SEMTECH

600kHz Step-Up Switching Regulator with 2.2A, 45V Switch

POWER MANAGEMENT

Features

- Input Voltage Range: 2.6V to 20V
- Boost and SEPIC Topologies
- Up to 40V Output in Boost Topology
- Integrated 2.2A/45V Switch
- 600kHz Constant Switching Frequency
- Current-Mode Control Eases Compensation
- Cycle-by-Cycle Current-Limiting
- Internal Soft-Start
- Thermal Shutdown Protection
- Low Shutdown Current (<1μA)
- 8-Pin SO Lead-Free Package
- Fully WEEE and RoHS Compliant

Applications

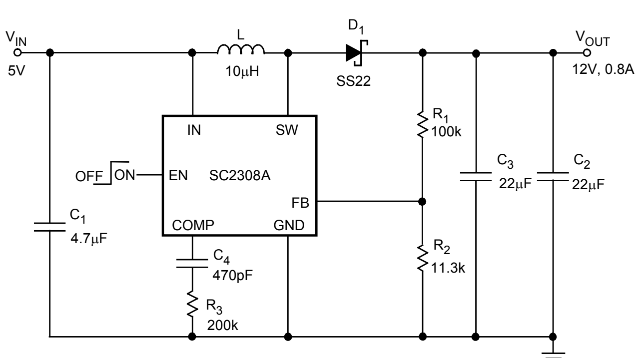
- Telecommunication Equipment
- Point of Load DC-DC Converters
- Portable Devices

Description

The SC2308A is a 600kHz current-mode switching regulator with an integrated low-side 2.2A power transistor. The operating supply voltage of the SC2308A ranges from that of a single Li-ion cell to various PC board power supplies. The internal switch is rated at 45V, making the device suitable for high voltage boost and SEPIC applications. The SC2308A shuts down to less than 1μA of supply current.

The SC2308A uses peak current-mode PWM control for ease of loop compensation and excellent transient response. Cycle-by-cycle current limiting lowers power transistor dissipation. An internal soft-start timer prevents output overshoot and limits the input current during start-up. Thermal shutdown prevents the chip from overheating.

Typical Application Circuit



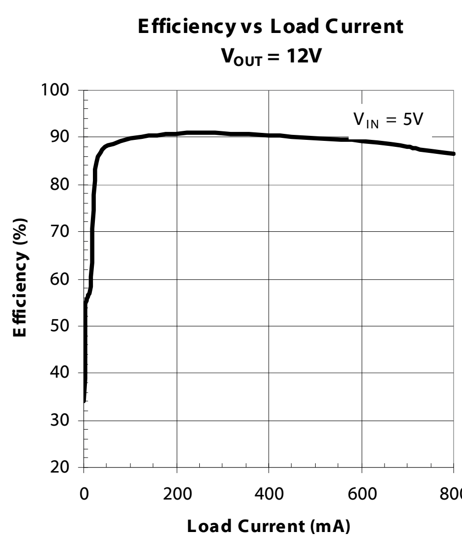
L: Coilcraft DO3316P103

D_1: ON SS22

C_1: Murata GRM31CR61A475K

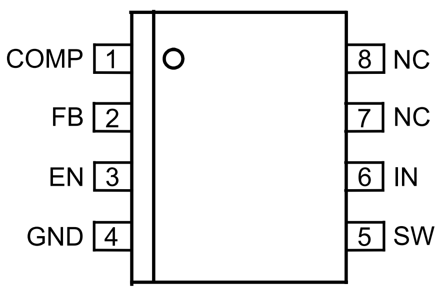
C_2,C_3: Murata GRM31CR61C226K

Figure 1. 5V to 12V Step-Up Converter



Pin Configuration

Top View



θ_{JA} = 160°C/W
8-Lead SOIC

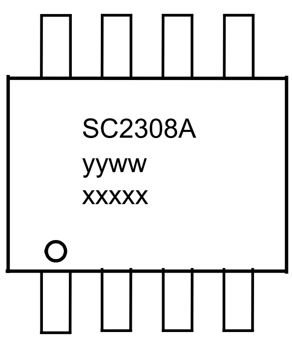
Ordering Information

Device	Package
SC2308ASTRT(1) (2)	SO-8
SC2308AEVB	Evaluation Board

Notes:
(1) Available in tape and reel only. A reel contains 2,500 devices.
(2) Available in lead-free package only. Device is WEEE and RoHS compliant and halogen free.

Marking Information

Top View



yyww - Date Code
xxxxx - Semtech Lot Number

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Absolute Maximum Ratings

IN to GND .... -0.3V to 24V

SW .... -0.3V to 45V

EN .... -0.3V to V_{IN} + 0.3V

FB .... -0.3V to V_{IN} + 0.3V

COMP .... -0.3V to V_{IN} + 0.3V

ESD Protection Level[1] 3.5kV

Recommended Operating Conditions

Junction Temperature Range........ -40°C to +105°C

V_{IN} .... 2.6V to 20V

Thermal Information

Θ_{JA}, 8-Lead SOIC[2] .... 160°C/W

Maximum Junction Temperature .... +150 °C

Storage Temperature Range .... -65°C to +150°C

Peak IR Reflow Temperature (10s to 30s) .... +260°C

Exceeding the above specifications may result in permanent damage to the device or device malfunction. Operation outside of the parameters specified in the Electrical Characteristics section is not recommended.

Notes:
(1) Tested according to JEDEC standard JESD22-A114-B.
(2) Calculated from package in still air, mounted to 3" x 4.5", 4 layer FR4 PCB with thermal vias under the exposed pad per JESD51 standards.

Electrical Characteristics

Unless otherwise noted: $V_{IN} = V_{EN} = 3V$, T_J = -40°C to 105°C. Typical values are at T_J = 25°C.

Parameter	Symbol	Conditions	Min	Typ	Max	Units
Input Supply						
Maximum Operating V_{IN}	$V_{IN(MAX)}$				20	V
V_{IN} Start Voltage		V_{IN} Rising		2.45	2.6	V
Shutdown Supply Current		$V_{EN} = 0$		0.01	1	µA
Quiescent Supply Current	I_Q	V_{FB} = 1.5V (Not Switching)		1.3	1.8	mA
Control Loop						
Feedback Regulation Voltage	V_{REF}		1.20	1.22	1.24	V
V_{REF} Line Regulation		V_{IN} = 3V to 20V		0.002	0.005	%/V
FB Pin Input Bias Current	I_{FB}	FB in Regulation		-15	-25	nA
Error Amplifier Transconductance	g_m	V_{COMP} = 1.1V, ΔI_{COMP} = ± 0.5µA		47		$\mu\Omega^{-1}$
Error Amplifier Open-Loop Gain	A_V			51		dB
COMP to Switch Current Gain				4		A/V
Soft-Start						
Soft-Start Time[3]	t_{SS}			3		ms

Notes:
(3) Time taken for the error amplifier soft-start input to rise from 0 to 1.22V.

