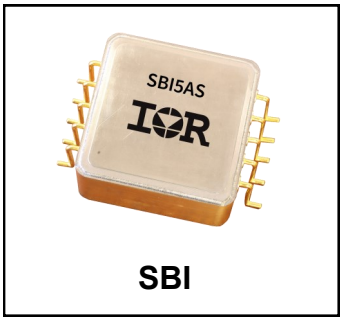
SBI5AS

HIGH RELIABILITY RADIATION HARDENED, HYBRID POINT OF LOAD (POL) VOLTAGE REGULATOR

Single Output
3.3V to 9.0V DC Input
0.8V to 3.3V DC Output



SBI

Description

The SBI5AS point of load (POL) DC-DC voltage regulator is part of the International Rectifier HiRel family of products. It is a space qualified, high-reliability, hermetically sealed, thick film hybrid designed to provide a single regulated DC output from a regulated or unregulated DC voltage power source. The output current rating is 6A maximum up to the output power of 20W, depending upon the output voltage. Output voltage is user adjustable with a single resistor.

The SBI5AS is qualified per MIL-PRF-38534 K Level and is designed to operate continuously onboard a spacecraft over the wide temperature range of -55°C to +125ºC. It has been characterized for total ionizing dose (TID) performance including enhanced low dose rate sensitivity (ELDRS) and for single events effects (SEE) and is suitable for harsh radiation environments normally encountered in the geo-synchronous orbit (GEO), medium earth orbit (MEO), low earth orbit (LEO), deep space and other challenging radiation design applications requiring mission life up to 15 years. For higher output power requirements, IR's SBB series is available for power requirements up to 30W or 14A design applications.

The SBI5AS POL operates from a DC input power source with the voltage range of 3.3 to 9V. It converts a DC input voltage down to a fixed and highly stable DC output as low as 0.8V to as high as 3.3V, or up to 85% of input voltage.

The SBI5AS is a non isolated synchronous buck regulator. It takes advantage of the PWM voltage-mode control and many other key functional features to accommodate power system design needs. It switches at a fixed frequency of 500kHz to provide an excellent output transient response, low output ripple and extremely high-efficiency performances. The highly integrated IC minimizes components count and makes the miniaturization of the form factor possible.

Features

- Input voltage range: 3.3V to 9.0V DC
- Output power: up to 20W.
  Output current: up to 6A maximum
- Output voltage range: 0.8V to 3.3V (limited to no more than 85% of V_{IN}), adjustable with an external resistor
- Efficiency: up to 88%
- 2.5% EOL total output voltage drift
- 20MΩ @ $100V_{DC}$ isolation, all pins to chassis
- Remote voltage sense compensation
- Fixed 500 kHz operating frequency
- Power Output Status telemetry (POK) signal
- Protection: short circuit and overload
- Adjustable Input Under voltage lockout (UVLO)
- Adjustable Soft start
- Integrated input EMI filter to ensure stable operation without need for large external filter components
- Output sequencing of multiple modules via Track and Enable pins
- Enable pin with comparator type input
- MTBF > 9 $x10^6$ hours
- Operating case temperature range:
  -55°C to +125°C

Package

- Size: 1.00"L x 1.00"W x 0.475"H (package body)
  "Z" style for surface mount assembly
- Low weight < 18 grams

Radiation Performance

- Total Ionization Dose > 100 kRads (Si)
- SEE Hardness: LET = 83 MeV.cm^2/mg

Applications

- Geosynchronous & low earth orbit satellites
- FPGAs, CPLDs, DSPs and microprocessors

The SBI5AS is a stand alone point of load voltage regulator; external filtering is not required for typical design applications. An internal input filter provides low input ripple current and stabilizes the input impedance which allows for up to 2µH of input wire inductance without affecting the overall converter performance. It also includes an internal output filter providing low ripple voltage and stabilizing the voltage control loop. This allows for a large variation in external filter without affecting the stability of the control loop.

The SBI5AS uses Intersil's ISL70003SEH pulse width modulator with integrated rad-hard MOSFETs for the control and power switching functions. The ISL70003 is a DLA Land and Maritime qualified radiation hardened (TID and SEE) integrated circuit (IC). Many of the available functional and diagnostic features of this device are incorporated into the SBI design.

The SBI5AS POL measures 1.36"L x 1.0"W x 0.475"H (including pins) with a footprint of 1.36 in^2 with no external filtering components required for typical applications. The package and lid materials are aluminum-silicon to minimize weight at 18 grams. The I/O pin material is Alloy 52 and are gold plated for long-term storage (gold is to be removed prior to assembly). It also has a chassis connected pin. The pins are formed for surface mount assembly.

With the inclusion of many useful functional, protection and diagnostic features, and with its high-efficiency performance, SBI5AS POL is ideal as the point of load regulator for the distributed power architecture (DPA) power design systems for digital devices. Many applications requiring high di/dt performance for a DPA system can be realized with multiple SBI modules.

The SBI5AS POL module includes output short circuit and overload protection. Operation down to no-load are permissible. An enable function with comparator type input is also provided to remotely turn-on and turn-off the regulator. Output sequencing of two or more POLs can be accomplished with via the Enable and Track pins. Power-good signal via the PGood pin is available to indicate status of the output. Bi-directional Sync pin allows two devices to be synchronized 180º out of phase to minimize input ripple current. Output voltage sense is also available to compensate for a voltage drop in the positive output line if needed.

The SBI5AS POL simplifies the design and procurement process. Users need to procure only one SBI5AS POL module type for all output voltage requirements. Only one external resistor is required to trim the output to a desired voltage Design analyses including WCA are available for the extended standard output voltages, 0.8V to 3.3V.

The SBI5AS POL is designed, manufactured, tested, and qualified at IR HiRel's facility in San Jose, California which is qualified to ISO9001 and MIL-PRF-38534 by DLA Land and Maritime. Flight hardware is 100% screened and fully compliant to class K per MIL-PRF-38534. Abbreviated screening version or Engineering Model (EM) of the SBI is available. Please refer to the Device Screening table for details.

The SBI5AS offers guaranteed end-of-life efficiency and total output voltage regulation performances through worst case analysis (WCA). Standard documentation including worst case analysis, radiation tests report, stress analysis, thermal analysis, and reliability report are available

Functional / Application Notes

Refer to Figure 5 for the following functional adjustments.

