO2801R5S			0		60	
LSO2801R8S			0		70	
LSO2802R5S			0		70	
LSO2803R3S			0		70	
LSO2805S			0		70	
LSO2812S			0		70	
LSO2815S			0		100	
LSO2805D			0		100	
LSO2812D						
LSO2815D						
Input current inhibited	1,2,3	Pin 4 shorted to Pin 3			8.0	mA
Output ripple (V_{RIP})						
LSO2801R5S					35	
LSO2801R8S					35	
LSO2802R5S					35	
LSO2803R3S		V_{IN} = 18, 28, 40 Volts			35	
LSO2805S	1,2,3	I_{OUT} = 100% rated load			50	mV $_{p-p}$
LSO2812S		Notes 4, 6			50	
LSO2815S					50	
LSO2805D					50	
LSO2812D					50	
LSO2815D					50	
Switching frequency (F_S)	1,2,3		425	500	575	kHz
Efficiency (E_{FF})						
LSO2801R5S			60	62		
LSO2801R8S			63	65		
LSO2802R5S			67	69		
LSO2803R3S			71	73		
LSO2805S	1,2,3	I_{OUT} = 100% rated load Notes 4	77	80		%
LSO2812S			77	80		
LSO2815S			77	80		
LSO2805D			76	79		
LSO2812D			78	81		
LSO2815D			78	81		

For Notes to Electrical Performance Characteristics, refer to page 12

Input Undervoltage lockout (UVLO)	1,2,3	No load to full load, Notes 4	14.0		16.5	V

Parameter	Group A Subgroups	Conditions -55°C ≤ TC ≤ +85°C V_{IN} = 28V DC ± 5%, CL = 0 unless otherwise specified	Limits			Unit
			Min	Nom	Max	
(turn off when input voltage decreasing)						
Input Undervoltage release (UVR) (turn on when input voltage rising)	1,2,3	No load to full load, Notes 4	15.5		17.9	V
Input Undervoltage Hysteresis (UVR-UVLO)	1,2,3	No load to full load, Notes 4	1.0		3.0	V
Input current telemetry ratio (ICT)	1,2,3	I_{OUT} = 100% rated load, Note 4	1.4		1.6	V/A
Overvoltage protection (OVP) Output voltage threshold (for single and each of dual output models)	1,2,3	No load to full load, Notes 1, 4	115		125	% of nominal V_{out}
Enable/Inhibit Input open circuit voltage drive current (sink) voltage range		Note 1	3.0 -0.5		6.0 100 50	V µA V
Current Limit Point Expressed as a percentage of full rated load current		V_{OUT} = 90% of Nominal, Note 4	105		145	%
Power dissipation, load fault (P_D)	1,2,3	Short Circuit, Overload, Note 8			16	W
Output response to step load changes (V_{TLD})	4,5,6	Half Load to/from Full Load, Notes 4,9	-300		300	mVpk
Recovery time, step load changes (T_{TLD})	4,5,6	Half Load to/from Full Load, Notes 4,9,10			200	µs
Output response to step line changes (V_{TLN})		18V to/from 40V I_{OUT} = 100% rated load, Notes 1,4,11	-300		300	mVpk
Recovery time, step line changes (T_{TLN})		18V to/from 40V I_{OUT} = 100% rated load, Notes 1,4,10,11			200	µs

For Notes to Electrical Performance Characteristics, refer to page 12

Turn-on Overshoot (V_{OS}) All Single and Dual Output Models Turn-on Delay (T_{DLY})	4,5,6	10% Load, Full Load Notes 4,12	 0		50 10	mV ms

Specification and Electrical Performance

Parameter	Group A Subgroups	Conditions -55°C ≤ TC ≤ +85°C V_{IN} = 28V DC ± 5%, CL = 0 unless otherwise specified	Limits			Unit
			Min	Nom	Max	
All Single and Dual Output Models						
Capacitive Load (C_L)						
LSO2801R5S					2500	
LSO2801R8S					2500	
LSO2802R5S		I_{OUT} = 100% rated load			2500	
LSO2803R3S		No effect on DC performance			2200	
LSO2805S		Notes 1,4,7			1000	µF
LSO2812S					180	
LSO2815S					120	
LSO2805D		Each output on duals			500	
LSO2812D		Each output on duals			90	
LSO2815D		Each output on duals			60	
Line Rejection		I_{OUT} = 100% rated load DC to 50kHz, Notes 1, 4	40	50		dB
Isolation	1	Input to Output or Any Pin to Case except Pin 6, test @ 100VDC	20			MΩ
Device Weight					125	g
MTBF		MIL-HDBK-217F2, SF, 35°C Note 14	4.0×10^6			Hrs

Notes: Electrical Performance Characteristics Table

1. Parameter is tested as part of design characterization or after design changes. Thereafter, parameter shall be guaranteed to the limits specified.
2. Parameter verified during line and load regulation tests.
3. Output load current must be distributed such that at least 20% of the total load current is being provided by one of the outputs.
4. Load current split equally between outputs on dual output models.

5. Cross regulation is measured with 20% rated load on output under test while changing the load on the other output from 20% to 80% of rated.
6. Guaranteed for a DC to 20MHz bandwidth. Tested using a 20kHz to 10MHz bandwidth. using the circuit shown in Figure 1.
7. Capacitive load may be any value from 0 to the maximum limit without compromising dc performance. For a capacitive load in excess of the maximum limit, consult the factory.
8. Overload power dissipation is defined as the device power dissipation with the load set such that V_{OUT} = 90% of nominal.
9. Load step transition time ≤ 10 µs.
10. Recovery time is measured from the initiation of the transient to where VOUT has returned to within ±1% of its steady state value.
11. Line step transition time ≤ 100 µs.
12. Turn-on delay time from either a step application of input power or a logic low to a logic high transition on the inhibit pin (pin 3) to the point where V_{OUT} = 90% of nominal.
13. End of Life (EOL) is ± 3%
14. MIL-HDBK MOSFET failure rates replaced by empirical failure rate data supplied by IR HiRel.