Electrical Characteristics (continued)

Unless otherwise noted: $V_{IN} = V_{EN} = 3V$, T_J = -40°C to 105°C. Typical values are at T_J = 25°C.

Parameter	Symbol	Conditions	Min	Typ	Max	Units
Oscillator						
Switching Frequency	f_{SW}		500	630	750	kHz
Minimum Switch Off-Time	$t_{OFF(MIN)}$			60		ns
Minimum Switch On-Time	$t_{ON(MIN)}$			200		ns
Minimum Duty Cycle	D_{MIN}				0	%
Maximum Duty Cycle	D_{MAX}		87	96		%
Power Switch						
Switch Current Limit[(4)]	I_{LIM}		2.2	2.9	3.7	A
Switch Saturation Voltage	V_{CESAT}	I_{SW}=2.2A		320	480	mV
Switch Leakage Current	I_{LK}	V_{SW} =12V		0.1	0.5	µA
Enable Pin						
High Voltage Threshold	V_{IH}		2			V
Low Voltage Threshold	V_{IL}				0.3	V
Enable Pin Current	I_{EN}	V_{EN} =0V		0.01	0.1	µA
		V_{EN} =2V		3.3	5.1	
		V_{EN} =6V		13	25	
Over Temperature Protection						
Thermal Shutdown Temperature	T_{SHDN}	T_j rising		160		°C
Hysteresis	T_{HYST}			12		°C

Notes:
(4) Switch current limit does not vary with duty cycle.

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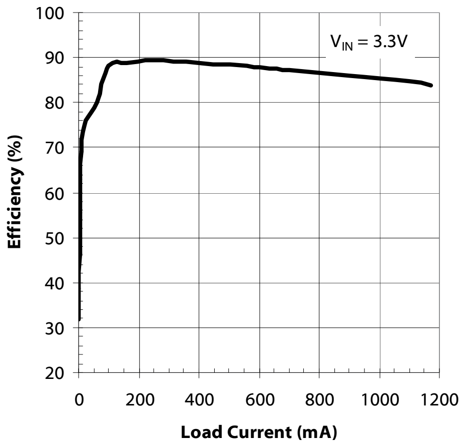
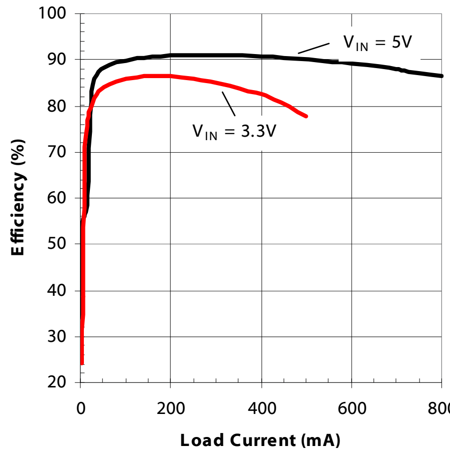
Typical Characteristics

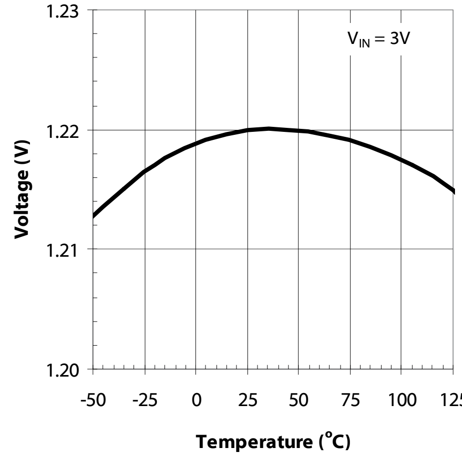
Efficiency vs Load Current
V_{OUT} = 5V



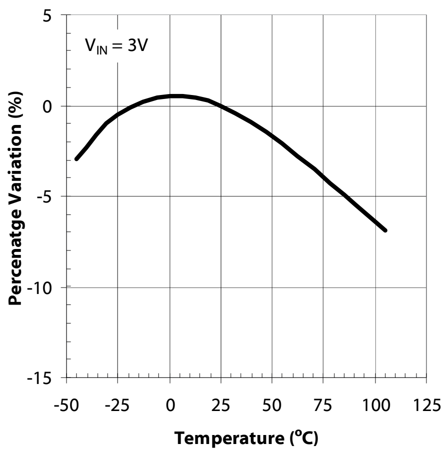
Efficiency vs Load Current
V_{OUT} = 12V



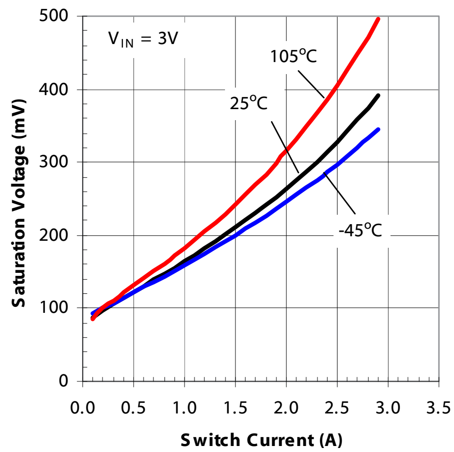
Feedback Voltage vs Temperature



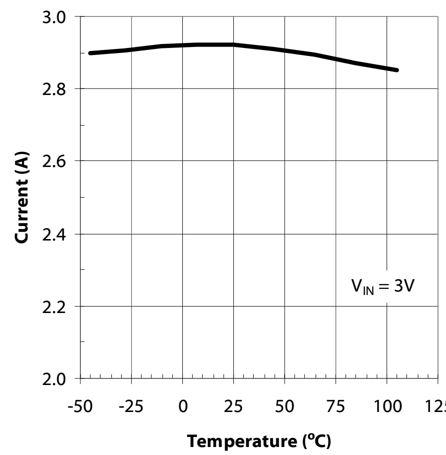
Percentage Frequency
Variation vs Temperature



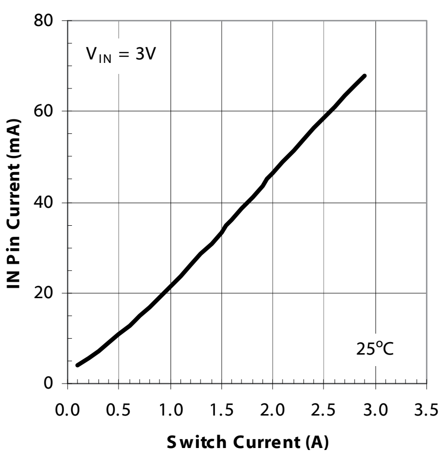
Switch Saturation
Voltage vs Switch Current



