

## 4.5V-100V Vin, 1A, Constant On-Time Synchronous BUCK Converter

### FEATURES

- Wide Input Range: 4.5V-100V
- 1A Continuous Output Current
- Integrated 530mΩ High-Side and 220mΩ Low-Side Power MOSFETs
- 1.2V  $\pm$ 1% Feedback Reference Voltage at Room Temperature
- 4.3ms Internal Soft-start Time
- Programmable Switching Frequency up to 600KHz
- COT Control Mode
- Forced PWM mode support Isolation Buck Topology
- Precision Enable Threshold for Programmable Input UVLO Threshold and Hysteresis
- Cycle-by-Cycle Current Limiting
- Over-Voltage Protection
- Over-Temperature Protection
- Available in an ESOP-8 Package

### DESCRIPTION

The SCT2A22 is a 1A synchronous buck converters with wide input voltage, ranging from 4.5V to 100V, which integrates an 530mΩ high-side MOSFET and a 220mΩ low-side MOSFET. The SCT2A22, adopting the constant-on time (COT) mode control, supports the Forced PWM mode to achieve smaller output ripple and support Isolation buck topology.

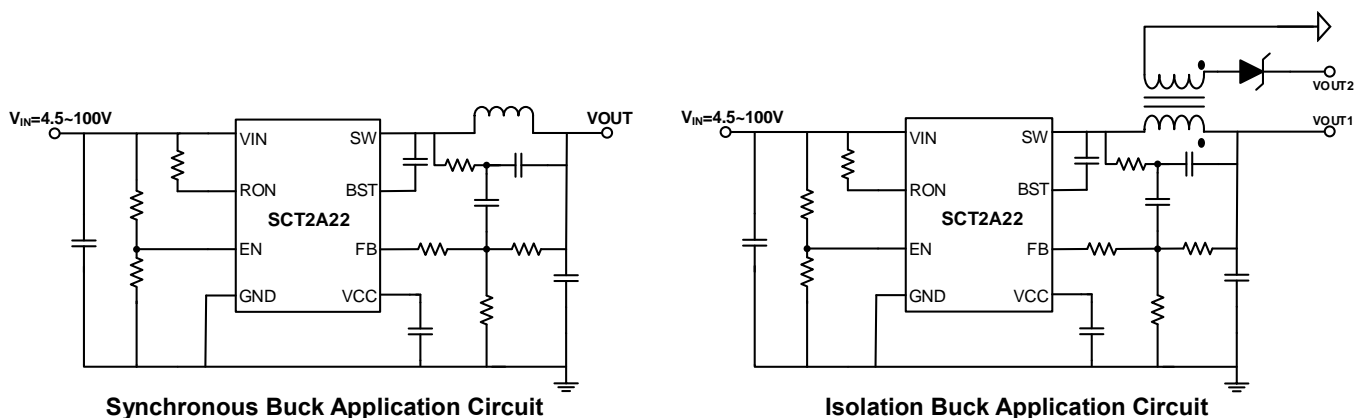
The SCT2A22 features programmable switching frequency from 100 kHz to 600KHz with an external resistor, which provides the flexibility to optimize either efficiency or external component size.

The SCT2A22 offers cycle-by-cycle current limit, thermal shutdown protection, output over-voltage protection and input voltage under-voltage protection. The device is available in an 8-pin thermally enhanced SOP-8 package.

### APPLICATIONS

- 48V Industry Power Bus System
- E-bike, Scooter
- BMS

### TYPICAL APPLICATION



## REVISION HISTORY

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

Revision 1.0: Released to production

Revision 1.1: Update Ripple injection, Add Type 1 and Type 2

Revision 1.2: Update Equations 10

## DEVICE ORDER INFORMATION

PART NUMBER	PACKAGE MARKING	PACKAGE DISCRIPTION
SCT2A22STER	2A22	8-Lead ESOP

1) For Tape & Reel, Add Suffix R (e.g. SCT2A22STER).

## ABSOLUTE MAXIMUM RATINGS

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

DESCRIPTION	MIN	MAX	UNIT
VIN, EN, RON	-0.3	105	V
BOOT	-0.3	110	V
SW	-1	105	V
VCC	-0.3	30	V
BOOT-SW	-0.3	6	V
FB	-0.3	6	V
Operating junction temperature $T_J^{(2)}$	-40	150	°C
Storage temperature TSTG	-65	150	°C

- (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
GND	1	Ground
VIN	2	Input supply voltage. Connect a local bypass capacitor from VIN pin to GND pin. Path from VIN pin to high frequency bypass capacitor and GND must be as short as possible.
EN	3	Enable pin to the regulator with internal pull-up current source. a) Float or connect to VIN to enable the converter. b) Pull below 1.22V to disable the converter. c) Resistor divider from VIN to GND connecting EN pin can adjust the input voltage lockout threshold.
RON	4	On-time programming pin. A resistor between this pin and VIN sets the switch ON time.
FB	5	Inverting input of the internal PWM comparator. The tap of external feedback resistor divider from the output to GND sets the output voltage. The device regulates FB voltage to the internal reference value of 1.2V typical.

## PIN CONFIGURATION

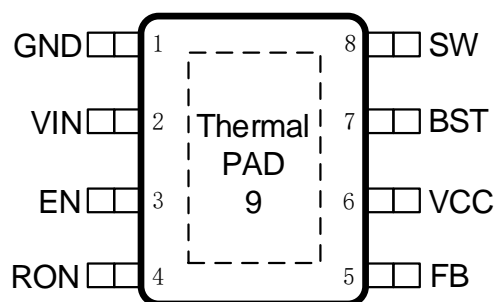


Figure 1. 8-Lead Plastic E-SOP8

VCC	6	Output from the Internal High Voltage Regulator. The internal VCC regulator provides bias supply for the gate drivers and other internal circuitry. A larger than 1.0 $\mu$ F decoupling capacitor is recommended.
BST	7	Power supply bias for high-side power MOSFET gate driver. Connect a 0.1 $\mu$ F capacitor from BOOT pin to SW pin. Bootstrap capacitor is charged when low-side power MOSFET is on or SW voltage is low.
SW	8	Regulator switching output. Connect SW to an external power inductor
Thermal Pad	9	Heat dissipation path of die. Electrically connection to GND pin. Must be connected to ground plane on PCB for proper operation and optimized thermal performance.

## RECOMMENDED OPERATING CONDITIONS

Over operating free-air temperature range unless otherwise noted

PARAMETER	DEFINITION	MIN	MAX	UNIT
V <sub>IN</sub>	Input voltage range	4.5	100	V
V <sub>CC</sub>	External V <sub>CC</sub> bias voltage	7.5	30	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>	-1	+1	kV
	Charged Device Model(CDM), per ANSI-JEDEC-JS-002-2014 specification, all pins <sup>(2)</sup>	-1	+1	kV

(1) JEDEC document JEP155 states that 500V HBM allows safe manufacturing with a standard ESD control process.

(2) JEDEC document JEP157 states that 250V CDM allows safe manufacturing with a standard ESD control process.

## THERMAL INFORMATION

PARAMETER	THERMAL METRIC	ESOP-8L	UNIT
R <sub>θJA</sub>	Junction to ambient thermal resistance <sup>(1)</sup>	41.1	°C/W
R <sub>θJC</sub>	Junction to case thermal resistance <sup>(1)</sup>	37.3	
R <sub>θJB</sub>	Junction to board thermal resistance	30.6	

- (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 the SCT2A22 is mounted, thermal pad size, and external environmental factors. The PCB board is a heat sink that is soldered to the leads and thermal pad of the SCT2A22. 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

$V_{IN}=48V$ ,  $T_J=-40^{\circ}C\sim 125^{\circ}C$ , typical value is tested under  $25^{\circ}C$ .

