



June 28, 2000

TEL:805-498-2111 FAX:805-498-3804 WEB:<http://www.semtech.com>

## DESCRIPTION

The SC1409 is a versatile, voltage-mode switching regulator designed for use in battery operated power supply applications. A simple, fixed-voltage buck regulator can be implemented using the SC1409 with a minimum of external components. Internal MOSFETs and control circuitry minimize board space and design time. The small device footprint allows for compact circuit design.

SC1409 features include a temperature compensated voltage reference, triangle wave oscillator, hiccup mode current limit, an internally compensated error amplifier, overcurrent temperature protection, soft start, and under voltage lock out.

The SC1409 operates at a selectable, fixed frequency of 300kHz or 500kHz, or can be synchronized to an external clock within this range, providing an optimum compromise between efficiency, external component size, and cost.

## FEATURES

- Internal MOSFETs
- Excellent efficiency >88%
- 1% Voltage accuracy
- Built-in over current protection
- 1A Output current
- 5 $\mu$ A Standby current
- Industrial temperature range
- 300kHz/500kHz selectable frequency

## APPLICATIONS

- Handheld equipment
- PDA power supplies
- Notebook I/O power supplies
- Peripheral card supplies
- High density DC/DC conversion

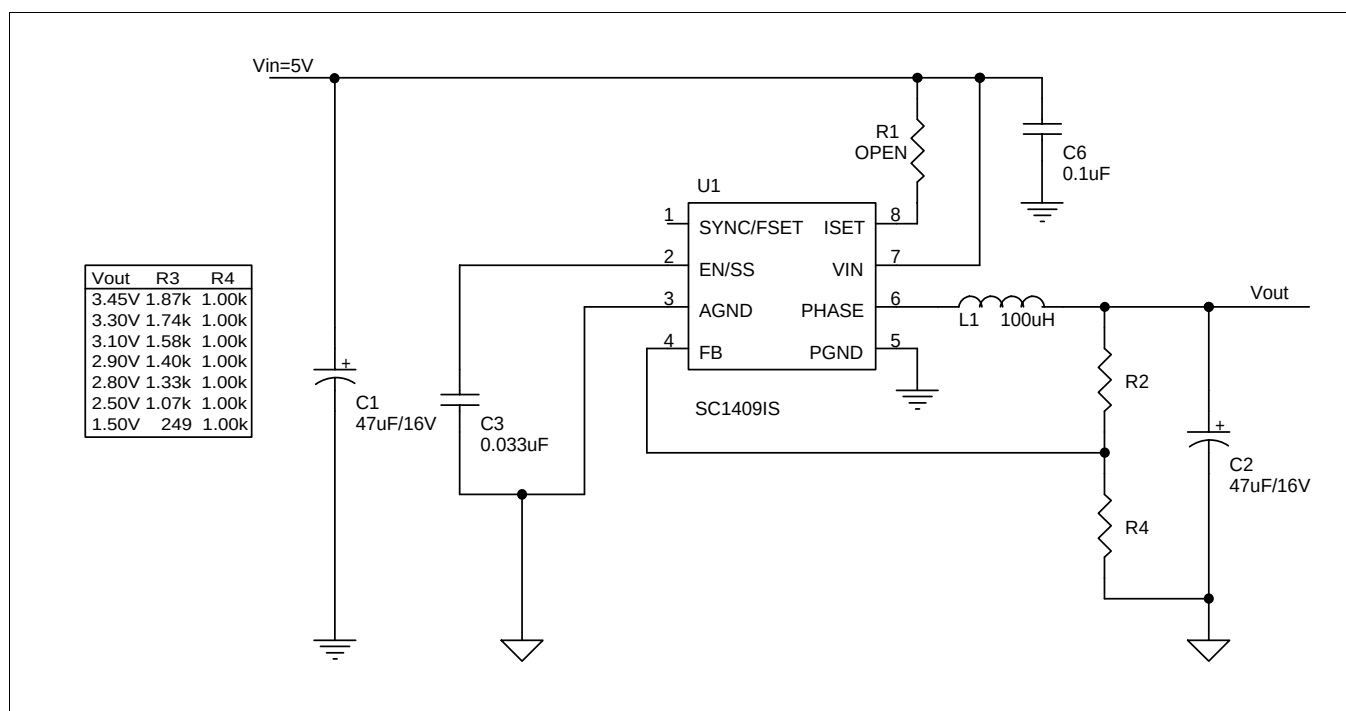
## ORDERING INFORMATION

| DEVICE <sup>(1)</sup> | PACKAGE |
|-----------------------|---------|
| SC1409ISTR            | SO-8    |

Note:

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

## APPLICATION CIRCUIT





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## ABSOLUTE MAXIMUM RATINGS

| Parameter                               | Symbol           | Maximum     | Units |
|-----------------------------------------|------------------|-------------|-------|
| Supply Voltage                          | $V_{CC}$         | -0.3 to +7  | V     |
| Ground Differential                     | $P_{GND}$ to GND | $\pm 1$     | V     |
| Input Voltage                           | $V_{IN}$         | -0.3 to +7  | V     |
| Operating Ambient Temperature Range     | $T_A$            | -40 to +85  | °C    |
| Operating Junction Temperature Range    | $T_J$            | -40 to +125 | °C    |
| Storage Temperature                     | $T_{STG}$        | -60 to +150 | °C    |
| Lead Temperature (Soldering) 10 seconds | $T_L$            | 300         | °C    |
| Thermal Resistance, Junction to Ambient | $\theta_{JA}$    | 165         | °C/W  |
| Thermal Resistance, Junction to Case    | $\theta_{JC}$    | 40          | °C/W  |
| ESD Rating (Human Body Model)           | ESD              | 2           | kV    |

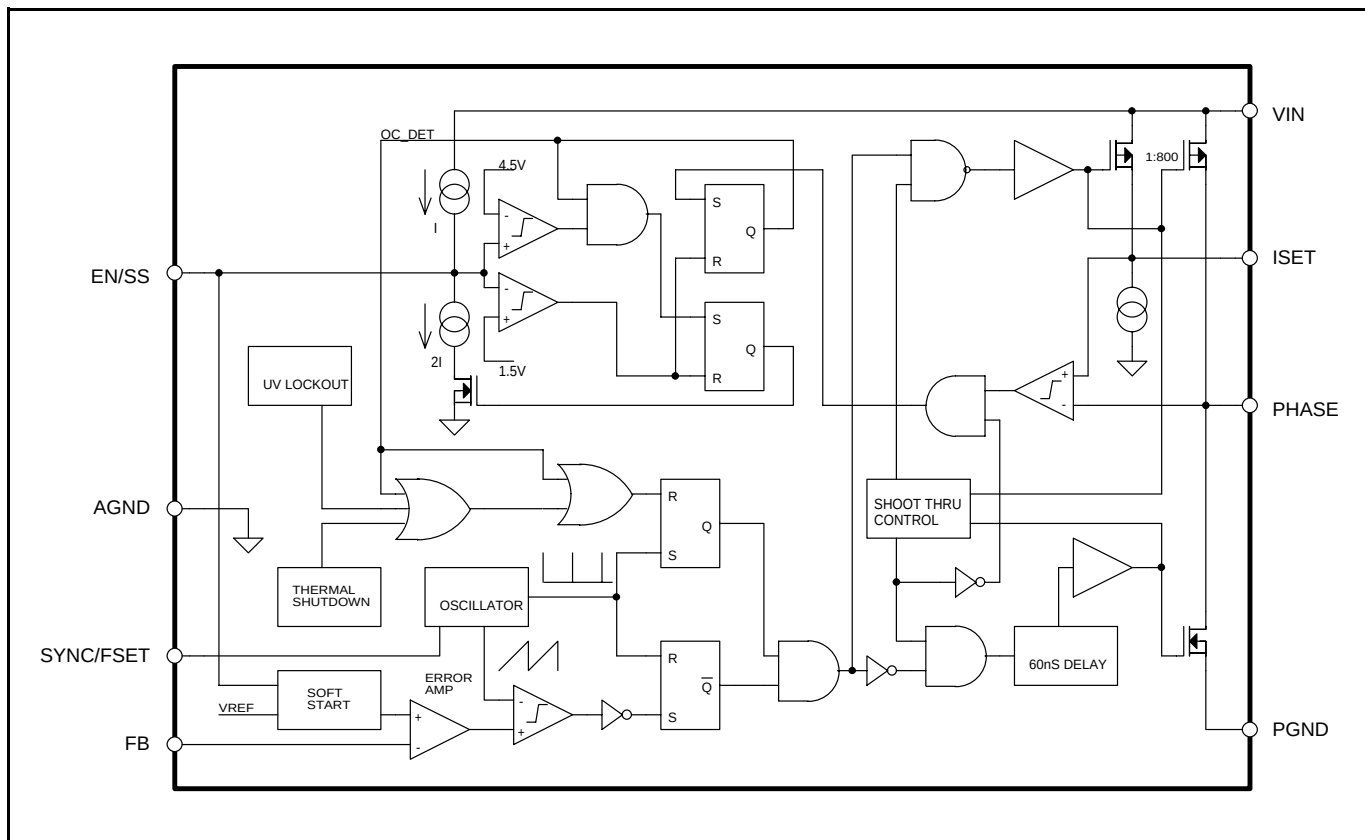
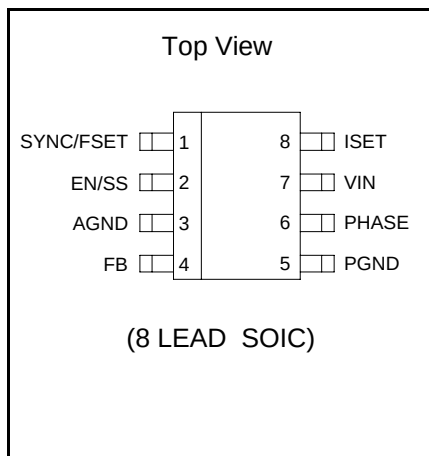
## ELECTRICAL CHARACTERISTICS