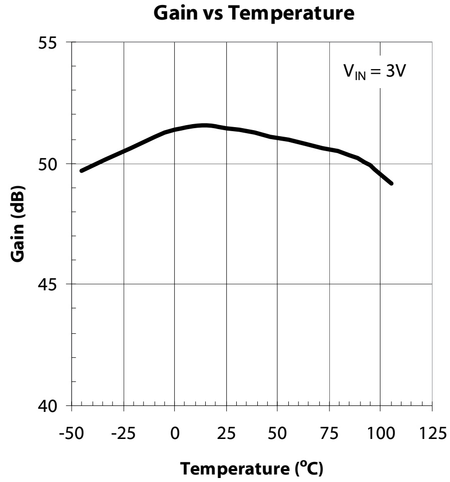
Switch Current Limit vs Temperature



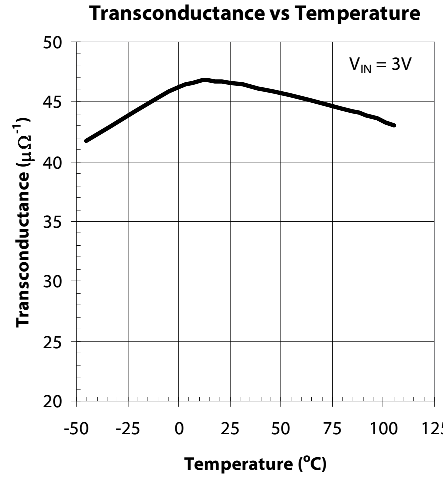
IN Pin Current vs Switch Current



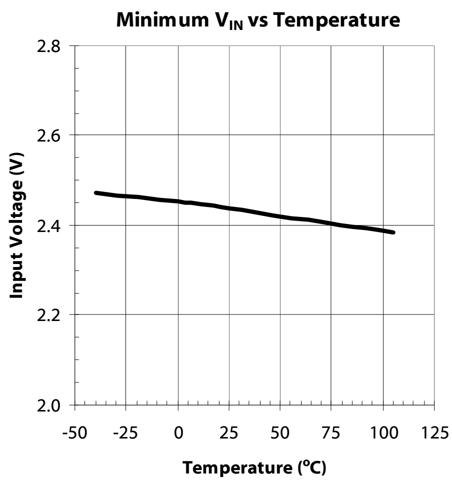
Error Amplifier Open-Loop
Gain vs Temperature

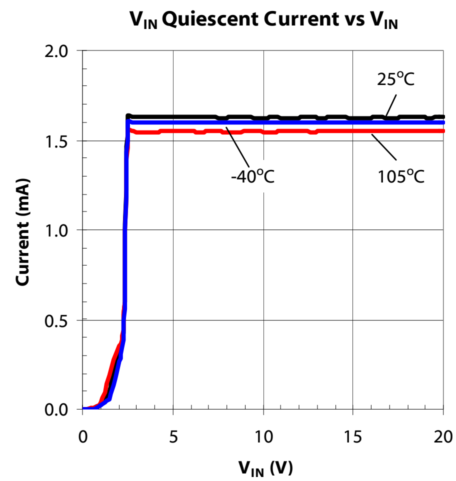


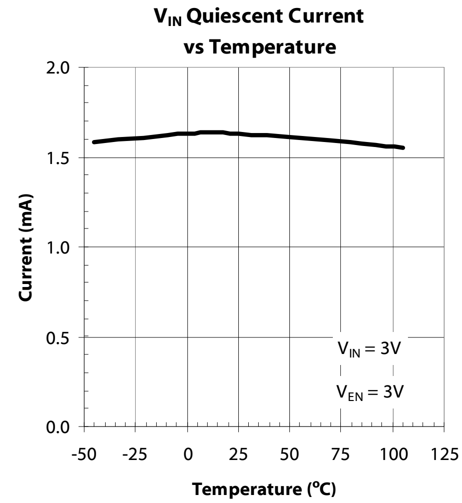
Error Amplifier
Transconductance vs Temperature

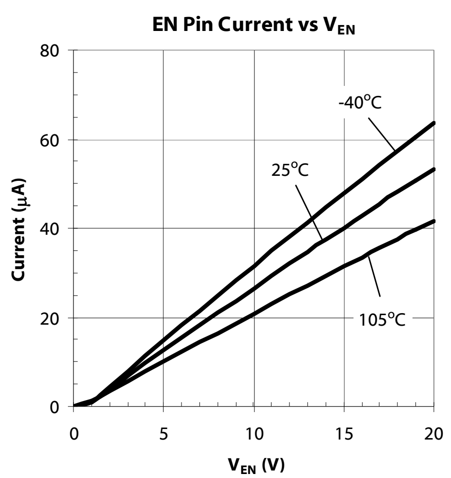


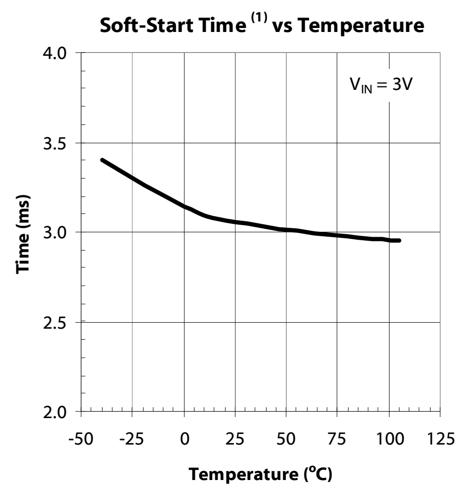
Typical Characteristics (Cont.)











Notes:
(1) Time taken for the error amplifier soft-start input to rise from 0 to 1.22V.

Pin Descriptions

Pin #	Pin Name	Pin Function
1	COMP	Error Amplifier Output. The voltage at this pin controls the peak switch current. A series RC network from this pin to ground compensates the control loop.
2	FB	The Inverting Input of the Error Amplifier. Tie to an external resistive divider to set the output voltage.
3	EN	Enable Pin. Pulling this pin below 0.3V shuts down the SC2308A to less than 1µA of quiescent current. Applying more than 2V at this pin enables the SC2308A. For normal operation, this pin can be tied to IN or driven from a logic gate with V_{OH} > 2V.
4	GND	Ground. Tie to the ground plane. The converter output capacitor must be closely bypassed to the ground pin.
5	SW	Collector of the Internal Power Transistor. Connect to a boost inductor and a freewheeling diode. The maximum switching voltage spike at this pin should be limited to less than 45V.
6	IN	Power Supply Pin. Bypassed with capacitor close to the pin.
7	NC	No connection.
8	NC	No connection.

