20V Output, 16A Switching Current, Fully Integrated Synchronous Boost Converter with Programmable Input Current Limit

FEATURES

- Wide Input Voltage Range: 2.7V-20V
- Wide Output Voltage Range: 4.5V-20V
- Fully Integrated 10mΩ High Side FET and 6.5mΩ Low Side FET
- Programmable Input Current Limit Up to 15A
- Internal Peak Current Limit: 16A
- Typical Shut-down Current: 5uA
- Quiescent Current: 170uA
- Fixed 600KHz Switching Frequency
- Selectable PFM and FCCM at Light-load
- Parallel Mode
- External Soft Start and Compensation
- Output Overvoltage Protection
- Thermal Shutdown Protection
- QFN-13 3mm x 4mm Package

APPLICATIONS

- Bluetooth Audio
- Wireless Charger
- POS
- Lighting

DESCRIPTION

The SCT12A5 is a high efficiency synchronous boost converter with fully integrated a 10mΩ high-side MOSFET and a 6.5mΩ low-side MOSFET, supporting 2.7V to 20V input voltage range and up to 16A switching current. The input average current limit can be adjustable with an external resistor. SCT12A5 supports up to 30W of load power from a 1-cell battery with integrated low Rds_on power MOSFETs.

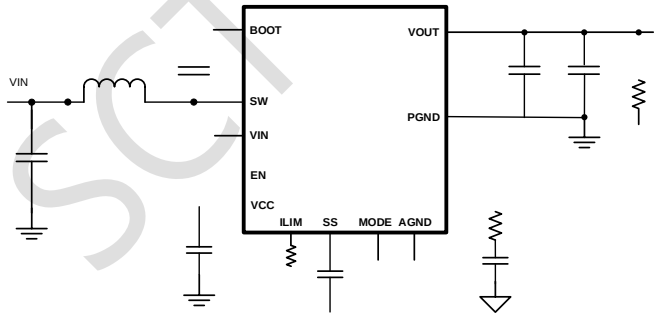
The SCT12A5 adopts constant off-time peak current control to provide fast transient response. An external compensation network allows flexibility setting loop dynamics to achieve optimal transient performance at different load conditions.

The SCT12A5 offers selectable PFM and FCCM in light load condition, and it also offers parallel mode for higher power application. The switching frequency is fixed 600KHz.

The SCT12A5 features output overvoltage protection and thermal shutdown protection when the device overloads.

The device is available in a QFN-13 3mm x 4mm package.

TYPICAL APPLICATION



SCT CONFIDENTIAL

 ©2024 Silicon Content Technology Co., Ltd. All Rights Reserved

REVISION HISTORY

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

Revision 0.8: Customer Sample.

DEVICE ORDER INFORMATION

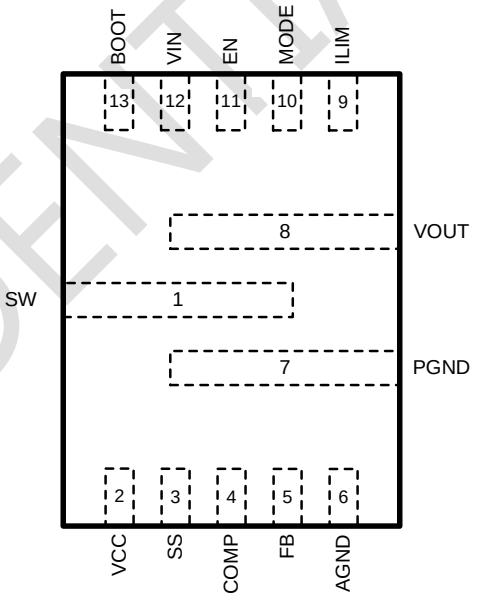
PART NUMBER	PACKAGING TYPE	STANDARD PACK QTY	PACKAGE MARKING	PINS	PACKAGE DESCRIPTION
SCT12A5FOAR	Tape & Reel	5000	12A5	13	QFN-13 3mm×4mm

ABSOLUTE MAXIMUM RATINGS

Over operating free-air temperature unless otherwise noted(1)

DESCRIPTION	MIN	MAX	UNIT
BOOT	-0.3	28	V
VIN, SW, VOUT, EN	-0.3	22	V
VCC, ILIM, FB, COMP, SS, MODE	-0.3	5.5	V
Operating Junction Temperature T_J(2)	-40	125	°C
Storage Temperature T_{STG}	-65	150	°C

PIN CONFIGURATION



Top View: 13-Lead Plastic QFN 3mm x 4mm

(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 175°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
SW	1	Switching node of the boost converter.
VCC	2	Internal linear regulator output. Connect a 1uF or larger ceramic capacitor to ground.

