

**3.8V-32V Vin, 500KHz, 2A Synchronous Step-down DCDC Converter with EMI Reduction**

**FEATURES**

- EMI Reduction with Switching Node Ringing-free
- 3.8V-32V Wide Input Voltage Range
- Up to 2A Continuous Output Load Current
- 5V ±1% Output Voltage
- Fully Integrated 130mΩ R<sub>dson</sub> High-side MOSFET and 70mΩ R<sub>dson</sub> Low-side MOSFET
- 1uA Shut-down Current
- 20uA Ultra Low Quiescent Current
- 500KHz Switching Frequency with ±6% Frequency Spread Spectrum FSS Modulation
- 80ns Minimum On-time
- Precision Enable Threshold for Programmable UVLO Threshold and Hysteresis
- Low Drop-Out LDO Operation
- Pulse Skipping Modulation PSM in Light Load
- 4ms Built-in Soft-start Time
- Thermal Shutdown Protection at 160°C
- Available in SOP-8L Package

**APPLICATIONS**

- White Goods, Air Conditioner, Refrigerator etc.
- Home Appliance
- Surveillance
- Audio, WiFi Speaker
- Printer
- DTV, STB, Monitor/LCD Display
- E-meter

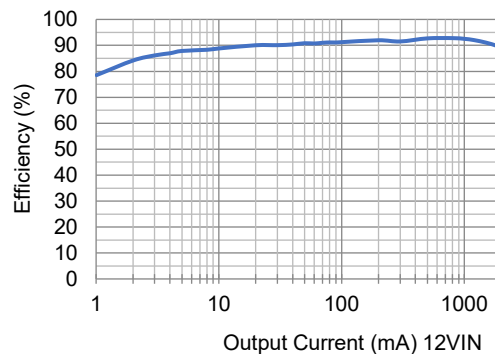
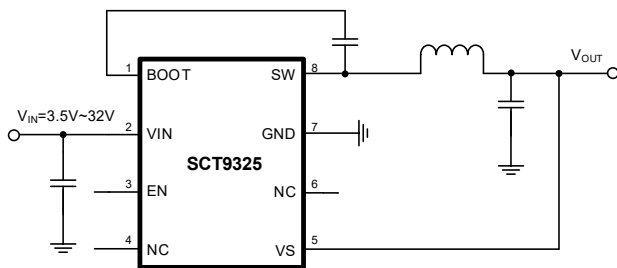
**DESCRIPTION**

The SCT9325 are 2A, 500KHz, synchronous buck converters with up to 32V wide input voltage range, which fully integrates a 130mΩ high-side MOSFET and a 70mΩ low-side MOSFET to provide high efficiency step-down DCDC conversion. The SCT9325 adopt peak current mode control with the integrated compensation network and the output feedback resistors network, which make the device easily to be used by minimizing the off-chip component counts. The SCT9325 support the Pulse Skipping Modulation (PSM) with typical 20uA Ultra-Low Quiescent and achieved 80% efficiency at 1mA and 85% at 5mA light load conditions.

The SCT9325 are Electromagnetic Interference (EMI) friendly buck converters. The SCT9325 feature Frequency Spread Spectrum (FSS) with ±6% jittering span of the 500KHz switching frequency and modulation rate 1/512 of switching frequency to reduce the conducted EMI. The converter has proprietary designed gate driver scheme to resist switching node high frequency ringing without sacrificing MOSFET turn on and turn off time, which further erases high frequency radiation EMI noise caused by the MOSFETs hard switching. When the converter enters PSM mode, the artificial switching node anti-ringing circuit is specially designed to address the radiation EMI noise in the light load condition.

The SCT9325 offers output over-voltage protection, cycle-by-cycle peak current limit, and thermal shutdown protection. The device is available in a low-profile SOP-8L package.

**TYPICAL APPLICATION**



## REVISION HISTORY

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Revision 1.0: Release to market

## DEVICE ORDER INFORMATION

| PART NUMBER | PACKAGE MARKING | PACKAGE DISCRIPTION |
|-------------|-----------------|---------------------|
| SCT9325STD  | 9325            | SOP-8L              |

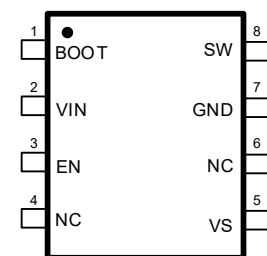
1) For Tape & Reel, Add Suffix R (e.g. SCT9325STDR).

## ABSOLUTE MAXIMUM RATINGS

Over operating free-air temperature unless otherwise noted<sup>(1)</sup>

| DESCRIPTION                                   | MIN  | MAX | UNIT |
|---|------|-----|------|
| BOOT  | -0.3 | 40  | V    |
| VIN, SW, EN                                   | -0.3 | 34  | V    |
| VS  | -0.3 | 6   | V    |
| Operating junction temperature <sup>(2)</sup> | -40  | 125 | C    |
| Storage temperature T <sub>STG</sub>          | -65  | 150 | C    |

## PIN CONFIGURATION



Top View: SOP-8, Plastic

- (1) Stresses beyond those listed under Absolute Maximum Rating may cause device permanent damage. The device is not guaranteed to function outside of its Recommended Operation Conditions.
- (2) The IC includes over temperature protection to protect the device during overload conditions. Junction temperature will exceed 150°C when over temperature protection is active. Continuous operation above the specified maximum operating junction temperature will reduce lifetime

## PIN FUNCTIONS

| NAME | NO.  | PIN FUNCTION   |
|------|------|--|
| BOOT | 1    | Power supply for the high-side power MOSFET gate driver. Must connect a 0.1uF or greater ceramic capacitor between BOOT pin and SW node.   |
| VIN  | 2    | Power supply input. Must be locally bypassed.  |
| EN   | 3    | Enable logic input. Floating the pin enables the device. This pin supports high voltage input up to VIN supply to be connected VIN directly to enable the device automatically. The device has precision enable thresholds 1.18V rising / 1.1V falling for programmable UVLO threshold and hysteresis. |
| VS   | 5    | Buck converter output Pin. SCT9325 output voltage is fixed as 5V   |
| NC   | 4, 6 | Not connected.   |
| GND  | 7    | Power ground. Must be soldered directly to ground plane.   |
| SW   | 8    | Switching node of the buck converter.  |

## RECOMMENDED OPERATING CONDITIONS

Over operating free-air temperature range unless otherwise noted

| PARAMETER       | DEFINITION                     | MIN | MAX | UNIT |
|-----------------|--------------------------------|-----|-----|------|
| V <sub>IN</sub> | Input voltage range            | 3.8 | 32  | V    |
| T <sub>J</sub>  | Operating junction temperature | -40 | 125 | °C   |

## ESD RATINGS

| PARAMETER        | DEFINITION  | MIN  | MAX  | UNIT |
|------------------|---|------|------|------|
| V <sub>ESD</sub> | Human Body Model(HBM), per ANSI-JEDEC-JS-001-2014 specification, all pins <sup>(1)</sup>    | -2   | +2   | kV   |
|                  | Charged Device Model(CDM), per ANSI-JEDEC-JS-002-2014specification, all pins <sup>(1)</sup> | -0.5 | +0.5 | kV   |

(1) HBM and CDM stressing are done in accordance with the ANSI/ESDA/JEDEC JS-001-2014 specification

## THERMAL INFORMATION

| PARAMETER        | THERMAL METRIC  | SOP-8L | UNIT |
|------------------|---|--------|------|
| R <sub>θJA</sub> | Junction to ambient thermal resistance <sup>(1)</sup> | 116    | °C/W |
| R <sub>θJC</sub> | Junction to case thermal resistance <sup>(1)</sup>    | 53     |      |

(1) SCT provides R<sub>θJA</sub> and R<sub>θJC</sub> numbers only as reference to estimate junction temperatures of the devices. R<sub>θJA</sub> and R<sub>θJC</sub> are not a characteristic of package itself, but of many other system level characteristics such as the design and layout of the printed circuit board (PCB) on which theSCT9325 is mounted, and external environmental factors. The PCB board is a heat sink that is soldered to the leads and thermal pad of the SCT9325. Changing the design or configuration of the PCB board changes the efficiency of the heat sink and therefore the actual R<sub>θJA</sub> and R<sub>θJC</sub>.