Block Diagram

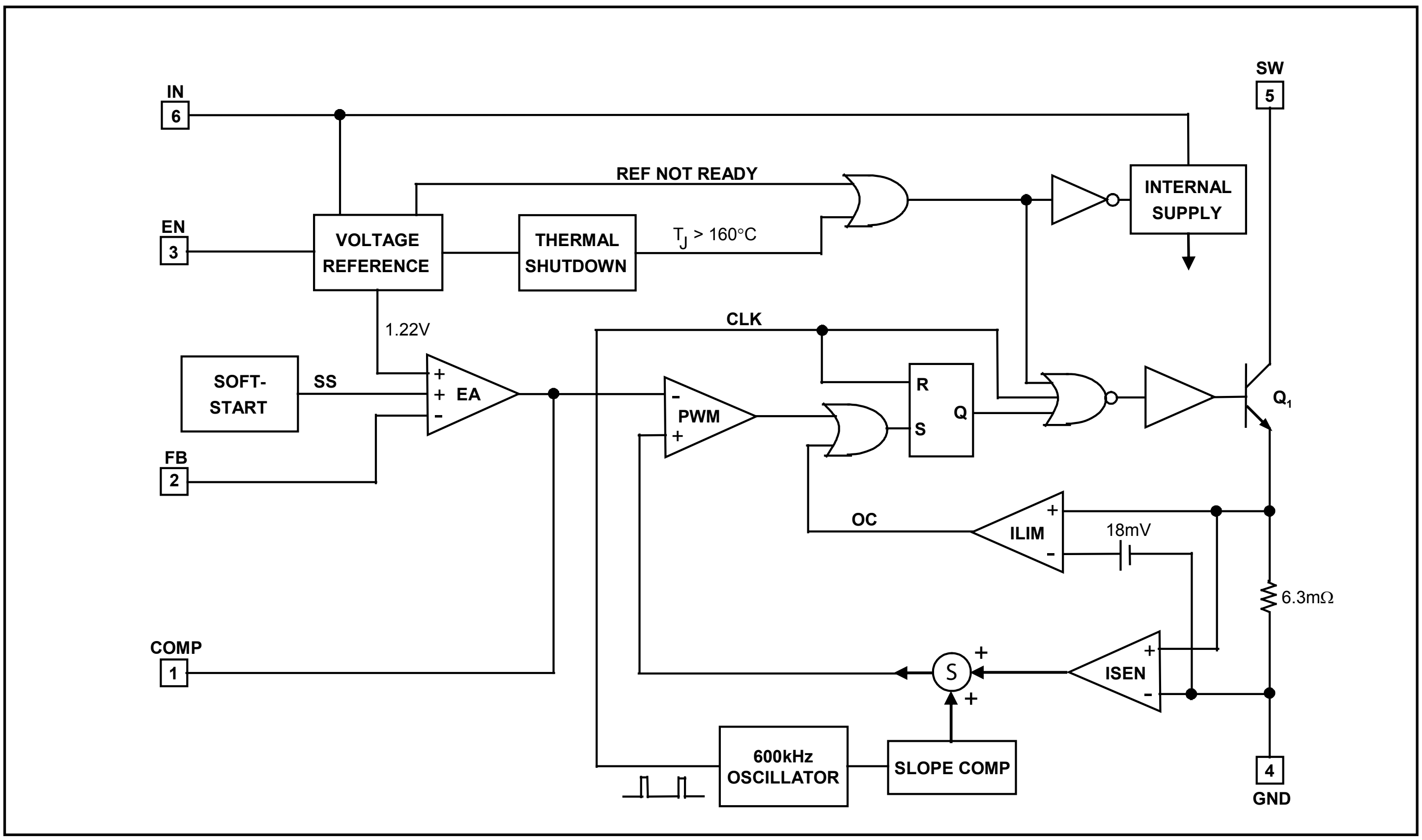


Figure 2. SC2308A Block Diagram

General Description and Operation

The SC2308A is a 600kHz peak current-mode switching regulator with an integrated 2.2A (minimum) low-side power transistor. The voltage reference runs off the input supply and is enabled by applying at least 2V at the EN pin, as shown in the block diagram in Figure 2. The reference also senses V_{IN} and produces a lockout signal "REF NOT READY". This signal does not go low until there is enough V_{IN} headroom for the reference to achieve regulation (typically V_{IN} = 2.45V). The "REF NOT READY" signal and the temperature sensor control the internal regulator, which powers all of the internal control circuits.

The error amplifier EA has two non-inverting inputs. The non-inverting input with the lower voltage predominates. One of the non-inverting inputs is biased to a precision 1.22V reference and the other non-inverting input is tied to a soft-start timer. Before the internal regulator turns on, the output SS of the soft-start timer is discharged to ground. As the internal regulator turns on, it also releases the timer. The soft-start timer generates a slow rising SS ramp, which is fed into one of the non-inverting inputs of the EA. During power-up, the SS voltage becomes the EA effective non-inverting input voltage. In a boost converter, the part starts switching as V_{SS} exceeds the FB voltage. If the soft-start ramp is sufficiently slow, then the FB voltage (hence the output voltage) will track V_{SS} and there will be no output overshoot during start-up. It takes about 3ms to charge V_{SS} from ground to the nominal feedback voltage. The end of charge V_{SS} is significantly higher than 1.22V so that it has no effect on the error amplifier. Soft-start also reduces the input start-up current.

The clock CLK resets the latch and blanks the power transistor Q_1 conduction. Q_1 is switched on at the trailing edge of the clock. The switch current is sensed with an integrated 6.3mΩ sense resistor. The sensed current summed with the slope-compensating ramp is fed into the modulating ramp input of the PWM comparator. The latch is set and Q_1 conduction is terminated when the modulating ramp intersects the error amplifier output. If the switch current exceeds 2.9A (the typical current limit), then the current-limit comparator ILIM will set the latch and turn off Q_1. Due to separate pulse-width modulating and current limiting paths, cycle-by-cycle current limiting is not affected by slope compensation.

The current-mode switching regulator is a dual-loop feedback control system, designed to simplify loop compensation. In the inner current loop, the EA output controls the peak inductor current. In the outer loop, the error amplifier regulates the output voltage. The double reactive poles of the output LC filter are reduced to a single real pole by the inner current loop, easing loop compensation. A simple, two-pole, single-zero compensator network connected from COMP to ground is adequate to stabilize the converter.

Applications Information

Duty Cycle

The duty cycle is the ratio of the switch on-time to the switching period. For a boost converter, the duty cycle in continuous-conduction mode (CCM) is:

$$D = \frac{V_{OUT} + V_D - V_{IN}}{V_{OUT} + V_D - V_{CESAT}} \quad (1)$$

where V_{CESAT} is the switch saturation voltage and V_D is the rectifying diode forward voltage.