SYMBOL	PARAMETER	TEST CONDITION	MIN	TYP	MAX	UNIT
Power Supply						
V <sub>IN</sub>	Operating input voltage		4.5		100	V
V <sub>CC</sub>	V <sub>CC</sub> Regulator Output			7.3		V
V <sub>CC_UVLO</sub>	V <sub>CC</sub> UVLO Threshold	V <sub>IN</sub> rising		4.1	4.48	V
	Hysteresis			220		mV
I <sub>VCC_LIM</sub>	V <sub>CC</sub> internal LDO current limit	V <sub>CC</sub> short to ground		30		mA
I <sub>SHDN</sub>	Shutdown current from VIN pin	EN=0, no load		3	8	μA
I <sub>Q</sub>	Quiescent current from VIN pin	EN floating, no load, non-switching, BOOT-SW=5V		500	800	μA
Power MOSFETs						
R <sub>DS<sub>ON</sub>_H</sub>	High-side MOSFET on-resistance	V <sub>BOOT</sub> -V <sub>SW</sub> =5V		530	950	mΩ
R <sub>DS<sub>ON</sub>_L</sub>	Low-side MOSFET on-resistance			220	450	mΩ
Reference and Control Loop						
V <sub>REF</sub>	Reference voltage of FB	T <sub>J</sub> =25°C	1.188	1.2	1.212	V
		T <sub>J</sub> =-40°C~125°C	1.178	1.2	1.222	V
Enable and Soft-startup						
V <sub>EN_H</sub>	Enable high threshold			1.23		V
V <sub>EN_L</sub>	Enable low threshold			1.22		V
V <sub>EN_HYS</sub>	Enable hysteresis threshold			10		mV
I <sub>EN_L</sub>	Enable pin pull-up current	EN=1V		0.35		μA
I <sub>EN_H</sub>	Enable pin pull-up current	EN=1.5V		17		uA
T <sub>SS</sub>	Internal soft start current			4.3		ms
Switching Frequency Timing						
T <sub>ON</sub>	ON time	V <sub>IN</sub> =24V, R <sub>ON</sub> =100k		420		ns
T <sub>OFF_MIN</sub>	Minimum off-time	V <sub>IN</sub> =12V		200	260	ns
Current Limit and Over Current Protection						
I <sub>LIM_HS</sub>	HS MOSFET current limit	From source to drain	1.25	1.5	1.8	A
I <sub>LIM_LS</sub>	LS MOSFET current limit	From source to drain		1.1		A
I <sub>LIM_LSROC</sub>	LS reverse current limit	From drain to source for FCCM mode		3.5		A
Protection						
V <sub>OVP</sub>	Feedback overvoltage with respect to reference voltage	V <sub>FB</sub> /V <sub>REF</sub> rising		120		%
		V <sub>FB</sub> /V <sub>REF</sub> falling		115		%
V <sub>UVP</sub>	Feedback undervoltage with respect to reference voltage	V <sub>FB</sub> /V <sub>REF</sub> rising		80		%
		V <sub>FB</sub> /V <sub>REF</sub> falling		75		%
T <sub>SD</sub>	Thermal shutdown threshold*	T <sub>J</sub> rising		173		°C
		Hysteresis		25		°C

