SC1408 Low Voltage, Boost DC-DC Controller

Description

The SC1408 is a low voltage boost controller that operates from a 1.8V to 16.5V input range. The SC1408 was designed for two cell Alkaline or single cell Lithium Ion battery applications. With the proper external components it can be used as a boost converter or a buck/boost converter. A Shutdown pin allows the user to turn the controller off, reducing supply current to less than 2µA typical. Output voltage can be preset to 5V or is adjustable from 3V to 16.5V with a resistor divider. The controller changes frequency in light load conditions to improve efficiency.

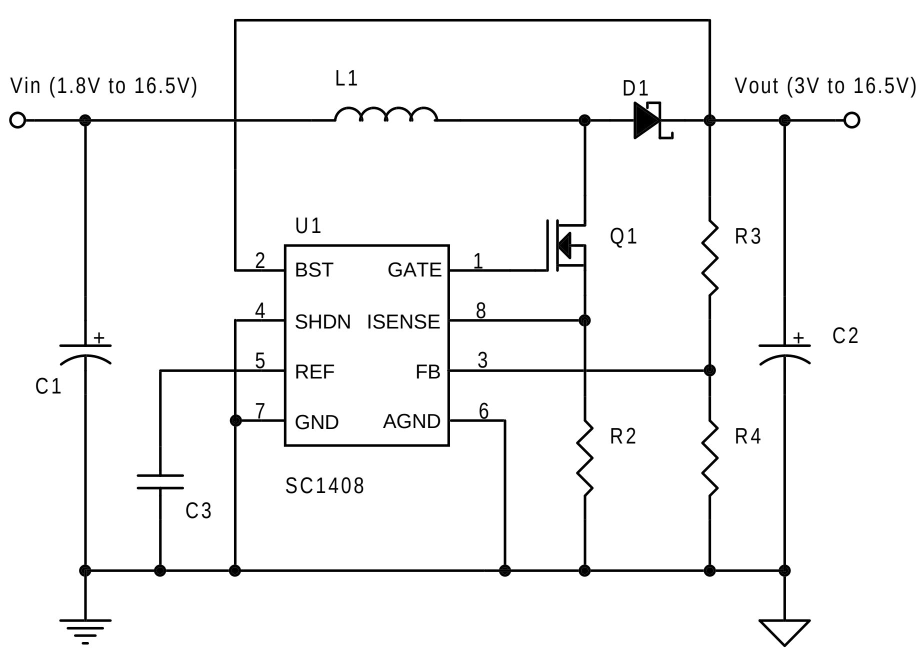
Features

- 1.8V to 16.5V input range
- Preset (5V) or Adjustable output
- Ground Referenced Current Limit
- On Chip Precision Reference
- Up to 300kHz switching frequency
- 10µA max shutdown current
- Industrial temperature range
- SO-8 and MSOP-8 packages

Applications

- PDA Power supplies
- Battery powered applications
- Positive LCD Bias generator
- Portable communications (cellular phones)
- Peripheral card supplies
- Industrial power supplies

Typical Application Circuit



Absolute Maximum Ratings

Parameter	Symbol	Maximum	Units
Input Voltage	BST to GND	-0.3 to 18	V
Small Signal Ground to Power Ground	GND to AGND	+0.1	V
GATE to GND		-0.3 to VBST +0.3 or 5	V
FB, SHDN, REF, ISENSE to GND		-0.3 to min. of VBST +0.3 or 5	V
Operating Temperature	T_A	-40 to +85	°C
Junction Temperature Range	T_J	-40 to +150	°C
Storage Temperature Range	T_{STG}	-65 to +160	°C
Lead Temperature (Soldering) 10 Sec.	T_L	+300	°C
Thermal Resistance, Junction to Ambient SO-8 MSOP-8	θ_{JA}	 165 206	°C/W
Thermal Resistance, Junction to Case SO-8/MSOP-8	θ_{JC}	40	°C/W

Electrical Characteristics

Unless specified: V_{OUT} = 5V; I_{LOAD} = 0mA; T_A = +25°C

Parameter	Sym	Conditions		Min	Typ	Max	Units
Input Voltage	V_{IN}	T_A = 25°C		1.8		16.5	V
		T_A = -40°C to +85°C		1.8		16.5	V
Supply Current		V_{OUT}=16.5V,SHDN < 0.4V	T_A = -40°C to +85°C		110	140	µA
		V_{OUT}=10V, 1.6V < SHDN < 5V	T_A = -40°C to +85°C		2	10	
Output Voltage	V_{OUT}	V_{IN} = 2.0V to 5.0V	T_A = -40°C to +85°C	4,800	5.0	5.200	V
Load Regulation		V_{IN} = 2.0V, V_{OUT} = 5V, I_{LOAD} = 0mA to 500mA			60		mV/A
Line Regulation		V_{IN} = 2.7V to 4.0V, V_{OUT} = 5V, I_{LOAD} = 500mA			7		mV/V
Minimum Start Up Voltage		No load				1.8	V
Minimum Switch On Time	$t_{ON(Max)}$			9.6	16	22.4	µs
Minimum Switch Off Time	$t_{OFF(Min)}$			1.4	2.3	3.2	µs
Efficiency		V_{IN} = 4V, V_{OUT} = 5V, I_{LOAD} = 0mA to 500mA			87		%
Reference Voltage	V_{REF}	I_{REF} =0µA	T_A = -40°C to +85°C	1.176	1.200	1.224	V
Reference Load Regulation		0µA < I_{REF} < 100µA			-4	10	mV
Reference Line Regulation		5V < V_{OUT} < 16.5V			40	100	µV/V

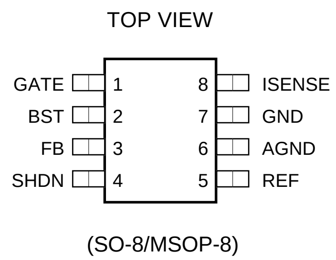
Electrical Characteristics (Cont.)