Enable / Input Undervoltage Protection: The POL can be turned ON and turned OFF via the Enable pin. With a power source of 3V or greater applied to the Input pin, the POL operates normally when the Enable pin is left open or connected to an open collector circuit. The POL will turn off when the Enable pin is pulled below 0.6V with respect to GND. The input turn-on threshold voltage and input turn-off hysteresis can be calibrated by external resistors. An undervoltage lockout (UVLO) circuit prohibits the POL from operating when the input voltage is too low to maintain the output voltage. The POL will not start until the input voltage rises to approximately 4.5 volts. The POL turns off when the input voltage drops below approximately 3.9 volts. These thresholds are adjustable with an external resistor.

Output Voltage Adjustment: The output voltage of a SBI POL can be set to a desired output voltage with a single resistor. Without external component, the output voltage is 0.8V nominal (0.75V to 0.80V). The voltage range of the output is 0.8V to 3.3V or 85% of the input voltage (75% of input voltage for large load variations). The resistor shall be connected between Output Adjust pin and GND. The resistor shall be a non-inductive type with a tolerance value of 1%, 100ppm and power rating of 150mW. The suggested resistor types are M55342. The resistor value for a desired voltage output can be determined using the following formula:

V_{OUT} = desired output voltage

With Remote Sense tied to the hybrid output or load:

$$R_{Adjust} = \frac{189,600}{31.6 \times V_{out} - 24.96} - 1,210$$.

R_{ADJUST} value is in Ohms

Remote Sense: Output pin must be connected to the Remote Sense pin for proper operation. For best possible output regulation the Remote Sense pin may be connected to the output line at the load to compensate for a voltage drop in the (+) output line.

Synchronization: A Synchronization pin is provided to allow multiple SBI5AS POL modules to be synchronized to a common operational frequency with an external signal source to control/minimize the noise interference coming from the switching operation of the POLs. The synchronization frequency range is 425kHz to 575kHz. The synchronization signal source must be able to source the current of 1.0mA with the voltage level of 2.0V minimum at high and 0.8V maximum at low.

Power Good (Power OK Monitor): The SBI5AS POL provides an output status signal at the PGood pin. The pin is an open drain connection. An open signal status is present when the POL output is within ±10% of the output voltage. A low signal (shorted to ground) at the PGood pin indicates the POL output voltage is outside of the ±10% of the output voltage.

Tracking: There are three main methods of tracking between several converters:

- One output after the other
- Ratio metric tracking
- Simultaneous tracking

Soft Start: Soft start can be increased by adding a capacitor between the Track pin and GND.

The internal and external output capacitance needs to be charged during the soft start event. This charge current is added to the load current during start up, and the sum needs to be within the maximum current rating.

$$t_{ss} = \frac{\left(C_{out,int} + C_{out,ent}\right) \times V_{out}}{I_{charge}}$$

C_{EXT} = (39nF x t_{SS}) -39nF
t_{SS} is the Soft Start time in msec
The internal capacitance is 470µF

Assembly Mounting and Cooling Considerations: Cooling of the SBI5AS POL can be accomplished by bonding the base of the package to a metal plate or heat sink with a thermally conductive material. Typical power loss at full load is 3.5W but can be smaller at a lighter load.

Specifications

Absolute Maximum Ratings		Recommended Operating Conditions	
Input voltage range	$3.3V_{DC}$ to $12V_{DC}$	Input voltage range (Note 2)	$3.3V_{DC}$ to $9.0V_{DC}$
Output power	Internally limited	Output power	0 to 20W or 6A maximum current
Lead temperature	+300°C for 10 seconds		
Operating case temperature	-55°C to +125°C (Note 1)	Operating case temperature	-55°C to +85°C (Note 2)
Storage temperature	-55°C to +135°C		

Electrical Performance Characteristics

Parameter	Group A Subgroup Note 3	Conditions -55°C ≤ T_C ≤ +85°C V_{IN} = 5.0V DC ± 5%, C_L = 0 Unless otherwise specified, Note 4	Limits			Unit
			Min	Nom	Max	
Input Voltage (V_{IN})		Note 5	3.3	5.0	9.0	V
Output Voltage (V_{OUT})	1, 2, 3	I_{OUT} = 100% rated load V_{IN} = 5.0V, 9.0V, Note 6 V_{OUT} = 0.8V (external resistor V_{ADJ} = none)	0.787	0.8	0.813	V
		V_{OUT} = 3.3V (external resistor V_{ADJ} = 1200Ω)	3.220	3.3	3.379	V
Output Power (P_{OUT})	1, 2, 3	V_{IN} = 5.0V, I_{OUT} = 6.0A maximum	0		20	W
Output Current (I_{OUT})	1, 2, 3	V_{IN} = 5.0V	0		6.0	A
Line Regulation (VR_{LINE})	1, 2, 3	I_{OUT} = 0%, 50%, 100% rated, V_{IN} = 3.3V, 5.0V, 9.0V, Note 7 V_{OUT} = 0.8V (external resistor V_{ADJ} = none)		0.5	0.75	%
		V_{OUT} = 3.3V (external resistor V_{ADJ} = 1200Ω)		0.3	0.75	
Load Regulation (VR_{LOAD})	1, 2, 3	I_{OUT} =10%-100% rated, Note 7 V_{IN} = 3.3V, 4.5V to 9.0V V_{OUT} = 0.8V	0	1.4	3.2	%
		V_{IN} = 4.5V to 9.0V V_{OUT} = 3.3V	0	0.6	1.0	
Input Current, No Load (I_{IN})	1, 2, 3	I_{OUT} = 0, Enable Pin open		50	70	mA
Input Current, Inhibited	1, 2, 3	I_{OUT} = 0, Enable Pin shorted to Input Return Pin		8.0	17	mA
Input Ripple Current	1, 2, 3	I_{OUT} = 100% of rated load, Bandwidth = 10MHz with internal EMI filter		50	100	mA_{P-P}

For Notes to Electrical Performance Characteristics, refer to page 7

Electrical Performance Characteristics (continued)