SCT CONFIDENTIAL

 © 2024 Silicon Content Technology Co., Ltd. All Rights Reserved

SCT CONFIDENTIA

SYMBOL PARAMETER

SCT CONFIDENTIAL

 © 2024 Silicon Content Technology Co., Ltd. All Rights Reserved

TYPICAL CHARACTERISTICS

V_{IN}=3.6V, V_{OUT}=12V, unless otherwise noted

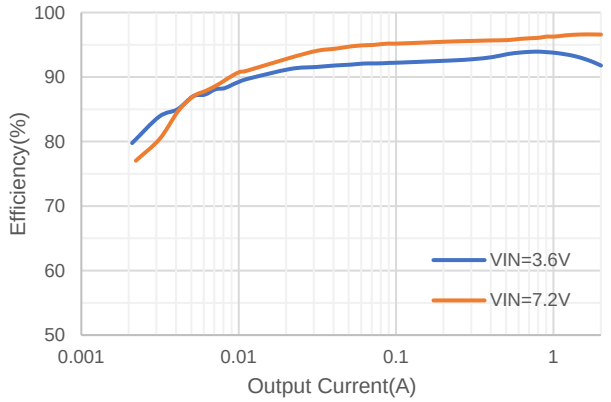


Figure 1. Efficiency, PFM

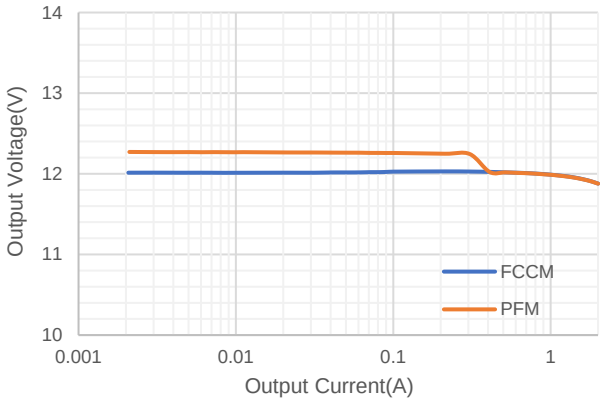


Figure 2. Load Regulation

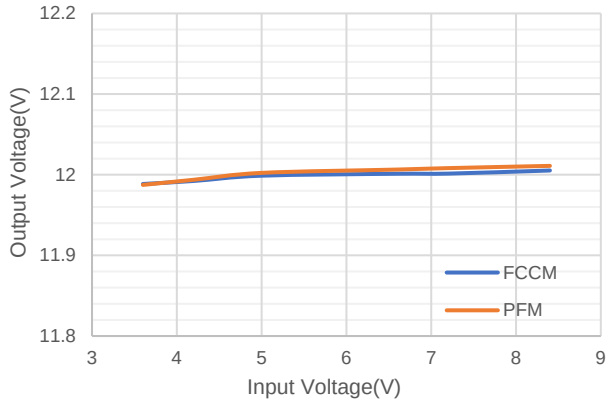


Figure 3. Line Regulation, I_{LOAD}=1A

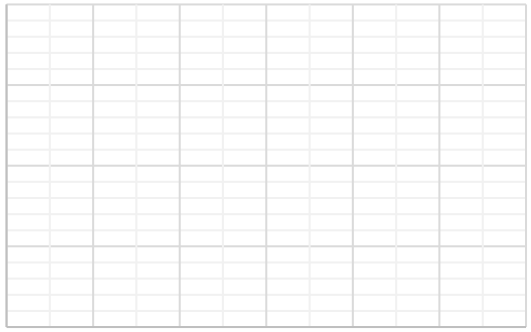


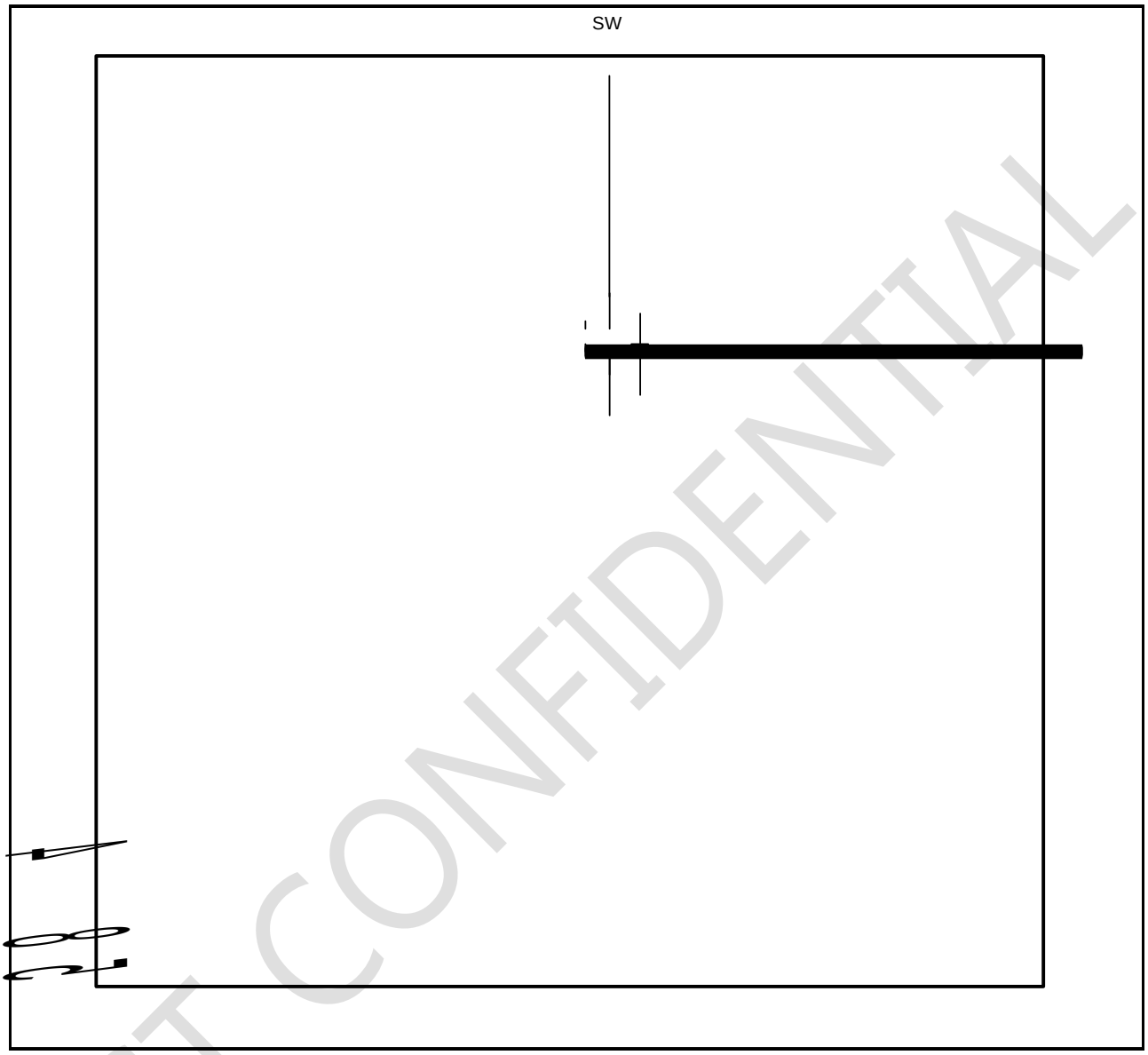
Figure 4. Input Average Current Limit vs. R_{ILIM}