Unless specified: V_{OUT} = 5V; I_{LOAD} = 0mA; T_A = +25°C

Parameter	Sym	Conditions		Min	Typ	Max	Units
FB Trip Point Voltage	V_{FB}	T_A = 25°C T_A = -40°C to +85°C		1.176	1.200	1.224	V
FB Input Current	I_{FM}	T_A = 25°C T_A = -40°C to +85°C			-4	±40	nA
SHDN Input High Voltage	V_{IN}	V_{OUT} = 2.7V to 16.5V		1.6			V
SHDN Input Low Voltage	V_{IL}	V_{OUT} = 2.7V to 16.5V				0.4	V
SHDN Input Current		V_{OUT} = 16.5V, SHDN = 0V or 5V				±1	µA
Current Limit Trip Level	V_{CS}	V_{OUT} = 3V to 16.5V	T_A = 25°C T_A = -40°C to +85°C	85 80	100	115 120	mV
ISENSE Input Current					0.01	±1	µA
GATE Rise Time		V_{OUT} = 5V, InF from GATE to GND			50		ns
GATE Fall Time		V_{OUT} = 5V, InF from GATE to GND			50		
GATE On Resistance		GATE = high or low			15	30	Ω

NOTE:
(1) This device is ESD sensitive. Use of standard ESD handling precautions is required.

Pin Configuration



Ordering Information

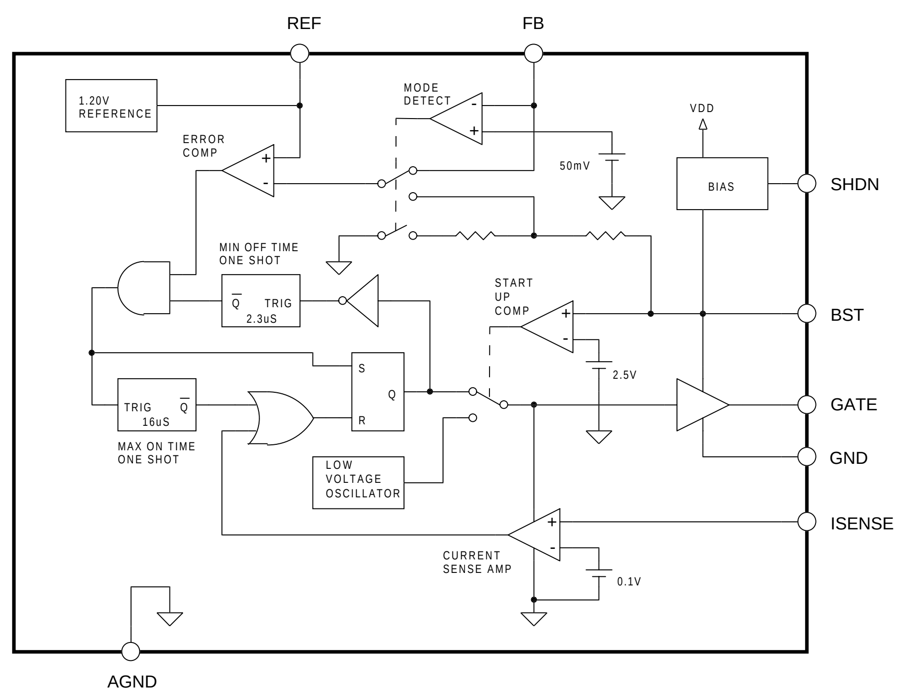
Part Number (1)	Package	Temp Range (T_A)
SC1408IS.TR	SO-8	-40° to +85°C
SC1408IMS.TR	MSOP-8	

Note:
(1) Only available in tape and reel packaging. A reel contains 2500 devices.

Pin Descriptions

Pin #	Pin Name	Pin Function
1	GATE	Gate drive output.
2	BST	Supply voltage.
3	FB	Voltage feedback
4	SHDN	Logic high shuts down the converter.
5	REF	Reference output pin.
6	AGND	Small signal analog and digital ground.
7	GND	Power ground.
8	ISENSE	Current sense pin.

Block Diagram



Theory of Operation

The SC1408 is a modified hysteretic boost converter controller. The power switch is turned on when the output voltage falls slightly below it's setpoint. It remains on for approximately 16ms, or until the inductor current reaches limit, whichever occurs first. The power switch is then turned off for 2.3ms, or until the output voltage once again falls below setpoint, whichever occurs last.

The SC1408 is normally powered from the output voltage. Internal circuitry, such as the bandgap, comparators and one shots, will not function properly until the BST pin voltage reaches 2.5V. To ensure start-up at low input voltages, the normal control circuitry is disabled and a special, low voltage start up oscillator generates an approximate square wave at the GATE pin, initiating boost action. When the output voltage reaches 2.5V, the normal control circuitry is enabled and the start up oscillator shuts down.

To conserve power, a SHDN pin is provided which, when pulled high, shuts down most internal circuitry. The output voltage will then be 1 diode drop below the input.

COMPONENT SELECTION

Boost Converter

RSENSE

The value of the sense resistor is the primary determining factor for maximum output current. The SC1408 has a fixed current limit voltage threshold, which is developed by the peak inductor current flowing through RSENSE. RSENSE may be determined either from the maximum output current curves or from the equation below:

$$I_{O(MAX)} = \frac{V_{CS}}{R_{SENSE}}\left(1 - \frac{V_O + V_F - V_{IN}}{V_O + V_F - V_{FET}}\right) - \frac{t_{off}}{2L}\left(\frac{(V_{IN} - V_{FET})(V_O + V_F - V_{IN})}{V_O + V_F - V_{FET}}\right)$$

Where :

V_F = Output Diode Forward Voltage Drop

V_{FET} = Voltage across FET, RSENSE and Inductor DCR

In the equation above, the use of 2.3µs for t_{off} may lead to slightly optimistic current values for low V_O/V_{IN} ratios. The theoretical curves use the actual value of t_{off}, V_F=0.5V, V_{FET}=0.3V and V_{CS}=0.08V and are generated for L=22µH.