## ELECTRICAL CHARACTERISTICS

$V_{IN}=12V$ ,  $T_J=-40^{\circ}C\sim 125^{\circ}C$ , typical values are tested under  $25^{\circ}C$ .

| SYMBOL                                      | PARAMETER  | TEST CONDITION                                     | MIN  | TYP        | MAX  | UNIT        |
|---|--|--|------|------------|------|-------------|
| <b>Power Supply and Output</b>              |  |  |      |            |      |             |
| $V_{IN}$                                    | Operating input voltage                            |  | 3.8  |            | 32   | V           |
| $V_{IN\_UVLO}$                              | Input UVLO Hysteresis                              | $V_{IN}$ rising                                    |      | 3.5<br>420 | 3.7  | V<br>mV     |
| $I_{SD}$                                    | Shutdown current                                   | EN=0, No load, $V_{IN}=12V$                        |      | 1          | 3    | $\mu A$     |
| $I_Q$                                       | Quiescent current                                  | EN=floating, No load, No switching. $V_{IN}=12V$ . |      | 20         |      | $\mu A$     |
| <b>Enable, Soft Start and Working Modes</b> |  |  |      |            |      |             |
| $V_{EN\_H}$                                 | Enable high threshold                              |  |      | 1.18       | 1.25 | V           |
| $V_{EN\_L}$                                 | Enable low threshold                               |  | 1.03 | 1.1        |      | V           |
| $I_{EN}$                                    | Enable pin input current                           | EN=1V  | 1    | 1.5        | 2    | $\mu A$     |
| $I_{EN\_HYS}$                               | Enable pin hysteresis current                      | EN=1.5V  |      | 4          |      | $\mu A$     |
| <b>Power MOSFETs</b>                        |  |  |      |            |      |             |
| $R_{DS(on)\_H}$                             | High side FET on-resistance                        |  |      | 130        |      | m $\Omega$  |
| $R_{DS(on)\_L}$                             | Low side FET on-resistance                         |  |      | 70         |      | m $\Omega$  |
| <b>Output Voltage</b>                       |  |  |      |            |      |             |
| $V_S$                                       | Output Voltage                                     |  | 4.95 | 5          | 5.05 | V           |
| <b>Current Limit</b>                        |  |  |      |            |      |             |
| $I_{LIM\_HSD}$                              | HSD peak current limit                             |  | 2.5  | 2.8        | 3.1  | A           |
| $I_{LIM\_LSD}$                              | LSD valley current limit                           |  | 2.8  | 3.2        | 3.6  |             |
| <b>Switching Frequency</b>                  |  |  |      |            |      |             |
| $F_{SW}$                                    | Switching frequency                                | $V_{IN}=12V$ , $V_{OUT}=5V$                        | 450  | 500        | 550  | KHz         |
| $t_{ON\_MIN}$                               | Minimum on-time                                    |  |      | 80         |      | ns          |
| $F_{JITTER}$                                | FSS percentage                                     |  |      | $\pm 6$    |      | %           |
| <b>Soft Start Time</b>                      |  |  |      |            |      |             |
| $t_{SS}$                                    | Internal soft-start time                           |  |      | 4          |      | ms          |
| <b>Protection</b>                           |  |  |      |            |      |             |
| $V_{OVP}$                                   | Output overvoltage protection threshold Hysteresis | $V_{OUT}$ rising                                   |      | 110<br>5   |      | %<br>%      |
| $T_{HIC\_W}$                                | Over current protection hiccup wait time           |  |      | 512        |      | Cycles      |
| $T_{HIC\_R}$                                | Over current protection hiccup restart time        |  |      | 8192       |      | Cycles      |
| $T_{SD}$                                    | Thermal shutdown threshold                         | $T_J$ rising                                       |      | 160        |      | $^{\circ}C$ |
|   | Hysteresis   | $T_J$ falling below TSD                            |      | 25         |      | $^{\circ}C$ |