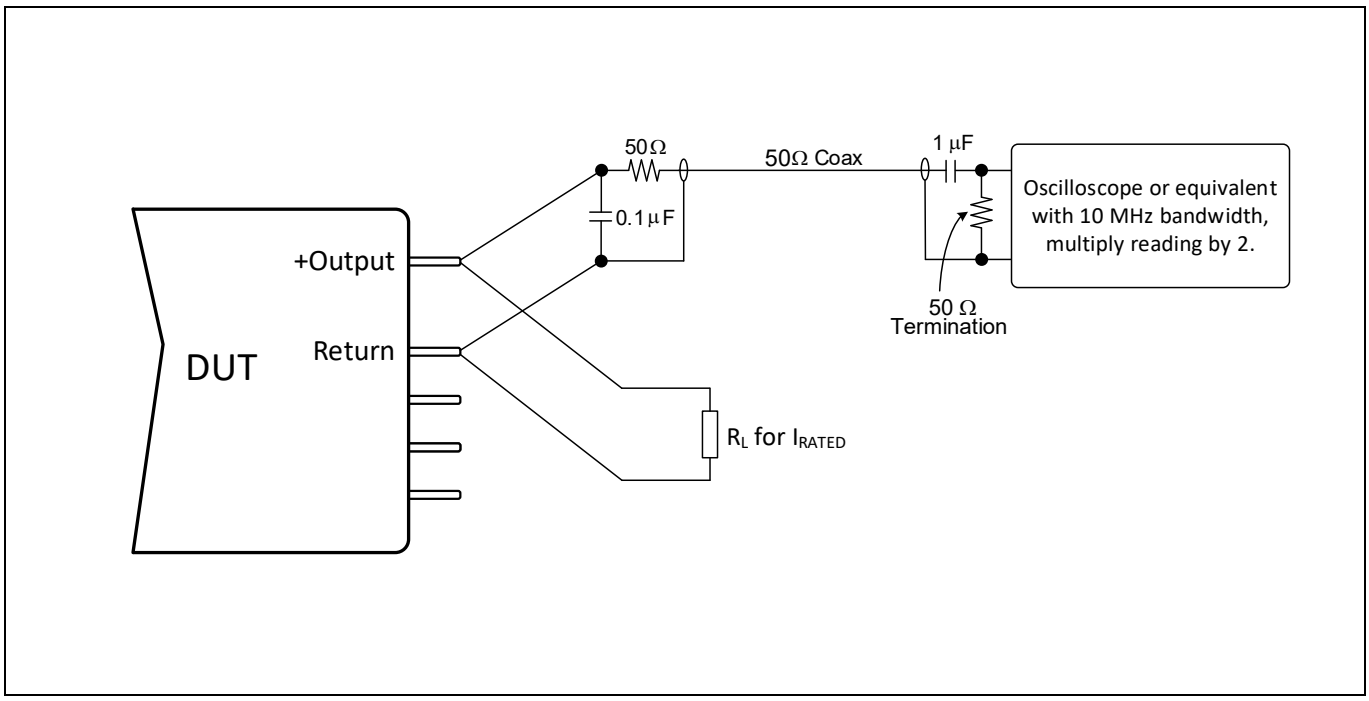


Figure 1 Circuit for measuring Output Ripple Voltage

2 Block Diagram

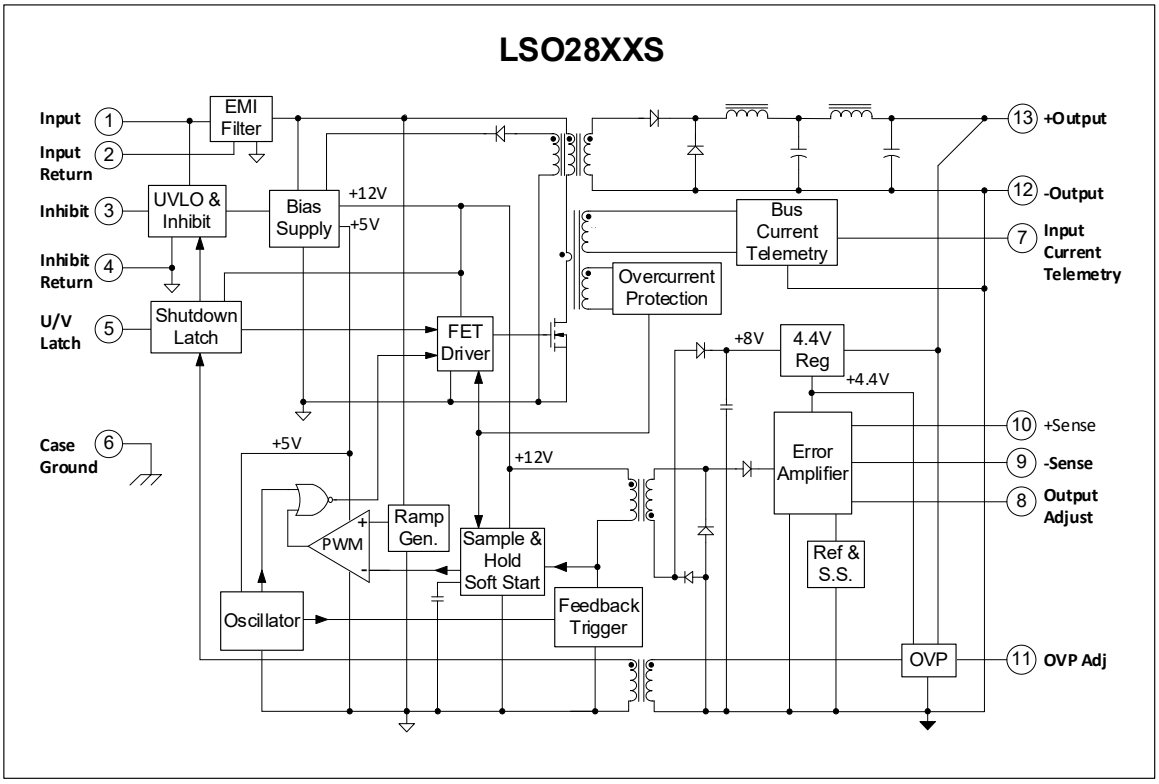


Figure 2 Block Diagram - Single Output

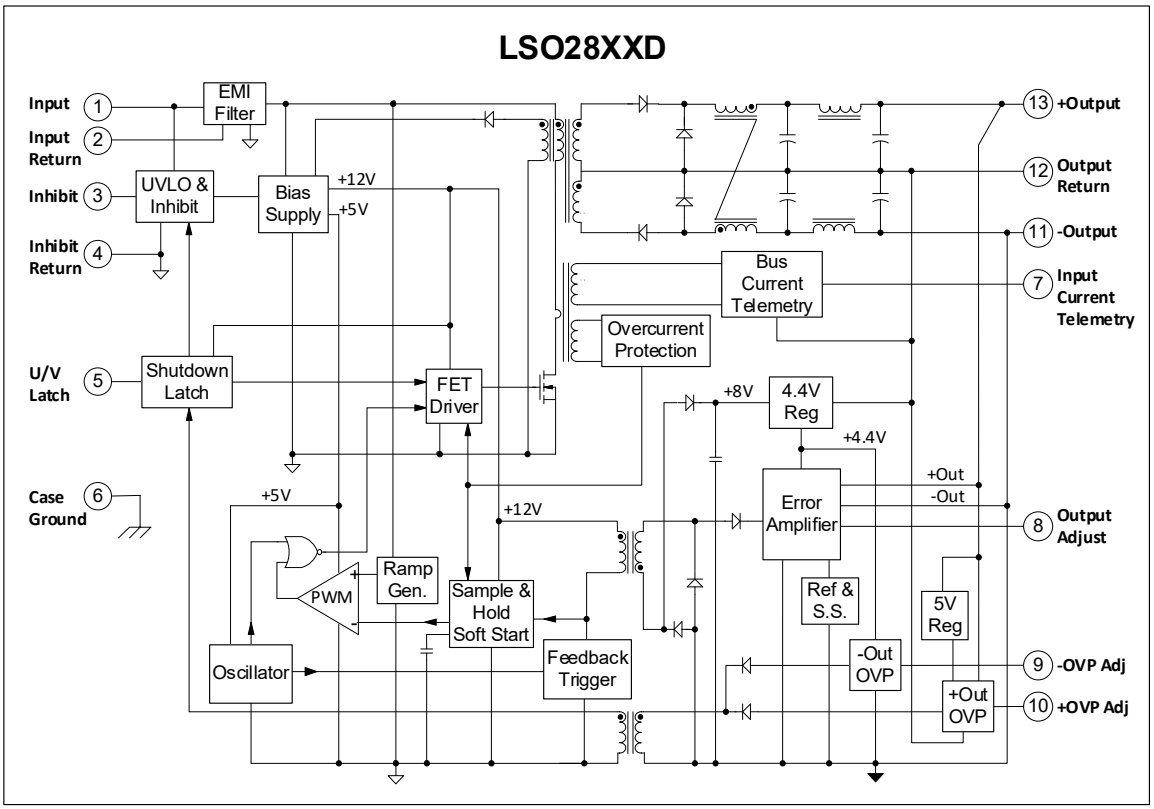


Figure 3 Block Diagram - Dual Output

3 Typical curves

Typical Performance Curves: 25°C T_C, 28 V_{DC} V_{IN}, Rated Load, unless otherwise specified

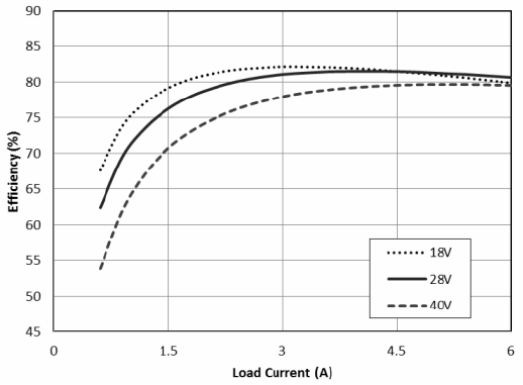


Figure 4 LSO2805S Efficiency

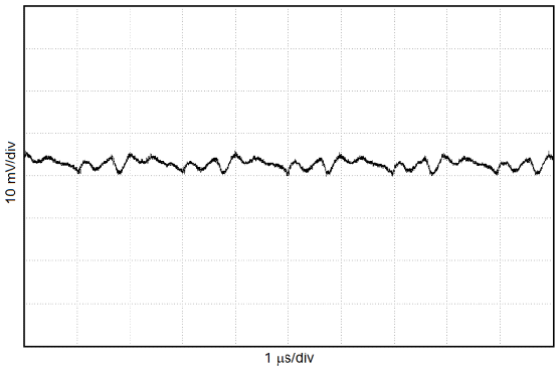


Figure 5 LSO2805S Output Ripple

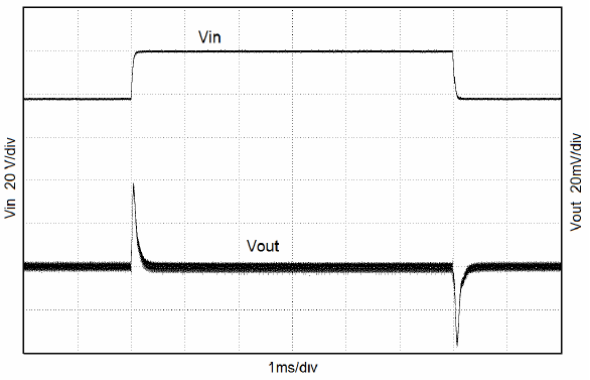


Figure 6 LSO2805S Step Line Response 18V to/from 40V

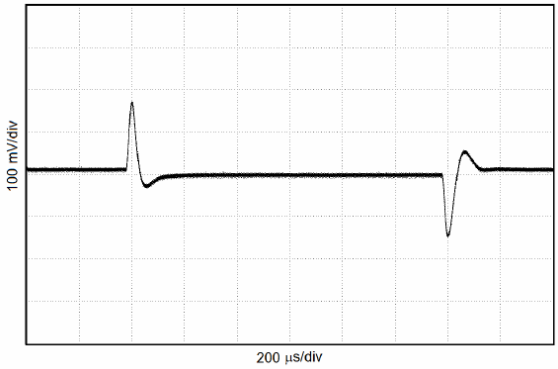


Figure 7 LSO2805S Step Load Response. Half load to/from Full Load, 0.25A/µs Slew Rate