Figure 5. Reference Voltage vs. Junction Temperature

Figure 6. Switching Frequency vs. Junction Temperature

 © 2024 Silicon Content Technology Co., Ltd. All Rights Reserved

FUNCTIONAL BLOCK DIAGRAM



SCT CONFIDENTIAL

 © 2024 Silicon Content Technology Co., Ltd. All Rights Reserved

OPERATION

Overview

The SCT12A5 device is a fully integrated synchronous boost converter with programmable input average current limit. The constant off-time peak current mode control provides fast transient with pseudo fixed switching frequency. When low-side MOSFET Q1 turns on, input voltage forces the inductor current rise. Sensed voltage on low-side MOSFET peak current rises above the voltage of COMP. After the inductor current reaches the peak current, the device turns off low-side MOSFET and inductor goes through body diode of high-side MOSFET Q2 during dead time. After dead time duration, the device turns on high-side MOSFET Q2 and the inductor current decreases. Based on VIN and VOUT voltage, the device predicts required off-time and turns off high-side MOSFET Q2. This repeats on cycle-by-cycle based.

The voltage feedback loop regulates the FB voltage to an internal voltage reference with an integrated trans-conductance error amplifier. The feedback loop stability and transient response are optimized through an external loop compensation network connected to the COMP pin.

The SCT12A5 can work at PFM mode to further increase the efficiency in light load condition. The quiescent current of SCT12A5 is 170uA typical with no load and no switching. Disabling the device, the typical supply shutdown current on VIN pin is 5μA.

VIN Power

The SCT12A5 is designed to operate from an input voltage supply range between 2.7 V to 20V. If the input supply is located more than a few inches from the converter, additional bulk capacitance is required in addition to the ceramic bypass capacitors. A typical choice is ceramic capacitor with a value of 47μF or 2 x 22uF.

VCC Power

The internal VCC LDO provides the bias power supply for internal circuitries. A ceramic capacitor of no less than 1uF is required to bypass from VCC pin to ground. During starting up, input of VCC LDO is from VIN pin. Once the output voltage at VOUT pin exceeds VIN voltage, VCC LDO switches its input to VOUT pin. This allows higher voltage headroom of VCC at lower input voltage. No additional components or loading are recommended on this pin.

Under Voltage Lockout UVLO

The SCT12A5 features UVLO protection for voltage rails of VIN, VCC and BOOT-SW from the converter malfunctioning and the battery over discharging. The default VIN rising threshold is 2.5V typical at startup and falling threshold is 2.3V typical at shutdown. The internal charge pump from BOOT to SW powers the gate driver to high-side MOSFET Q2. The BOOT UVLO circuit monitors the capacitor voltage between BOOT pin and SW pin. When the voltage of BOOT to SW falls below a preset threshold 3V typical, high-side MOSFET Q2 turns off. As a result, the device works as a non-synchronous boost converter.

Enable and Start-up

The SCT12A5 enables all functions and starts converter operation when EN pin is pulled high. To disable the device, EN voltage needs to fall below its low threshold. The SCT12A5 sinks a current of 5uA typical on VIN pin after shutdown. Do not float EN pin and connect it to VIN for automatic start-up.

The SCT12A5 features programmable soft start to prevent inrush current during power-up. SS pin sources an internal 8μA current charging the external soft-start capacitor C_{SS} after EN pin is pulled high. The device uses the lower voltage between the internal voltage reference 1V and the SS pin voltage as the reference input voltage of error amplifier and regulates the output. The soft-start completes when SS pin voltage exceeds the internal 1V reference. Use Equation 1 to calculate the soft-start time. When EN pin is pulled low to disable the device, the SS pin will be discharged to ground.