Output Voltage

Output voltage can be set to 5V by connecting the FB pin to GND, or to any voltage in the 3.0V to 16.5V range using external divider resistors.

The bottom resistor in the divider chain (R4 in the typical application circuits) should be 300kΩ or less and the top resistor (R3 in the application circuits) can be calculated from

$$R3 = R4\left(\frac{V_O}{V_{REF}} - 1\right)$$

Inductor

The SC1408 will work with a wide range of inductor values. A good choice for most applications is 22µH. Smaller inductor values result in higher peak currents and increase output ripple, while larger values will result in slower loop response.

Transistor selection

Normally the power switch will be an N-channel MOSFET, although in certain circumstances an NPN bipolar may be substituted.

The choice of FET can be critical, especially in battery powered applications where the converter must be able to use all of the available energy in the battery. This requires that the converter be capable of starting up from very low input voltages. For example a two cell alkaline system's terminal voltage will drop to 1.8V as it approaches full discharge. For these demanding applications, a FET with low $V_{GS(th)}$ is required. A good rule of thumb is that $V_{GS(th)}$ should be at least 0.5V less than the minimum input voltage.

Diode

For most applications, a Schottky diode should be used as the output rectifier. It will be subjected to reverse voltages of at least V_O, and average current will be somewhat less than the Inductor peak current. Industry standard 1N5817 series or an equivalent surface mount part would be suitable.

Output Capacitors

Output capacitors should be low ESR to minimize ripple voltage and maximize efficiency. Low ESR tantalum or OSCON capacitors should be used. Ripple voltage will be approximately:

Input Capacitors

Input capacitors on a boost converter are less critical than the output capacitors, since there are no fast current pulses drawn from the input supply. A 100µF tantalum will be adequate for most applications.

COMPONENT SELECTION

SEPIC Converter

RSENSE

Again, with the SEPIC topology, the value of the sense resistor is the primary determining factor for maximum output current. The simplest approach to select RSENSE is to add Vin to Vo and use this value as the output voltage in the output current curves or in the equation for Boost converter.

Output Voltage

Output voltage setting works exactly the same in SEPIC topology as in Boost, including the ability to set to 5V by connecting the FB pin to GND. Care must be taken to ensure that the IC supply (pin2; BST) does not exceed its 16.5V rating. In the circuit of Fig.2: This requires maximum output voltage to be limited to 16.5V-Vin. Higher output voltages are possible with different IC supply strategies.

Inductor

The SEPIC topology requires a coupled inductor. Again A good choice for most applications is 22uH. Smaller inductor values result in higher peak currents and increase output ripple, while larger values will result in slower loop response.

Transistor selection

The choice of FET can be critical, especially in battery powered applications where the converter must be able to use all of the available energy in the battery. This requires that the converter be capable of starting up from very low input voltages. For example a two cell alkaline system's terminal voltage will drop to 1.8V as it approaches full discharge. For these demanding applications, a FET with low $V_{GS(th)}$ is required. A good rule of thumb is that $V_{GS(th)}$ should be at least 0.5V less than the minimum input voltage.

Diode

For most applications, a Schottky diode should be used as the output rectifier. It will be subjected to reverse voltages of at least $V_O + V_{IN}$ and average current will be somewhat less than the Inductor peak current. Industry standard 1N5817 series or an equivalent surface mount part would be suitable.

Output Capacitors

Output capacitors should be low ESR to minimize ripple voltage and maximize efficiency. Low ESR tantalums, OSCONs or the newer Polymer capacitors should be used.

Input Capacitors

Input capacitors on a SEPIC converter are less critical than the output capacitors, since there are no fast current pulses drawn from the input supply. A 100mF tantalum will be adequate for most applications.