Setting the Output Voltage

The converter output voltage is set with an external resistive divider. The center tap of the divider is tied to the FB pin (Figure 3).

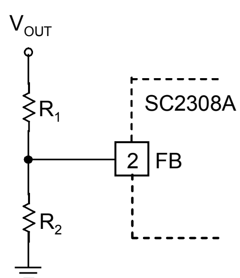


Figure 3. R_1 and R_2 Divider Sets V_{OUT}

The expression for V_{OUT} is:

$$V_{OUT} = 1.220\left(1 + \frac{R_1}{R_2}\right) \quad (2)$$

R_1 can be calculated from the output voltage and R_2 as follows:

$$R_1 = R_2 \cdot \left(\frac{V_{OUT}}{1.220} - 1\right) \quad (3)$$

Using large resistors for the FB voltage divider reduces power consumption.

Minimum Off-Time Limitation

There is also a 100ns minimum switch off-time, which limits the maximum duty cycle. This determines the maximum attainable output voltage for a given V_{IN}. Using Equation (1), the maximum output voltage for a boost converter can be derived:

$$V_{OUT} \le \frac{V_{IN} - D_{MAX}V_{CESAT}}{1 - D_{MAX}} - V_D \quad (4)$$

where D_{MAX} is the maximum duty cycle.

Example: Determine the highest output voltage that can be achieved from a 3V input using the SC2308A as a boost regulator. Assuming V_D= 0.5V, V_{CESAT}= 0.3V and using D_{MAX}= 0.87:

$$V_{OUT} \le \frac{3 - 0.87 \times 0.3}{1 - 0.87} - 0.5 = 20.6V$$

The transient headroom requirement further reduces the maximum achievable output voltage to less than 20V.

Maximum Output Current

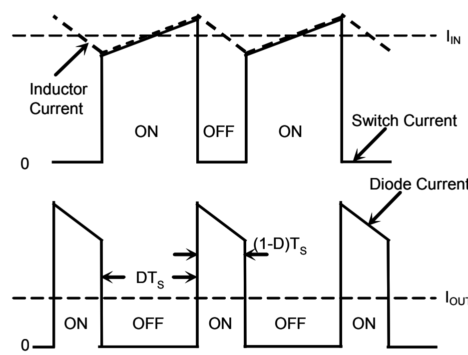


Figure 4. Current Waveforms in a Boost Converter

In a boost converter, the inductor is connected to the input. The inductor DC current is the regulator input current. When the power switch is turned on, the inductor current flows into the switch. When the power switch is off, the inductor current flows through the rectifying diode to the output. The output current is the average diode current. The diode current waveform is trapezoidal with a pulse width of $(1–D)T_S$ (Figure 4). The output current available from a boost converter, therefore, depends on the converter operating duty cycle. The power switch current in the SC2308A is internally limited to at least 2.2A. This is also the maximum peak inductor or the peak input current. If the inductor ripple current is low, then the maximum regulator input current will be very close to the switch current limit I_{LIM}. By estimating the conduction

Applications Information (Continued)

losses in both the switch and the diode, an expression for the maximum available output current of a boost converter can be derived using Equation (5):

$$I_{OUT(MAX)} = \frac{I_{LIM} V_{IN}}{V_{OUT}} \left[1 - \frac{D}{45} - \frac{V_D - D(V_D - V_{CESAT})}{V_{IN}} \right] \quad (5)$$

Since switching losses are excluded in the derivation, the actual output current is over-estimated in Equation (5). Nevertheless, this calculation still provides a useful initial approximation.

Inductor Selection

The inductor must be able to handle the peak current I_{LIM}. First, the inductor should not saturate at I_{LIM}. Second, the inductor needs to have low core loss at the switching frequency. Inductors with ferrite cores are preferrable. Moreover, the inductor should have low DCR for low copper loss. The inductance can be selected such that the inductor ripple current is between 20% to 40% of its average current for improved efficiency.

The inductance can be calculated using Equation (6):

$$L = \frac{D(V_{IN} - V_{CESAT})}{\Delta I_L \cdot f_{SW}} \quad (6)$$

The Coilcraft DO3316P series and the Sumida CDRH8D38NP series inductors perform well in boost converters. The inductors selected must be suitable for a 750kHz switching frequency.

Input Capacitor Selection

The input current in a boost converter is the inductor current, which is continuous with low RMS current ripples. A 2.2µF~4.7µF ceramic capacitor is adequate for most applications. Use X5R or better ceramic capacitors, since they have stable temperature and voltage coefficients. The voltage rating for the input capacitor should exceed the maximum input voltage by 10% to 25%. Murata and TDK are two ceramic capacitor suppliers.

Output Capacitor Selection

Ceramic and low equivalent series resistance (ESR) tantalum or polymer capacitors can be used for output filtering. In a buck converter, the inductor ripple current flows in the output capacitor, whereas in a boost converter, the output capacitor current is the difference between the rectifying diode current and the output current (Figure 4). This current is discontinuous with high current amplitudes. For this reason, the output ripple voltage of a boost converter is always higher than that of a buck converter with the same inductor current and the same output capacitor.

If tantalum or polymer capacitors are used at the converter output, then the converter output ripple voltage will be primarily determined by the capacitor ESR, due to the relatively high ESR of these capacitors. The output voltage ripple is the product of the peak inductor current and the output capacitor ESR. For example, if two Sanyo 6TPG100M (100µF, ESR=70mΩ) polymer capacitors are used for output filtering, then the output peak-to-peak ripple voltage will be 70mV, assuming a 2A peak inductor current.

Tantalum capacitor voltage derating is generally 50%.

Multi-layer ceramic capacitors, due to their extremely low ESR (<5mΩ), are particularly well suited for output filtering. It is worth noting that the output ripple voltage resulting from charging and discharging of a 10µF or a 22µF ceramic capacitor is higher than the ripple voltage resulting from the capacitor ESR. The output ripple voltage due to charging and discharging effects is calculated using the following equation:

$$\Delta V_{OUT} = \frac{DI_{OUT}}{f_{SW} \cdot C_{OUT}} \quad (7)$$

X5R and X7R ceramic capacitors are the preferred types.

Rectifying Diode

For high efficiency, Schottky barrier diodes should be used as rectifying diodes for the SC2308A. These diodes should have an average forward current rating at least equal to the output current. The reverse blocking voltage of the Schottky diode should be derated by 10%-20% for reliability. The Schottky diode used in a 12V output step-up converter should have a reverse voltage rating of at least 15V (20% derating).

Applications Information (Continued)

SS22 and SS24 from ON Semiconductor and 10BQ020 and 10BQ040 from International Rectifier are widely used Schottky diodes.