\*Derived from bench characterization

## TYPICAL CHARACTERISTICS

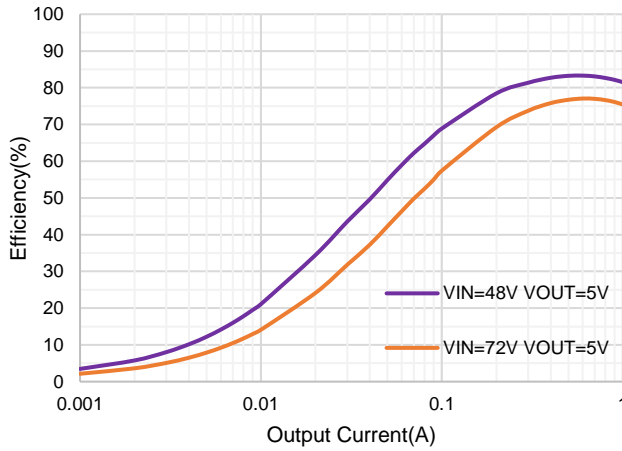


Figure 2. Efficiency, Fsw=300k, Vout=5V

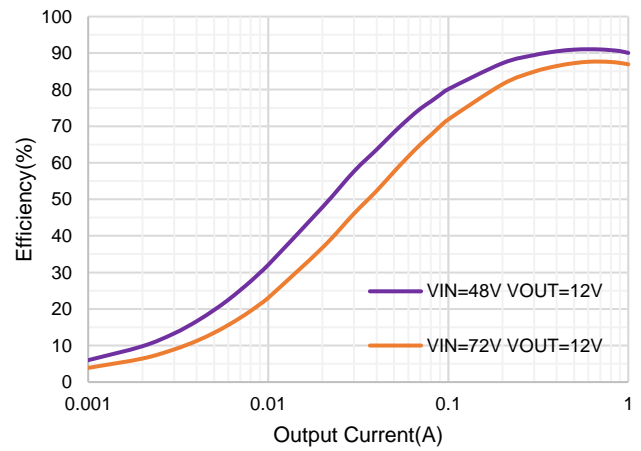


Figure 3. Efficiency, Fsw=300k, Vout=12V

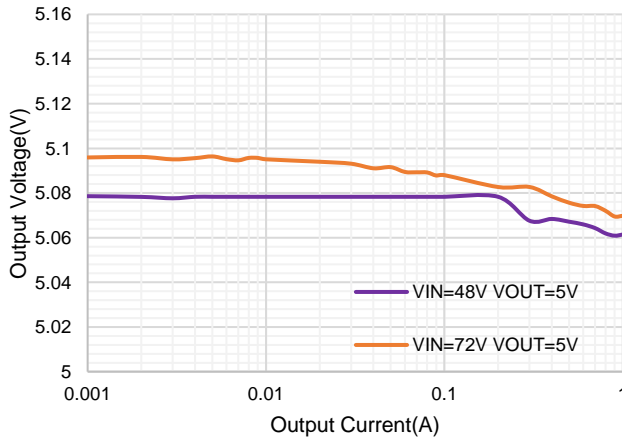


Figure 4. Load Regulation, Fsw=300k, Vout=5V

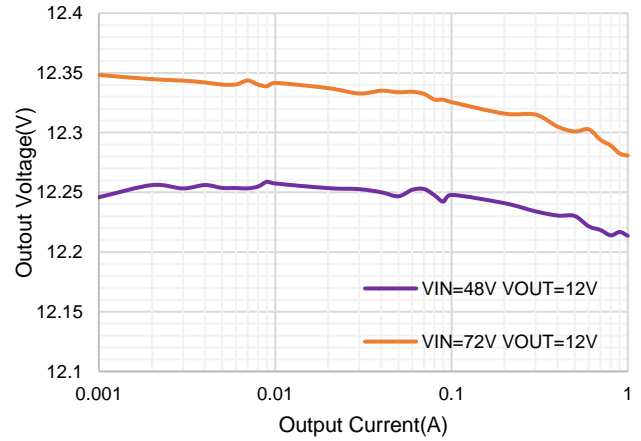


Figure 5. Load Regulation, Fsw=300k, Vout=12V

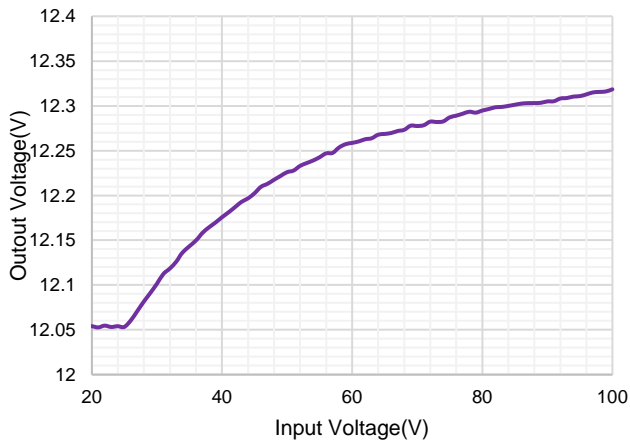


Figure 6. Line Regulation, Vout=12V, Iload=1A

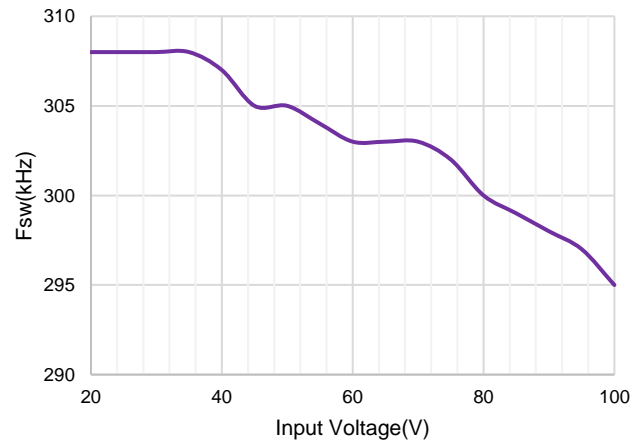


Figure 7. Fsw VS Vin, Vout=12V, Ron=400K

## FUNCTIONAL BLOCK DIAGRAM

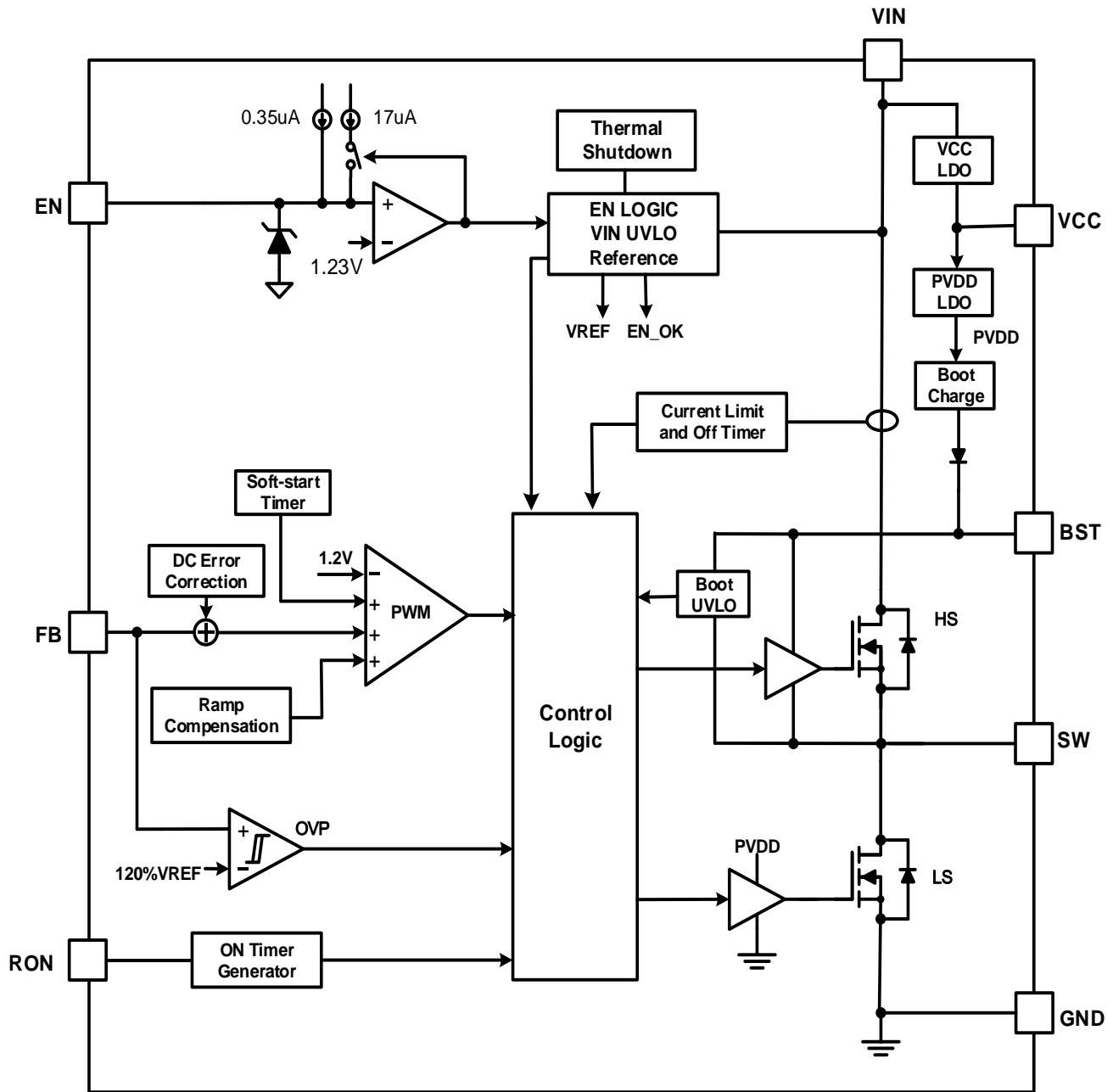


Figure 8. Functional Block Diagram

## OPERATION

### Overview

The SCT2A22 is a 4.5V-100V input, 1A output, synchronous buck converter with built-in 530mΩ high-side and 220mΩ low-side power MOSFETs. It implements constant on time control to regulate output voltage, providing excellent line and load transient response.

The SCT2A22 operates in Forced PWM mode to achieve low light load ripple and support isolation buck topology. Applying an external diode on VCC pin from converter output, the quiescent current can be decrease.

The SCT2A22 features an internal 4.3ms soft-start time to avoid large inrush current and output voltage overshoot during startup. The switching frequency is programmed by the resistor from V<sub>IN</sub> pin to R<sub>ON</sub> pin.

The SCT2A22 has a default input start-up voltage of 4.1V with 220mV hysteresis. The EN pin is a high-voltage pin with a precision threshold that can be used to adjust the input voltage lockout thresholds with two external resistors to meet accurate higher UVLO system requirements. Floating EN pin enables the device with the internal pull-up current to the pin. Connecting EN pin to VIN directly starts up the device automatically.

The SCT2A22 full protection features include the input under-voltage lockout, the output over-voltage protection, over current protection with cycle-by-cycle current limiting, output hard short protection and thermal shutdown protection.

### Constant On-Time Mode Control

The SCT2A22 employs constant on-time (COT) Mode control providing fast transient with pseudo fixed switching frequency. At the beginning of each switching cycle, since the feedback voltage (VFB) is lower than the internal reference voltage (VREF), the high-side MOSFET (Q1) is turned on during one on-time and the inductor current rises to charge up the output voltage. The on-time is determined by the input voltage and Ron resistor. After the on-time, the Q1 turns off and the low-side MOSFET (Q2) turns on after dead time duration. The inductor current drops and the output capacitors are discharged. When the output voltage decreases and the VFB decreased below the VREF, the Q1 turns on during one on-time after another dead time duration. This repeats on cycle-by-cycle based.

The on time of the SCT2A22 is determined by the R<sub>ON</sub> resistor and is inversely proportional to the input voltage. The inverse relationship with V<sub>IN</sub> results in a nearly constant frequency as V<sub>IN</sub> is varied. The On time can be calculated from Equation 1.

$$T_{ON} = \frac{1 \times 10^{-10} \times R_{ON}}{V_{IN}} \quad (1)$$

To set a specific continuous conduction mode switching frequency, the R<sub>ON</sub> resistor is determined by Equation 2:

$$R_{ON} = \frac{V_{OUT}}{1 \times 10^{-10} \times F_{SW}} \quad (2)$$

R<sub>ON</sub> must be selected for a minimum on-time (at maximum VIN) greater than 150 ns for proper operation.

### Current limit

The inductor current is monitored during high-side MOSFET turn on. The SCT2A22 implements over current protection with cycle-by-cycle limiting high-side MOSFET peak current during unexpected overload or output hard short condition.

SCT2A22 also provide a HS current limit off timer for making the IC safer when trigger over current condition. Once trigger HS over current, the present on-time period is immediately terminated, and will force LS turn on a non-resettable off timer for avoiding the inductor current run away. The length of off time is controlled by FB voltage and VIN voltage and could be calculated by the following equation.

$$T_{off} = 1.5 * \left( \frac{V_{IN}}{20 * V_{FB} + 4.35} \right) \mu s \quad (3)$$

## Ripple Injection

SCT2A22 adopts Constant-On-Time (COT) control in which the on-time is terminated by an on-timer and the off-time is terminated by the feedback voltage (VFB) falling below the reference voltage (VREF). Therefore, for stable operation, the feedback voltage must decrease monotonically, in phase with the inductor current during the off time. Furthermore, this change in feedback voltage (VFB) during off-time must be larger than any noise component present at the feedback node. A type 3 ripple injection configuration is recommended for minimum output ripple.

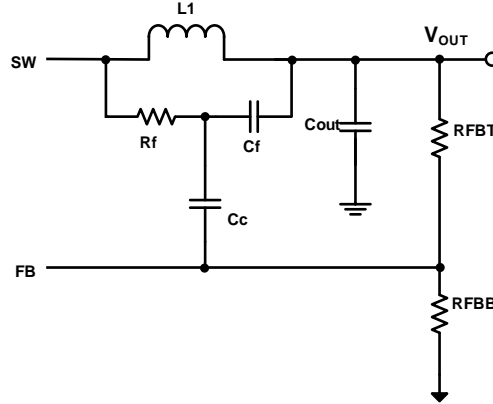


Figure 9. type 3 Ripple Injection Network

The ripple injection network applies an RC filter ( $R_f$  and  $C_f$ ) across SW and VOUT to generate a triangular ramp that is in phase with the inductor current. Then this triangular ramp is coupled into the feedback node via capacitor  $C_c$ . RC filter value is calculated as Equation 4 to provide the required ripple amplitude at the FB pin..

$$R_f C_f \leq \frac{(V_{IN} - V_{OUT}) \times t_{ON}}{V_{ripple}} \quad (4)$$

Where

- $F_{SW}$  is switching frequency
- $R_{FBT}$  Top feedback resistor;  $R_{FBB}$  Bottom feedback resistor
- $V_{ripple}$  is ripple voltage injected to FB pin, 25mV is recommended

$C_c$  value should be chosen to avoid excessive coupling capacitor discharge by the feedback resistors during sleep intervals when operating at light loads. Use Equation 6 to calculate  $C_c$  value.

$$C_c \geq \frac{t_{settle}}{3 \times R_{FBT}} \quad (5)$$

Where

- $t_{settle}$  desired load transient response settle time
- $R_{FBT}$  Top feedback resistor

Except for Type 3 ripple injection, the Type 1 and Type 2 ripple injection circuit is shown in Figure 9 and Figure 10. The Type 1 and Type 2 ripple injection circuit usually uses a large ESR electrolytic capacitor to generate output ripple in phase with the current ripple to ensure stable operation of the conversion circuit.