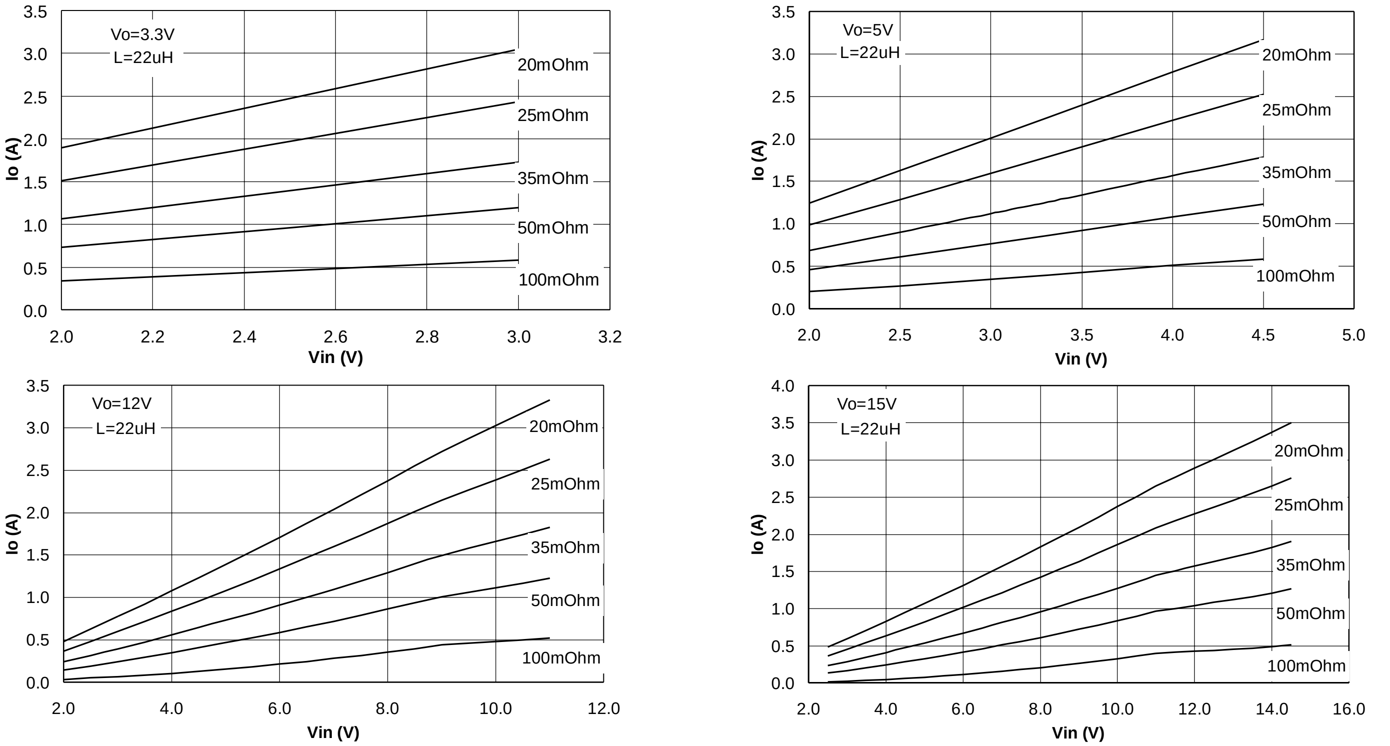
Series Capacitors

The Series capacitor(s) must be capable of handling an RMS current given by:-

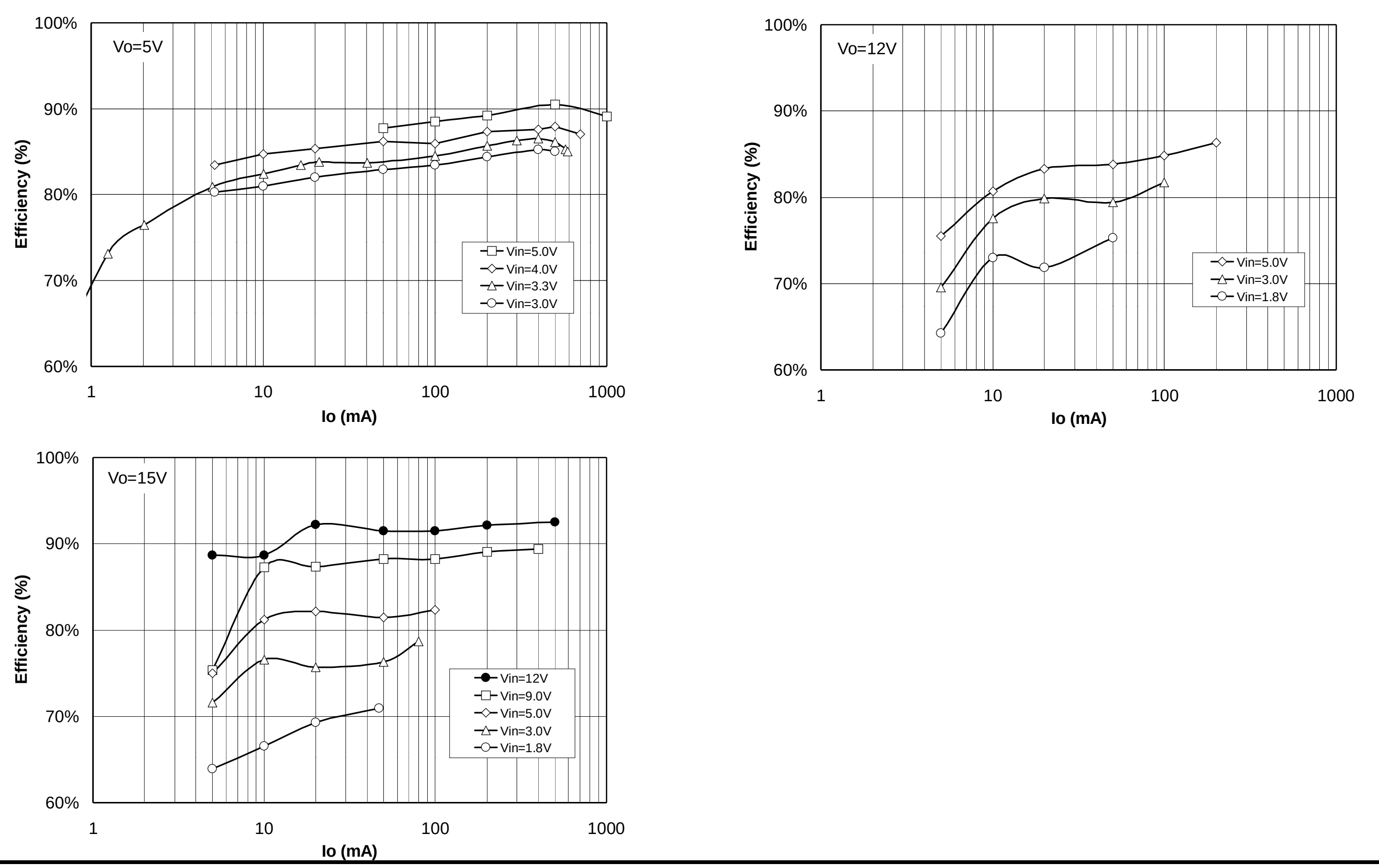
$$I_{RMS} = I_O \sqrt{\frac{V_O + 0.5}{V_{IN}}}$$