Unless specified;  $T_A = 25^\circ\text{C}$ ,  $V_{IN} = 5\text{V}$ ,  $V_O = 1.8\text{V}$ . Output current = 1A. Per typical application circuit.  
 Values in **bold** apply over full operating temperature range.

| Parameter                   | Symbol         | Conditions                                      | Min          | Typ   | Max          | Units |
|-----------------------------|----------------|-------------------------------------------------|--------------|-------|--------------|-------|
| Reference                   | $V_{REF}$      |                                                 | 1.191        | 1.203 | 1.215        | V     |
|                             |                |                                                 | <b>1.179</b> |       | <b>1.227</b> |       |
| Feedback Bias Current       | $I_{FB}$       |                                                 |              | 10.0  | 50.0         | nA    |
| Quiescent Current           | $I_Q$          | Current into $V_{CC}$ pin<br>$I_O = 0\text{mA}$ |              | 2.0   | 4.0          | mA    |
|                             |                |                                                 |              |       | <b>15</b>    |       |
| Shutdown Quiescent Current  | $I_Q$          | Enable = 0V                                     |              | 5.0   |              | uA    |
|                             |                |                                                 |              |       | <b>10</b>    |       |
| Regulation Load             | $REG_{LOAD}$   | $I_O = 100\text{mA}$ to 1A                      |              | 0.5   | 1.0          | %     |
| Regulation Line             | $REG_{LINE}$   |                                                 |              |       | 0.5          | %     |
| Oscillator Frequency        | OSC            | FSET= $V_{IN}$<br>FSET=GND                      | 425          | 500   | 575          | kHz   |
|                             |                |                                                 | 255          | 300   | 345          |       |
| Max Duty Cycle              | $\delta_{max}$ |                                                 | 90           | 95    |              | %     |
| Output Current Limit        | $I_O$          |                                                 | 1.5          |       |              | A     |
| Soft start charging current |                |                                                 |              | 32    |              | uA    |
| EN/SS Shutdown Threshold    |                |                                                 |              |       | 1.0          | V     |
| UVLO Trip point             |                | Vin Increasing                                  |              | 4.5   |              | V     |
|                             |                | Vin decreasing                                  |              | 4.1   |              | V     |
| RDS(ON)                     | $R_{DS(ON)}$   | Top side PFET                                   |              | 250   | 375          | mΩ    |
|                             |                |                                                 |              |       | <b>525</b>   |       |
|                             |                | Bottom side NFET                                |              | 175   | 250          | mΩ    |
|                             |                |                                                 |              |       | <b>350</b>   |       |



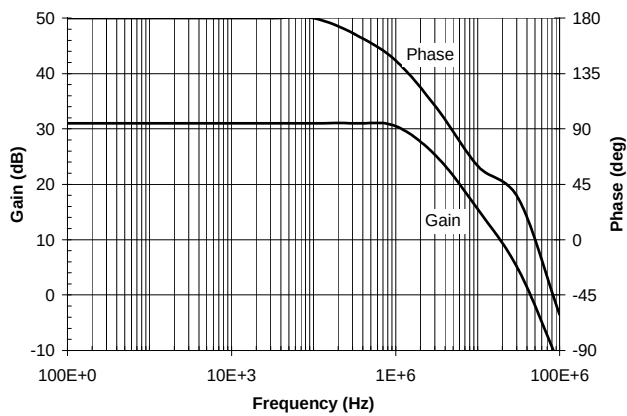
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**BLOCK DIAGRAM****PIN CONFIGURATION****PIN DESCRIPTION**

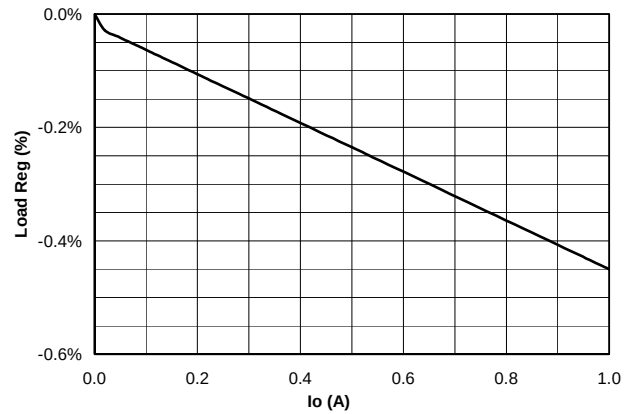
| Pin # | Pin Name  | Pin Function                                                                                                           |
|-------|-----------|------------------------------------------------------------------------------------------------------------------------|
| 1     | SYNC/FSET | Sets frequency, allows synchronization.<br>$FSET = V_{IN}$ , $f = 500\text{kHz}$<br>$FSET = GND$ , $f = 300\text{kHz}$ |
| 2     | EN/SS     | Enable and Soft Start pin.                                                                                             |
| 3     | AGND      | Analog ground.                                                                                                         |
| 4     | FB        | Output voltage feedback.                                                                                               |
| 5     | PGND      | Device power ground.                                                                                                   |
| 6     | PHASE     | Power output to the inductor.                                                                                          |
| 7     | VIN       | Input voltage.                                                                                                         |
| 8     | ISET      | Current limit programming input.                                                                                       |