Parameter	Group A Subgroup Note 3	Conditions -55°C ≤ T_C ≤ +85°C V_{IN} = 5.0V DC ± 5%, C_L = 0 Unless otherwise specified, Note 4	Limits			Unit
			Min	Nom	Max	
Input Under-Voltage Lockout (UVLO)	1, 2, 3	Note 5				V
		Turn-on (input increasing)	4.40	4.55	4.75	
		Turn-off (input decreasing)	3.85	3.97	4.20	
		Hysteresis	0.40	0.575	0.80	
Output Ripple Voltage (V_{RIP})	1, 2, 3	V_{IN} = 4.5V to 9.0V I_{OUT} = 0% - 100% rated load, Bandwidth = 10 MHz, Note 8		35	100	mV_{P-P}
Efficiency (E_{FF})	1 (25°C)	I_{OUT} = 100% rated load V_{OUT} = 3.3V V_{IN} = 4.5V, V_{IN} = 9.0V	84	86		%
	2 (85°C)		83	84		
	3 (-55°C)		88	89		
Efficiency (E_{FF})	1 (25°C)	I_{OUT} = 100% rated load V_{OUT} = 0.8V V_{IN} = 3.3V, V_{IN} = 9.0V	60	61		%
	2 (85°C)		60	61		
	3 (-55°C)		63	65		
Switching Frequency (F_S)	1, 2, 3	Sync In Pin open	450	500	550	kHz
Synchronization Input	1, 2, 3	External clock on Sync In Pin				
Frequency Range			425		575	kHz
Pulse Amplitude (high)			2.0			V
Pulse Amplitude (low)			-0.3		0.8	V
Pulse Transition Time					0.2	µs
Pulse Duty Cycle			10		90	%
Enable Input (inhibit function)	1, 2, 3					
Open Circuit Voltage			0.6		2.0	V
Drive Current (sink)					300	µA
Current Limit Point Expressed as a percentage of Full Rated Load Current	1, 2, 3	Note 9	110		150	%
Power Dissipation (P_D)	1, 2, 3	Short circuit			3.0	W
		Overload (load fault), Note 10			6.2	W

For Notes to Electrical Performance Characteristics, refer to page 7

Electrical Performance Characteristics (continued)

Parameter	Group A Subgroup Note 3	Conditions -55°C ≤ T_C ≤ +85°C V_{IN} = 5.0V DC ± 5%, C_L = 0 Unless otherwise specified, Note 4	Limits			Unit
			Min	Nom	Max	
Load Transient Response	4, 5, 6	Notes 11, 12				
Amplitude (V_{TLD})		V_{OUT} = 3.3V, Load steps		40	100	mV_{P-P}
Recovery (T_{TLD})		10% to 50% & 50% to 100%	0	18	200	ms
Recovery (T_{TLD})		50% to 10% & 100% to 50%	0	90	200	ms
Amplitude (V_{TLD})		V_{OUT} = 0.8V, Load steps		40	100	mV_{P-P}
Recovery (T_{TLD})		10% to 50% & 50% to 100%	0	200	500	ms
Recovery (T_{TLD})		50% to 10% & 100% to 50%	0	600	700	ms
Line Transient Response	4, 5, 6	Line steps: 6.5V to 9.0V, I_{OUT} = 100% rated load, Notes 12, 13				
Amplitude (V_{TLN})			-5.0		+5.0	%
Recovery (T_{TLN})				200	500	ms
Turn-On Response	4, 5, 6	I_{OUT} = 10% & 100% of rated load, Note 14				
Overshoot (V_{OS})			0	3.0	25	mV
Turn-On Delay (T_{DLY})			1.0		3.0	ms
Capacitive Load (C_L)	1	I_{OUT} = 100% rated load No effect on DC performance Note 15	0		8000	µF
EMC Conducted Susceptibility (line rejection)		I_{OUT} = 100% rated load Primary power sine wave injection of $2V_{p-p}$, from 100 Hz to 50 MHz		22		dB
Electromagnetic Interference (EMI), Conducted Emission (CE)		I_{OUT} = 100% rated load		10		mV_{RMS}
Isolation		Input to Output or any pin to case, except Pin 12, test at $100V_{DC}$	20			MΩ
Device Weight					18	g
MTBF		MIL-HDBK-217F2, SF, 35°C	$9x10^6$			Hrs

For Notes to Electrical Performance Characteristics, refer to page 7

Notes: Electrical Performance Characteristics Table

1. Although operation at temperatures between +85°C and +125°C is guaranteed, no parameter limits are specified.
2. Meets de-rating requirements of MIL-HDBK-1547 and EEE-INST-002 – except for ceramic capacitors with voltage stress below 10V will minimum be rated at 25V. Because of the wide operational voltage ranges defined for this unit, tantalum capacitors used on the input and output determine conditional temperature / input voltage / output voltage derating limits. Refer Figures 1 and 2.
3. Parameter is tested as part of design characterization or after design changes. Thereafter, parameter shall be guaranteed to the limits specified. The Subgroups (SG) below refer to MIL-PRF-38534 Appendix C, Group A. SG 1 is static test at +25°C, SG 2 is static test at +85°C, SG 3 is static test at -55°C, SG 4 is dynamic test at +25°C, SG 5 is dynamic test at +85°C, SG 6 is dynamic test at -55°C.
4. Parameter verified during line and load regulation tests.
5. UVLO adjusted with external resistance (91kΩ to V_{IN}) allows operation at $3.3V_{IN}$. The default UVLO is 4.5V.
6. V_{OUT} is to be trimmed by a user with an external resistor. See resistor selection and allowable output range in the Application notes.
7. Best line and load regulation results requires a low impedance connection between the three Return (ground) Pins (2, 5, 9).
8. Guaranteed for a DC to 20 MHz bandwidth. Tested using a 20 KHz to 10 MHz bandwidth.
9. Current limit point expressed as a percentage of full rated load current.
10. Overload power dissipation is defined as the device power dissipation with maximum load prior to V_{OUT} drop (into hiccup mode protection).
11. Load step transition time ≥ 10µs.
12. Recovery time is measured from the initiation of the transient to where V_{OUT} has returned to within ±1% of its steady state value.
13. Line step transition time ≥ 100µs.
14. Turn-on delay time from either a step application of input power or a logic-low to a logic-high transition on the enable pin to the point where V_{OUT} = 90% of nominal.
15. Capacitive load may be any value from 0 to the maximum limit without compromising dc performance. A capacitive load in excess of the maximum limit may interfere with the proper operation of the converter's overload protection, causing erratic behavior during turn-on. Turn-on delay during start-up may require an adjustment of Soft Start (Track, Pin 4) capacitance when capacitive load is present (see Application notes).

Radiation Performance Characteristics

Test	Conditions	Min	Typ	Max	Unit
Total Ionizing Dose (TID) (Gamma)	MIL-STD-883, Method 1019.5 Operating bias applied during exposure Half Rated Load, V_{IN} = 5V	100			kRrads (Si)
Single Event Effects (SEE) SEU, SEGR, SEB - Note 1	Heavy Ions (LET) Operating bias applied during exposure, Full Rated Load, V_{IN} = 3.3V to 9V	83			MeV.cm^2/mg
Single Event Effects (SEE) SEL - Note 2	Heavy Ions (LET) Operating bias applied during exposure, Full Rated Load, V_{IN} = 3.3V to 9V	83			MeV.cm^2/mg

Notes:
1. Output perturbation is less than + 5% of nominal output voltage.
2. Added failure rate is 0.1FIT (failure per $10E^9$ hrs) based on critical cross section at $1E^{-7}cm^2$ (LET = 43, LET = 60), depth of critical cross section at 50µm, GEO integral LET spectrum.