Typical Characteristics

Figs.5 - 8: Maximum output current vs. input voltage and sense resistor value. (Boost Mode)

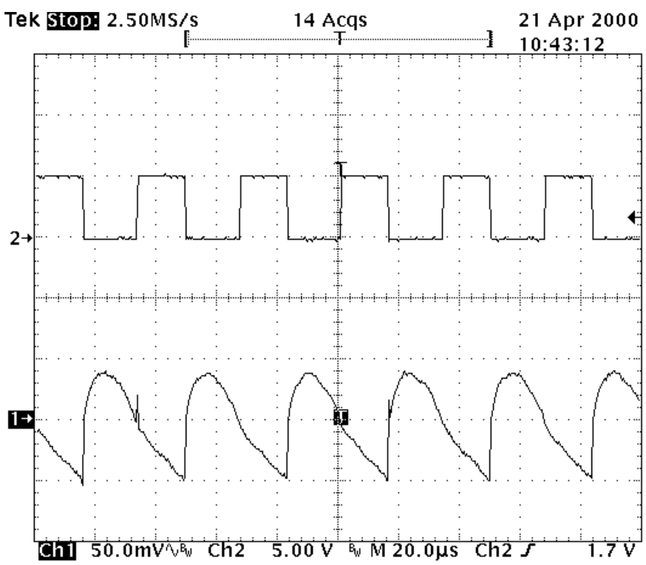


Figs.9-11:Efficiency in the Boost Application circuit of Fig.1

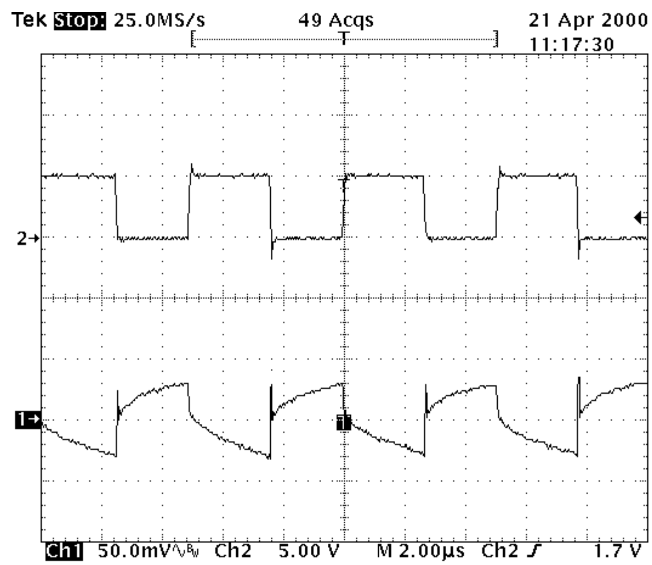


Typical Characteristics

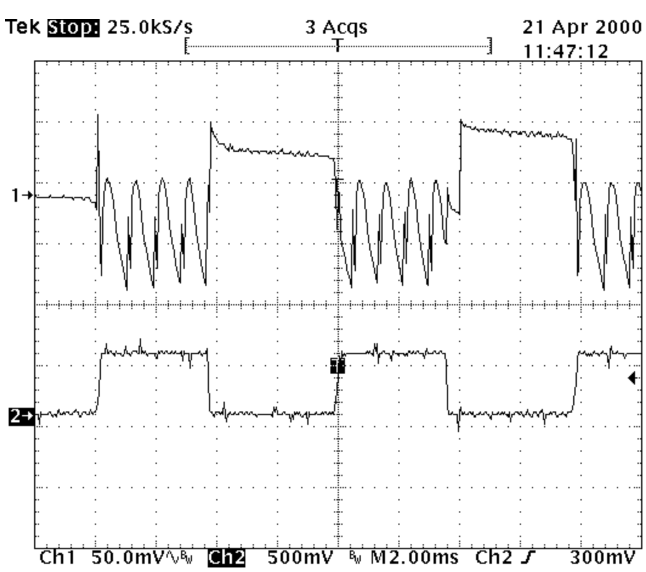
Output Ripple Voltage; Vin=3V, Vo=5V, Io=470mA
Ch1 = Output Ripple
Ch2 = Voltage at GATE pin



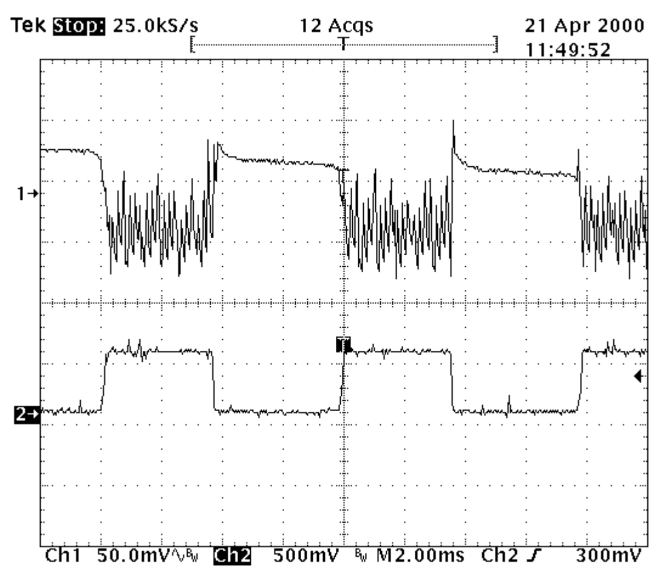
Output Ripple Voltage; Vin=3V, Vo=5V, Io=810mA
Ch1 = Output Ripple
Ch2 = Voltage at GATE pin



Load Transient; Vin=3V, Vo=5V, Io=0 to 500mA
Ch1 = Output Voltage
Ch2 = Load Current (0.5A/div)



Load Transient; Vin=2V, Vo=5V, Io=0 to 500mA
Ch1 = Output Voltage
Ch2 = Load Current (0.5A/div)



Typical Application Circuit (Cont.)