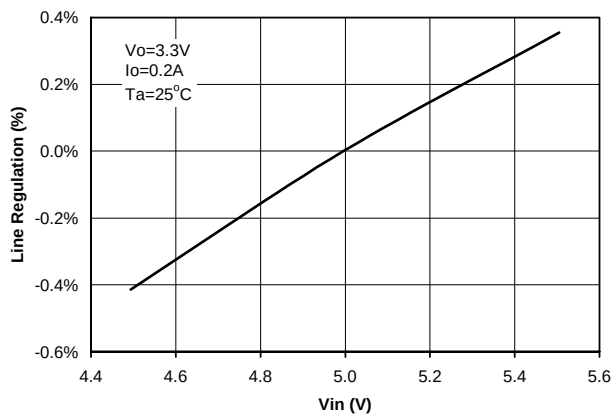
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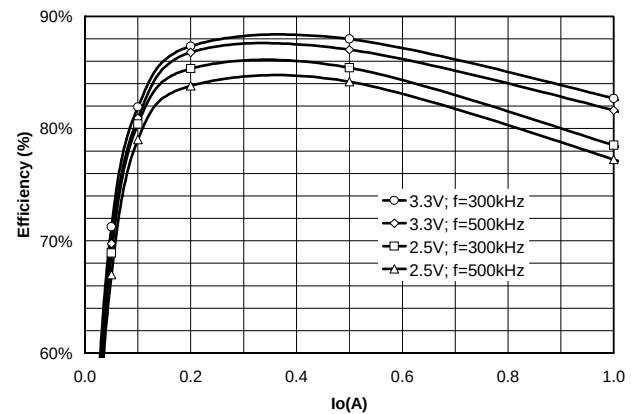
Error Amplifier, Gain and Phase