TYPICAL CHARACTERISTICS

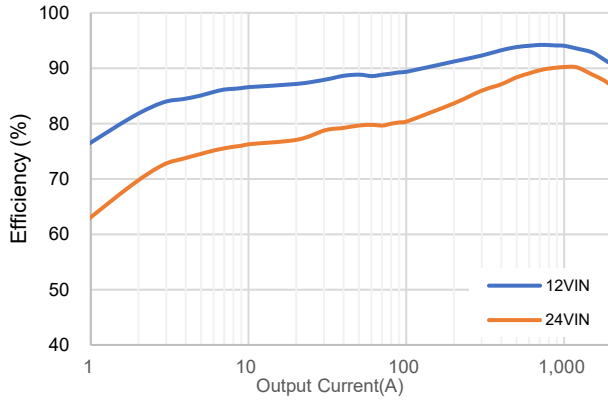


Figure 1. Efficiency, Vout=5V

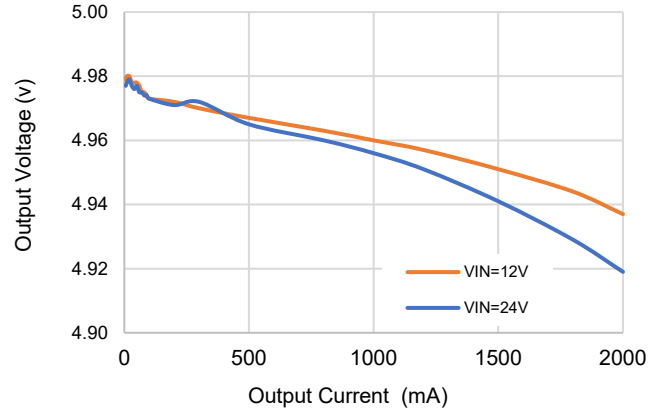


Figure 2. Load Regulation, Vout=5V

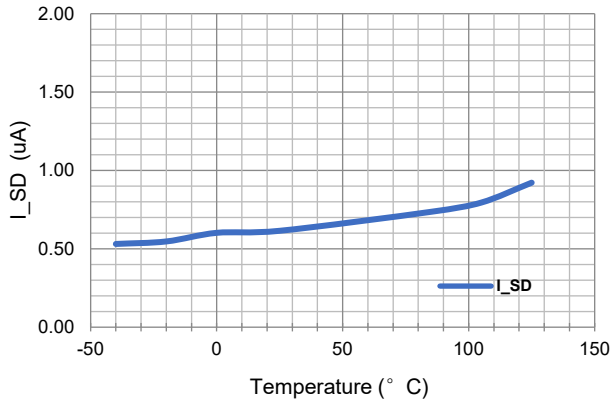


Figure 3. Shut down Current vs Temperature

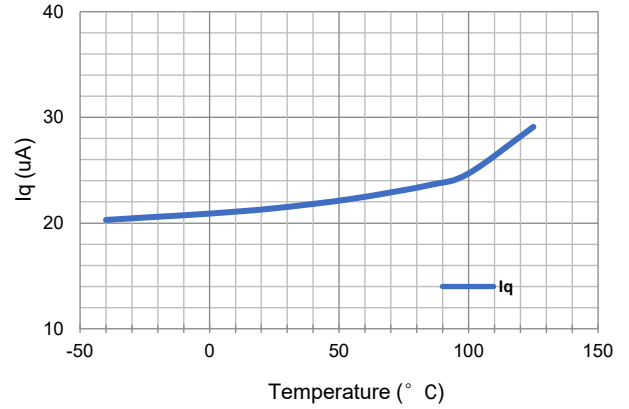


Figure 4. Quiescent Current vs Temperature

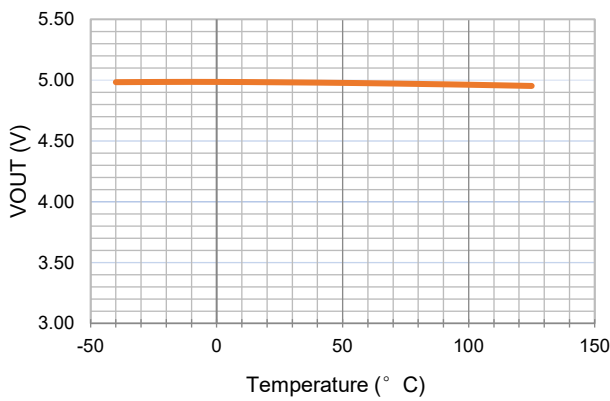


Figure 5. Output Voltage & Temperature

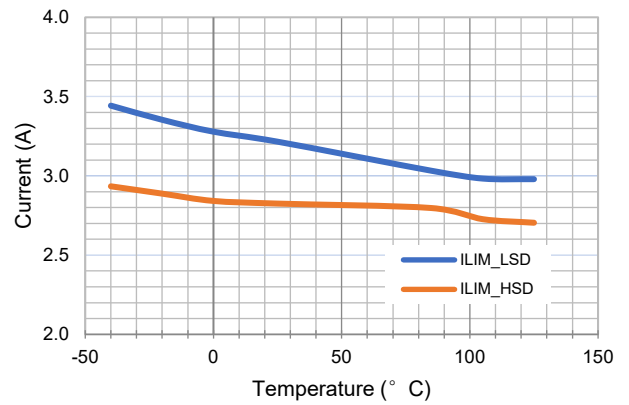


Figure 6. Peak Current Limit & Temperature

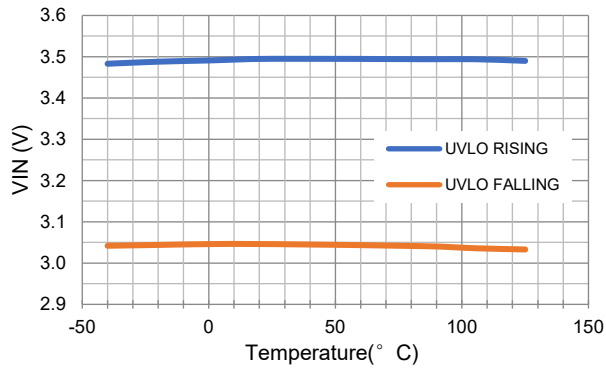


Figure 7. VIN UVLO & Temperature

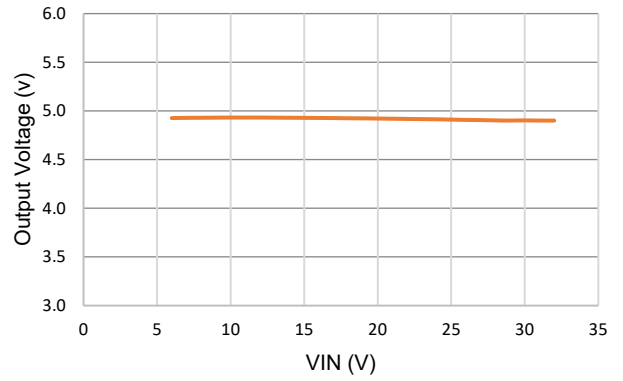
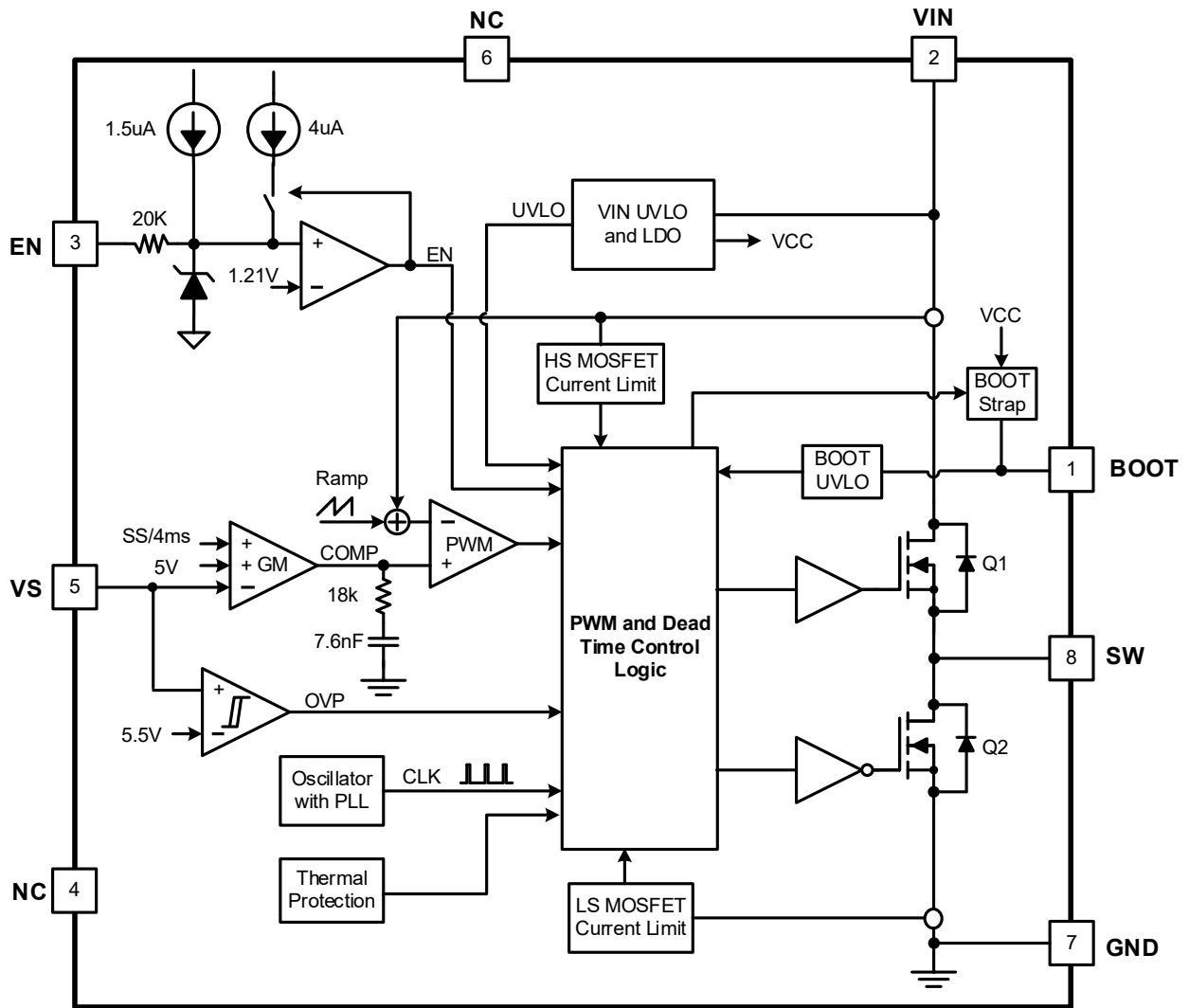


Figure 8. Line Regulation, ILoad=2A

FUNCTIONAL BLOCK DIAGRAM



## OPERATION

### Overview

The SCT9325 devices are 3.8V-32V input, 2A output, EMI friendly, fully integrated synchronous buck converters. The device employs fixed frequency peak current mode control. An internal clock with 500KHz frequency initiates turning on the integrated high-side power MOSFET Q1 in each cycle, then inductor current rises linearly and the converter charges output cap. When sensed voltage on high-side MOSFET peak current rising above the voltage of internal COMP (see functional block diagram), the device turns off high-side MOSFET Q1 and turns on low-side MOSFET Q2. The inductor current decreases when MOSFET Q2 is ON. In the next rising edge of clock cycle, the low-side MOSFET Q2 turns off. This repeats on cycle-by-cycle based.