There are limitations in equations 6 and 7 for the electrolytic capacitor Resr of type 1 ripple injection circuit.



$$R_{esr} \geq \frac{V_{ripple} \times V_{out}}{V_{REF} \times I_{LPP}} \quad (6)$$

Where

- $V_{REF}$  is the feedback reference voltage of 1.2V
- $I_{LPP}$  is the inductor peak-to-peak current
- $V_{rippleis}$  is ripple voltage injected to FB pin, 25mV is recommended

$$R_{esr} \geq \frac{V_{out}}{2\pi \times V_{in} \times F_{SW} \times C_{out}} \quad (7)$$

Where

- $F_{SW}$  is switching frequency
- $C_{out}$  is Output capacitance value

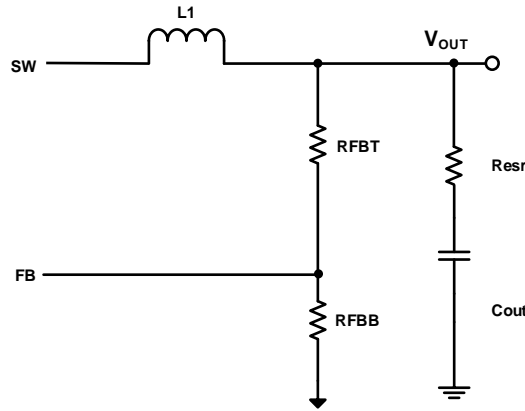


Figure 10. type 1 Ripple Injection Network

The use of Cff capacitors for Type 2 compensation can effectively reduce the requirement for electrolytic capacitor Resr, while Type 2 compensation Resr and Cff capacitors are limited by equations 8, 9 and 10.

$$R_{esr} \geq \frac{V_{ripple}}{I_{LPP}} \quad (8)$$

Where

- $I_{LPP}$  is the inductor peak-to-peak current
- $V_{rippleis}$  is ripple voltage injected to FB pin, 25mV is recommended

$$R_{esr} \geq \frac{V_{out}}{2\pi \times V_{in} \times F_{SW} \times C_{out}} \quad (9)$$

Where

- $F_{SW}$  is switching frequency
- $C_{out}$  is Output capacitance value

$$C_{ff} \geq \frac{R_{FBT} + R_{FBB}}{2\pi \times F_{SW} \times (R_{FBT} \times R_{FBB})} \quad (10)$$

Where

- $F_{SW}$  is switching frequency

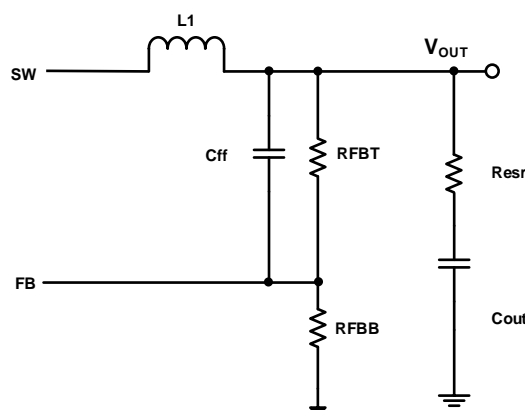


Figure 11. type 2 Ripple Injection Network

The use of Type 1 and Type 2 ripple injection circuits requires consideration of the Resr temperature characteristics of electrolytic capacitors to ensure stable operation over the entire temperature range.

## VCC Regulator

The SCT2A22 contains an internal high voltage linear regulator with a nominal output voltage of 7.5 V. This regulator supplies power to internal circuit blocks including the synchronous FET gate driver and the logic circuits. An external capacitor at the VCC pin stabilizes the regulator and supplies transient VCC current to the gate drivers. An internal diode connected from VCC to the BST pin replenishes the charge in the high-side gate drive bootstrap capacitor when the SW pin is low.

In high input voltage applications, the power dissipated in the regulator is significant and can limit the efficiency and maximum achievable output power. The SCT2A22 allows the internal VCC regulator power loss to be reduced by supplying the VCC voltage via a diode from an external voltage. The external VCC bias can be supplied from the SCT2A22 converter output rail if the regulation voltage. When the VCC pin of the SCT2A22 is raised above the regulation voltage (7.5 V typical), the internal regulator is disabled and the power dissipation in the IC is reduced.

## Enable and Under Voltage Lockout Threshold

The SCT2A22 is enabled when the VIN pin voltage rises about 4.1V and the EN pin voltage exceeds the enable threshold of 1.23V. The device is disabled when the VIN pin voltage falls below 3.88V or when the EN pin voltage is below 1.22V. An internal 0.35uA pull up current source to EN pin allows the device enable when EN pin floats.

EN pin is a high voltage pin that can be connected to VIN directly to start up the device.

For a higher system UVLO threshold, connect an external resistor divider (R3 and R4) shown in Figure 12 from VIN to EN. The UVLO rising and falling threshold can be calculated by Equation 11 and Equation 12 respectively.

$$VIN_{rise} = VEN * \frac{R3 + R4}{R4} \quad (11)$$

$$VIN_{hys} = I2 * R3 \quad (12)$$

Where

VIN\_rise: Vin rise threshold to enable the device

VIN\_hys: Vin hysteresis threshold

I<sub>1</sub>=0.35uA: neglect in calculation

I<sub>2</sub>=17uA

V<sub>EN</sub>=1.23V, assume VEN\_r = VEN\_f =1.23V

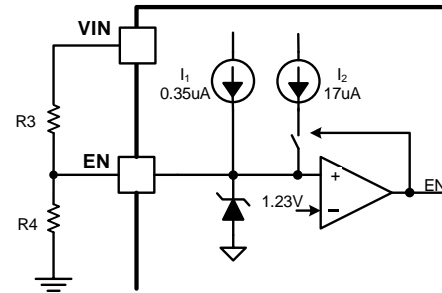


Figure 12. System UVLO by enable divide

## Output Voltage

The SCT2A22 regulates the internal reference voltage at 1.2V with  $\pm 1\%$  tolerance at room temperature. The output voltage is set by a resistor divider from the output node to the FB pin. It is recommended to use 1% tolerance or better resistors. Use Equation 13 to calculate resistance of resistor dividers. To improve efficiency at light loads, larger value resistors are recommended. However, if the values are too high, the regulator will be more susceptible to noise affecting output voltage accuracy.

$$R_{FB\_TOP} = \left( \frac{V_{OUT}}{V_{REF}} - 1 \right) * R_{FB\_BOT} \quad (13)$$

where

- R<sub>FB\_TOP</sub> is the resistor connecting the output to the FB pin.
- R<sub>FB\_BOT</sub> is the resistor connecting the FB pin to the ground.

## Internal Soft-Start

The SCT2A22 integrates an internal soft-start circuit that ramps the reference voltage from zero volts to 1.2V reference voltage in 4.3ms. If the EN pin is pulled below 1.22V, switching stops and the internal soft-start resets. The soft-start also resets during shutdown due to thermal overloading.

## Bootstrap Voltage Regulator

An external bootstrap capacitor between BOOT pin and SW pin powers the floating gate driver to high-side power MOSFET. 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.

## Over voltage Protection

The SCT2A22 implements the Over-Voltage Protection OVP circuitry to minimize output voltage overshoot during load transient, recovering from output fault condition or light load transient. The overvoltage comparator in OVP

# SCT2A22

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circuit compares the FB pin voltage to the internal reference voltage. When FB voltage exceeds 120% of internal 1.2V reference voltage, the high-side MOSFET turns off to avoid output voltage continue to increase. When the FB pin voltage falls below 115% of the 1.2V reference voltage, the high-side MOSFET can turn on again.

## Thermal Shutdown

The SCT2A22 protects the device from the damage during excessive heat and power dissipation conditions. Once the junction temperature exceeds 173C, the internal thermal sensor stops power MOSFETs switching. When the junction temperature falls below 148C, the device restarts with internal soft start phase.

## APPLICATION INFORMATION

## Typical Synchronous Buck Application

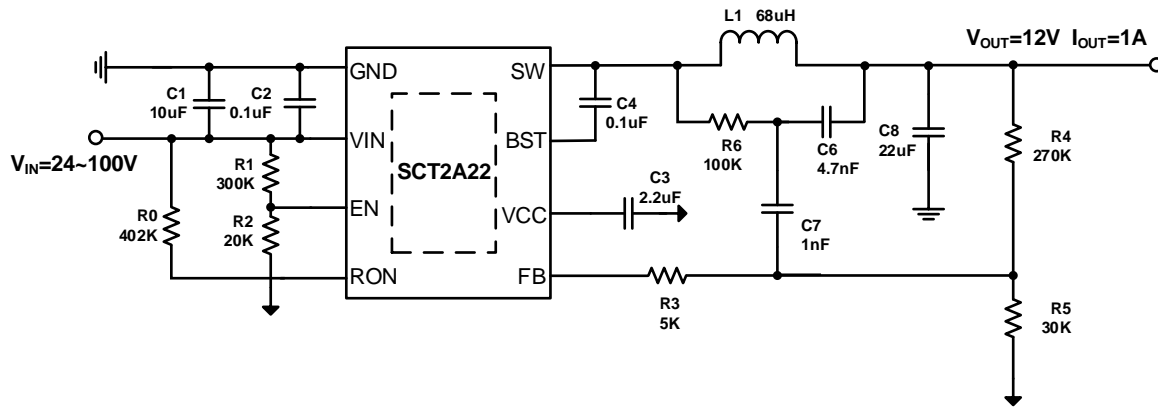


Figure 13. SCT2A22 Design Example, 12V Output with Programmable UVLO

## Design Parameters

Design Parameters	Example Value
Input Voltage	48V Normal, 24V to 100V
Output Voltage	12V
Maximum Output Current	1A
Switching Frequency	300 KHz
Output voltage ripple (peak to peak)	30mV
Transient Response 0.1A to 0.9A load step	$\Delta V_{out} = 120mV$

## Output Voltage

The output voltage is set by an external resistor divider R4 and R5 in typical application schematic. Recommended R5 resistance is 30KΩ. Use equation 14 to calculate R4.