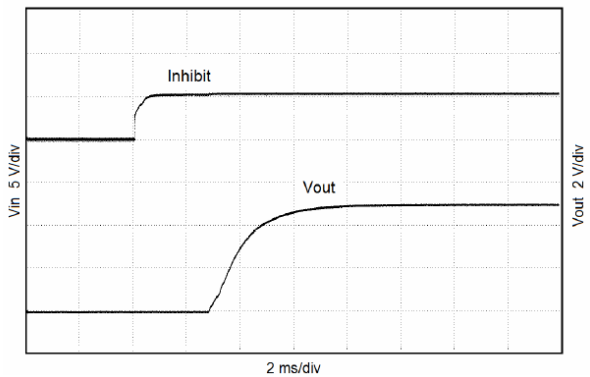


Figure 8 LSO2805S Turn on Response

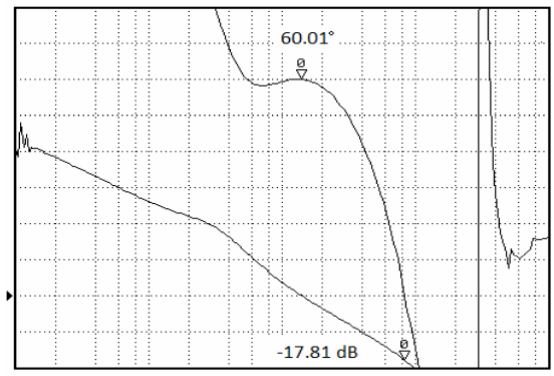


Figure 9 LSO2805S Loop Response, Phase = 63.51° and Gain = -17.42dB

Typical curves

Typical Performance Curves: 25°C T_C, 28 V_{DC} V_{IN}, Rated Load, unless otherwise specified

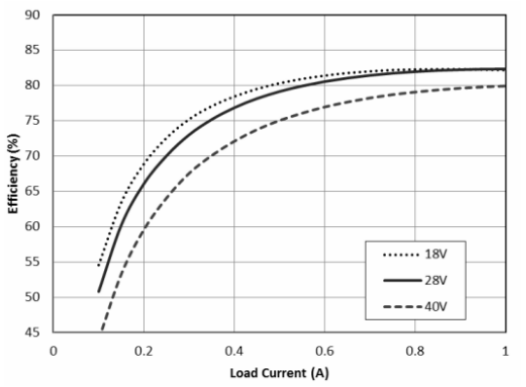


Figure 10 LSO2815D Efficiency

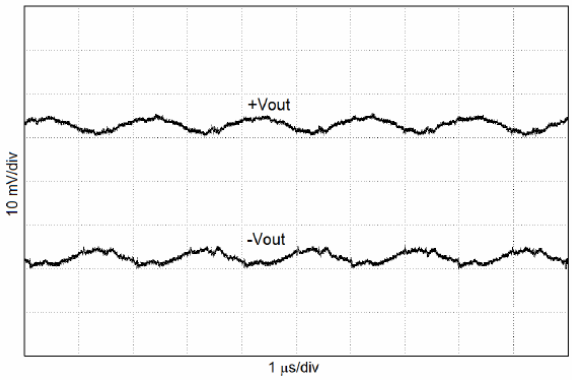


Figure 11 LSO2815D Output Ripple

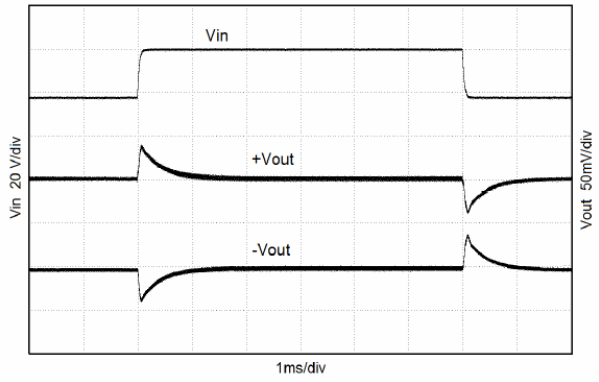


Figure 12 LSO2815D Step Line Response 18V to/from 40V

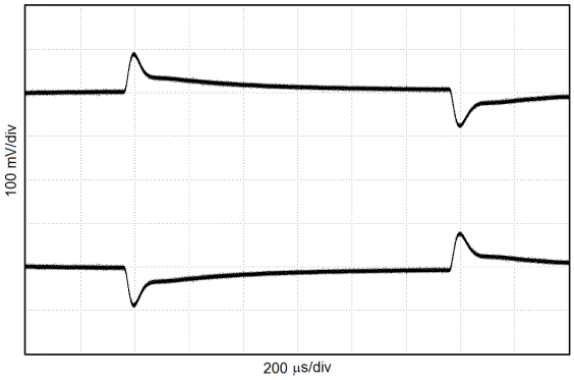


Figure 13 LSO2815D Step Load Response. Half load to/from Full Load, 0.05A/µs Slew Rate

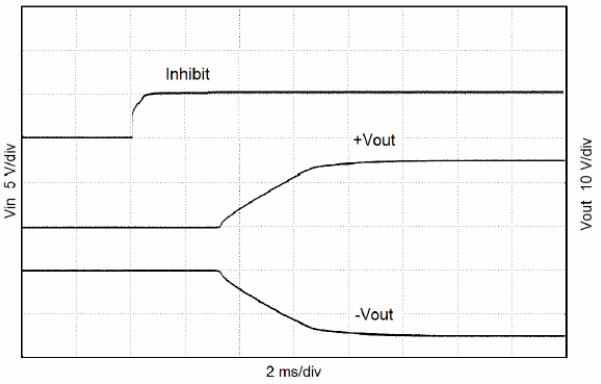


Figure 14 LSO2815D Turn on Response

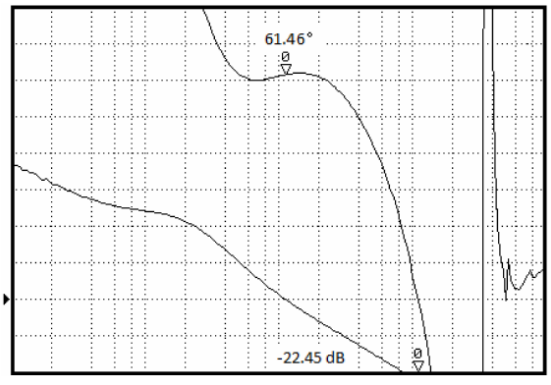


Figure 15 LSO2815D Loop Response, Phase = 61.46° and Gain = -22.45dB

Typical curves

Typical Performance Curves: 25°C T_C, 28 V_{DC} V_{IN}, Rated Load, unless otherwise specified