The peak current mode control with the internal loop compensation network and the built-in 4ms soft-start simplify the SCT9325 footprints and minimize the off-chip component counts. The SCT9325 integrate the output voltage feedback resistor divider network to further simplify the off-chip components design. The SCT9325 has 5V output.

The error amplifier serves the COMP node by comparing the voltage on the FB pin with an internal 0.8V reference voltage. When the load current increases, a reduction in the feedback voltage relative to the reference raises COMP voltage till the average inductor current matches the increased load current. This feedback loop well regulates the output voltage. The device also integrates an internal slope compensation circuitry to prevent sub-harmonic oscillation when duty cycle is greater than 50% for a fixed frequency peak current mode control.

The quiescent current of SCT9325 is 20uA typical under no-load condition and no switching. When disabling the device, the supply shut down current is only 1uA. The SCT9325 work at Pulse Skipping Mode (PSM) to further increase the power efficiency in light load condition. Hence the power efficiency can be achieved up to 88% at 5mA load condition.

The SCT9325 implement the Frequency Spread Spectrum (FSS) modulation spreading of  $\pm 6\%$  centered 500KHz switching frequency. FSS improves EMI performance by not allowing emitted energy to stay in any one receiver band for a significant length of time. The converter has optimized gate driver scheme to achieve switching node voltage ringing-free without sacrificing the MOSFET switching time to further damping high frequency radiation EMI noise.

The hiccup mode minimizes power dissipation during prolonged output over current or short conditions. The hiccup wait time is 512 cycles and the hiccup restart time is 8192 cycles. The SCT9325 device also features full protections including cycle-by-cycle high-side MOSFET peak current limit, over-voltage protection, and over-temperature protection.

### VIN Power

The SCT9325 are designed to operate from an input voltage supply range between 3.8V to 32V, at least 0.1uF decoupling ceramic cap is recommended to bypass the supply noise. If the input supply locates more than a few inches from the converter, an additional electrolytic or tantalum bulk capacitor or with recommended 22uF may be required in addition to the local ceramic bypass capacitors.

### Under Voltage Lockout UVLO

The SCT9325 feature Under Voltage Lock Out(UVLO) functions. The default startup threshold is typical 3.5V with VIN rising and shutdown threshold is 3.1V with VIN falling. The more accurate UVLO threshold can be programmed through the precision enable threshold of EN pin.



### Enable and Start up

When applying a voltage higher than the EN high threshold (typical 1.18V rising), the SCT9325 enable all functions and the devices start soft-start phase. The SCT9325 have the built-in 4ms soft-start time to prevent the output overshoot and inrush current. When EN pin is pulled low, the internal SS net will be discharged to ground. Buck operation is disabled when EN voltage falls below its lower threshold (typically 1.1V falling).

An internal 1.5uA pull up current source connected from internal LDO power rail to EN pin guarantees that floating EN pin automatically enables the device. For the application requiring higher VIN UVLO voltage than the default setup, there is a 4uA hysteresis pull up current source on EN pin which configures the VIN UVLO voltage with an off-chip resistor divider R3 and R4, shown in Figure 11. The resistor divider R3 and R4 are calculated by equation (1) and (2).

EN pin is a high voltage pin, and can be directly connected to VIN to automatically start up the device with VIN rising to its internal UVLO threshold.

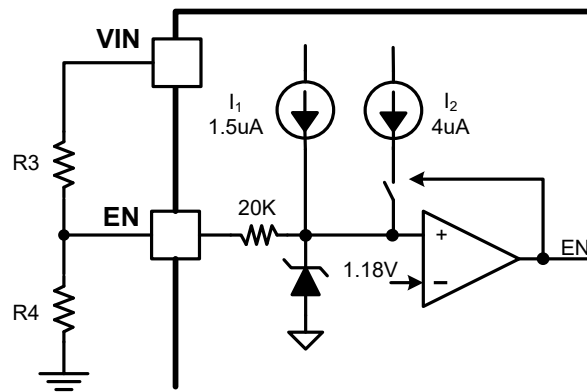


Figure 11. Adjustable VIN UVLO

$$R3 = \frac{V_{Start} \left( \frac{V_{ENF}}{V_{ENR}} \right) - V_{Stop}}{I_1 \left( 1 - \frac{V_{ENF}}{V_{ENR}} \right) + I_2} \quad (1)$$

$$R4 = \frac{R_3 \times V_{ENF}}{V_{Stop} - V_{ENF} + R_3(I_1 + I_2)} \quad (2)$$

Where,

Vstart: Vin rise threshold to enable the device

Vstop: Vin fall threshold to disable the device

$I_1=1.5\mu A$

$I_2=4\mu A$

$V_{ENR}=1.18V$

$V_{EMF}=1.1V$

### EMI Reduction with Frequency Spread Spectrum and Switching Node Ringing-free(Patent Submitted)

In the some applications, the system EMI test must meet EMI standards EN55011 and EN55022. To improve EMI performance, the SCT9325 adopt Frequency Spread Spectrum (FSS) to spread the switching noise over a wider

band and therefore reduces conducted and radiated interference peak amplitude at a particular frequency. The SCT9325 feature 500KHz switching frequency with spreading frequency of +/-6% and modulation rate 1/512 of switching frequency. The FSS technique effectively decreases the EMI noise by spreading the switching frequency from fixed 500KHz. As a result, the harmonic wave amplitude is reduced and the harmonic wave band is wider.

In buck converter, the switching node ringing amplitude and cycles are critical especially related to the high frequency radiation EMI noise. The SCT9325 implement the multi-level gate driver speed technique to achieve the switching node ringing-free without sacrificing the switching node rise/fall slew rate and power efficiency of the converter. The switching node ringing amplitude and cycles are damped by the built-in MOSFETs gate driving technique (SCT Proprietary Design). The switching node zoomed in wave form is shown in Figure 12.

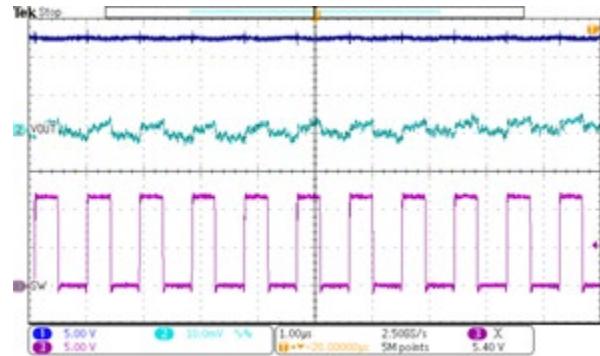


Figure 12. Switching Node Waveform

### Peak Current Limit and Hiccup Mode

The SCT9325 have cycle-by-cycle peak current limit with sensing the internal high side MOSFET Q1 current during over current condition. While the Q1 turns on, its conduction current is monitored by the internal sensing circuitry. Once the high-side MOSFET Q1 current exceeds the limit, it turns off immediately. If the Q1 over current time exceeds 512 switching cycles (hiccup waiting time), the buck converter enters hiccup mode and shuts down. After 8192 cycles off, the buck converter restarts to power up. The hiccup modes reduce the power dissipation in over current condition.

### Over Voltage Protection and Minimum On-time

The SCT9325 feature the output over-voltage protection (OVP). If the output pin voltage exceeds 110% of reference output voltage (5V or 3.3V), the converter stops switching immediately. When the output feedback pin voltage drops below 105% of set output voltage, the converter resumes to switching. The OVP function prevents the connected output circuitry damaged from un-predictive overvoltage. Featured feedback overvoltage protection also prevents dynamic voltage spike to damage the circuitry at load during fast loading transient.