$$R_4 = \left( \frac{V_{OUT}}{V_{REF}} - 1 \right) * R_5 \quad (14)$$

where:

- $V_{REF}$  is the feedback reference voltage of 1.2V

**Table 1. R<sub>1</sub>, R<sub>2</sub> Value for Common Output Voltage (Room Temperature)**

V <sub>OUT</sub>	R <sub>4</sub>	R <sub>5</sub>
5 V	95 KΩ	30 KΩ
12V	271 KΩ	30 KΩ
24V	576 KΩ	30 KΩ

## Under Voltage Lock-Out

An external voltage divider network of R<sub>3</sub> from the input to EN pin and R<sub>4</sub> from EN pin to the ground can set the input voltage's Under Voltage Lock-Out (UVLO) threshold. The UVLO has two thresholds, one for power up when the input voltage is rising and the other for power down or brown outs when the input voltage is falling. For the example design, the supply should turn on and start switching once the input voltage increases above 19.84V (start or enable). After the regulator starts switching, it should continue to do so until the input voltage falls below 14.74V (stop or disable). Use Equation 15 and Equation 16 to calculate the values 300 kΩ and 20 kΩ of R<sub>1</sub> and R<sub>2</sub> resistors.

$$VIN_{rise} = V_{EN\_H} * \frac{R_1 + R_2}{R_2} \quad (15)$$

$$VIN_{hys} = I_2 * R_1 \quad (16)$$

Where

VIN<sub>rise</sub>: Vin rise threshold to enable the device

VIN<sub>hys</sub>: Vin hysteresis threshold

I<sub>2</sub>=17uA

V<sub>EN\_H</sub>=1.24V

## Inductor Selection

There are several factors should be considered in selecting inductor such as inductance, saturation current, the RMS current and DC resistance(DCR). Larger inductance results in less inductor current ripple and therefore leads to lower output voltage ripple. However, the larger value inductor always corresponds to a bigger physical size, higher series resistance, and lower saturation current. A good rule for determining the inductance to use is to allow the inductor peak-to-peak ripple current to be approximately 20%~40% of the maximum output current.

The peak-to-peak ripple current in the inductor I<sub>LPP</sub> can be calculated as in Equation 17.

$$I_{LPP} = \frac{V_{OUT} * (V_{IN} - V_{OUT})}{V_{IN} * L * f_{SW}} \quad (17)$$

Where

- I<sub>LPP</sub> is the inductor peak-to-peak current
- L is the inductance of inductor
- f<sub>SW</sub> is the switching frequency
- V<sub>OUT</sub> is the output voltage
- V<sub>IN</sub> is the input voltage

Since the inductor-current ripple increases with the input voltage, so the maximum input voltage in application is always used to calculate the minimum inductance required. Use Equation 18 to calculate the inductance value.

$$L_{MIN} = \frac{V_{OUT}}{f_{SW} * LIR * I_{OUT(max)}} * (1 - \frac{V_{OUT}}{V_{IN(max)}}) \quad (18)$$

Where

- $L_{MIN}$  is the minimum inductance required
- $f_{SW}$  is the switching frequency
- $V_{OUT}$  is the output voltage
- $V_{IN(max)}$  is the maximum input voltage
- $I_{OUT(max)}$  is the maximum DC load current
- $LIR$  is coefficient of  $I_{LPP}$  to  $I_{OUT}$

The total current flowing through the inductor is the inductor ripple current plus the output current. When selecting an inductor, choose its rated current especially the saturation current larger than its peak operation current and RMS current also not be exceeded. Therefore, the peak switching current of inductor,  $I_{LPEAK}$  and  $I_{LRMS}$  can be calculated as in equation 19 and equation 20.

$$I_{LPEAK} = I_{OUT} + \frac{I_{LPP}}{2} \quad (19)$$

$$I_{LRMS} = \sqrt{(I_{OUT})^2 + \frac{1}{12} * (I_{LPP})^2} \quad (20)$$

Where

- $I_{LPEAK}$  is the inductor peak current
- $I_{OUT}$  is the DC load current
- $I_{LPP}$  is the inductor peak-to-peak current
- $I_{LRMS}$  is the inductor RMS current

In overloading or load transient conditions, the inductor peak current can increase up to the switch current limit of the device which is typically 1.5A. The most conservative approach is to choose an inductor with a saturation current rating greater than 1.5A. Because of the maximum  $I_{LPEAK}$  limited by device, the maximum output current that the SCT2A22 can deliver also depends on the inductor current ripple. Thus, the maximum desired output current also affects the selection of inductance. The smaller inductor results in larger inductor current ripple leading to a lower maximum output current.

## Input Capacitor Selection

The input current to the step-down DCDC converter is discontinuous, therefore it requires a capacitor to supply the AC current to the step-down DCDC converter while maintaining the DC input voltage. Use capacitors with low ESR for better performance. Ceramic capacitors with X5R or X7R dielectrics are usually suggested because of their low ESR and small temperature coefficients, and it is strongly recommended to use another lower value capacitor (e.g. 0.1uF) with small package size (0603) to filter high frequency switching noise. Place the small size capacitor as close to VIN and GND pins as possible.

The voltage rating of the input capacitor must be greater than the maximum input voltage. And the capacitor must also have a ripple current rating greater than the maximum input current ripple. The RMS current in the input capacitor can be calculated using Equation 21.

$$I_{CINRMS} = I_{OUT} * \sqrt{\frac{V_{OUT}}{V_{IN}} * (1 - \frac{V_{OUT}}{V_{IN}})} \quad (21)$$

The worst case condition occurs at  $V_{IN}=2*V_{OUT}$ , where:

$$I_{CINRMS} = 0.5 * I_{OUT} \quad (22)$$

For simplification, choose an input capacitor with an RMS current rating greater than half of the maximum load current.

When selecting ceramic capacitors, it needs to consider the effective value of a capacitor decreasing as the DC bias voltage across a capacitor increasing.

The input capacitance value determines the input ripple voltage of the regulator. The input voltage ripple can be calculated using Equation 23 and the maximum input voltage ripple occurs at 50% duty cycle.

$$\Delta V_{IN} = \frac{I_{OUT}}{f_{SW} * C_{IN}} * \frac{V_{OUT}}{V_{IN}} * (1 - \frac{V_{OUT}}{V_{IN}}) \quad (23)$$

For this example, one 10μF, X7R ceramic capacitors rated for 100 V in parallel are used. And a 0.1 μF for high-frequency filtering capacitor is placed as close as possible to the device pins.

## Bootstrap Capacitor Selection

A 0.1μF ceramic capacitor must be connected between BOOT pin and SW pin for proper operation. A ceramic capacitor with X7R or better grade dielectric is recommended. The capacitor should have a 10V or higher voltage rating.

## Output Capacitor Selection

The selection of output capacitor will affect output voltage ripple in steady state and load transient performance.

The output ripple is essentially composed of two parts. One is caused by the inductor current ripple going through the Equivalent Series Resistance ESR of the output capacitors and the other is caused by the inductor current ripple charging and discharging the output capacitors. To achieve small output voltage ripple, choose a low-ESR output capacitor like ceramic capacitor. For ceramic capacitors, the capacitance dominates the output ripple. For simplification, the output voltage ripple can be estimated by Equation 24 desired.

$$\Delta V_{OUT} = \frac{V_{OUT} * (V_{IN} - V_{OUT})}{8 * f_{SW}^2 * L * C_{OUT} * V_{IN}} \quad (24)$$

Where

- $\Delta V_{OUT}$  is the output voltage ripple
- $f_{SW}$  is the switching frequency
- $L$  is the inductance of inductor
- $C_{OUT}$  is the output capacitance
- $V_{OUT}$  is the output voltage
- $V_{IN}$  is the input voltage

Due to capacitor's degrading under DC bias, the bias voltage 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. Typically, two 22μF ceramic output capacitors work for most applications.

Table 2 and Table 3 lists typical values of external components for some standard output voltages.