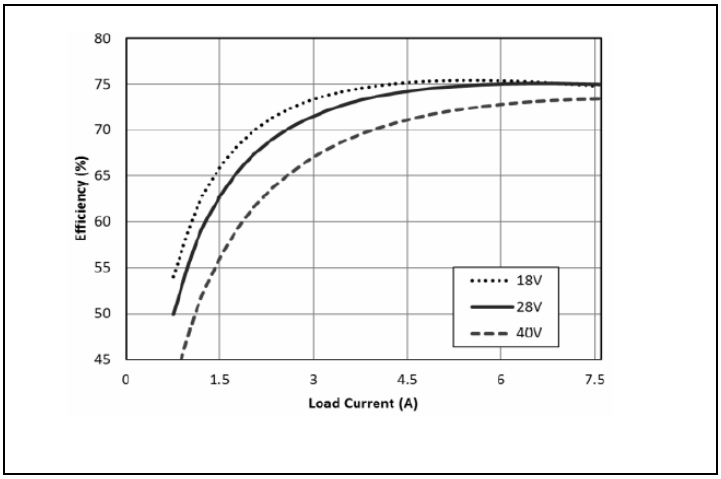


Figure 16 LSO2803R3S Efficiency

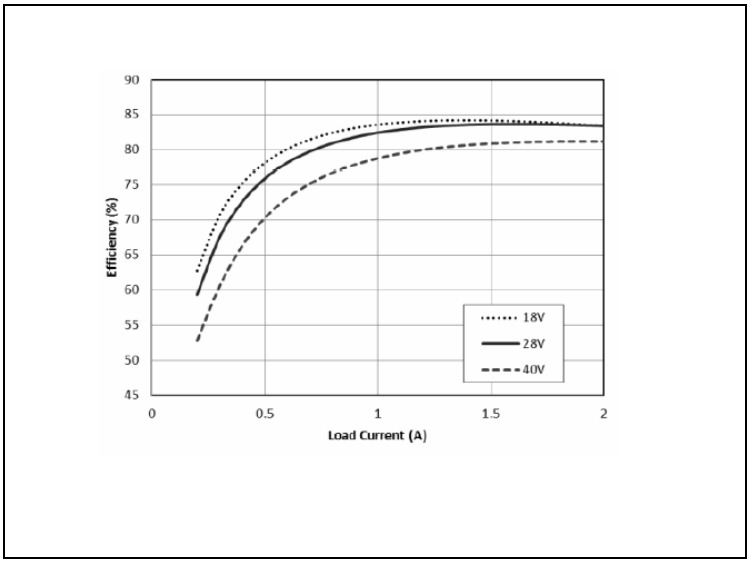


Figure 17 LSO2815S Efficiency

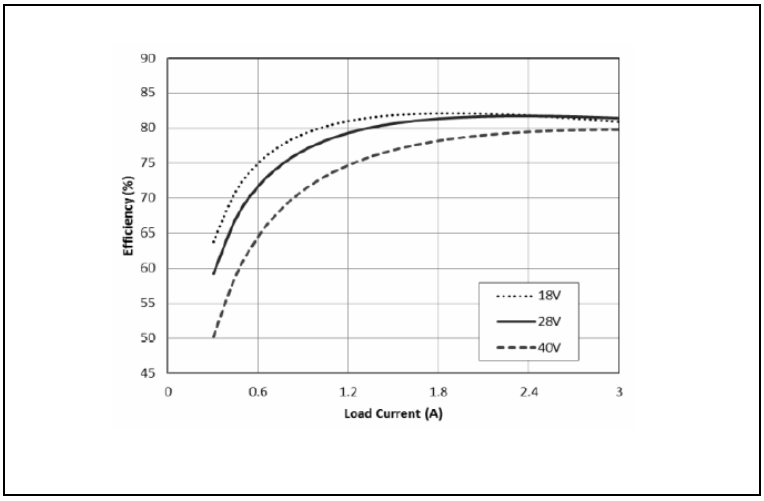


Figure 18 LSO2805D Efficiency

Typical Performance Curves: 25°C T_C, 28 V_{DC} V_{IN}, Rated Load, unless otherwise specified

Typical curves

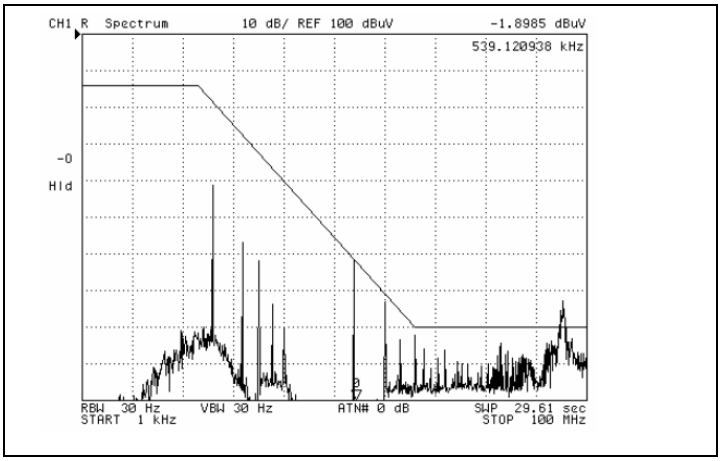


Figure 19 LSO2805S Full Load, Negative Lead

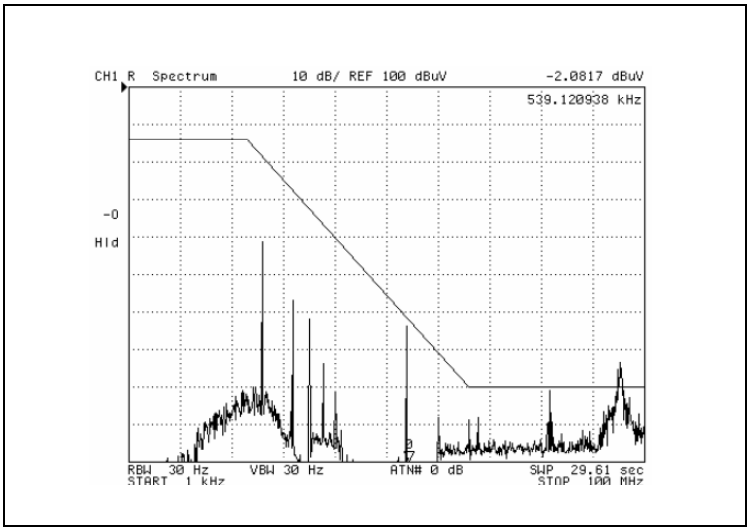


Figure 20 LSO2805S Full Load, Positive Lead

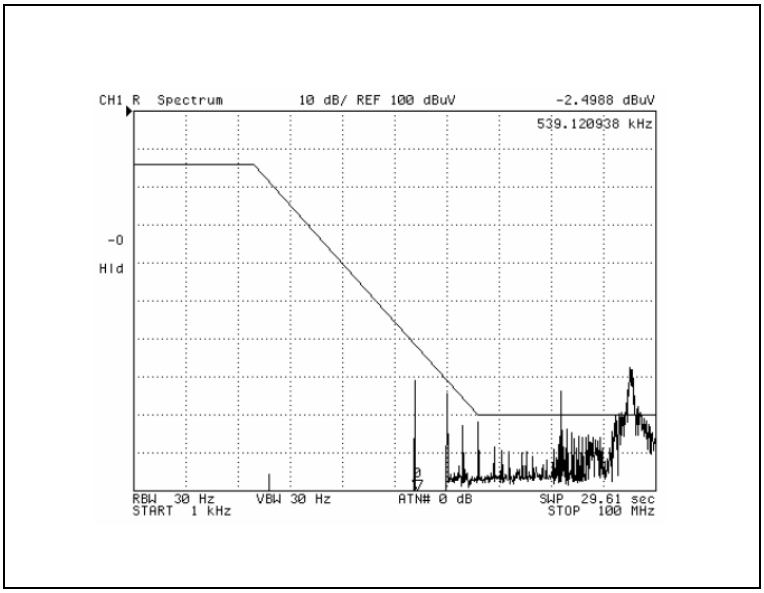


Figure 21 LSO2805S Full Load, Common Mode

Typical Performance Curves: 25°C T_C, 28 V_{DC} V_{IN}, Rated Load, unless otherwise specified