The high-side MOSFET Q1 has minimum on-time 80ns typical limitation. While the device operates at minimum on-time, further increasing VIN results in pushing output voltage beyond regulation point. With output feedback over voltage protection, the converter skips pulse by turning off high-side MOSFET Q1 and prevents output running away higher to damage the load.

### Pulse Skipping Modulation PSM Mode

In heavy load condition, the SCT9325 force the device operating at forced Pulse Width Modulation (PWM) mode. When the load current decreasing, the internal COMP net voltage decreases as the inductor current down. With the load current further decreasing, the COMP net voltage decreases and be clamped at a voltage corresponding to the 450mA peak inductor current. When the load current approaches zero, the SCT9325 enter Pulse Skipping Modulation (PSM) mode to increase the converter power efficiency at light load condition. When the inductor current decreases to zero, zero-cross detection circuitry on high-side MOSFET Q1 forces the Q1 off till the beginning of the next switching cycle. The buck converter does not sink current from the load when the output load is light and converter works in PSM mode.

### Bootstrap Voltage Regulator

An external bootstrap capacitor between BST and SW pin powers floating high-side power MOSFET gate driver. The bootstrap capacitor voltage is charged from an integrated voltage regulator when high-side power MOSFET is off and low-side power MOSFET is on.

The floating supply (BST to SW) UVLO threshold is 2.7V rising and hysteresis of 350mV. When the converter operates with high duty cycle or prolongs in sleep mode for certain long time, the required time interval to recharging bootstrap capacitor is too long to keep the voltage at bootstrap capacitor sufficient. When the voltage across bootstrap capacitor drops below 2.35V, BST UVLO occurs. The SCT9325 intervenes to turn on low side MOSFET periodically to refresh the voltage of bootstrap capacitor to guarantee operation over a wide duty range.

### Low Drop-Out LDO Regulation

In some applications, the system EMI test must meet EMI standards EN55011 and EN55022. To improve EMI performance, SCT9325 adopts Frequency Spread Spectrum (FSS) to spread the switching noise over a wider band and therefore reduces conducted and radiated interference peak amplitude at particular frequency. The SCT9325 features 500kHz switching frequency with spreading frequency of +/-6% and modulation rate 1/512 of switching frequency. The FSS technique effectively decreases the EMI noise by spreading the switching frequency from fixed 500kHz to a range 517kHz ~ 583kHz. As a result, the harmonic wave amplitude is reduced and the harmonic wave band is wider.

In buck converter, the switching node ringing amplitude and cycles are critical especially related to the high frequency radiation EMI noise. The SCT9325 implements the multi-level gate driver speed technique to achieve the switching node ringing-free without scarifying the switching node rise/fall slew rate and power efficiency of the converter. The switching node ringing amplitude and cycles are damped by the built-in MOSFETs gate driving technique (SCT Patented Proprietary Design). The switching node zoomed in wave form is shown in Figure 12.

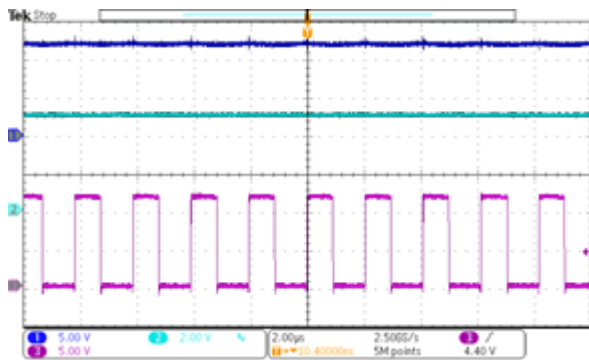


Figure 12. SCT9325 Switching Node Waveform

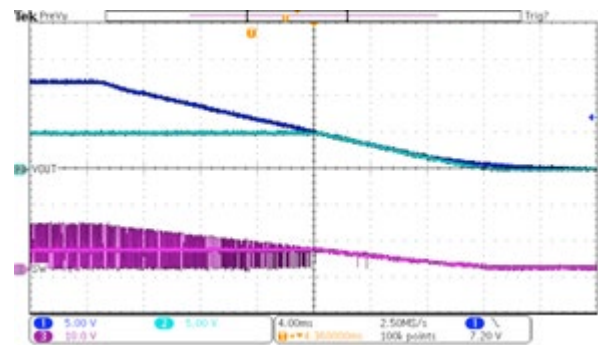


Figure 13. SCT9325 LDO Mode Waveform

### Thermal Shutdown

Once the junction temperature in the SCT9325 exceeds 160C, the thermal sensing circuit stops converter switching and restarts with the junction temperature falling below 125C. Thermal shutdown prevents the damage on device during excessive heat and power dissipation condition.

APPLICATION INFORMATION

Typical Application

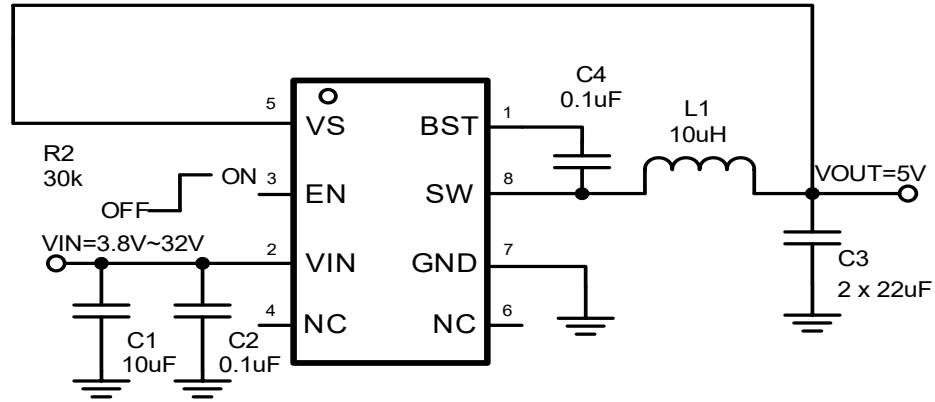


Figure 14. 12V Input, 5V/2A Output

Design Parameters

| Design Parameters                    | Example Value |
|--------------------------------------|---------------|
| Input Voltage                        | 12V           |
| Output Voltage                       | 5V            |
| Output Current                       | 2A            |
| Output voltage ripple (peak to peak) | ±0.3A         |
| Switching Frequency                  | 500KHz        |

### Input Capacitor Selection

For good input voltage filtering, choose low-ESR ceramic capacitors. A ceramic capacitor 10 $\mu$ F is recommended for the decoupling capacitor and a 0.1 $\mu$ F ceramic bypass capacitor is recommended to be placed as close as possible to the VIN pin of the SCT9325.

Use Equation (3) to calculate the input voltage ripple:

$$\Delta V_{IN} = \frac{I_{OUT}}{C_{IN} \times f_{SW}} \times \frac{V_{OUT}}{V_{IN}} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \quad (3)$$

Where:

- $C_{IN}$  is the input capacitor value
- $f_{sw}$  is the converter switching frequency
- $I_{OUT}$  is the maximum load current

Due to the inductor current ripple, the input voltage changes if there is parasitic inductance and resistance between the power supply and the VIN pin. It is recommended to have enough input capacitance to make the input voltage ripple less than 100mV. Generally, a 35V/10 $\mu$ F input ceramic capacitor is recommended for most of applications. Choose the right capacitor value carefully with considering high-capacitance ceramic capacitors DC bias effect, which has a strong influence on the final effective capacitance.

### Inductor Selection

The performance of inductor affects the power supply's steady state operation, transient behavior, loop stability, and buck converter efficiency. The inductor value, DC resistance (DCR), and saturation current influences both efficiency and the magnitude of the output voltage ripple. Larger inductance value reduces inductor current ripple and therefore leads to lower output voltage ripple. For a fixed DCR, a larger value inductor yields higher efficiency via reduced RMS and core losses. However, a larger inductor within a given inductor family will generally have a greater series resistance, thereby counteracting this efficiency advantage.