**Table 2: Component List with Typical Output Voltage BOM list(Fsw=300k)**

Vout	L1	COUT	R0	R4	R5	R6	C6	C7
5V	33uH	22uF	165K	95K	30K	100K	3.3nF	1nF
12V	68uH	22uF	402K	271K	30K	100K	4.7nF	1nF
24V	100uH	22uF	806K	576k	30K	100k	6.8nF	1nF



**Table 3: Component List with Typical Output Voltage BOM list(Fsw=600k)**

Vout	L1	COU	R0	R4	R5	R6	C6	C7
5V	15uH	22uF	82.5K	95K	30K	80.6K	1.5nF	1nF
12V	33uH	22uF	200K	271K	30K	100K	2.2nF	1nF
24V	56uH	22uF	402K	576k	30K	100k	3.3nF	1nF

## Application Waveforms

Vin=48V, Vout=12V, unless otherwise noted

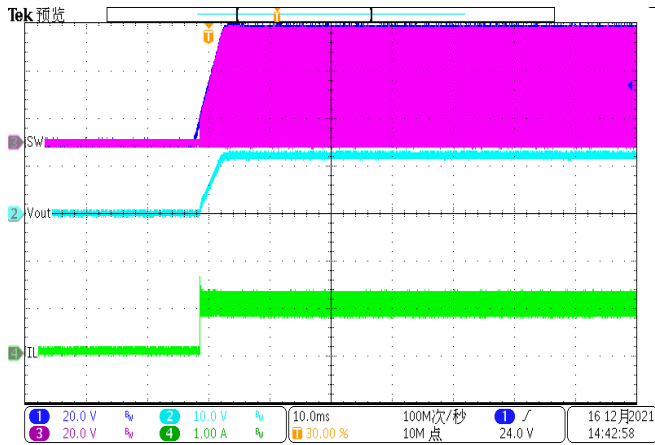


Figure 14. Power up (Iload=1A)

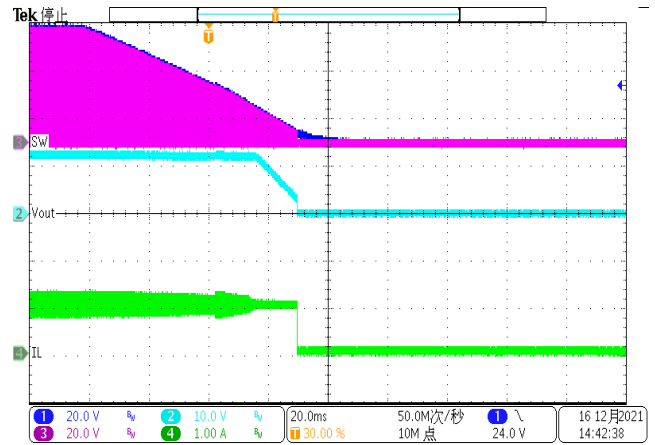


Figure 15. Power down (Iload=1A)

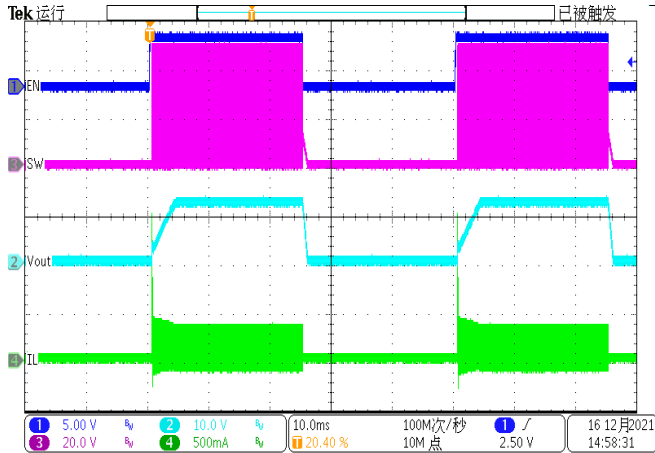


Figure 16. Enable toggle (Iload=0.1A)

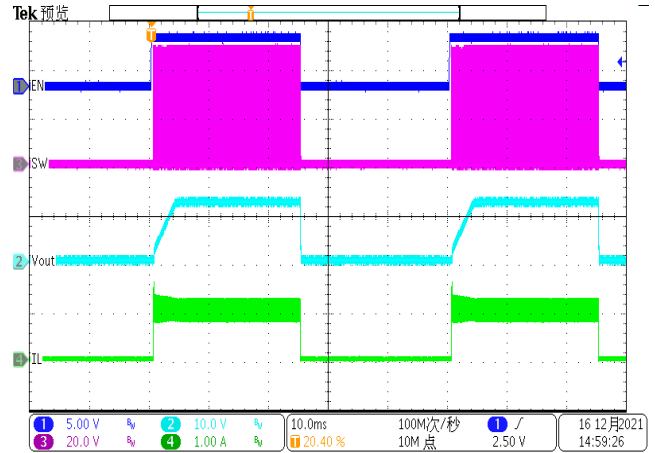


Figure 17. Enable toggle (Iload=1A)

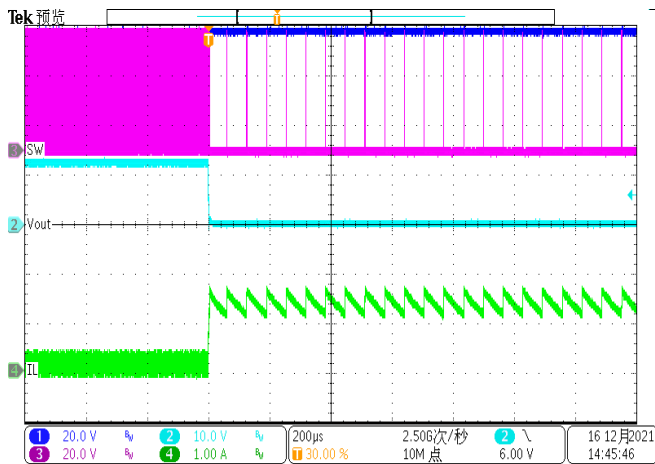


Figure 18. Output Hard Short

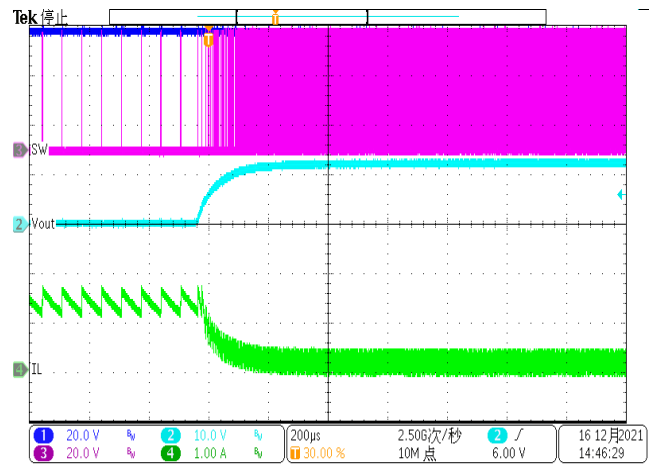


Figure 19. Output Hard Short Release

## Application Waveforms (Continued)

$V_{in}=48V$ ,  $V_{out}=12V$ , unless otherwise noted

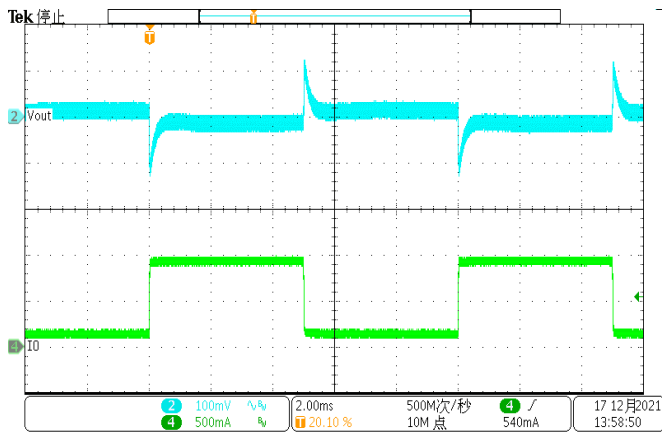


Figure 20. L load Transient (0.1A to 0.9A, 1.6A/us)

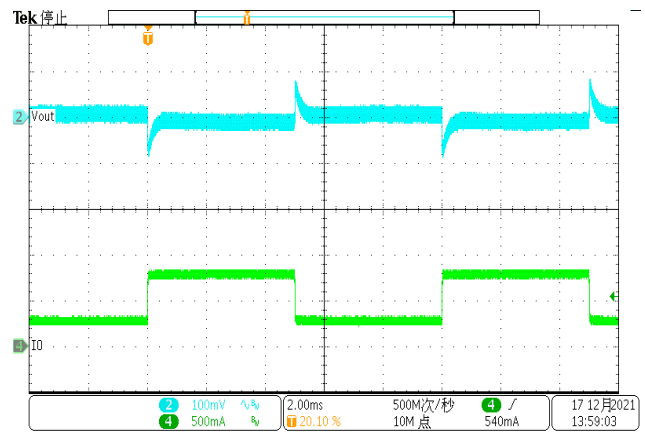


Figure 21. Load Transient (0.25A to 0.75A, 1.6A/us)

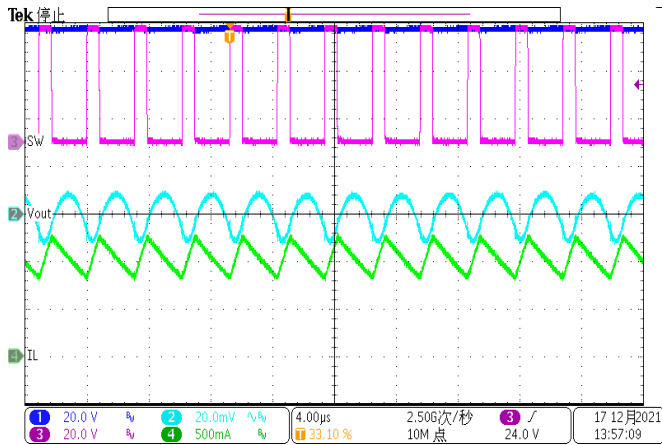


Figure 22. Output Ripple (Iload=1A)