SCT CONFIDENTIAL

 © 2024 Silicon Content Technology Co., Ltd. All Rights Reserved

$$= \frac{}{} \quad (1)$$

where

- t_{SS} is the soft start time
- V_{REF} is the internal reference voltage of 1V
- C_{SS} is the capacitance connecting to SS pin
- I_{SS} is the source current of 8uA to SS pin

Adjustable Input Current Limit

The SCT12A5 boost converter implements input average current limit function with sensing the internal low-side regulation lost power MOSFET Q1 during overcurrent condition. While the Q1 is turned on, its conduction current is monitored by the internal sensing circuitry. The device calculates the average input current by Q1 current and operational duty cycle, and coverts it to a voltage signal by a ratio set by an external resistor, R_{ILIM}. This voltage signal is sent to the current limit error amplifier and compared with an internal reference, where the COMP signal will be clamped by error amplifier output once the reference been exceeded. As a result, the input average current is limited by the COMP signal which determines cycle-by-cycle peak current.

Use Equation 2 to calculate the input average current limit.

$$- = \frac{420}{+1} - 2 \quad (2)$$

where:

- I_{LIM_AVG} is the input average current limit
- R_{ILIM} is the input average current limit setting resistor in kΩ

To avoid noise affection, a 10nF ceramic capacitor in parallel with R_{ILIM} and a 1kΩ resistor in series to ILIM pin are recommended, as shown in Figure 8. The minimum current limit must be higher than the required input current at lowest input voltage and the highest output power to avoid hitting the current limit, where output voltage regulation might be lost. Notice the input average current limit shall be set no higher than 15A and see Table 1 for a quick reference.

Table 1. R_{ILIM} Value for Input Average Current Limit
(V_{IN}=3.6V, V_{OUT}=12V, L=1.5uH, room temperature)

I_{LIM}	R_{ILIM}
13A	27kΩ
10A	34kΩ
8.5A	39kΩ

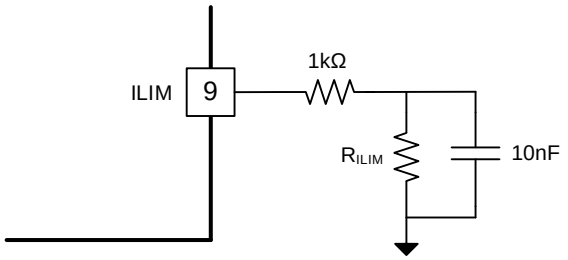


Figure 8. Input Average Current Limit Configuration

This current limit function is realized by detecting the current flowing through the low-side MOSFET. The current limit feature loses function in the output hard short circuit conditions. At normal operation, when the output hard shorts to ground, there is a direct path to short the input voltage through high-side MOSFET Q2 or its body diode even the Q2 is turned off. This could damage the circuit components and cause catastrophic failure at load circuit.

Mode Selection

The SCT12A5 features PFM or FCCM mode at light load by MODE pin configuration. The configuration information is listed in Table 2. The mode setting is latched in at each power up and is not able to be modified during operation. Cycling the input power or the EN pin can reselect the mode.

SCT CONFIDENTIAL

 © 2024 Silicon Content Technology Co., Ltd. All Rights Reserved

SCT CONFIDEN

Output Voltage

The output voltage V_{OUT} is set by an external resistor divider, R1 and R2 in typical application schematic. A minimum current of typical 20uA flowing through feedback resistor divider gives good accuracy and noise covering. The value of R1 can be calculated by Equation 3.

$$R1 = \frac{(\quad - \quad) \times R2}{} \tag{3}$$

where:

- V_{REF} is the feedback reference voltage for V_{OUT}, typical 1.0V

Table 3. Feedback Resistor R1 and R2 Value for Output Voltage

V_{OUT}	R1	R2
9 V	472 KΩ	59 KΩ
12 V	649 KΩ	59 KΩ
15 V	826 KΩ	59 KΩ
18 V	1 MΩ	59 KΩ

Inductor Selection

The performance of inductor affects the power supply's steady state operation, transient behavior, loop stability, and boost converter efficiency. The inductor value, DC resistance, and saturation current influences both efficiency and the magnitude of the output voltage ripple. A larger inductance value reduces inductor current ripple and therefore leads to lower output voltage ripple. For a fixed DC resistance, 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 ±20% or even ±30% tolerance with no current bias. When the inductor current approaches saturation level, its inductance can decrease 20% to 35% from the value at zero 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 minimum input voltage, maximum output voltage, maxim load current and minimum switching frequency of the application, while considering the inductance with -30% tolerance and low power conversion efficiency.