Fig.1: Typical Application - Boost Configuration

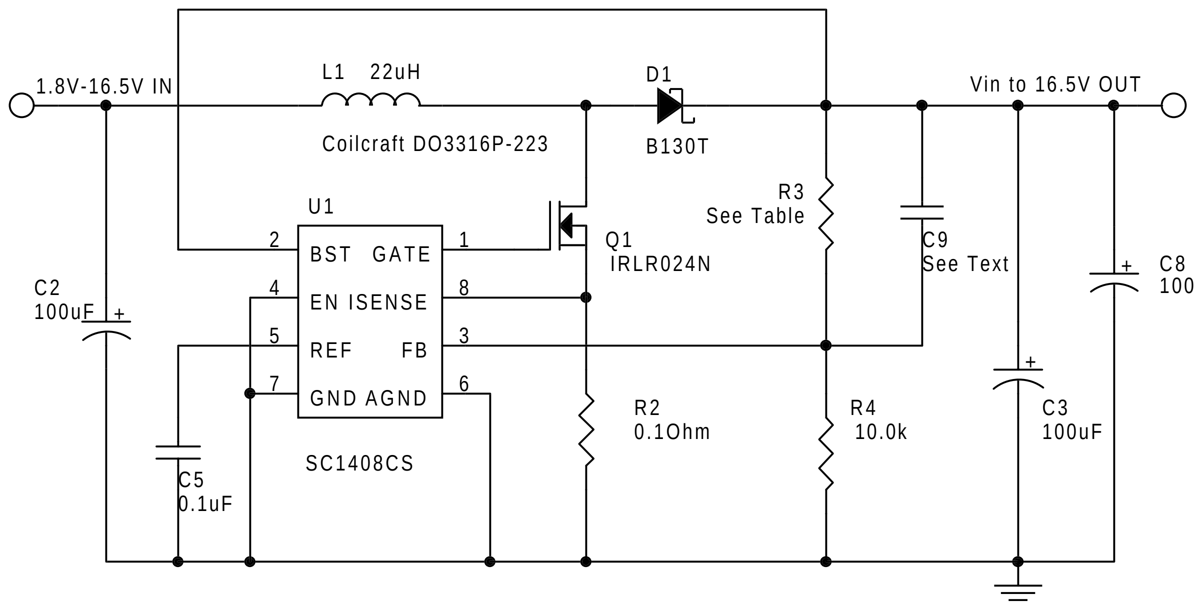
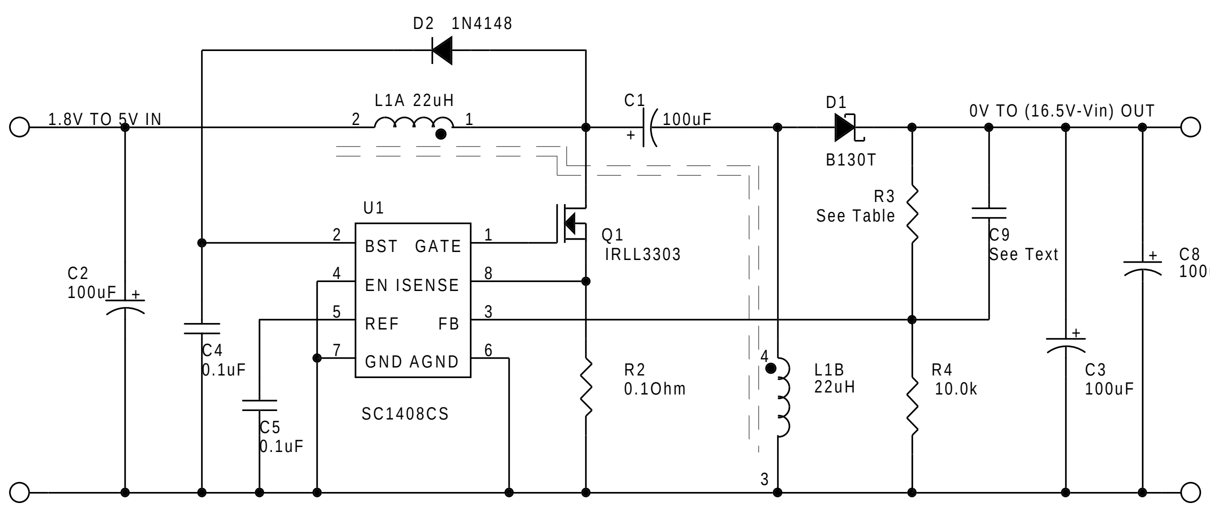


Fig.2: Typical Application - Buck/Boost (SEPIC) Configuration



Typical Application Circuit (Cont.)