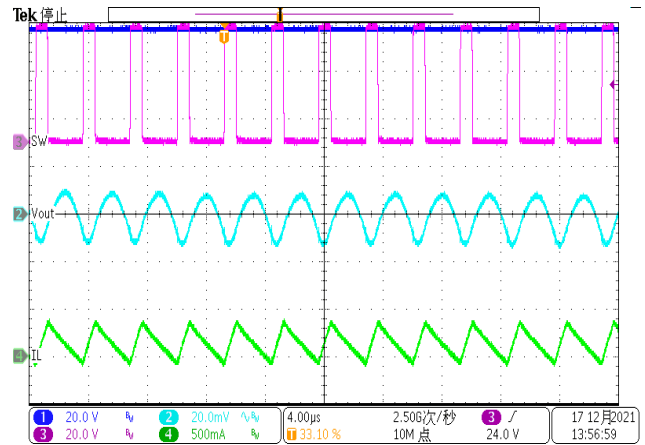


Figure 23. Output Ripple (Iload=0.1A)

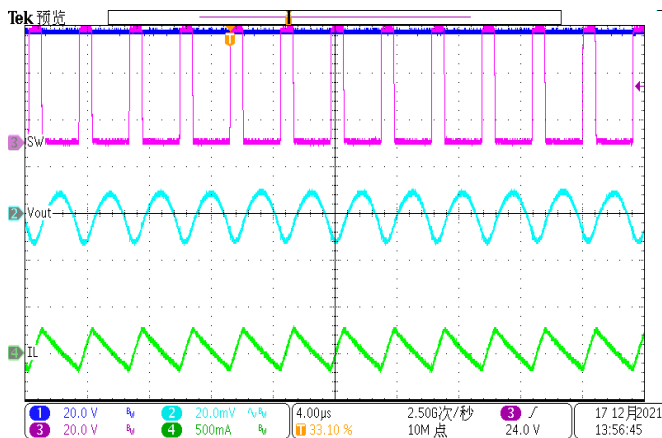


Figure 24. Output Ripple (Iload=0A)

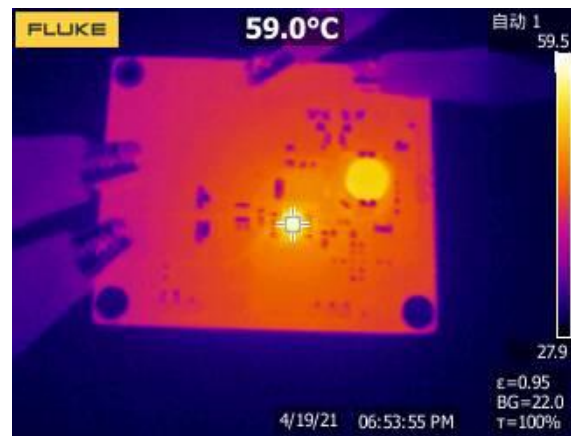


Figure 25. Thermal, 48VIN, 12Vout, 1A



**Design of Isolation Buck****Selection of VOUT and Turns Ratio**

The primary output voltage in an Isolation Buck converter should be no more than one half of the minimum input voltage. For example, at the minimum  $V_{IN}$  of 36 V, the primary output voltage ( $V_{OUT1}$ ) should be no higher than 18V. The isolated output voltage  $V_{OUT2}$  is set by selecting a transformer with a turns ratio ( $N_1:N_2 = N_{PRI}: N_{SEC}$ ). Using this turns ratio, the required primary output voltage  $V_{OUT1}$  is calculated by the following equation:

$$V_{out1} = \frac{V_{out2} + V_{d1}}{N_2/N_1} \quad (25)$$

The 0.7 V ( $V_{d1}$ ) represents the forward voltage drop of the secondary rectifier diode. By setting the primary output voltage  $V_{OUT1}$  by selecting the correct feedback resistors, the secondary voltage is regulated at  $V_{OUT2}$  nominally. Adjustment of the primary side  $V_{OUT1}$  may be required to compensate for voltage errors due to the leakage inductance of the transformer, the resistance of the transformer windings, the diode drop in the power path on the secondary side.

**Secondary Rectifier Diode**

The secondary side rectifier diode must block the maximum input voltage reflected at secondary side switch node. The minimum diode reverse voltage  $V_{RD1}$  rating is given below

$$V_{RD1} = (V_{IN(max)} - V_{out1}) * \frac{N_2}{N_1} + V_{out2} \quad (26)$$

A diode with higher reverse voltage rating must be selected in this application. If the input voltage ( $V_{IN}$ ) has transients above the normal operating maximum input voltage, then the worst-case transient input voltage must be used in calculation while selecting the secondary side rectifier diode.

## Isolation Buck Application Waveforms

$V_{in}=48V$ ,  $V_{out}=12V$ ,  $V_{iso}=5V$ , unless otherwise noted

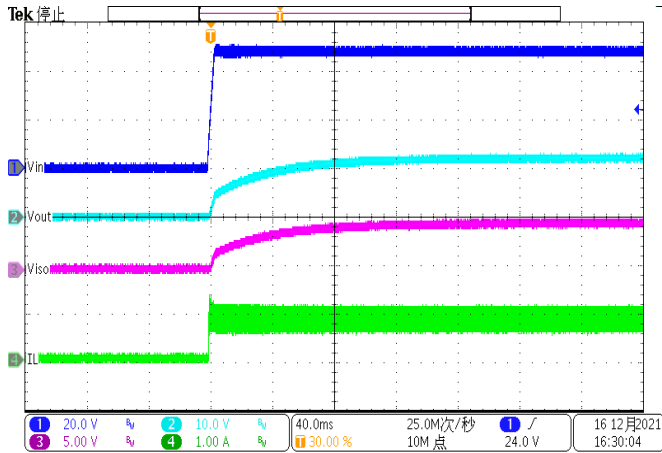


Figure 27. Power up( $I_o=0.8A$ ,  $I_{iso}=0.1A$ )

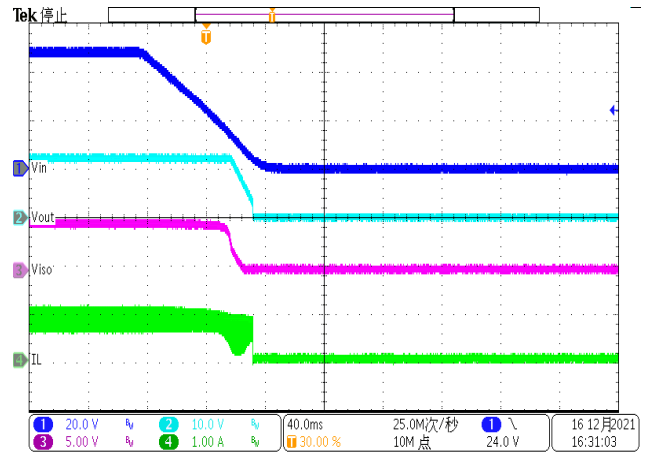


Figure 28. Power down( $I_o=0.8A$ ,  $I_{iso}=0.1A$ )

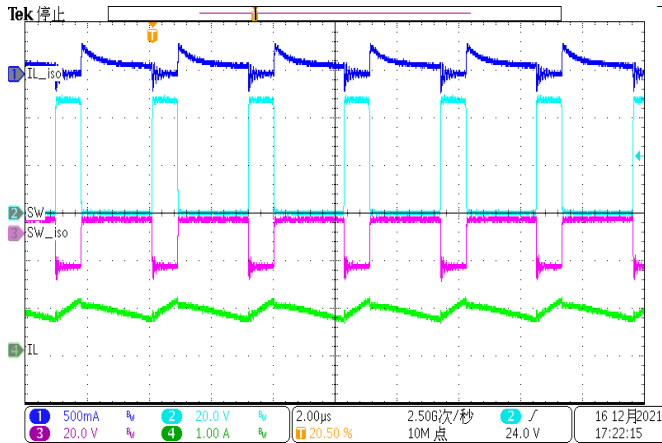


Figure 29. Steady State( $I_o=0.8A$ ,  $I_{iso}=0.1A$ )

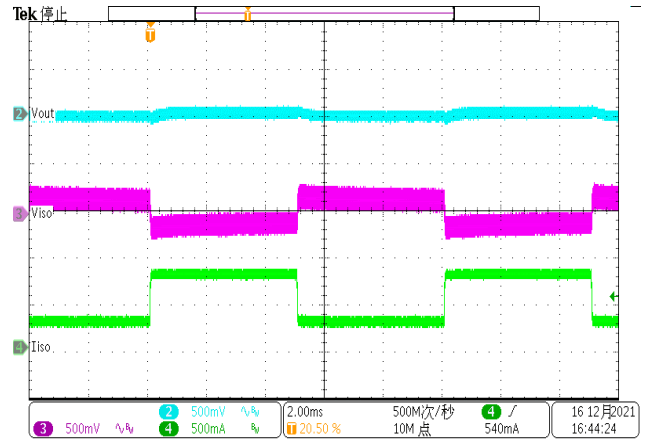


Figure 30. Load Transient 0.25A to 0.75A (isoload)