Inductor values can have  $\pm 20\%$  or even  $\pm 30\%$  tolerance with no current bias. When the inductor current approaches saturation level, its inductance can decrease 20% to 35% from the value at 0-A current depending on how the inductor vendor defines saturation. When selecting an inductor, choose its rated current especially the saturation current larger than its peak current during the operation.

To calculate the current in the worst case, use the maximum input voltage, minimum output voltage, maximum load current and minimum switching frequency of the application, while considering the inductance with -30% tolerance and low-power conversion efficiency.

For a buck converter, calculate the inductor minimum value as shown in equation (4).

$$L_{INDMIN} = \frac{V_{OUT} \times (V_{INMAX} - V_{OUT})}{V_{INMAX} \times K_{IND} \times I_{OUT} \times f_{SW}} \quad (4)$$

Where:

- $K_{IND}$  is the coefficient of inductor ripple current relative to the maximum output current.

Therefore, the peak switching current of inductor,  $I_{LPEAK}$ , is calculated as in equation (5).

$$I_{LPEAK} = I_{OUT} + K_{IND} \times \frac{I_{OUT}}{2} \quad (5)$$

Set the current limit of the SCT9325 higher than the peak current  $I_{LPEAK}$  and select the inductor with the saturation current higher than the current limit. The inductor's DC resistance (DCR) and the core loss significantly affect the efficiency of power conversion. Core loss is related to the core material and different inductors have different core

loss. For a certain inductor, larger current ripple generates higher DCR and ESR conduction losses and higher core loss.

Table 1 lists recommended inductors for the SCT9325. Verify whether the recommended inductor can support the user's target application with the previous calculations and bench evaluation. In this application, the WE's inductor 744314101 is used on SCT9325 evaluation board.

**Table 1. Recommended Inductors**

| Part Number | L (uH) | DCR Max (mΩ) | Saturation Current/Heat Rating Current (A) | Size Max (LxWxH mm) | Vendor           |
|-------------|--------|--------------|--|---------------------|------------------|
| 744314101   | 10     | 33           | 3.5  | 7x7x5               | Würth Elektronik |

### Output Capacitor Selection

For buck converter, the output capacitor value determines the regulator pole, the output voltage ripple, and how the regulator responds to a large change in load current. The output capacitance needs to be selected based on the most stringent of these three criteria.

For small output voltage ripple, choose a low-ESR output capacitor like a ceramic capacitor, for example, X5R and X7R family. Typically, 1~3x 22μF ceramic output capacitors work for most applications. Higher capacitor values can be used to improve the load transient response. Due to a capacitor's de-rating under DC bias, the bias can significantly reduce capacitance. Ceramic capacitors can lose most of their capacitance at rated voltage. Therefore, leave margin on the voltage rating to ensure adequate effective capacitance.

From the required output voltage ripple, use the equation (6) to calculate the minimum required effective capacitance,  $C_{OUT}$ .

$$C_{OUT} = \frac{\Delta I_{LPP}}{8 \times V_{OUTRipple} \times f_{SW}} \quad (6)$$

Where

- $V_{OUTRipple}$  is output voltage ripple caused by charging and discharging of the output capacitor.
- $\Delta I_{LPP}$  is the inductor peak to peak ripple current, equal to  $k_{IND} \cdot I_{OUT}$ .
- $f_{SW}$  is the converter switching frequency.

The allowed maximum ESR of the output capacitor is calculated by the equation (7).

$$R_{ESR} = \frac{V_{OUTRipple}}{\Delta I_{LPP}} \quad (7)$$

The output capacitor affects the crossover frequency  $f_c$ . Considering the loop stability and effect of the internal loop compensation parameters, choose the crossover frequency less than 55 kHz ( $\frac{1}{10} \times f_{SW}$ ) without considering the feed-forward capacitor. A simple estimation for the crossover frequency without feed forward capacitor is shown in equation (8), assuming  $C_{OUT}$  has small ESR.

$$C_{OUT} > \frac{18k \times G_M \times G_{MP} \times 0.8V}{2\pi \times V_{OUT} \times f_c} \quad (8)$$

Where

- $G_M$  is the transfer conductance of the error amplifier (300uS).
- $G_{MP}$  is the gain from internal COMP to inductor current, which is 5A/V.

- $f_c$  is the cross over frequency.

Additional capacitance de-rating for aging, temperature and DC bias should be factored in which increases this minimum value. Capacitors generally have limits to the amount of ripple current they can handle without failing or producing excess heat. An output capacitor that can support the inductor ripple current must be specified. The capacitor data sheets specify the RMS (Root Mean Square) value of the maximum ripple current. Equation (9) can be used to calculate the RMS ripple current the output capacitor needs to support.

$$I_{COUTRMS} = \frac{V_{OUT} \cdot (V_{IN} - V_{OUT})}{\sqrt{12} \cdot V_{IN} \cdot L_{IND} \cdot f_{SW}} \quad (9)$$

### Output Feed-Forward Capacitor Selection

The SCT9325 have the internal integrated loop compensation as shown in the function block diagram. The compensation network includes a 18k resistor and a 7.6nF capacitor. Usually, the type II compensation network has a phase margin between 60 and 90 degree. However, if the output capacitor has ultra-low ESR, the converter results in low phase margin. To increase the converter phase margin, a feed-forward cap  $C_{ff}$  is used to boost the phase margin at the converter cross-over frequency  $f_c$ . Equation (10) is used to calculate the feed-forward capacitor.

$$C_{ff} = \frac{1}{2\pi \cdot f_c \times R_1} \quad (10)$$

### Output Feed-back Resistor Divider Selection

The SCT9325 feature external programmable output voltage by using a resistor divider network  $R_1$  and  $R_2$  as shown in the typical application circuit Figure. 19. Use equation (11) to calculate the resistor divider value.

$$R_1 = \frac{(V_{OUT} - V_{ref}) \times R_2}{V_{ref}} \quad (11)$$

Set the resistor  $R_2$  value to be approximately 30k. Slightly increasing or decreasing  $R_1$  can result in closer output voltage matching when using standard value resistors.