For a boost converter, calculate the inductor DC current as in Equation 4

$$= \frac{\times}{\times} \tag{4}$$

Where

- V_{OUT} is the output voltage of the boost converter
- I_{OUT} is the output current of the boost converter
- V_{IN} is the input voltage of the boost converter
- η is the power conversion efficiency

Calculate the inductor current peak-to-peak ripple, I_{LPP}, as in Equation 5

$$= \frac{1}{\times (\frac{1}{\_} + \frac{1}{}) \times} \tag{5}$$

Where

- I_{LPP} is the inductor peak-to-peak current
- L is the inductance of inductor
- f_{SW} is the switching frequency
- V_{OUT} is the output voltage

SCT CONFIDENTIAL

 © 2024 Silicon Content Technology Co., Ltd. All Rights Reserved

- V_{IN} is the input voltage

peak switch -1002 Tw 7.5 -0-0 0 10.02 106.145m (3.6669.66 51 2006552 0Tw 8.329 0.29 ( )Tj E)001 TcTd (

SCT CONFIDENTIAL

 © 2024 Silicon Content Technology Co., Ltd. All Rights Reserved

Loop Stability

An external loop compensation network comprises resister R3, ceramic capacitors C1 and C2 connected to the COMP pin to optimize the loop response of the converter. The power stage small signal loop response of constant off time with peak current control can be modeled by Equation 9.

$$(\ ) = \frac{\times (1 - \ )}{2 \times} \times \frac{(1 + \frac{}{2 \times})(1 + \frac{}{2 \times})}{1 + \frac{}{2 \times}} \quad (9)$$

where

- *D* is the switching duty cycle
- R_{load} is the output load resistance
- R_{SENSE} is the equivalent internal current sense resistor, which is 0.04Ω

$$= \frac{1}{2 \times \times} \quad (10)$$

where

- C_O is the output capacitance

$$= \frac{1}{2 \times \times} \quad (11)$$

where

- ESR is the equivalent series resistance of the output capacitor

$$= \frac{\times (1 -)^2}{2 \times} \quad (12)$$

The COMP pin is the output of the internal trans-conductance amplifier. Equation 13 shows the small signal transfer function of compensation network.

$$(\ ) = \frac{\times}{\times} \times \frac{(1 + \frac{}{2 \times})}{(1 + \frac{}{2 \times \ _1})(1 + \frac{}{2 \times \ _2})} \quad (13)$$

where

- G_{EA} is the amplifier's trans-conductance
- R_{EA} is the amplifier's output resistance
- V_{REF} is the reference voltage at the FB pin
- V_{OUT} is the output voltage
- f_{COMP1}, f_{COMP2} are the poles' frequency of the compensation network
- f_{COMZ} is the zero's frequency of the compensation network

The next step is to choose the loop crossover frequency, f_C. The higher frequency that the loop gain stays above zero before crossing over, the faster the loop response is. It is generally accepted that the loop gain cross over no higher than the lower of either 1/10 of the switching frequency, f_{SW}, or 1/5 of the RHPZ frequency, f_{RHPZ}.

Then set the value of R3, C1, and C2 in typical application circuit by following these equations.

$$\mathrm{R3} = \frac{2 \times \times \times \times}{(1 -) \times \times} \quad (14)$$

where

- f_C is the selected crossover frequency.

$$\mathrm{C1} = \frac{\times}{2 \times \mathrm{R3}} \quad (15)$$

$$\mathrm{C2} = \frac{\times}{\mathrm{R3}} \quad (16)$$

If the calculated value of C2 is less than 10pF, it can be left open. Designing the loop for greater than 45°of phase margin and greater than 10-dB gain margin eliminates output voltage ringing during the line and load transient.

SCT CONFIDENTIAL

 © 2024 Silicon Content Technology Co., Ltd. All Rights Reserved

Application Waveforms

V_{IN}=3.6V, V_{OUT}=12V, unless otherwise noted

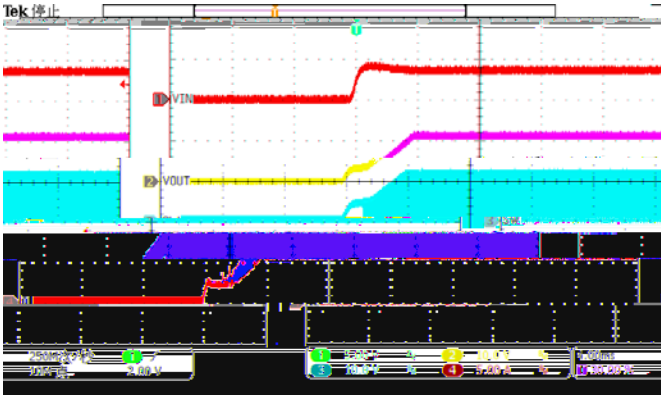


Figure 9. Power up (I_{LOAD}=2A)

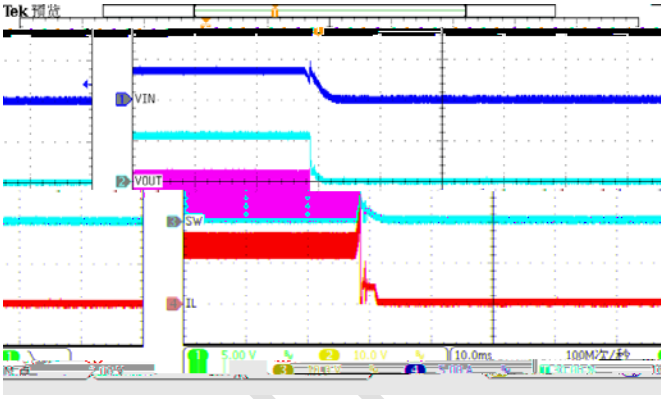


Figure 10. Power down (I_{LOAD}=2A)