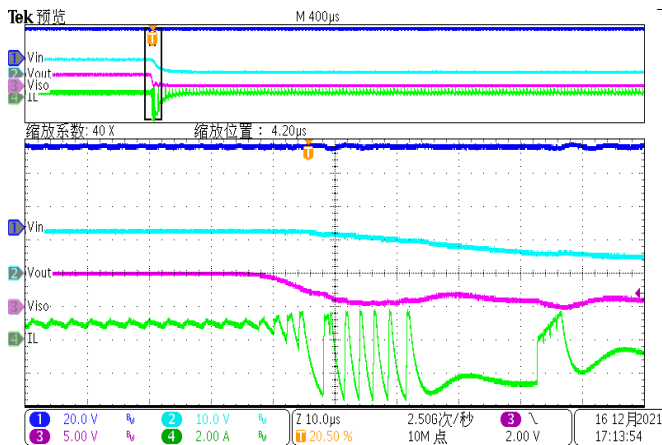


Figure 31. Secondary-Side Short( $I_o=1A$ )

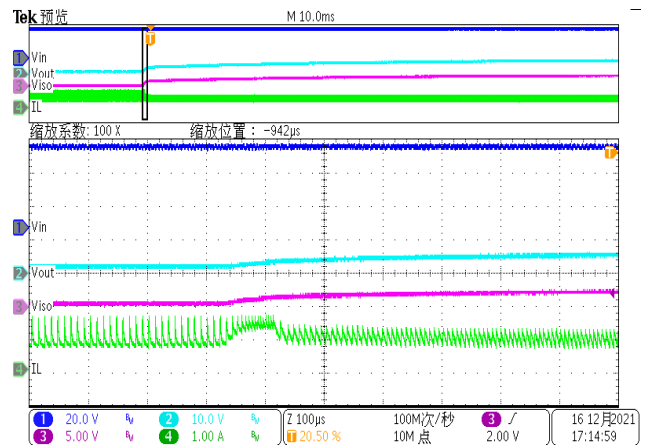
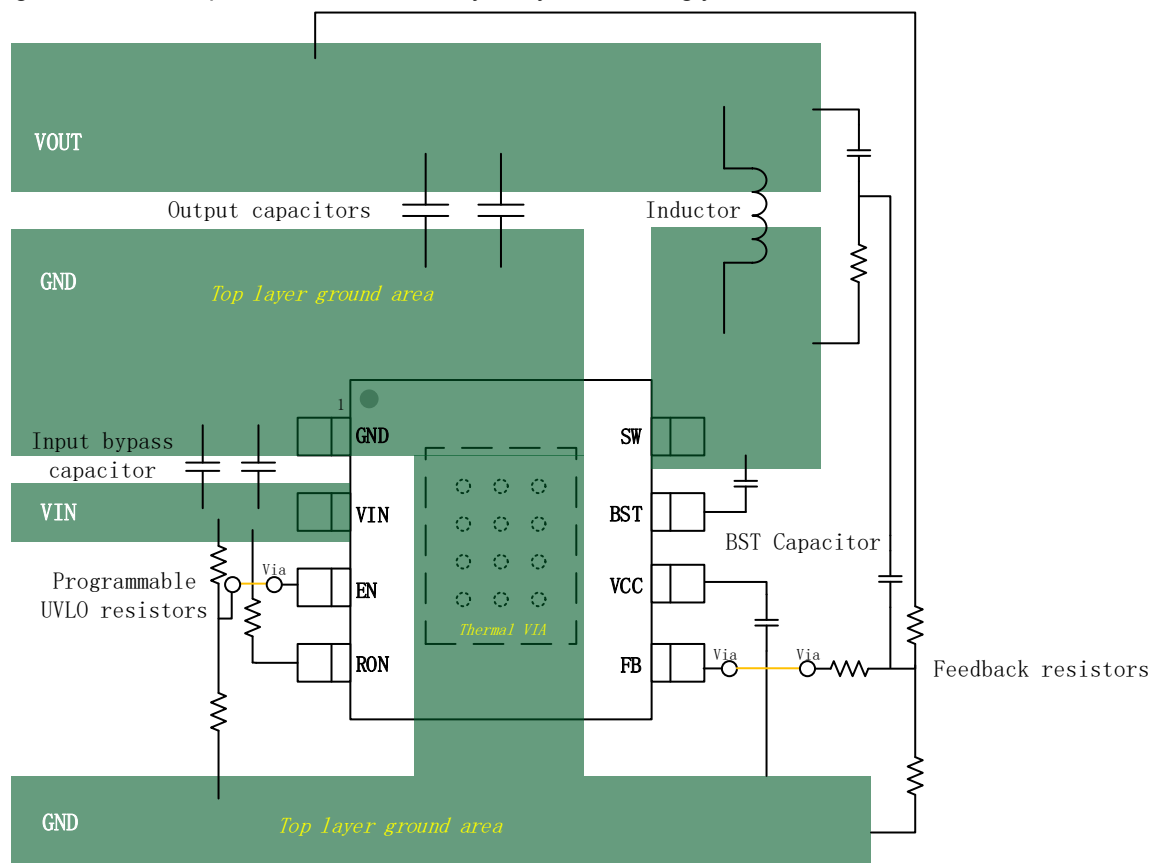


Figure 32. Secondary-Side Short Release ( $I_o=1A$ )

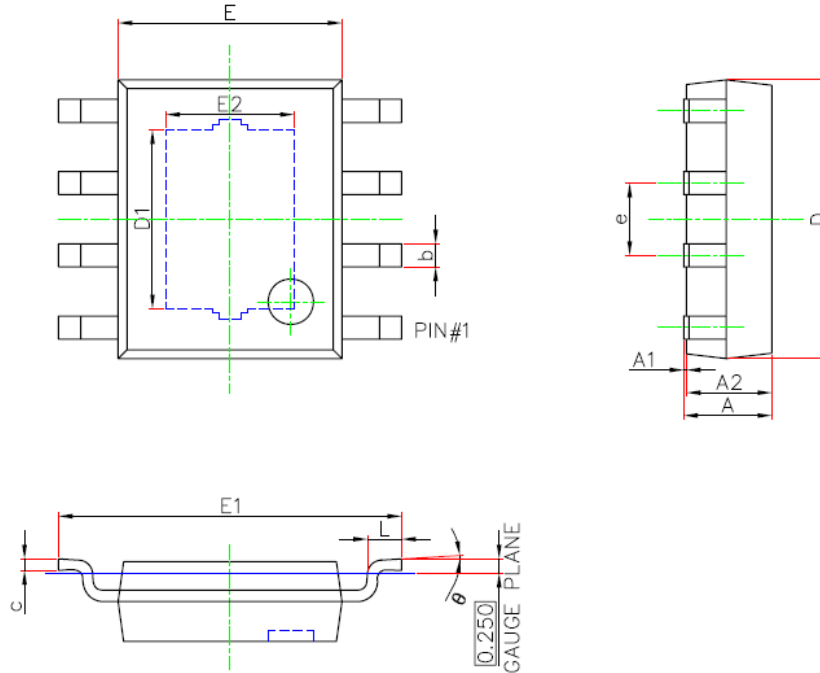
## Layout Guideline

Proper PCB layout is a critical for SCT2A22's stable and efficient operation. The traces conducting fast switching currents or voltages are easy to interact with stray inductance and parasitic capacitance to generate noise and degrade performance. For better results, follow these guidelines as below:

1. Power grounding scheme is very critical because of carrying power, thermal, and glitch/bouncing noise associated with clock frequency. The thumb of rule is to make ground trace lowest impedance and power are distributed evenly on PCB. Sufficiently placing ground area will optimize thermal and not causing over heat area.
2. Place a low ESR ceramic capacitor as close to VIN pin and the ground as possible to reduce parasitic effect.
3. For operation at full rated load, the top side ground area must provide adequate heat dissipating area. Make sure top switching loop with power have lower impedance of grounding.
4. The bottom layer is a large ground plane connected to the ground plane on top layer by vias. The power pad should be connected to bottom PCB ground planes using multiple vias directly under the IC. The center thermal pad should always be soldered to the board for mechanical strength and reliability, using multiple thermal vias underneath the thermal pad. Improper soldering thermal pad to ground plate on PCB will cause SW higher ringing and overshoot besides downgrading thermal performance. It is recommended 8mil diameter drill holes of thermal vias, but a smaller via offers less risk of solder volume loss. On applications where solder volume loss thru the vias is of concern, plugging or tenting can be used to achieve a repeatable process.
5. Output inductor should be placed close to the SW pin. The area of the PCB conductor minimized to prevent excessive capacitive coupling.
6. UVLO adjust, VCC capacitor and feedback components should connect to small signal ground which must return to the GND pin without any interleaving with power ground.
7. For achieving better thermal performance, a four-layer layout is strongly recommended.



## PACKAGE INFORMATION



ESOP8(95x130) Package Outline Dimensions

Symbol	Dimensions in Millimeters		Dimensions in Inches	
	Min.	Max.	Min.	Max.
A	1.300	1.700	0.051	0.067
A1	0.000	0.100	0.000	0.004
A2	1.350	1.550	0.053	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.007	0.010
D	4.700	5.100	0.185	0.201
D1	3.050	3.250	0.120	0.128
E	3.800	4.000	0.150	0.157
E1	5.800	6.200	0.228	0.244
E2	2.160	2.360	0.085	0.093
e	1.270(BSC)		0.050(BSC)	
L	0.400	1.270	0.016	0.050
θ	0°	8°	0°	8°

### 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.



## TAPE AND REEL INFORMATION

Orderable Device	Package Type	Pins	SPQ
SCT2A22STER	ESOP	8	4000