Figure 1: Device Input Tantalum Capacitor Voltage Stress Derating Limits:

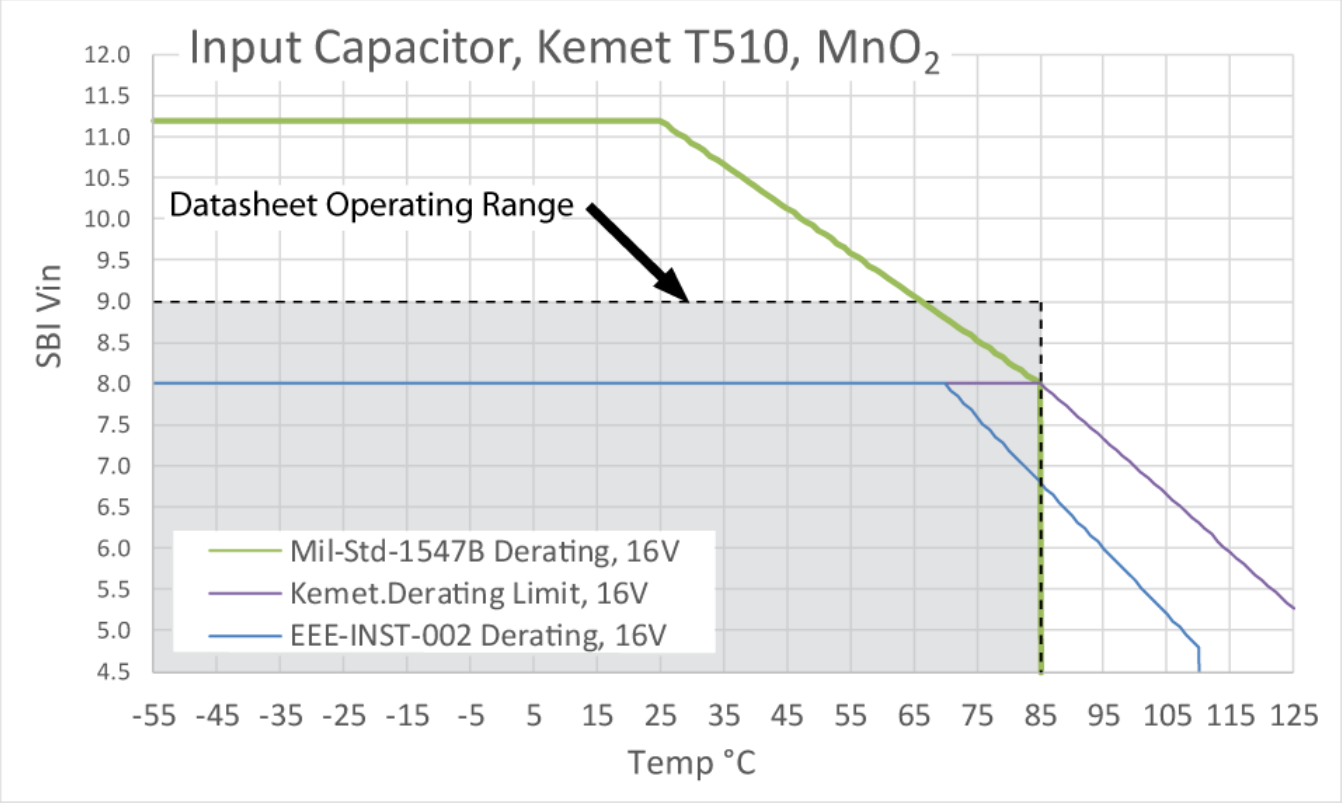


Figure 2: Device Output Tantalum Capacitor Voltage Stress Derating Limits:
(MIL & EEE Limits based on CWR cap.)