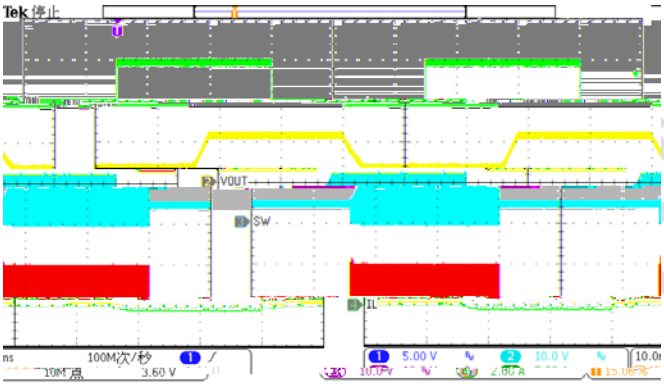


Figure 11. EN toggle (I_{LOAD}=0.1A)

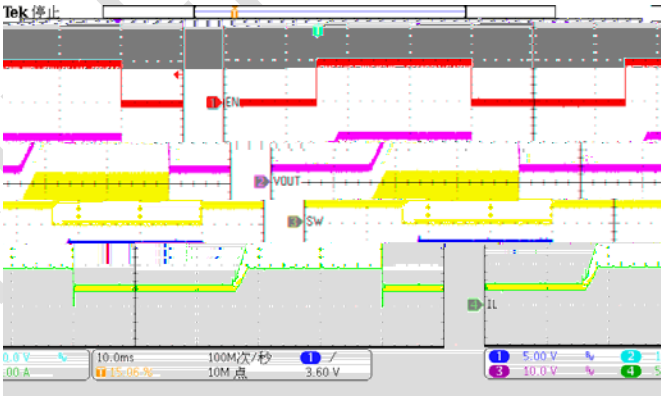


Figure 12. EN toggle (I_{LOAD}=2A)

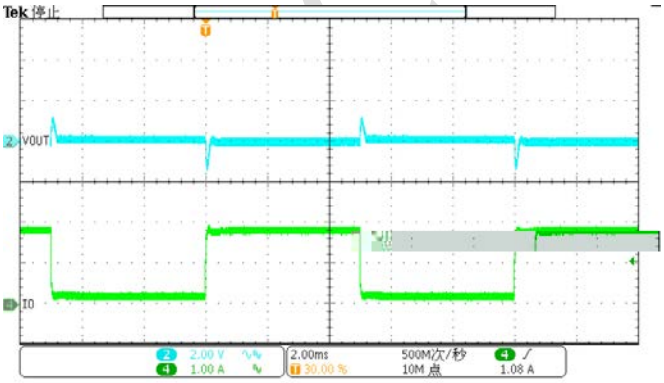


Figure 13. Load Transient (0.2A-1.8A)

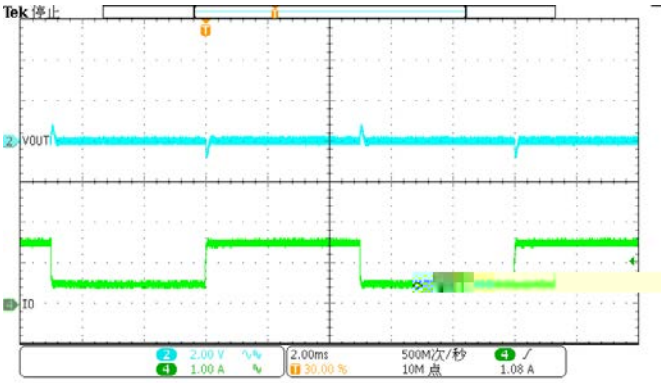


Figure 14. Load Transient (0.25A-1.5A)

 © 2024 Silicon Content Technology Co., Ltd. All Rights Reserved

SCT CONFIDEN

Layout Guideline

The regulator could suffer from instability and noise problems without careful 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 close to the VIN pin and ground pad to reduce the input supply ripple. The placement and ground trace for the output capacitor is critical for the performance of SW ringing voltage. Place the output capacitor as close to VOUT pins and power ground pad as possible to reduce high frequency ringing voltage on SW pin.