Application Waveforms

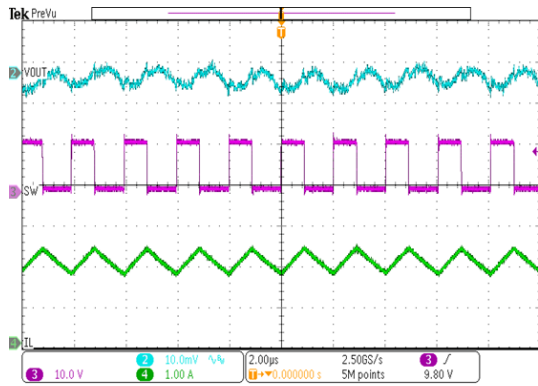


Figure 15. SW node waveform and Output Ripple, Iout=2A

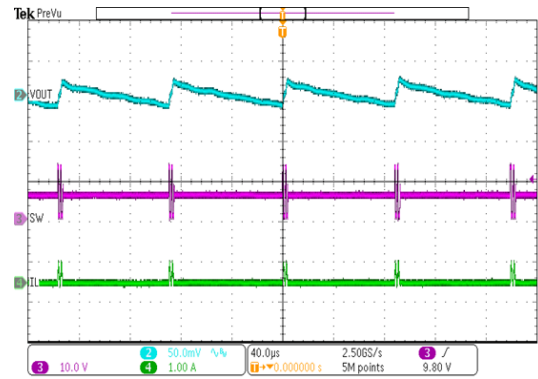


Figure 16. SW node Waveform and Output Ripple, Iout=10mA

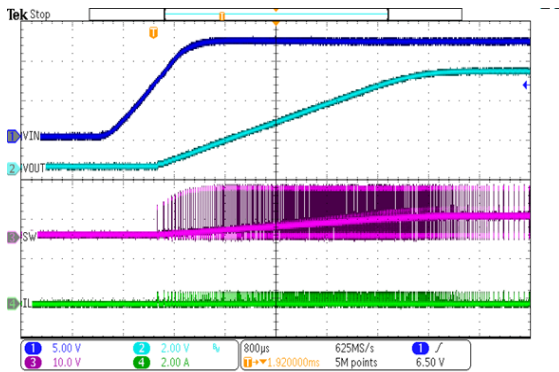


Figure 17. Power Up, Iout=10mA

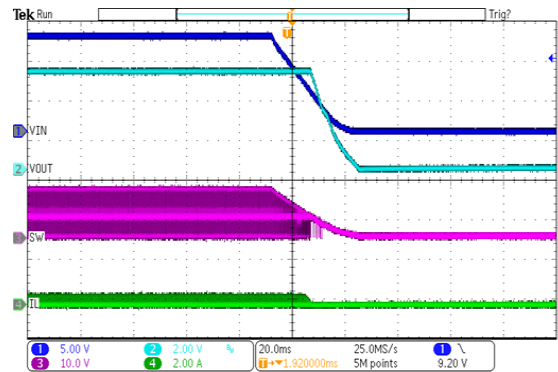


Figure 18. Power Down, Iout=10mA

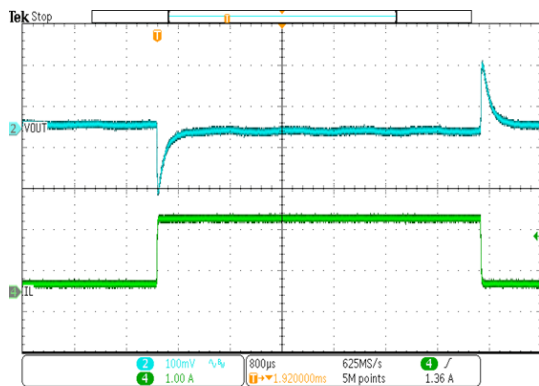


Figure 19. Load Transient (Vout=5V, Iout=0.2A to 1.8A, SR=250mA/us)

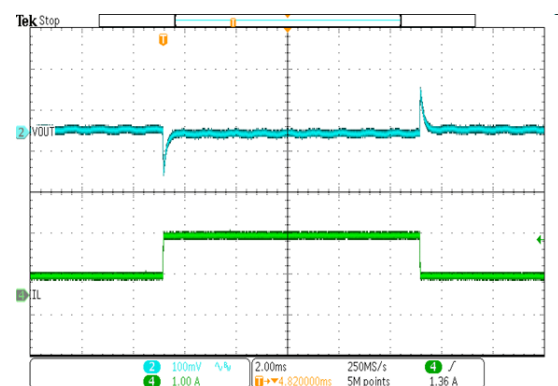


Figure 20. Load Transient (Vout=5V, Iout=0.5A to 1.5A, SR=250mA/us)



## Layout Guideline

The regulator could suffer from instability and noise problems without carefully layout of PCB. Radiation of high-frequency noise induces EMI, so proper layout of the high-frequency switching path is essential. Minimize the length and area of all traces connected to the SW pin, and always use a ground plane under the switching regulator to minimize coupling. The input capacitor needs to be very close to the VIN pin and GND pin to reduce the input supply ripple. Place the capacitor as close to VIN pin as possible to reduce high frequency ringing voltage on SW pin as well. Figure 21 is the recommended PCB layout of the SCT9325.

The layout needs be done with well consideration of the thermal. A large top layer ground plate using multiple thermal vias is used to improve the thermal dissipation. The bottom layer is a large ground plane connected to the top layer ground by vias.

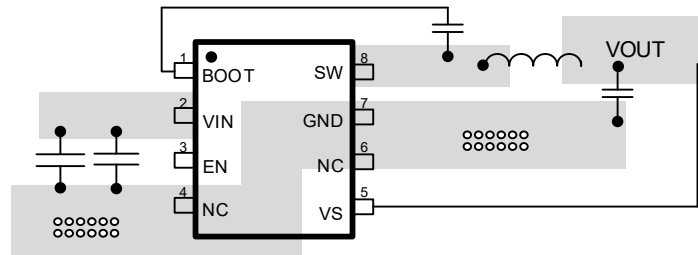


Figure 21. PCB Layout Example

## Thermal Considerations

The maximum IC junction temperature should be restricted to 125°C under normal operating conditions. Calculate the maximum allowable dissipation,  $P_{D(max)}$ , and keep the actual power dissipation less than or equal to  $P_{D(max)}$ . The maximum-power-dissipation limit is determined using Equation (12).

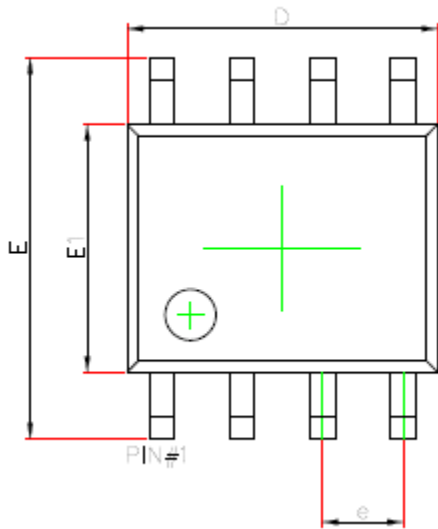
$$P_{D(MAX)} = \frac{125 - T_{CA}}{R_{\theta JA}} \quad (12)$$

where

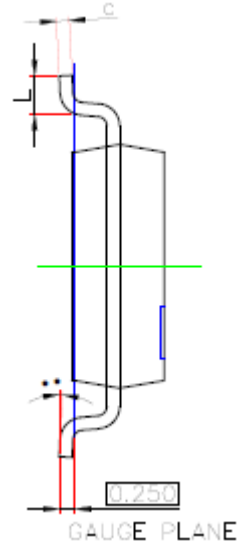
- $T_A$  is the maximum ambient temperature for the application.
- $R_{\theta JA}$  is the junction-to-ambient thermal resistance given in the Thermal Information table.

The real junction-to-ambient thermal resistance  $R_{\theta JA}$  of the package greatly depends on the PCB type, layout, thermal pad connection and environmental factor. Using thick PCB copper and soldering the GND to a large ground plate enhance the thermal performance. Using more vias connects the ground plane on the top layer and bottom layer around the IC without solder mask also improves the thermal capability.