Typical curves

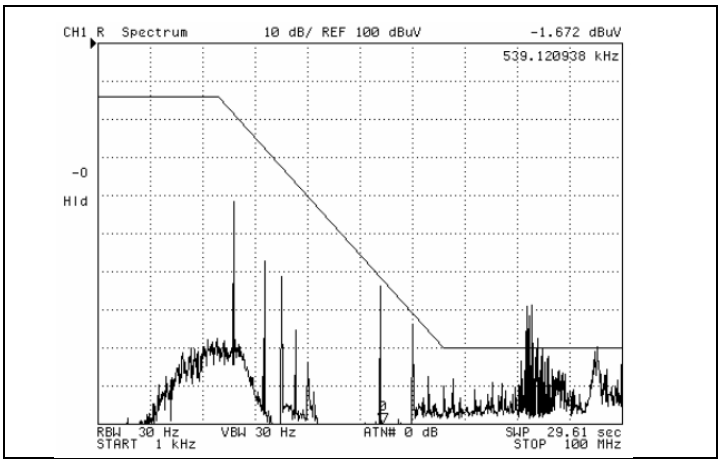


Figure 22 LSO2815D Full Load, Negative Lead

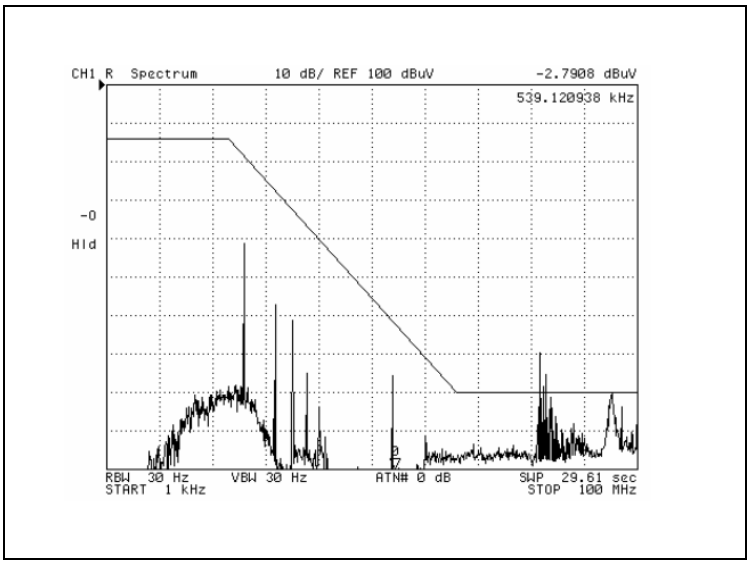


Figure 23 LSO2815D Full Load, Positive Lead

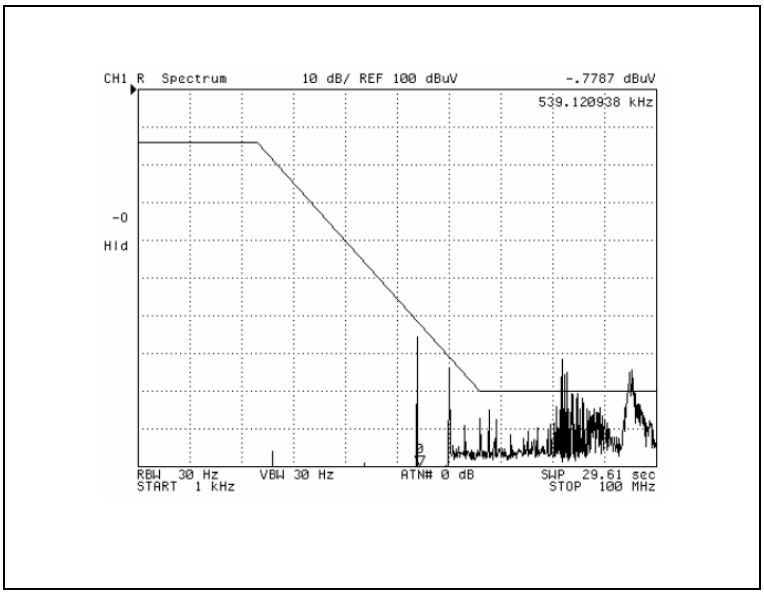


Figure 24 LSO2815D Full Load, Common Mode

4 Radiation Performance table and Application Notes

4.1 Radiation Performance table

Table 4 Radiation Performance Characteristics

Test	Conditions	Min	Typ	Unit
Total Ionizing Dose (Gamma)	MIL-STD-883 Method 1019 Operating bias applied during exposure, Full Rated Load, V_{IN} = 28V	100	150	kRads (Si)
Single Event Effects SEU, SEL, SEGR, SEB	Heavy ions (LET) Operating bias applied during exposure, Full Rated Load, V_{IN} = 18V, 28V, 40V **Test lab: Cyclotron Institute Texas A & M University**	82		MeV·cm²/mg

4.2 Application Notes

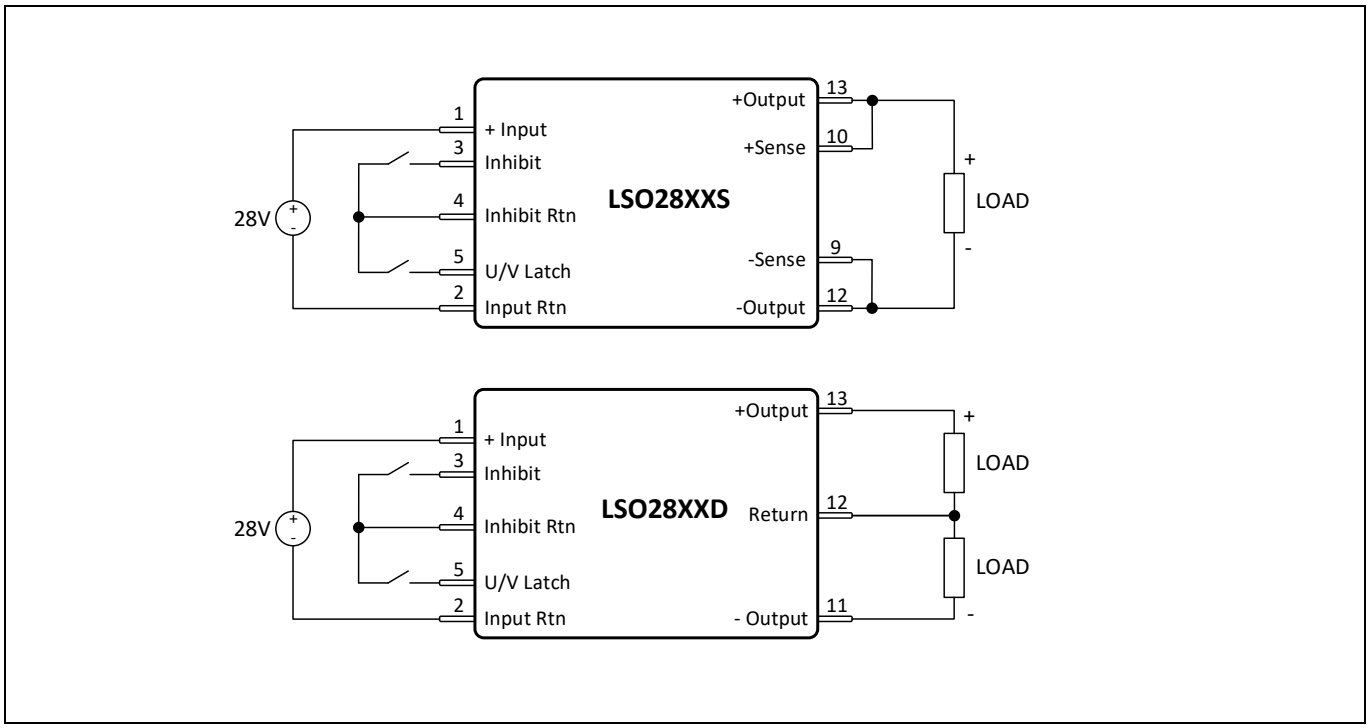


Figure 25 Typical Connections Diagram

Application Notes

Inhibit Function:

The converter is disabled when the INHIBIT pin is shorted to the INHIBIT RETURN with an impedance less than or equal to 1K ohm, and that the converter be enabled when the impedance between the INHIBIT pin and INHIBIT RETURN is greater than or equal to 500 kOhms.

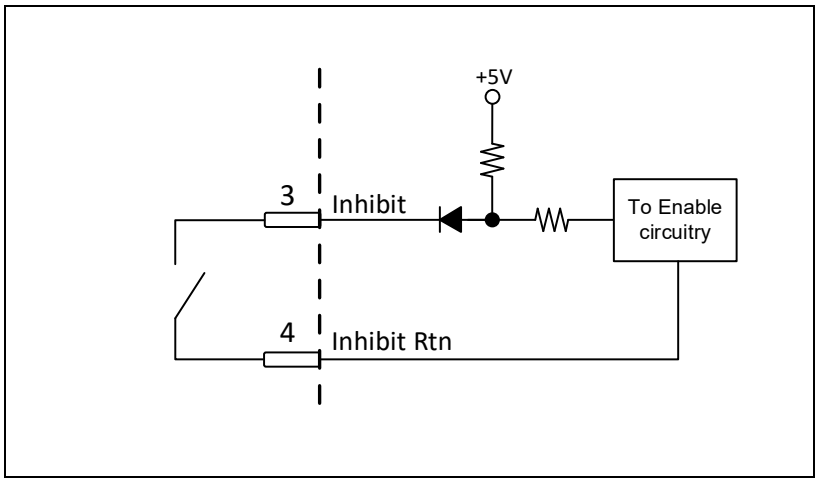


Figure 26 Inhibit Function

Remote Sense:

A remote sense feature maintains the desired output voltage regulation at the load. It corrects the voltage drop along the conductors between converter's output and the load. To use this function, connect ±sense pins directly to the load as shown in Figure 27. To use a converter without remote sense function, connect the ±sense pins to output pins respectively. This function is available just on single output models.