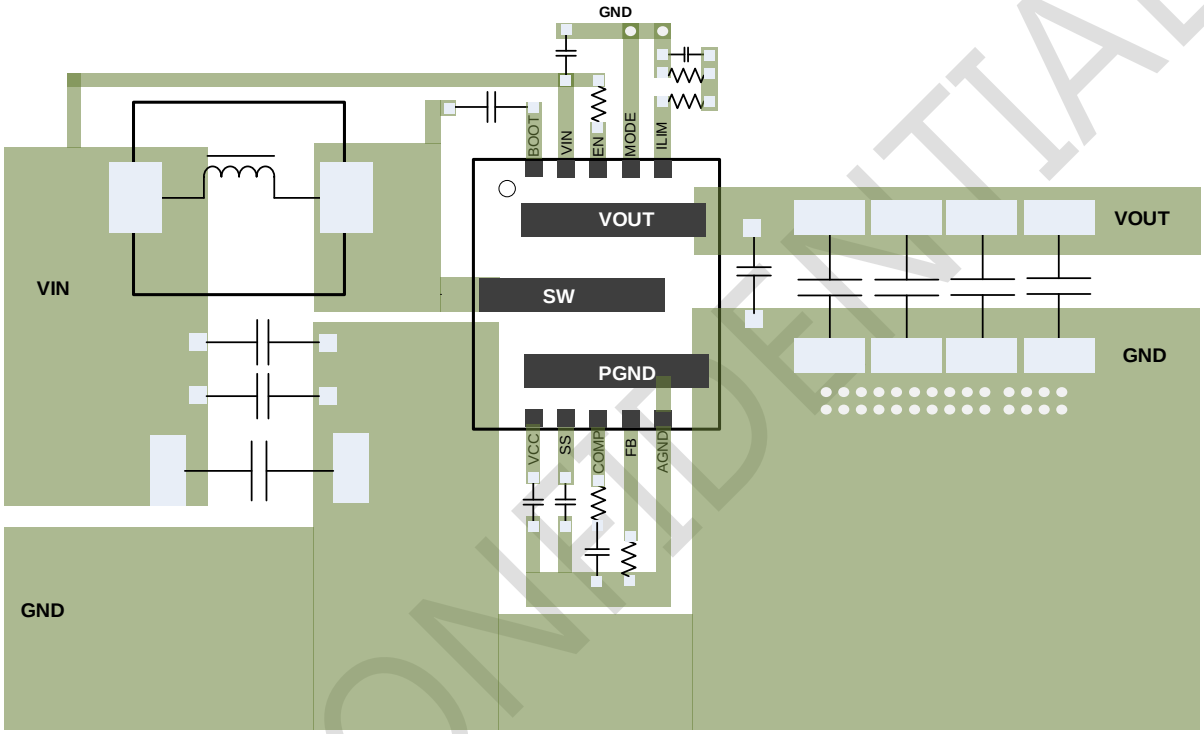


Figure 19. PCB Layout Example Top Layer

SCT CONFIDENTIAL

 © 2024 Silicon Content Technology Co., Ltd. All Rights Reserved

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 17.

$$(\quad) = \frac{125 -}{\theta JA} \tag{17}$$

where

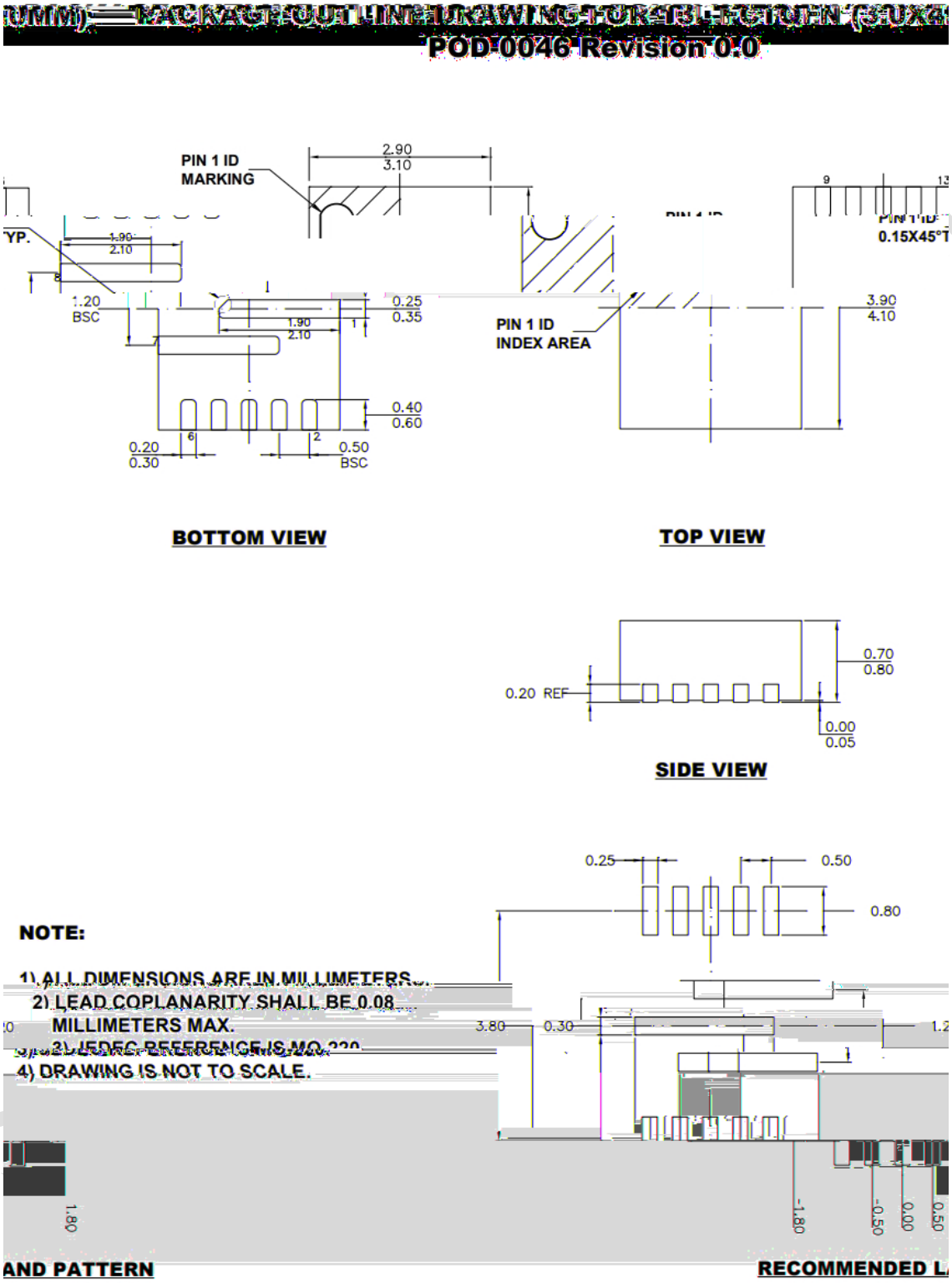
- T_A is the maximum ambient temperature for the application
- $R_{\theta JA}$ is the junction-to-ambient thermal resistance given in the Thermal Information table