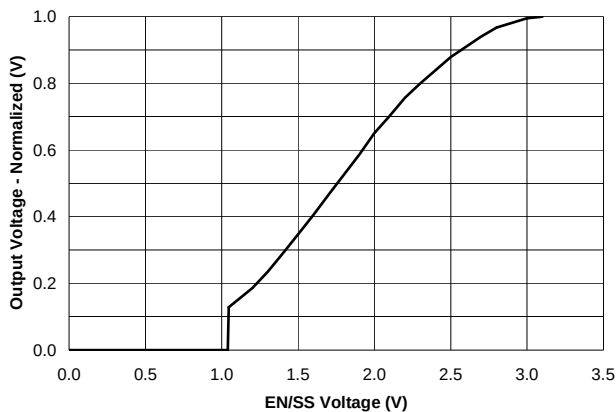
Load Regulation Characteristic



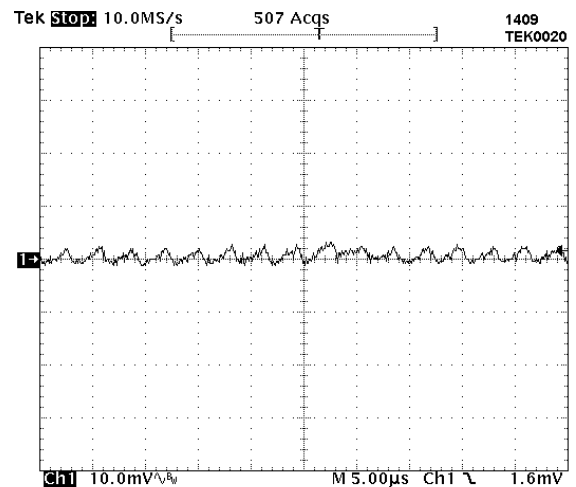
Typical Line Regulation



Efficiency



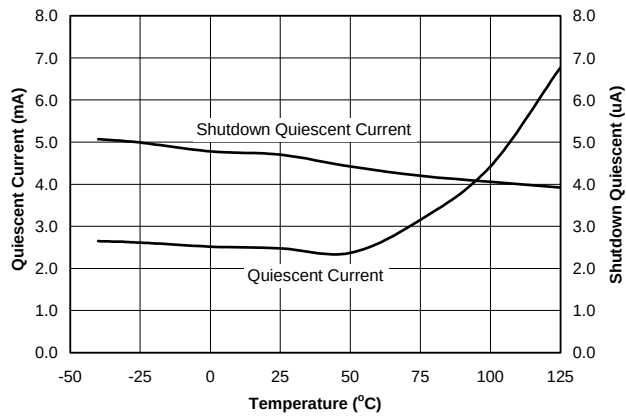
Soft Start control of Vout



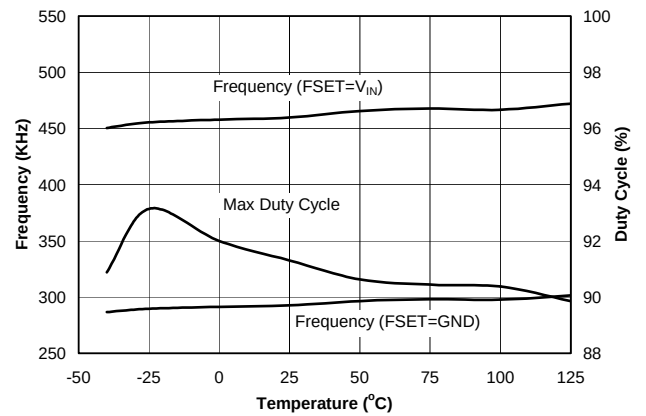
Ripple; Vo=3.3V; Io=1A; f=300kHz



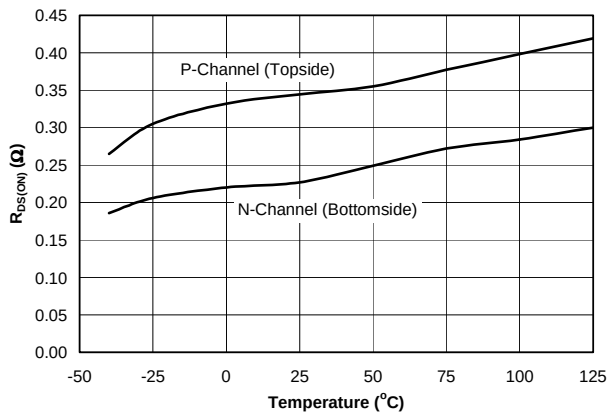
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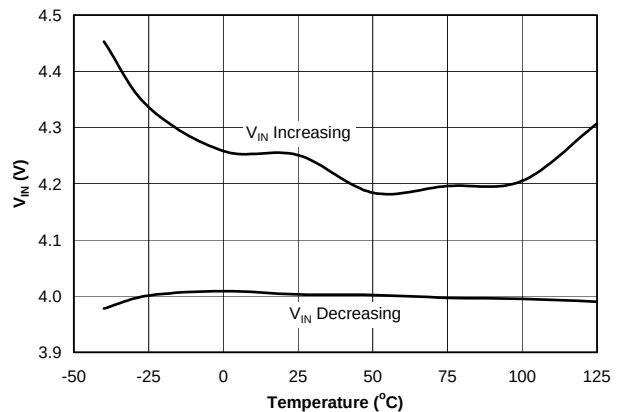
Quiescent current vs temperature



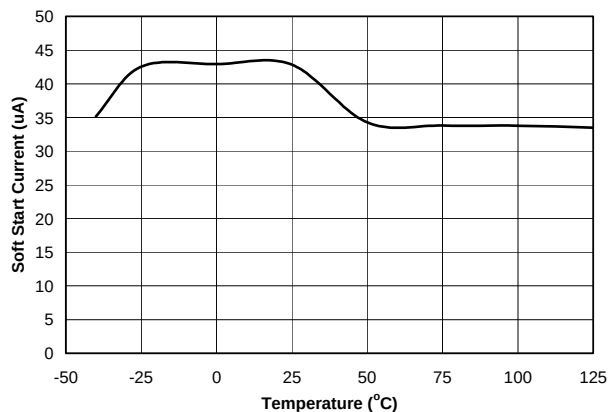
Frequency and max. duty cycle vs temperature



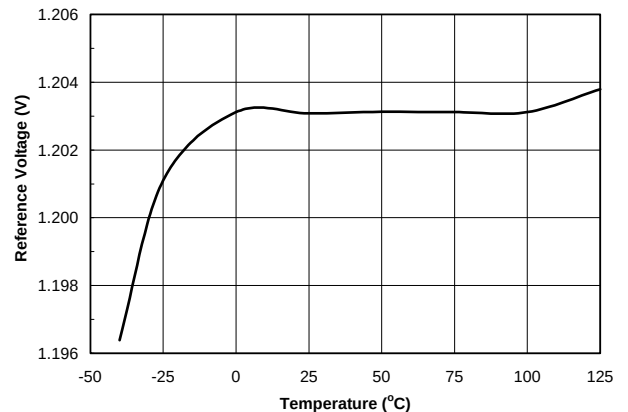
FET  $R_{DS(ON)}$  vs temperature



UVLO trip point vs temperature



Soft start current vs temperature



Reference voltage vs temperature

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## THEORY OF OPERATION

### General

The SC1409 is a synchronous buck controller with on-board FETs. It uses top FET sensing for current limit together with a soft-start circuit and hiccup overcurrent protection. The EN/SS pin can be pulled low to put the SC1409 in a low quiescent shutdown state. It uses a wide bandwidth error amplifier for optimum transient response and minimum external compensation requirements. Overcurrent limit is preset at 1.5A, but can be set at a lower value by use of an external ISET resistor.