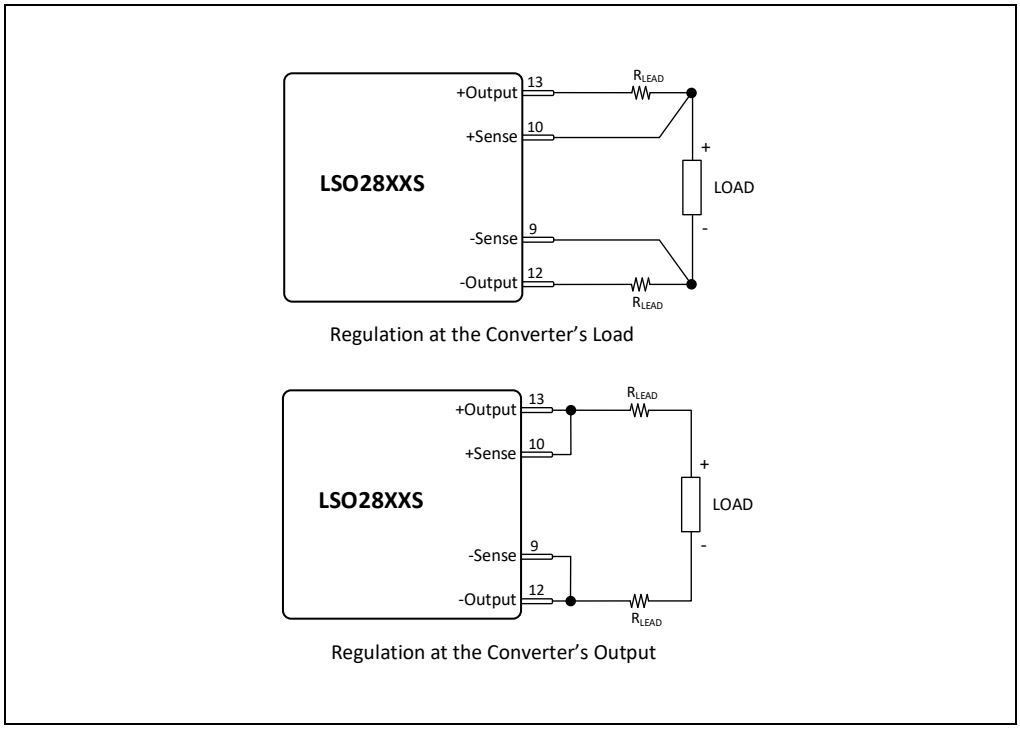


Figure 27 Remote Sense – Single Models

Output Voltage Adjustment:

Application Notes

Output of LSO singles and duals can be adjusted to be greater or less the nominal output voltage with an external resistor. However, the ranges of the output voltages are limited depending on the model as specified in Table 5 thru Table 11. An approximate value of the resistor can be determined using the following formula.

For Single Output Models:

$$Radj = \frac{A - (B * Vout)}{(C * Vout) - D}$$

For Dual Output Models:

$$Radj = \frac{A - (B * 2 * Vout)}{(C * 2 * Vout) - D}$$

Where:

Radj is the external resistor in ohms, as shown in Figure 28. Power rating of the resistor shall be ≥ 0.125 W. Metal film resistor with temperature coefficient of ≤ ± 50 ppm and tolerance of ≤ 1% is recommended. However, the final selection is dependent on specific design requirements.

Vout is the output voltage in volts.

A, B, C and D are unique constants depending on every model as shown in Table 5 thru Table 8 for single output models and Table 9 thru Table 11 for dual output models.

Placement of Radj: An external resistor must be added in order to trim the output voltage of a LSO converter. The placement of a Radj resistor must be connected as shown in Figure 28.

Singles: Radj is placed across Out Adj and ± Sense pins. For output voltage greater than nominal voltage, Radj is placed from Out Adj to –Sense. To have output voltage less than nominal voltage, place Radj across Out Adj and +Sense.

Duals: Radj is placed across Out Adj and ± Output pins respectively.

Table 5 LSO2803R3S. Output Voltage Ranges and Constants

	Output voltage Low range	Output voltage High range
Constants	**3.135V to 3.300V**	**3.300V to 3.465V**
A	466.4 x10^6	466.0 x10^6
B	238.3 x10^6	84 x10^6
C	9550	9550
D	31489	31489

Table 6 LSO2805S. Output Voltage Ranges and Constants

	Output voltage Low range	Output voltage High range

Constants	4.750V to 5.000V	5.000V to 5.250V
A	588.3 x10⁶	587.8 x10⁶
B	264.5 x10⁶	69.96 x10⁶
C	7950	7950
D	39717	39717

Table 7 LSO2812S. Output Voltage Ranges and Constants

	Output voltage Low range	Output voltage High range
Constants	11.400V to 12.000V	12.000V to 12.600V
A	1188.3 x10⁶	1187.3 x10⁶
B	452.0 x10⁶	58.8 x10⁶
C	6690	6690
D	80193	80193

Table 8 LSO2815S. Output Voltage Ranges and Constants

	Output voltage Low range	Output voltage High range
Constants	14.250V to 15.000V	15.000V to 15.750V
A	1452.4 x10⁶	1451.2 x10⁶
B	538.1 x10⁶	57.5 x10⁶
C	6540	6540
D	98020	98020

Table 9 LSO2805D. Output Voltage Ranges and Constants

	Output voltage Low range	Output voltage High range
Constants	±4.750V to ±5.000V	±5.000V to ±5.250V

A	1012.4 x10⁶	1011.5 x10⁶
B	395.0 x10⁶	60.1 x10⁶
C	6840	6840
D	68344	68344

Table 10 LSO2812D. Output Voltage Ranges and Constants

	Output voltage Low range	Output voltage High range
Constants	±11.400V to ±12.000V	±12.000V to ±12.600V
A	2246.1 x10⁶	2244.3 x10⁶
B	798.1 x10⁶	55.6 x10⁶
C	6320	6320
D	151669	151669

Table 11 LSO2815D. Output Voltage Ranges and Constants

	Output voltage Low range	Output voltage High range
Constants	±14.250V to ±15.000V	±15.000V to ±15.750V
A	2780.2 x10⁶	2777.9 x10⁶
B	974.8 x10⁶	55.0 x10⁶
C	6260	6260
D	187646	187646

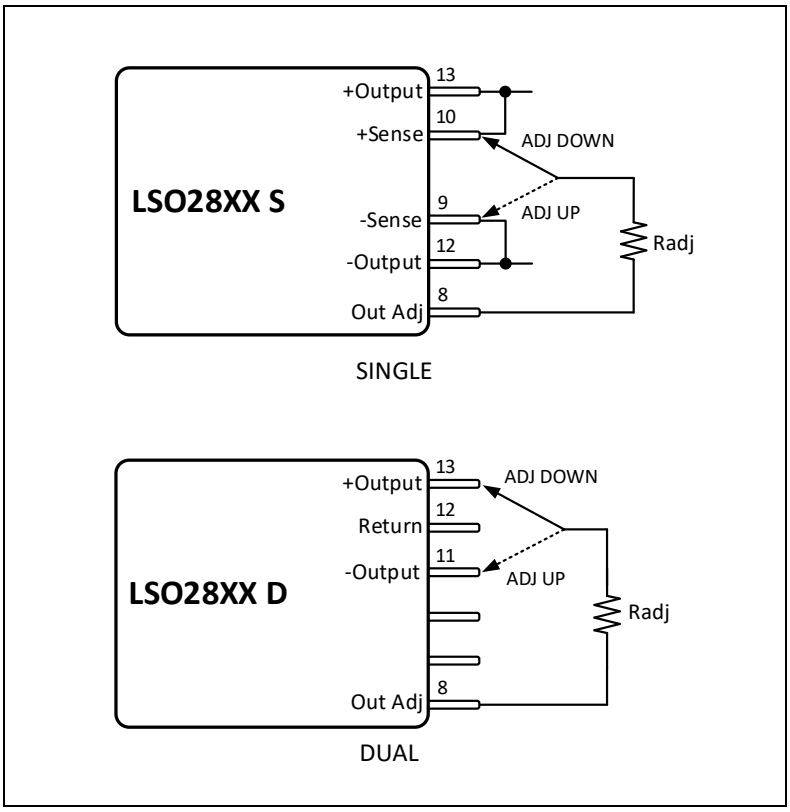


Figure 28 Output Voltage Adjustment

OVP External Adjustment:

Over-voltage Protection threshold of LSO singles and duals can be adjusted to be greater or less the nominal OVP with a couple of external resistors. Lower resistors, R1 and R2 are 10 kΩ resistors, while Radj set the new OVP threshold as stated in Table 12 for single output models and Table 13 for dual output models. Ranges of LSO series converter can be adjusted from 115% to 125% of the nominal output voltage. See Figure 29 to place external resistors.

An approximate value of the resistor can be determined using the following formula.

$$Radj = \frac{(A * Vovp) - B}{C - (D * Vovp)}$$

Where:

Radj is the upper external resistor in kilo-ohms, as shown in Figure 29. Power rating of the resistor shall be ≥ 0.125 W. Metal film resistor with temperature coefficient of ≤ ± 50 ppm and tolerance of ≤ 1% is recommended. However, the final selection is dependent on specific design requirements.