Soft-Start

The SC2308A comprises an internal soft-start timer. The output (SS) of the soft-start timer (see Figure 2), which forms the second non-inverting input of the feedback amplifier, is reset to zero before V_{IN} rises above its turn-on threshold. The SS voltage is subsequently charged from zero to the nominal feedback voltage (1.22V) in about 3ms.

If a step-up converter is enabled by stepping the EN input while connected to a live power supply, then its output voltage will rise linearly from approximately V_{IN} to its set voltage. The current drawn from the input power supply will be less than the switch current limit and there will be no output overshoot during start-up. Figure 5 shows the start-up waveforms of the 5V to 12V step-up converter in Figure 1 and the 3.3V to 5V step-up converter in Figure 10. Notice that the regulator does not switch until the internal SS voltage exceeds the FB voltage.

If the input power supply to a step-up converter is turned on with the EN and the IN pins shorted, then the start-up waveforms will depend on the input voltage ramp rate and the output load. The internal 3ms soft-start interval may be insufficient to keep the input start-up current below the switch current limit, especially with heavy loads and slow V_{IN} ramp. Figure 6 shows the start-up waveforms of the step-up converters in Figure 1 and Figure 10 when powering on using the Agilent 6652A DC power supply. Before V_{IN} rises above the input start voltage, there is no switching and the converter output simply follows V_{IN}. When starting into an 800mA constant-current load, the 5V to 12V converter reaches the cycle-by-cycle current limit and the output voltage ramp becomes non-linear {Figure 6(c)}. There is, however, very little output voltage overshoot.

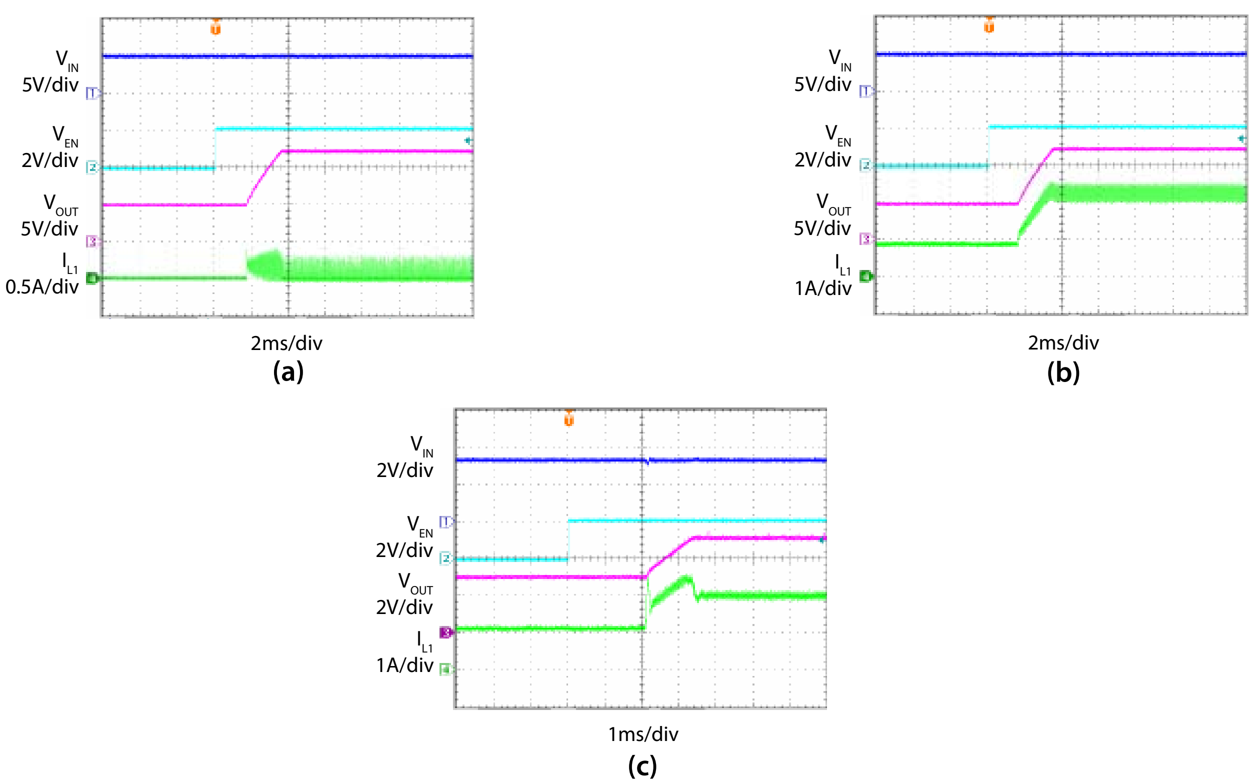


Figure 5. Boost Converter Start-Up Waveforms. EN is Stepped with Input Applied.
(a) 5V to 12 V Step-Up Regulator (Figure 1), I_{OUT} = 10mA
(b) 5V to 12 V Step-Up Regulator, I_{OUT} = 800mA
(c) 3.3V to 5V Step-Up Regulator (Figure 10), I_{OUT} = 1.1A

Applications Information (Continued)