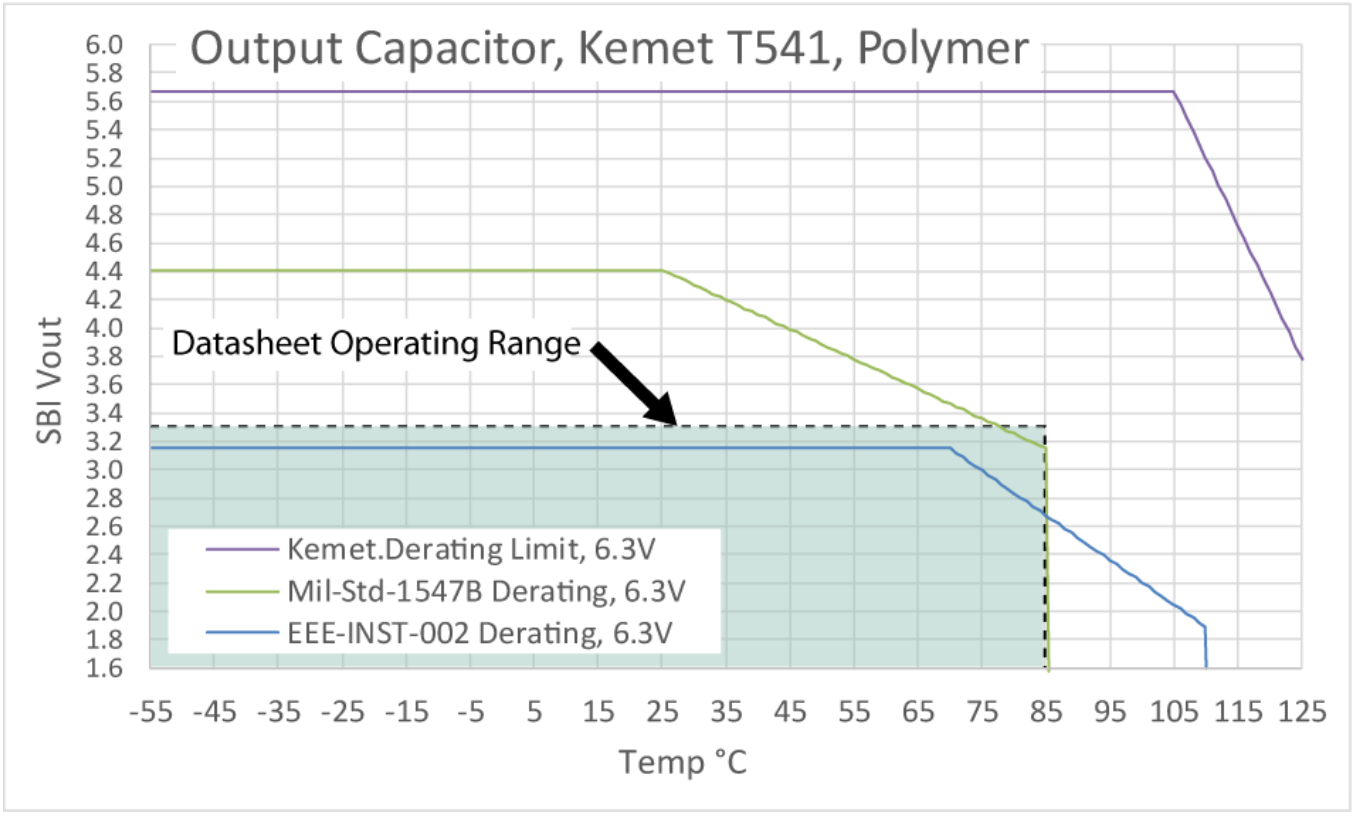


Figure 3: Typical Conducted Emission Performance on Input (current), 1µH harness, Vin 5V, Iout 6A