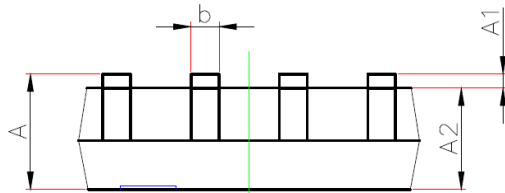
**PACKAGE INFORMATION**



TOP VIEW



BOTTOM VIEW



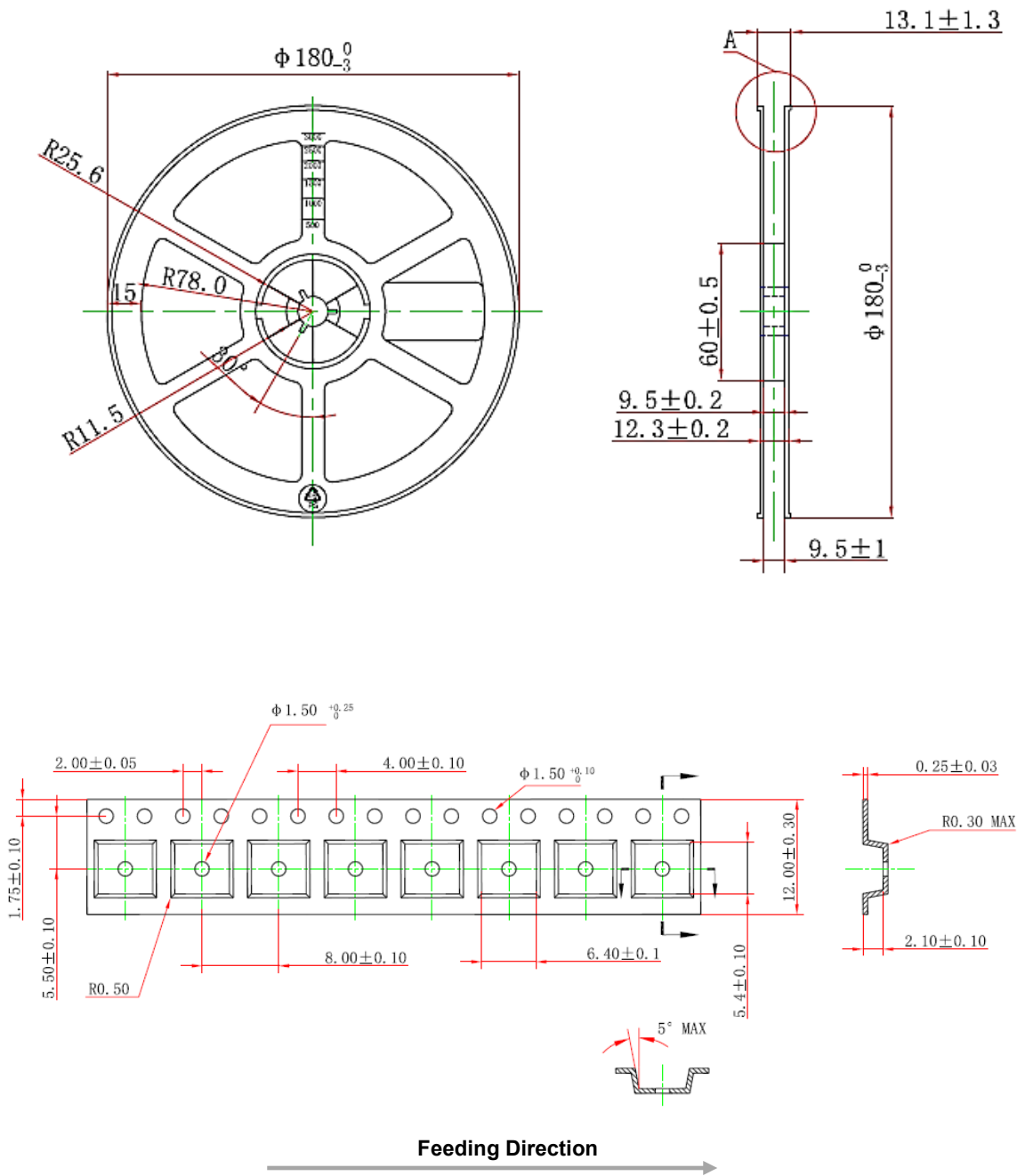
SIDE VIEW

**NOTE:**

1. Drawing proposed to be made a JEDEC package outline MO-220 variation.
2. Drawing not to scale.
3. All linear dimensions are in millimeters.
4. Thermal pad shall be soldered on the board.
5. Dimensions of exposed pad on bottom of package do not include mold flash.
6. Contact PCB board fabrication for minimum solder mask web tolerances between the pins.

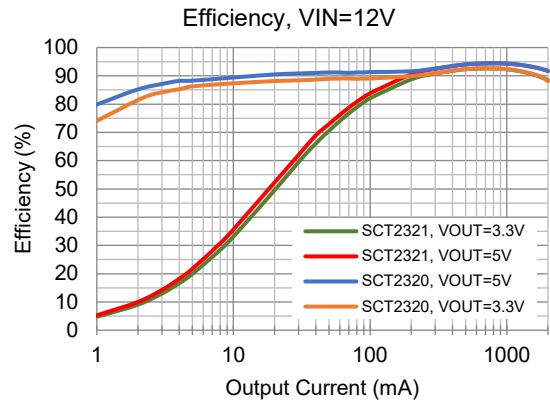
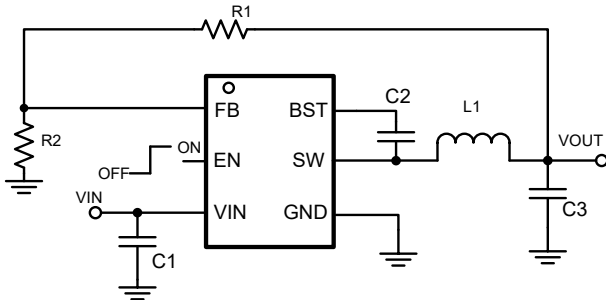
| SYMBOL | Unit: Millimeter |     |      |
|--------|------------------|-----|------|
|        | MIN              | TYP | MAX  |
| A      | 1.35             |     | 1.75 |
| A1     | 0.1              |     | 0.25 |
| A2     | 1.35             |     | 1.55 |
| D      | 4.8              |     | 5    |
| E      | 5.8              |     | 6.2  |
| E1     | 3.8              |     | 4.0  |
| b      | 0.33             |     | 0.51 |
| c      | 0.17             |     | 0.25 |
| e      | 1.27(BSC)        |     |      |
| L      | 0.40             |     | 1.27 |
| θ      | 0°               |     | 8°   |

**TAPE AND REEL INFORMATION**



## TYPICAL APPLICATION

24V Input, 5V Output, 500kHz Synchronous Buck Converter



## RELATED PARTS

| PART NUMBERS                     | DESCRIPTION   | COMMENTS   |
|----------------------------------|---|--|
| <b>SCT2320</b><br><b>SCT2330</b> | 3.8V-32V Vin, 2A/3A, 500kHz Synchronous Buck Converter with EMI Reduction | <ul style="list-style-type: none"> <li>• 20uA quiescent current</li> <li>• 500kHz switching frequency with <math>\pm 6\%</math> frequency spread spectrum.</li> <li>• EMI reduction with switching node ringing-free.</li> </ul> |
| <b>SCT2321</b><br><b>SCT2331</b> | 3.8V-32V Vin, 2A/3A, 500kHz Synchronous Buck Converter with PWM Mode      | <ul style="list-style-type: none"> <li>• Forced PWM mode operation.</li> <li>• Fixed 500kHz Switching Frequency.</li> </ul>  |

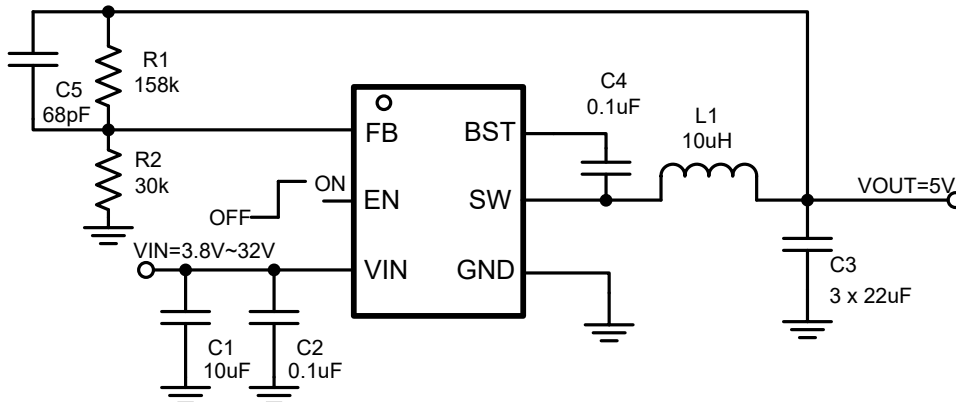


Figure 22. SCT2320 and SCT2321 Typical Application

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