### EN/SS

When power is first applied to the device, the EN/SS pin sources approximately 1uA to the external soft-start capacitor, most of the rest of the internal circuitry is disabled and the device is in low-power mode. If the soft-start pin is held low, the SC1409 will remain in low-power mode, drawing approximately 5uA from the supply. Once the soft start pin is released, the external soft-start capacitor will charge up slowly to the EN/SS threshold, where the source current will increase to approximately 30uA, charging the soft-start capacitor more quickly. The voltage at the soft-start pin modifies the internal reference voltage and hence controls the output voltage (see Soft-Start control of Vout). Once the soft start capacitor has charged to approximately 3V, the reference voltage at the input to the error amp will have reached its final value and the output voltage will no longer be under the control of the soft-start.

### Overcurrent Limit

The SC1409 internally mirrors and scales the current through the top FET. This scaled, mirrored current is used to detect an overcurrent condition. In the event an overcurrent is detected, the output is immediately disabled and the soft-start capacitor is discharged at approximately 30uA until SS/EN reaches 1.5V. At this point the output is enabled and a normal soft-start cycle is initiated. If the fault persists, the output will be disabled, the soft-start capacitor will continue charging at 30uA until SS/EN reaches 4.5V before the discharge cycle is initiated.

Some combinations of high output voltage, low inductance and high output capacitance will cause this "hiccup" mode of operation to continue even if the fault is cleared. In this case, input power will need to be cycled, or EN/SS cycled through shutdown to restore normal operation.

### Operating Frequency

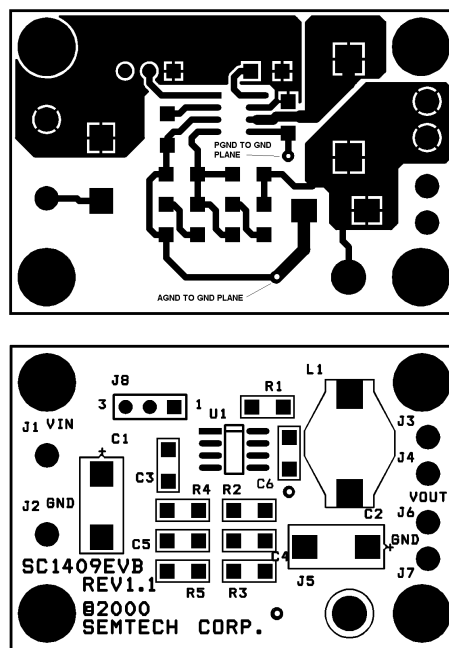
The frequency of operation can be set to a nominal 300kHz by grounding the FSET pin, or to a nominal 500kHz by returning the FSET pin to VIN. The SC1409 can also be synchronized to an external clock using the FSET pin.

## LAYOUT GUIDELINES

The SC1409 should preferably be laid out over a ground plane. Since the power section and the control section of the IC share a common VIN pin, the VIN pin must be decoupled to ground by a 0.1uF ceramic capacitor as close to the IC as possible. The traces between VIN and the decoupling capacitor and the decoupling capacitor and the PGND pin should be 25 mils wide and no more than 100 mils long. The main input capacitor should be placed within about 1" of the IC using solid copper areas to connect to the IC.

Ideally AGND should be returned to the output capacitor and connected to the ground plane at that point. Feedback resistors and all traces associated with them should be kept away from the phase node. The inductor should be placed as close to the PHASE pin as possible to minimize EMI.