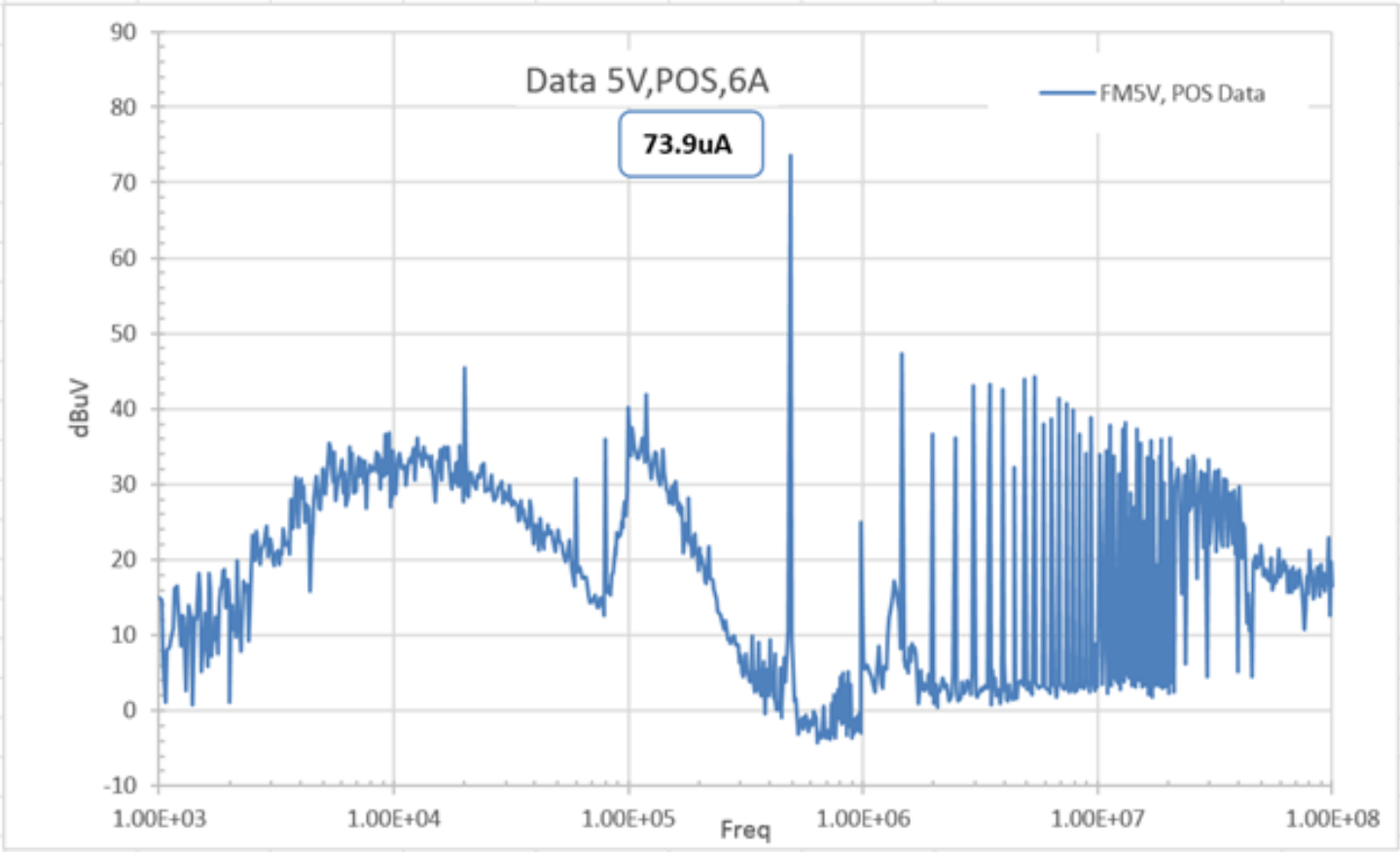
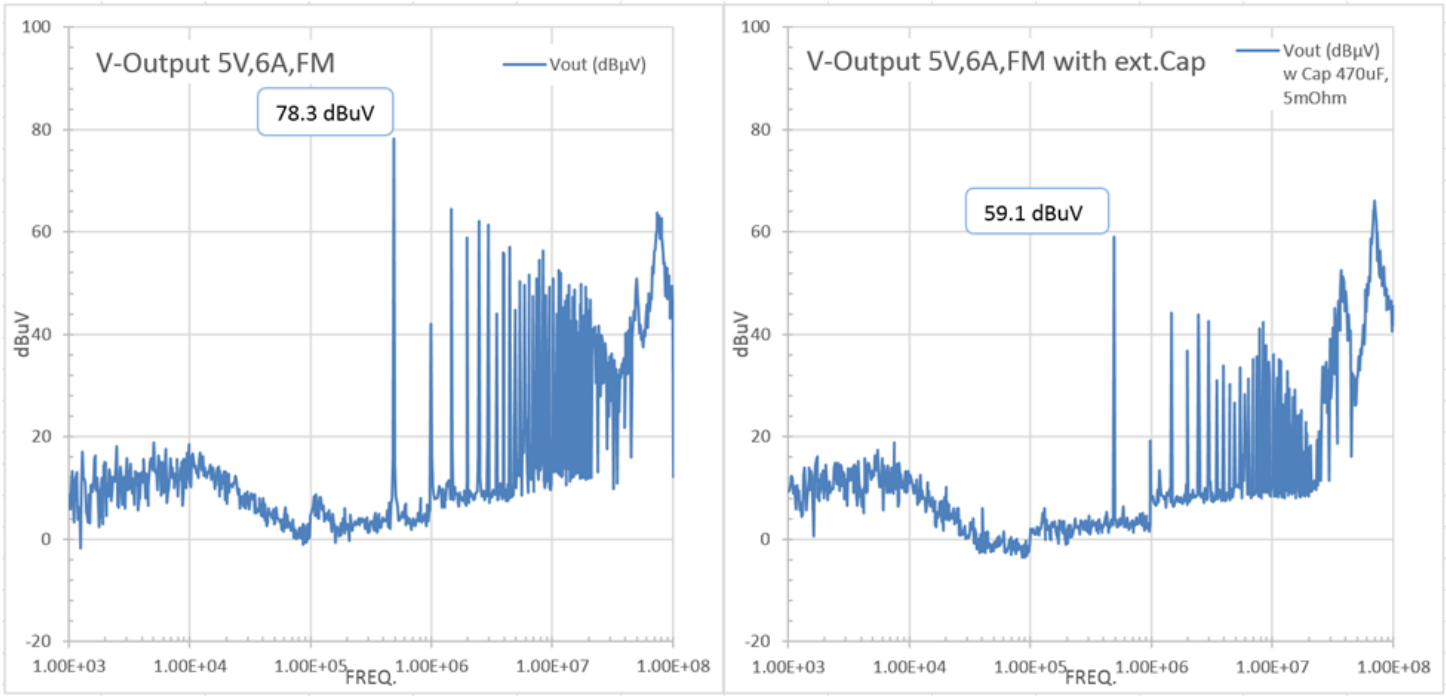
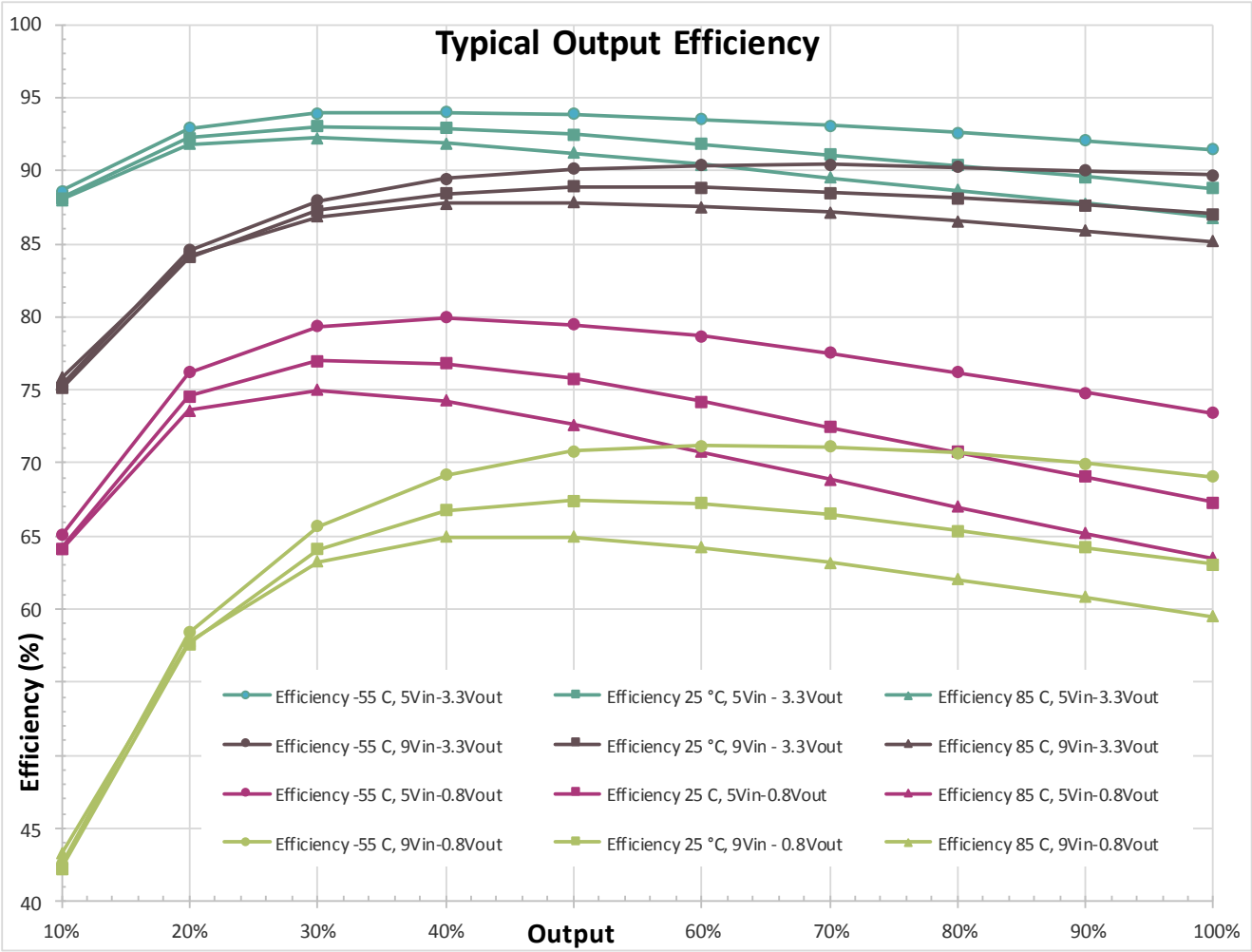