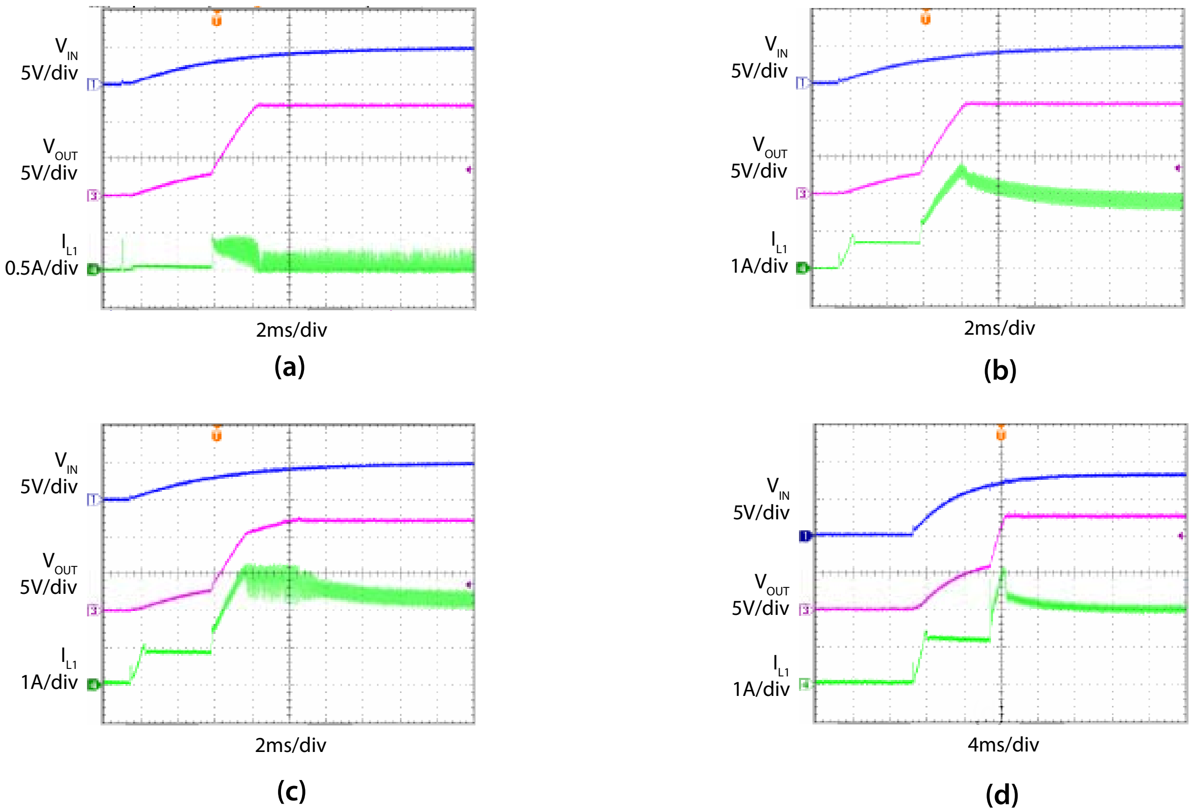


Figure 6. Boost Converter Start-Up Waveforms. EN is Tied to IN and the Regulator is Powered on Using the Agilent 6652A Power Supply.
(a) 5V to 12 V Step-Up Regulator (Figure 1), I_{OUT} = 10mA
(b) 5V to 12 V Step-Up Regulator, I_{OUT} = 650mA
(c) 5V to 12 V Step-Up Regulator, I_{OUT} = 800mA
(d) 3.3V to 5V Step-Up Regulator (Figure 10), I_{OUT} = 1.1A

Frequency Compensation

Figure 7 shows the simplified equivalent model of a boost converter using the SC2308A.

Due to current-mode control, the double reactive poles attributed to the inductor are reduced to a single real pole. This pole results from the output capacitor and is at frequency:

$$f_{p2} = \frac{1}{\pi R_L C_{OUT}} \quad (8)$$

where R_L is the equivalent output load resistance and C_{OUT} is the output capacitance.

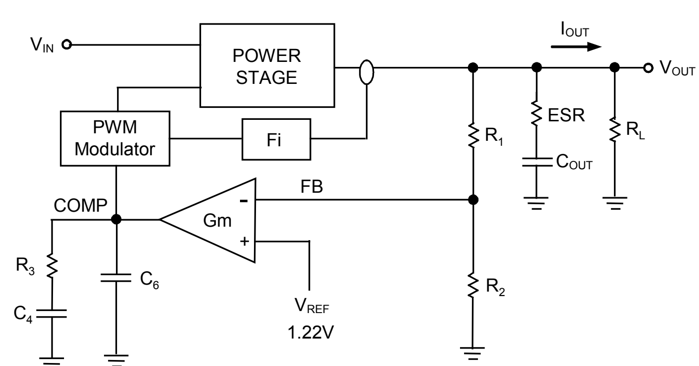


Figure 7. The Simplified Model of a Boost Converter

Applications Information (Continued)

The power stage also has a right half plane (RHP) zero at:

$$f_{z2} = \frac{(1-D)^2 R_L}{2\pi L} \qquad (9)$$

The ESR zero frequency is:

$$f_{z3} = \frac{1}{2\pi R_C C_{OUT}} \qquad (10)$$

where R_C is the ESR of the output capacitor.

R_3 and C_4 form a zero at:

$$f_{z1} = \frac{1}{2\pi R_3 C_4} \qquad (11)$$

With the assumption that $C_4 >> C_6$, R_3 and C_6 also form a pole p_3 at frequency:

$$f_{p3} = \frac{1}{2\pi R_3 C_6} \qquad (12)$$

There is also a low-frequency integrator pole p_1 formed by C_4 and the equivalent output resistance of the transconductance amplifier. The corresponding bode plots are shown in Figure 8.

The poles p_1, p_2 and the RHP zero z_2 all increase phase shift in the loop response. For stable operation, the overall loop gain should cross 0dB with -20dB/decade slope. Due to the presence of the RHP zero, it is suggested that the 0dB crossover frequency should not be more than $\frac{f_{z2}}{3}$.

A simple two-pole, single-zero compensator network is adequate. The loop is compensated with R_3, C_4 and C_6 from the COMP pin to ground. The compensating zero z_1 provides phase boost beyond p_2. In general, the converter will be more stable if the filter pole p_2 and the RHP zero z_2 are widely separated. The RHP zero moves to low frequency when either the duty cycle D or the output current I_{OUT} increases. It is beneficial to use small inductors and larger output capacitors, especially when stepping up from low V_{IN} to high V_{OUT}. An optional second pole can be placed at the power stage ESR zero to attentuate any high-frequency noise.

Thermal Shutdown

Thermal shutdown turns off the power switch and the control circuit as the junction temperature exceeds 160°C. Switching resumes when the junction temperature falls by 12°C.

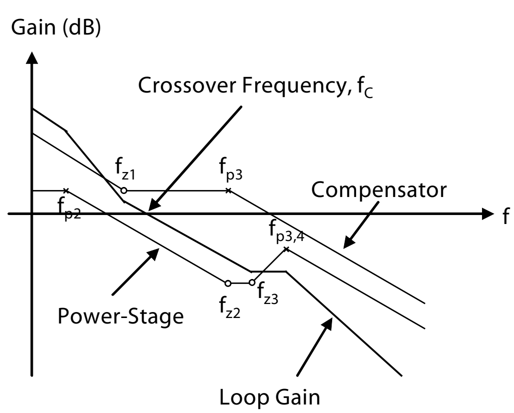


Figure 8. Bode Magnitude Plots of the Power Stage, the Compensator, and the Overall Loop Gain

Applications Information (Continued)

Board Layout Considerations

In a boost converter, the main power switch, the rectifying diode, and the output filter capacitor carry pulse currents with high di/dt. For jitter-free operation, the size of the loop formed by these components should be minimized. The main power switch is integrated inside the SC2308A. Therefore, the output capacitor should be connected close to the device ground pin. Shortening the trace at the SW pin reduces the parasitic trace inductance. This decreases voltage ringing at the SW node. The input capacitor should be placed close to the input and the GND pins. Figure 9 shows an example of external component placement around the SC2308A.