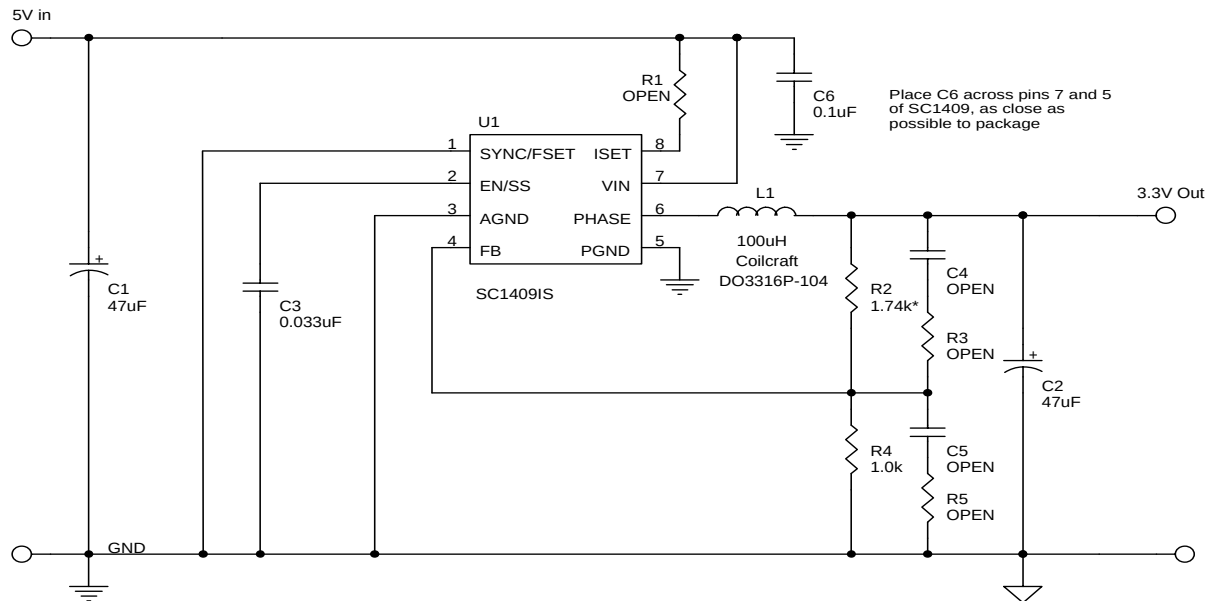
These principles are illustrated in the Evaluation Board shown below.



Evaluation Board Top Copper and Assembly Diagrams



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## Typical Application Circuit

### COMPONENT SELECTION

#### Input Capacitor

The Input capacitor(s) must be capable of 0.5A RMS ripple current. Total capacitance values of 22uF to 47uF are suitable with ESR of less than 350mΩ. Typical capacitors would be AVX TPS Tantalum surface mount type TPSC476M010R350 or Panasonic Specialty Polymer Aluminum Electrolytic surface mount type ECGC0KB470RA. Other types of capacitor are also suitable, such as high value ceramic or Aluminum electrolytics.

#### Inductor

Suitable Inductor values are in the range of 47uH to 330uH, higher inductor values give lower output voltage ripple and slower transient response time. Inductor ripple current acts with the output capacitor ESR to produce output voltage ripple. For a given output voltage ripple requirement, L can be calculated from

$$L \geq \frac{(V_{IN} - V_{OUT}) \cdot ESR \cdot V_{OUT}}{V_{RIPPLE} \cdot f \cdot V_{IN}}$$

#### Output Capacitor

The output capacitor requirements are similar to the input capacitor except ripple current is lower. Similar capacitors will be suitable.

#### Soft Start Capacitor

The soft start capacitor value determines the soft start time according to the following equation:-

$$C = 0.015t$$

where C is the soft start capacitor value in uF and t is the soft start time in mS

Startup from a shutdown condition will take longer than this since the soft start capacitor must charge from its shutdown value to approximately 1V at a charge current of 1uA before the shutdown is released and true soft start begins.

#### Divider Resistors

The current through the divider chain should be at least 1000 times higher than the FB input bias current to eliminate ratio errors. This gives a maximum value for the bottom divider resistor (R4) of 24kΩ