Figure 4: Typical Conducted Emission Performance on Output (voltage), with and without an external capacitor, (T541, 470µF, 5mOhms), Vin 5V, Iout 6A



Output Efficiency

Figure 5: Typical Output Efficiency



Block Diagram

Figure 6: Simplified Block Diagram

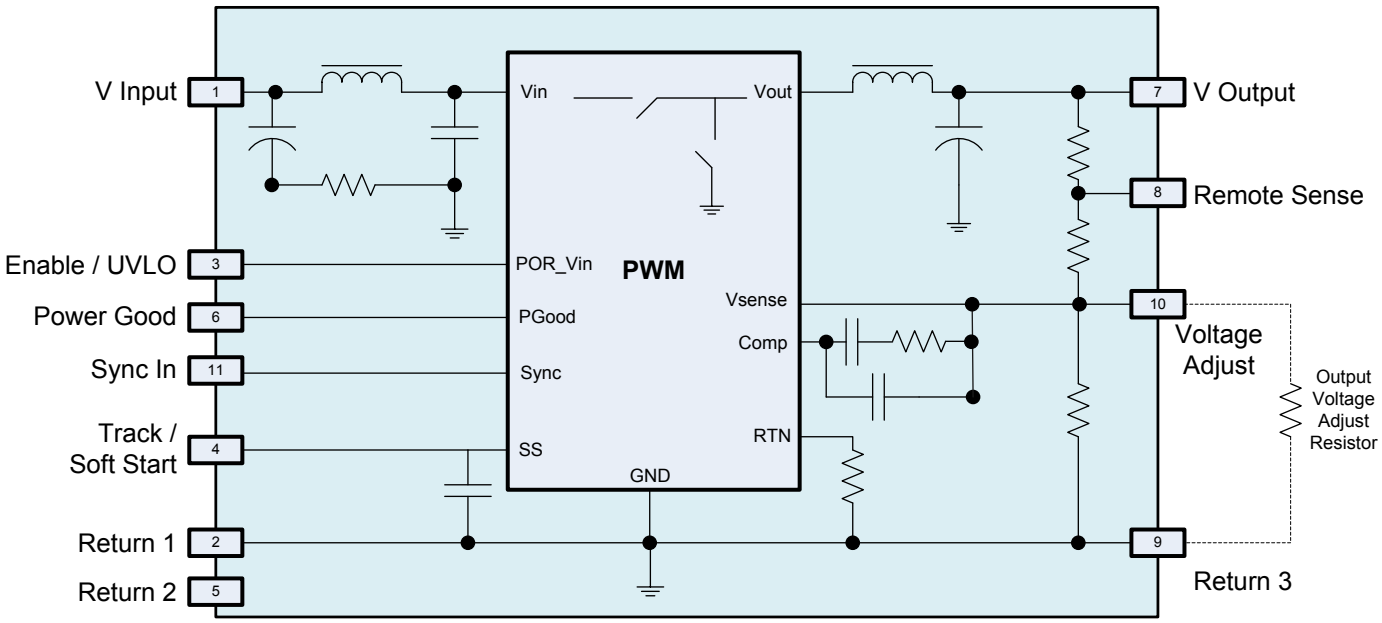
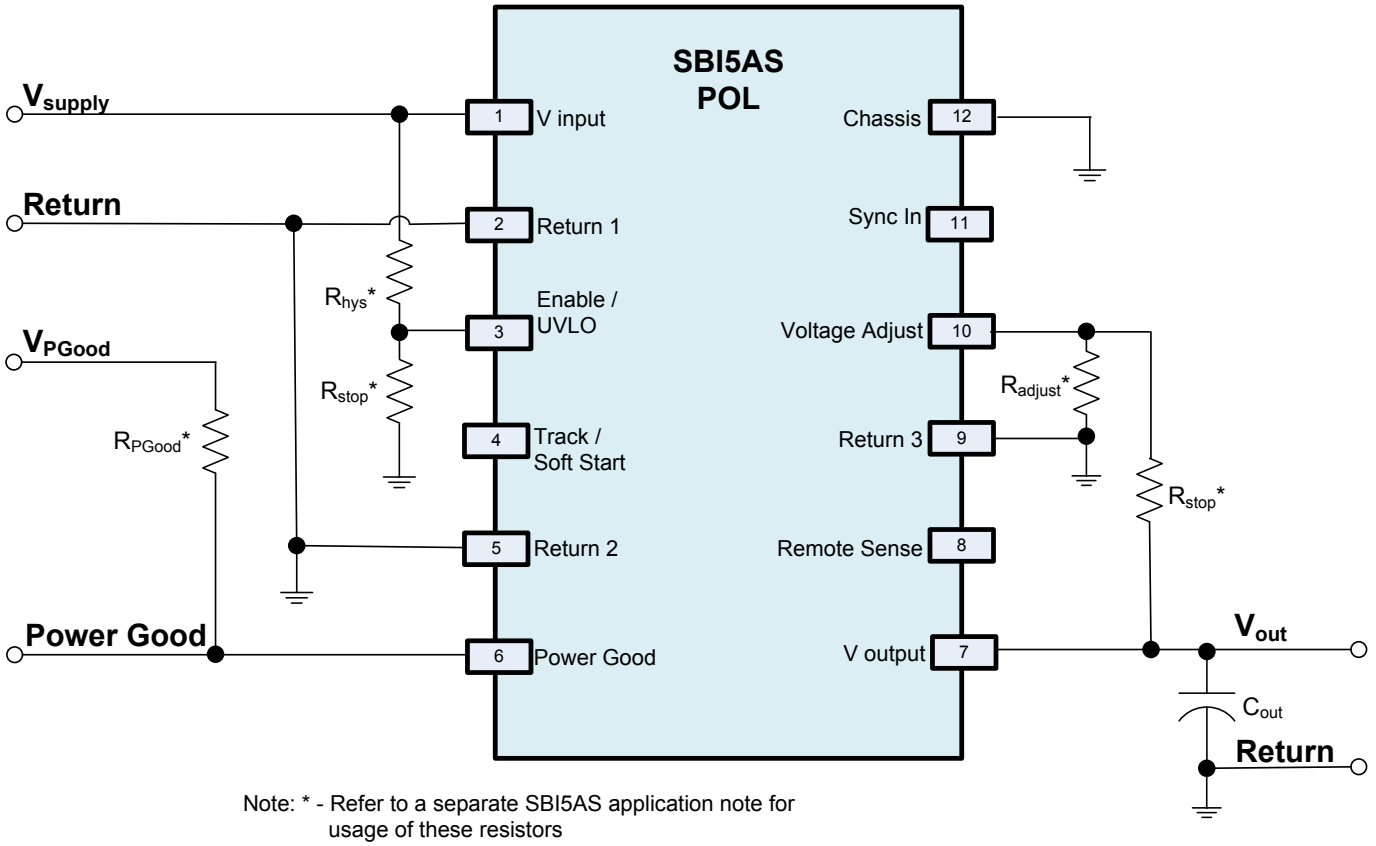
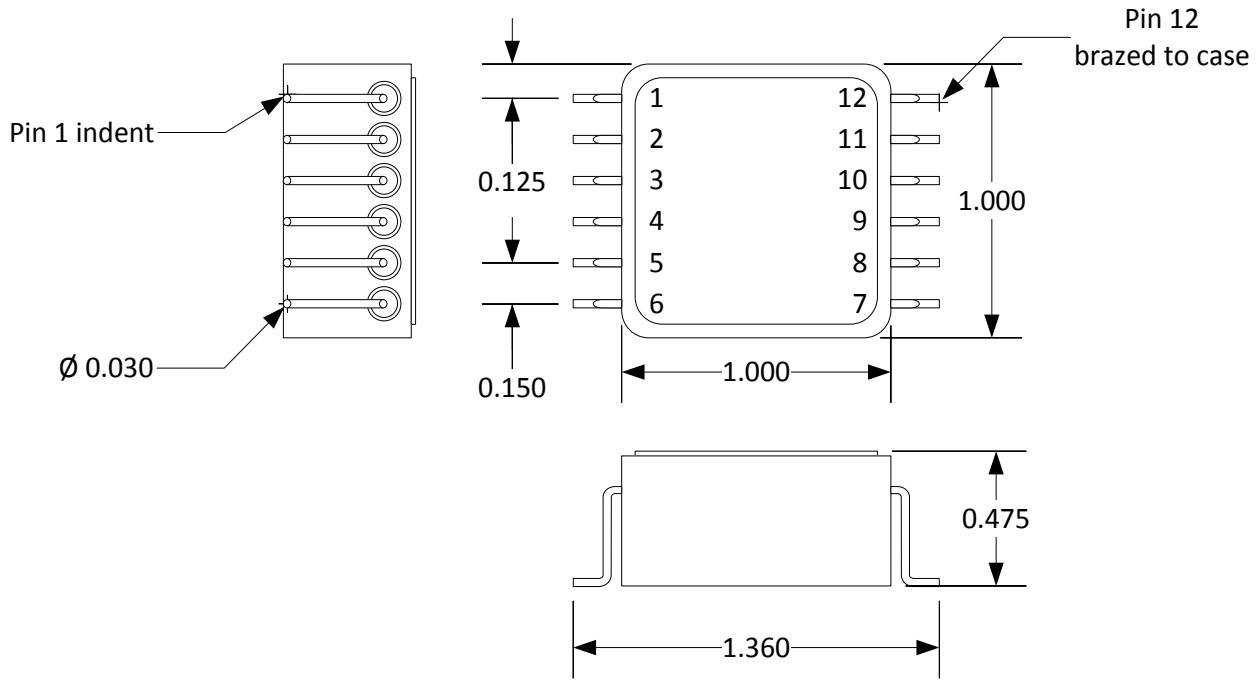