Fig.3: Achieving output voltages greater than 16.5V

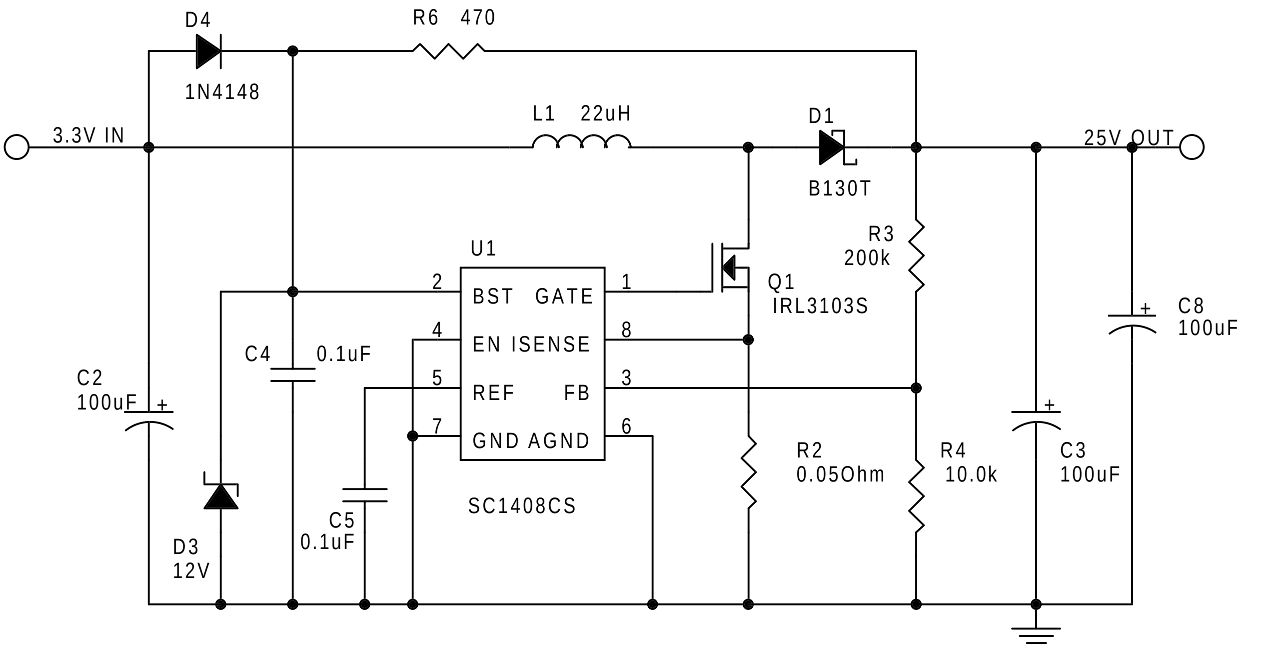
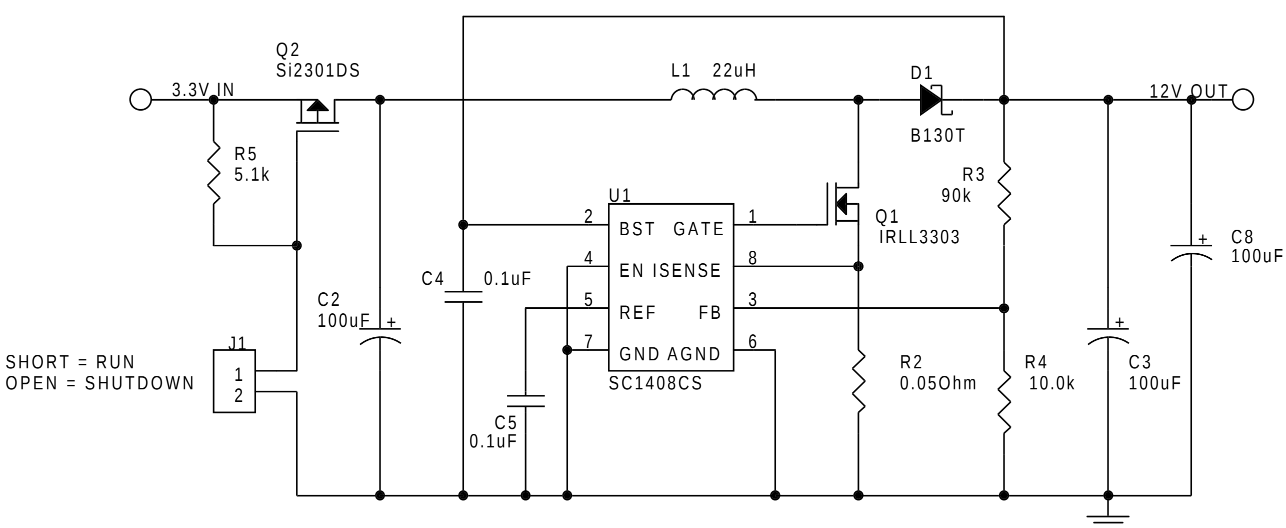
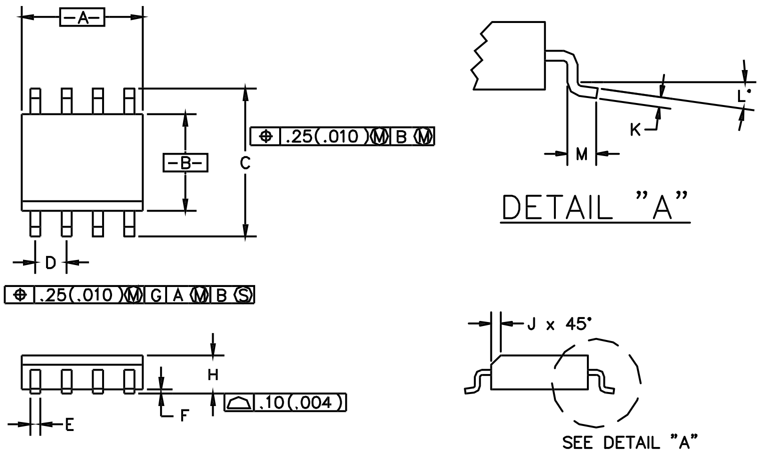