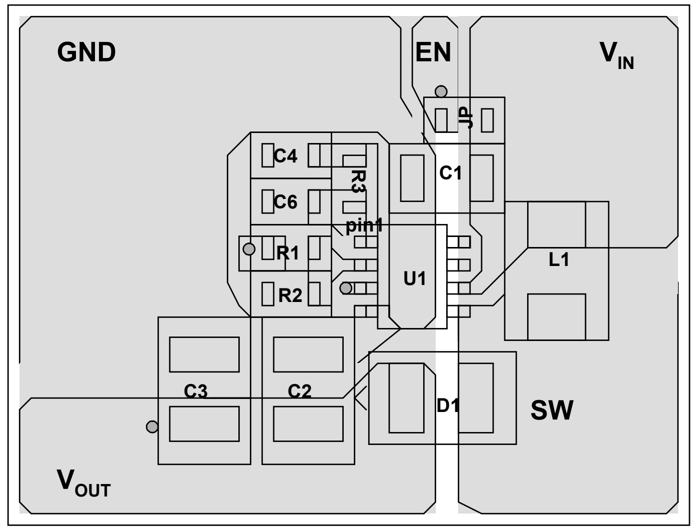
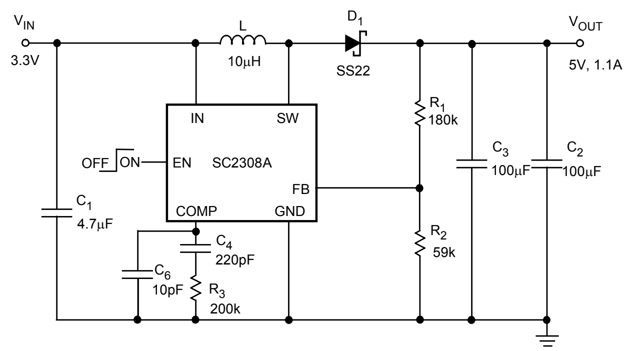


Figure 9. Suggested PCB Layout for the SC2308A

Typical Application Circuits



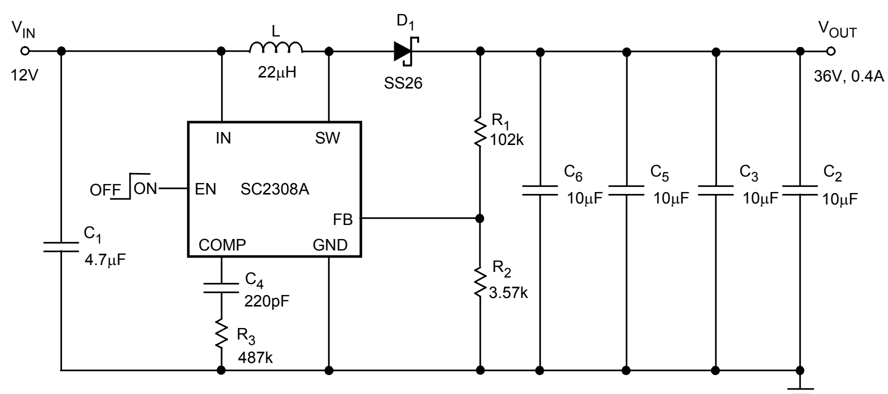
L: Coilcraft DO3316P103

D_1: ON SS22

C_1: Murata GRM31CR61A475K

C_2,C_3: Sanyo 6TPG100M

Figure 10. 3.3V to 5V Step-Up Converter



L: Cooper CD1-220

D_1: ON SS26

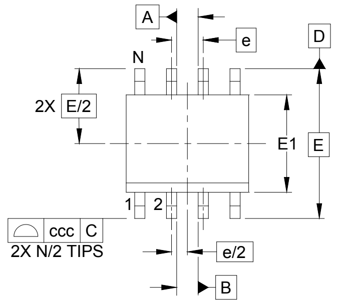
C_1: Murata GRM31CR61C475K

C_2,C_3 ,C_5,C_6: Murata GRM31CR61H106K

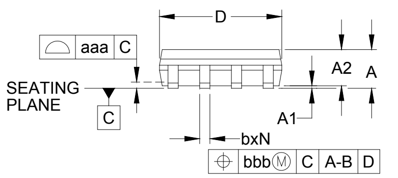
Figure 11. 12V to 36V Step-Up Converter

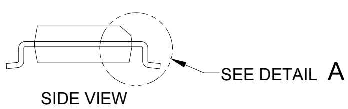
SEMTECH

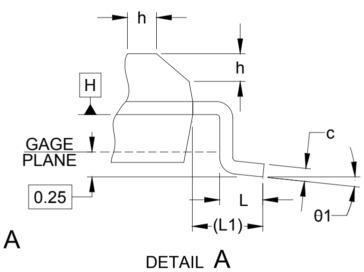
Outline Drawing — SOIC-8



DIM	INCHES MIN	INCHES NOM	INCHES MAX	MILLIMETERS MIN	MILLIMETERS NOM	MILLIMETERS MAX
A	.053	-	.069	1.35	-	1.75
A1	.004	-	.010	0.10	-	0.25
A2	.049	-	.065	1.25	-	1.65
b	.012	-	.020	0.31	-	0.51
c	.007	-	.010	0.17	-	0.25
D	.189	.193	.197	4.80	4.90	5.00
E1	.150	.154	.157	3.80	3.90	4.00
E	.236 BSC			6.00 BSC		
e	.050 BSC			1.27 BSC		
h	.010	-	.020	0.25	-	0.50
L	.016	.028	.041	0.40	0.72	1.04
L1	(.041)			(1.04)		
N	8			8		
θ1	0°	-	8°	0°	-	8°
aaa	.004			0.10		
bbb	.010			0.25		
ccc	.008			0.20		



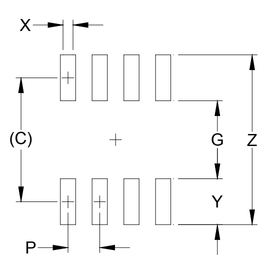




NOTES:

1. CONTROLLING DIMENSIONS ARE IN MILLIMETERS (ANGLES IN DEGREES).
2. DATUMS -A- AND -B- TO BE DETERMINED AT DATUM PLANE -H-
3. DIMENSIONS "E1" AND "D" DO NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS.
4. REFERENCE JEDEC STD MS-012, VARIATION AA.

Land Pattern – SOIC-8



DIM	INCHES	MILLIMETERS
C	(.205)	(5.20)
G	.118	3.00
P	.050	1.27
X	.024	0.60
Y	.087	2.20
Z	.291	7.40

NOTES:

1. THIS LAND PATTERN IS FOR REFERENCE PURPOSES ONLY. CONSULT YOUR MANUFACTURING GROUP TO ENSURE YOUR COMPANY'S MANUFACTURING GUIDELINES ARE MET.
2. REFERENCE IPC-SM-782A, RLP NO. 300A.

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