The top resistor (R2) can then be determined from

$$R2 = (V_o - 1.203) \cdot R4 / 1.203$$

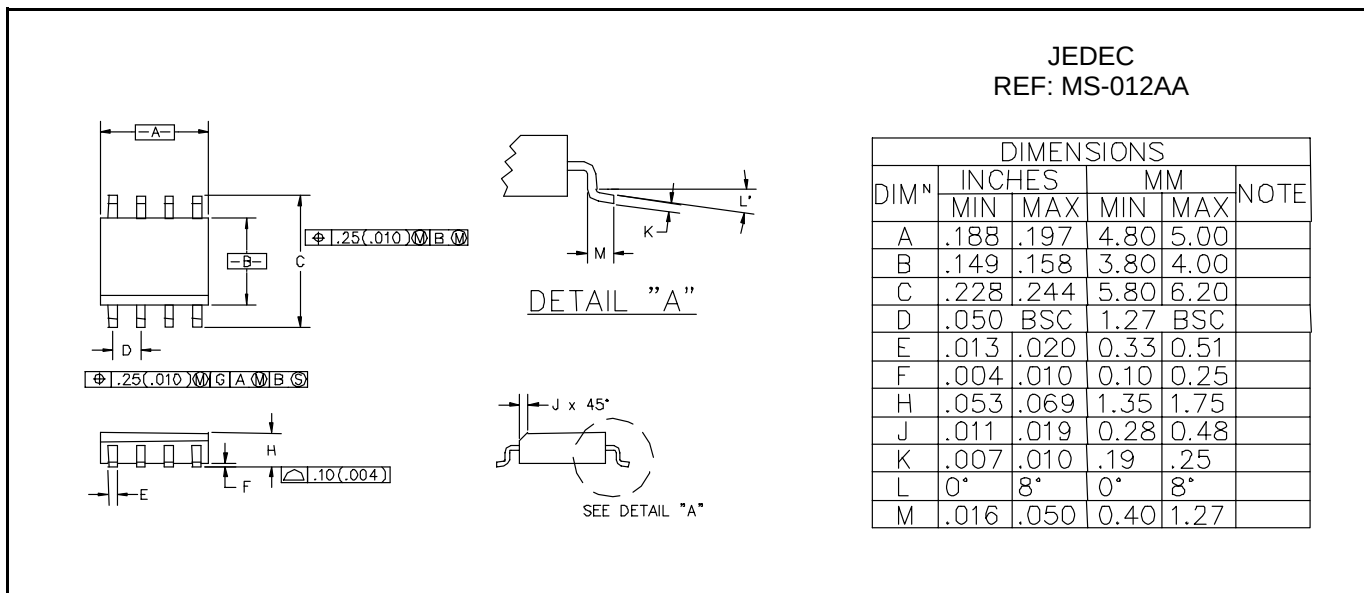
#### Compensation

Normally, external compensation is not recommended, however, if required, loop response can be tailored with suitable values for R3, R5, C4 and C5. Consult the factory for details.

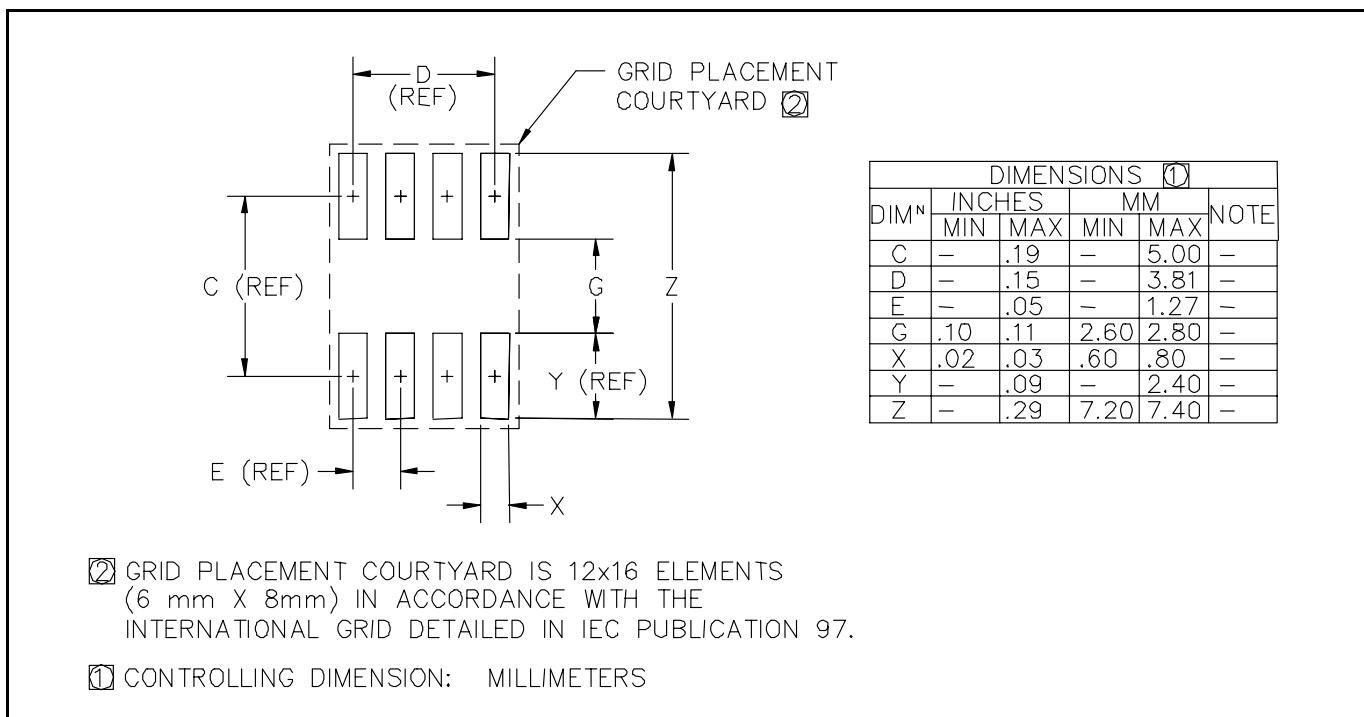


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## OUTLINE DRAWING



## LAND PATTERN SO-8



ECN00-1096



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