Fig.4: Implementing shutdown with input/output isolation

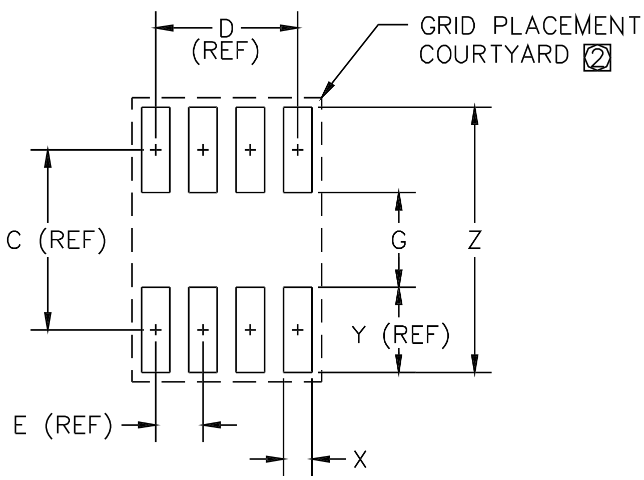


Outline Drawing - SO-8



DIM^N	INCHES		MM		NOTE
	MIN	MAX	MIN	MAX	
A	.188	.197	4.80	5.00	
B	.149	.158	3.80	4.00	
C	.228	.244	5.80	6.20	
D	.050 BSC		1.27 BSC		
E	.013	.020	0.33	0.51	
F	.004	.010	0.10	0.25	
H	.053	.069	1.35	1.75	
J	.011	.019	0.28	0.48	
K	.007	.010	.19	.25	
L	0°	8°	0°	8°	
M	.016	.050	0.40	1.27	

Land Pattern - SO-8



DIM^N	INCHES		MM		NOTE
	MIN	MAX	MIN	MAX	
C	–	.19	–	5.00	–
D	–	.15	–	3.81	–
E	–	.05	–	1.27	–
G	.10	.11	2.60	2.80	–
X	.02	.03	.60	.80	–
Y	–	.09	–	2.40	–
Z	–	.29	7.20	7.40	–

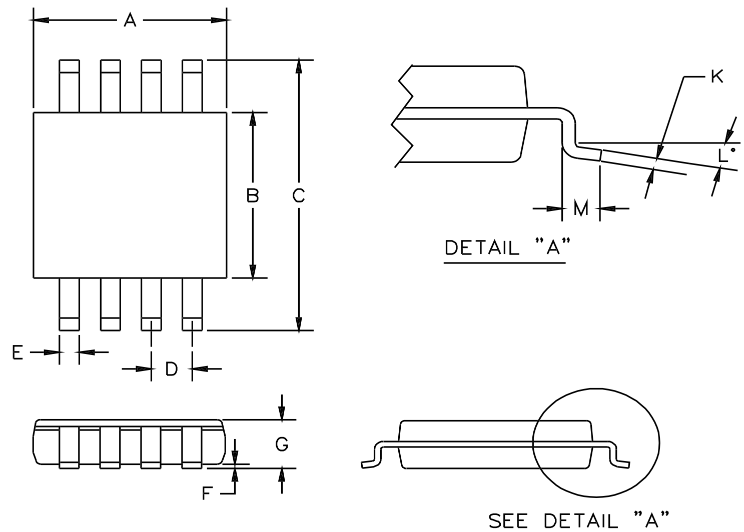
(DIMENSIONS 1)

2 GRID PLACEMENT COURTYARD IS 12x16 ELEMENTS (6 mm X 8mm) IN ACCORDANCE WITH THE INTERNATIONAL GRID DETAILED IN IEC PUBLICATION 97.

1 CONTROLLING DIMENSION: MILLIMETERS

POWER MANAGEMENT

Outline Drawing - MSOP-8

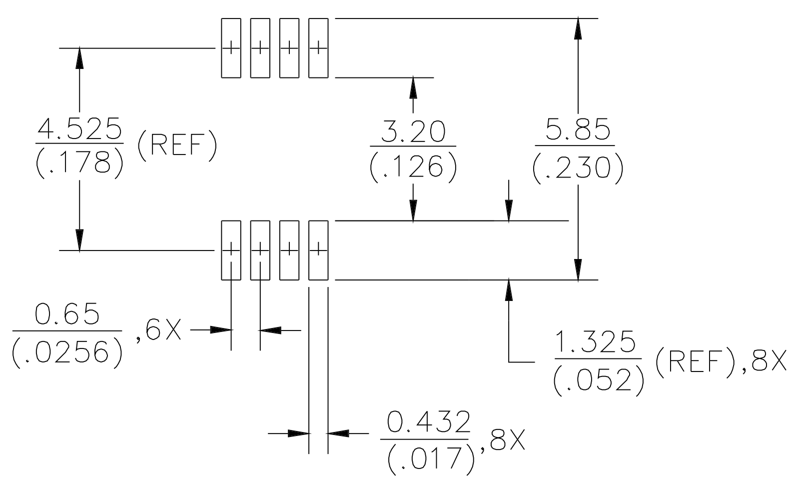


DIM	DIMENSIONS INCHES MIN	INCHES MAX	MM MIN	MM MAX	NOTE
A	.114	.122	2.90	3.10	
B	.114	.122	2.90	3.10	
C	.187	.199	4.75	5.05	
D	.025 BSC		.65 BSC		
E	.010	.016	.25	.40	
F	.002	.006	.05	.15	
G	–	.043	–	1.10	
K	.005	.009	.13	.23	
L	0°	6°	0°	6°	
M	.016	.028	.40	.70	

2 PACKAGE OUTLINE EXCLUSIVE OF MOLD FLASH AND METAL BURR.

1 CONTROLLING DIMENSIONS: MILLIMETERS.

Land Pattern - MSOP-8



1 DIMENSIONS ARE IN MILLIMETERS (INCHES).

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