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 thermal pad to a large ground plate enhance the thermal performance. Using more vias connects the ground plate on the top layer and bottom layer around the IC without solder mask also improves the thermal capability.

SCT CONFIDENTIAL

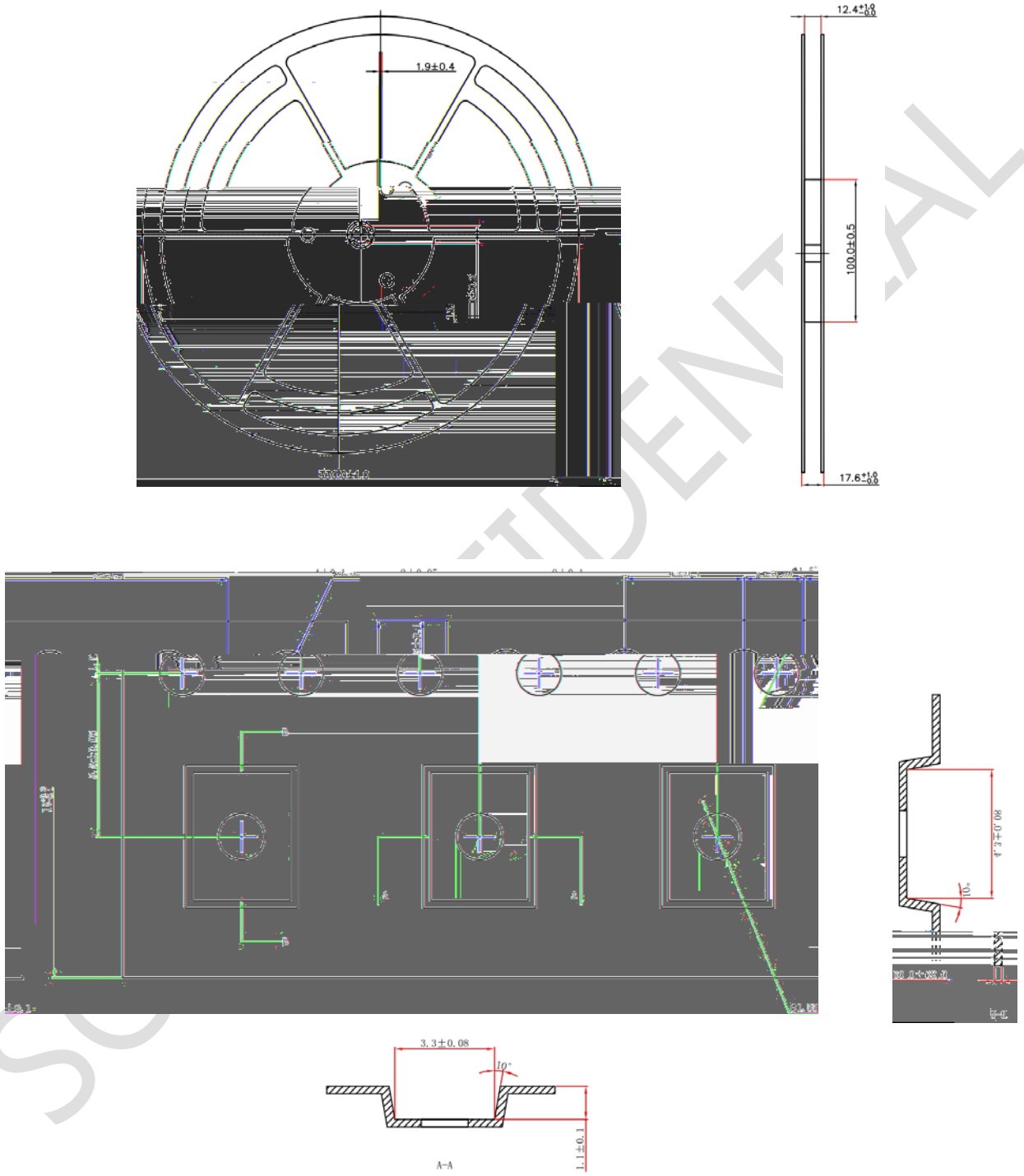
 © 2024 Silicon Content Technology Co., Ltd. All Rights Reserved

PACKAGE INFORMATION



 © 2024 Silicon Content Technology Co., Ltd. All Rights Reserved

TAPE AND REEL INFORMATION



SCT CONFIDENTIAL

 © 2024 Silicon Content Technology Co., Ltd. All Rights Reserved