Vovp is the output voltage protection limit in volts.

A, B, C and D are unique constants depending on every model.

Placement of Radj: Two external resistors must be added in order to set new OVP threshold.

Singles: Radj (OVP) is placed across +Output and OVP Adj pins and R1 from OVP Adj to -Output.

Duals: Radj (+OVP) is placed across +Output and +OVP Adj pins and R1 from +OVP Adj to -Return. Radj (-OVP) is placed across +Return and -OVP Adj pins while R2 is placed across -OVP Adj to –Output

Table 12 LSO Singles. OVP External

	LSO2803R3S		LSO2805S		LSO2812S		LSO2815S	
Range	OVP (V)	Radj (KΩ)	OVP (V)	Radj (KΩ)	OVP (V)	Radj (KΩ)	OVP (V)	Radj (KΩ)
Vo* (115%)	3.795	13.5	5.75	26.4	13.80	79.3	17.25	101.9
Vo* (116%)	3.828	14.9	5.80	28.4	13.92	83.9	17.40	107.7
Vo* (117%)	3.861	16.4	5.85	30.7	14.04	89.0	17.55	114.0
Vo* (118%)	3.894	18.1	5.90	33.1	14.16	94.6	17.70	120.9
Vo* (119%)	3.927	20.1	5.95	35.9	14.28	100.7	17.85	128.4
Vo* (120%)	3.96	22.3	6.00	38.9	14.4	107.5	18.00	136.8
Vo* (121%)	3.993	24.9	6.05	42.4	14.52	115.0	18.15	146.1
Vo* (122%)	4.026	27.9	6.10	46.4	14.64	123.4	18.30	156.5
Vo* (123%)	4.059	31.4	6.15	51.0	14.76	133.0	18.45	168.2
Vo* (124%)	4.092	35.6	6.20	56.3	14.88	143.8	18.60	181.5
Vo* (125%)	4.125	40.8	6.25	62.6	15.00	156.2	18.75	196.6

Table 13 LSO Duals. OVP External

	LSO2805D		LSO2812D		LSO2815D	
Range	OVP (V)	Radj (KΩ)	OVP (V)	Radj (KΩ)	OVP (V)	Radj (KΩ)
Vo* (115%)	5.75	26.4	13.80	78.8	17.25	101.2
Vo* (116%)	5.80	28.4	13.92	83.5	17.40	107.1
Vo* (117%)	5.85	30.7	14.04	88.6	17.55	113.5
Vo* (118%)	5.90	33.1	14.16	94.3	17.70	120.5
Vo* (119%)	5.95	35.9	14.28	100.5	17.85	128.2
Vo* (120%)	6.00	38.9	14.40	107.5	18.00	136.8
Vo* (121%)	6.05	42.4	14.52	115.2	18.15	146.4
Vo* (122%)	6.10	46.4	14.64	123.9	18.30	157.1
Vo* (123%)	6.15	51.0	14.76	133.8	18.45	169.2
Vo* (124%)	6.20	56.3	14.88	145.1	18.60	183.0
Vo* (125%)	6.25	62.6	15.00	158.0	18.75	198.9

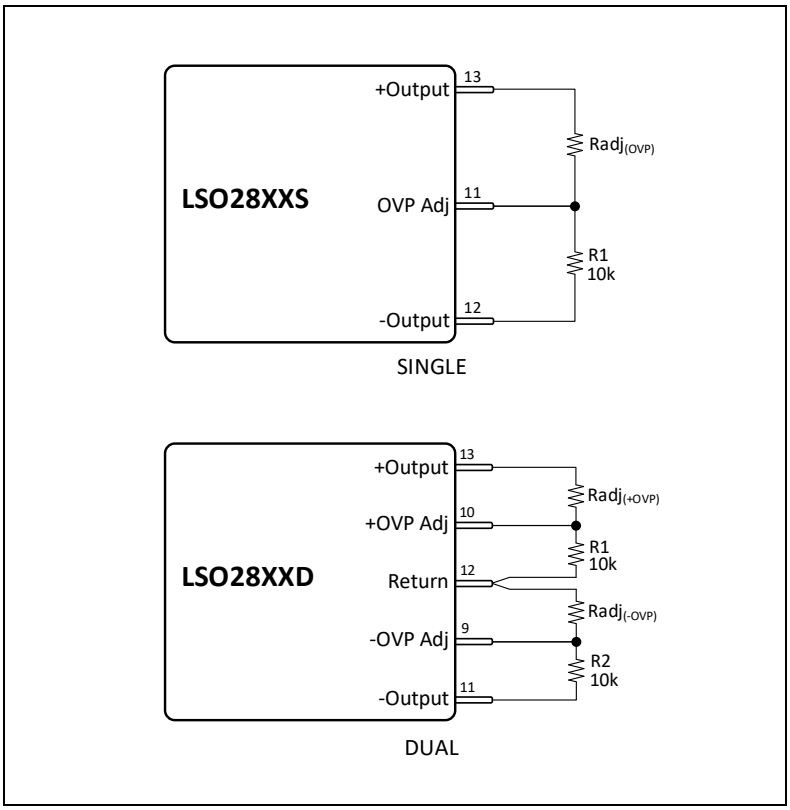


Figure 29 OVP with External Adjustment

Stacking Outputs:
On dual output models, output can be stacked to double the output voltage as shown in Figure 30.