Figure 7: Typical Application Block Diagram



Note: * - Refer to a separate SBI5AS application note for usage of these resistors

Mechanical Outline (Surface Mount Pins)



Notes: 1. dimensional tolerance is: x.XXX ±0.005"
x.XX ±0.01"
2. lead finish is Gold plated

Pin Designation

Pin #	Designation	Pin #	Designation
1	V Input	7	V Output
2	Return 1	8	Remote Sense
3	Enable / UVLO	9	Return 3
4	Track / Soft-Start	10	Voltage Adjust
5	Return 2	11	Sync In
6	Power Good	12	Chassis

Device Screening

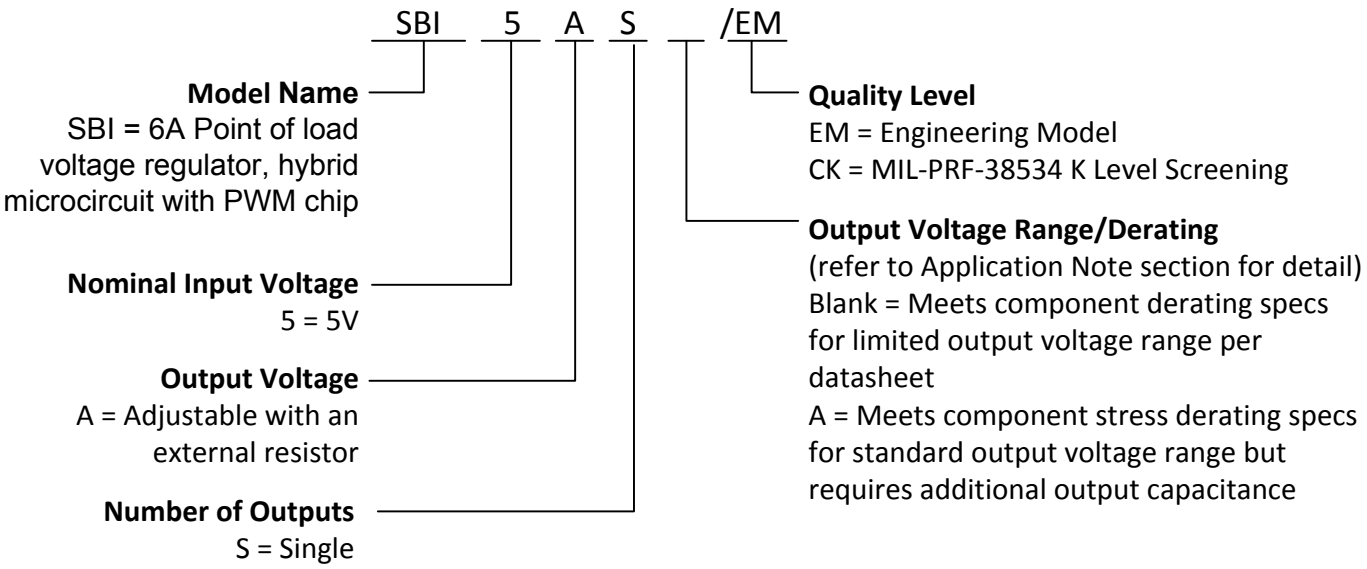
Requirement	MIL-STD-883 Method	CK Suffix (flight)	EM Suffix ①
Temperature Range	—	-55°C to +85°C	-55°C to +85°C
Element Evaluation	MIL-PRF-38534	K Level	N/A
Non-Destructive Bond Pull	2023	Yes	N/A
Internal Visual	2017	Yes	②
Temperature Cycle	1010	Condition C	Condition C
Constant Acceleration	2001, Y1, Y2 Axis	3000 Gs	3000 Gs
PIND	2020	Condition A	N/A
Burn-In	1015	320 hrs @ 125°C (2 x 160 hrs)	48 hrs @ 125°C
Final Electrical (Group A)	MIL-PRF-38534 & Specification	-55°C, +25°C, +85°C	-55°C, +25°C, +85°C
PDA	MIL-PRF-38534	2%	N/A
Seal, Fine and Gross	1014	Cond A, C	Cond C
Radiographic	2012	Yes	N/A
External Visual	2009	Yes	②

Notes:

① Any Engineering Model (EM) build with the "EM" Suffix shall only be form, fit and functional equivalent to its Flight Model (FM) counterpart, and it may not meet the radiation performance. The EM Model shall not be expected comply with MIL-PRF-38534 flight quality/workmanship standards, and configuration control. An EM build may use electrical equivalent commercial grade components. IR HiRel will provide a list of non-compliant items upon request.

② Best commercial practice.

Part Numbering



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