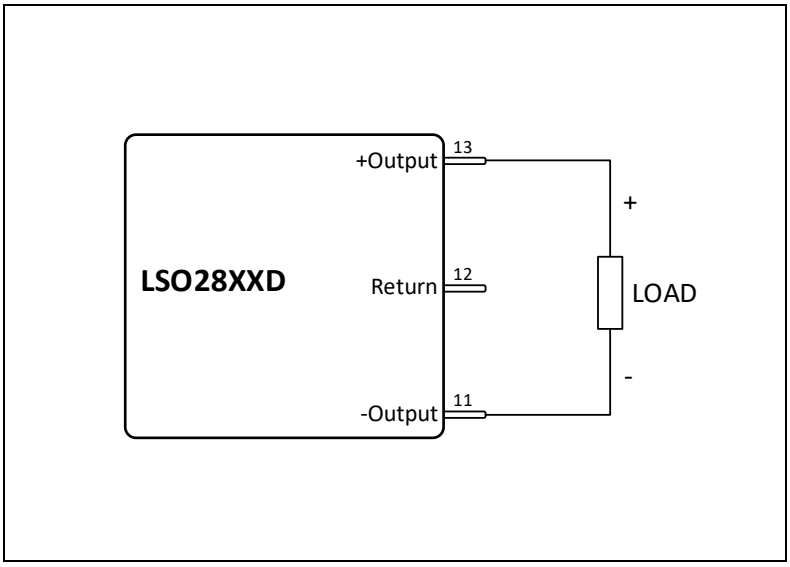


Figure 30 Stacked Outputs on Dual Models

5 Mechanical Outlines

Note: For the most updated package outline, please see the website: LSO-SERIES

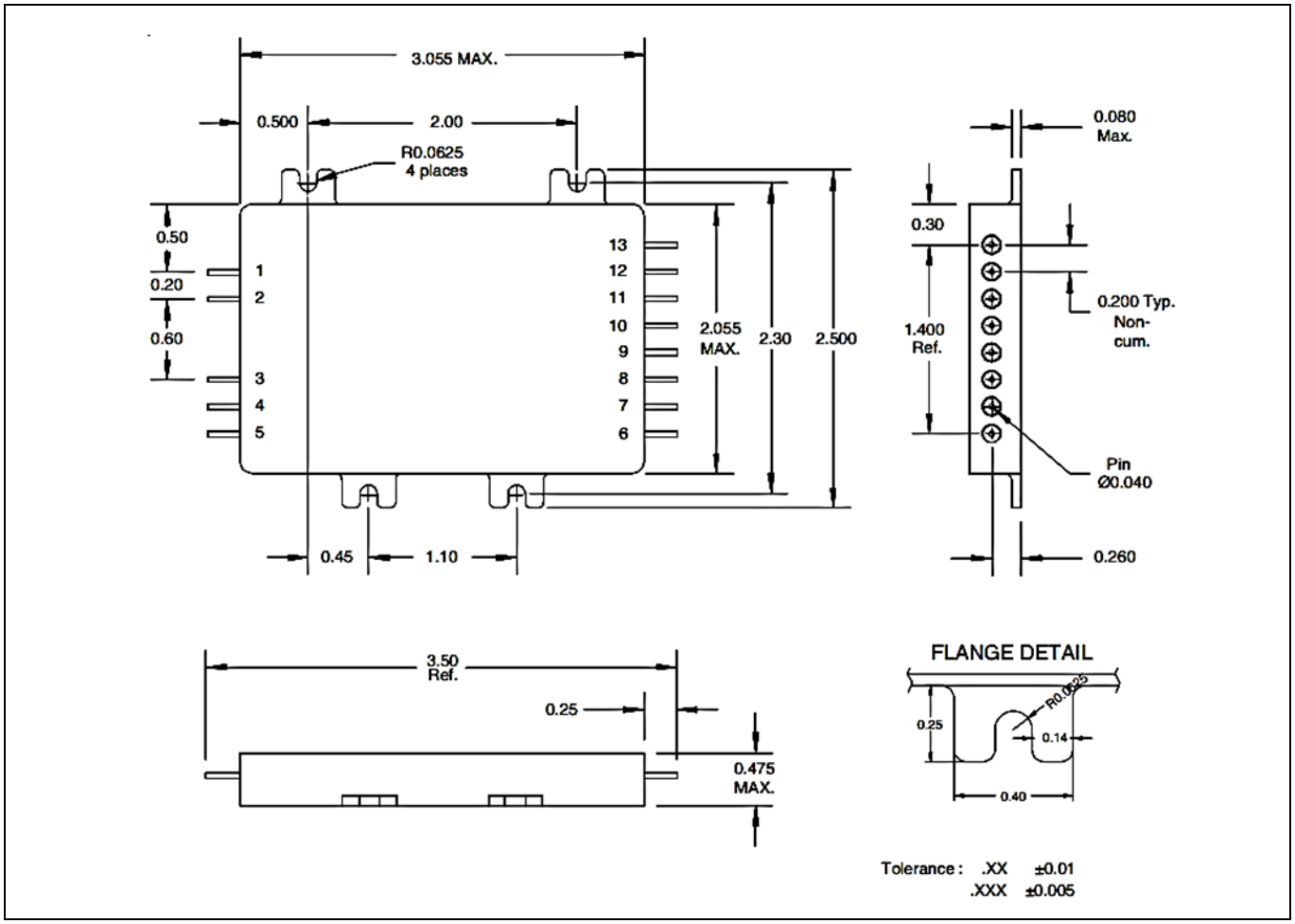


Figure 31 Package outline

Note: Standard leads finish is solder dipped.

6 Pin Designation

6.1 Pin Designation (Single / Dual)

Table 14 Designation

Pin Number	Single	Dual
1	Input	Input
2	Input Return	Input Return
3	Inhibit	Inhibit
4	Inhibit Return	Inhibit Return
5	U/V Latch	U/V Latch
6	Case Ground	Case Ground
7	Input Current Telemetry	Input Current Telemetry
8	Output Adjust	Output Adjust
9	- Sense	- OVP Adjust
10	+ Sense	+ OVP Adjust
11	OVP Adjust	- Output
12	- Output	Output Return
13	+ Output	+ Output

7 Devices Screening

Part Number Designator		/EM①	/CK②	5962-xxxxxxxKyy③	5962-RxxxxxxxKyy④
Compliance Level	**MIL-PRF-38534**	—	**K level compliant**	**Class K SMD**	**Class K RHA SMD**
Certification Mark		—	**CK**	**QML**	**QML**
Screening Requirement	**MIL-STD-883 Method**	—	—	—	—
Temperature Range	—	Room Temperature	-55°C to +85°C	-55°C to +85°C	-55°C to +85°C
Element Evaluation	MIL-PRF-38534	N/A	Class K	Class K	Class K ⑤
Non-Destructive Bond Pull	2023	N/A	Yes	Yes	Yes
Internal Visual	2017	IR Defined	Yes	Yes	Yes
Temperature Cycle	1010	N/A	Cond C	Cond C	Cond C
Constant Acceleration	2001, Y1 Axis	N/A	3000 Gs	3000 Gs	3000 Gs
PIND	2020	N/A	Cond A	Cond A	Cond A
Burn-In	1015	N/A	320 hrs @ 125°C (2 x 160 hrs)	320 hrs @ 125°C (2 x 160 hrs)	320 hrs @ 125°C (2 x 160 hrs)
Final Electrical (Group A)	MIL-PRF-38534 & Specification	Room Temperature	-55°C, +25°C, +85°C	-55°C, +25°C, +85°C	-55°C, +25°C, +85°C
PDA	MIL-PRF-38534	N/A	2%	2%	2%
Seal, Fine and Gross	1014	N/A	Cond CH	Cond CH	Cond CH
Radiographic	2012	N/A	Yes	Yes	Yes
External Visual	2009	IR Defined	Yes	Yes	Yes

Notes:

① **EM" grade** shall only be form, fit and function equivalent to its Flight Model (FM) counterpart for electrical evaluation, and it may not meet the radiation performance. The EM Model shall not be expected to comply with MIL-PRF-38534 flight quality/workmanship standards, and configuration control. An EM build may use electrical equivalent commercial grade components

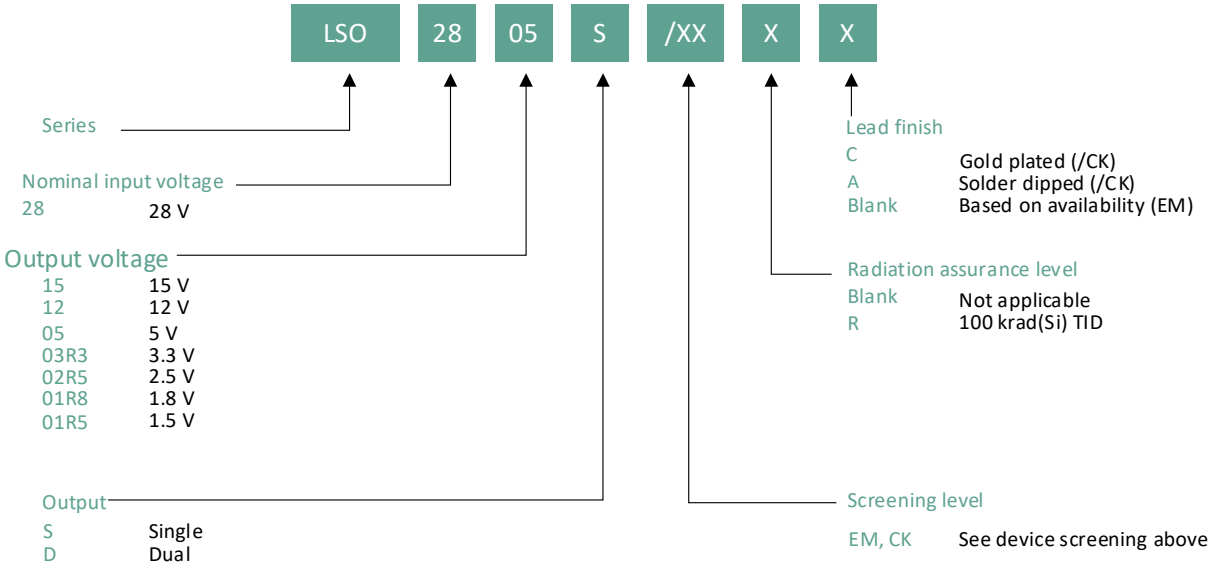
② **"CK" grade** is the flight model (FM) compliant to K Level screening as defined in the DLA Land and Maritime MIL-PRF-38534 requirements, but is not necessarily a DLA Land and Maritime qualified SMD per MIL-PRF-38534. The governing document for this part number designator is the IR HiRel datasheet (this document). Radiation rating as stated in the "Radiation Performance Characteristics" section, is verified by analysis and test per IR HiRel internal procedure. The part is marked with the IR base part number and the "CK" certification mark.

③ **"Class K SMD" grade** has a DLA qualified SMD per DLA MIL-PRF-38534 Class K which is the governing document for this part. The part is marked with the IR base part number, the SMD part number and the "QML" certification mark.

④ **"Class K RHA SMD" grade** has a DLA qualified SMD per MIL-PRF-38534 Class K with an RHA Level Designator per MIL-PRF-38534 and the governing document of this part is the DLA SMD. The part is marked with the IR base part number, the SMD part number and the "QML" certification mark.

⑤ **"Class K RHA SMD" Element Evaluation** is screened to Class K requirements with additional Radiation Lot Acceptance Testing (RLAT) screening per the DLA MILPRF-38534 approved RHA Test Plan.

Part Numbering



Revision history

Document version	Date of release	Description of changes
	08/27/2013	Datasheet (PD-97812)
Rev A	08/09/2016	Updated based on ECO-1110_27442
Rev B	05/11/2020	Updated based on ECO-1110_29731
Rev C	07/15/2020	Updated based on ECO-1110_29823
Rev D	03/17/2021	Updated based on ECO-1110_30036
Rev E	05/09/2022	Updated based on ECO-1110_30397