



SC81532Q 36V/3A, Buck Converter with USB Charging Port Supporting DCP and Type-C DFP Mode, AEC-Q100 Qualified

1 Descriptions

SC81532Q is a USB Type-C and BC1.2 charging port controller that includes a synchronous step-down converter. It integrates a single USB current-limit switch and achieves 3A of output current across a wide input supply range, with excellent load and line regulation.

SC81532Q Integrates current-limited USB switch, which supports Apple 2.4A divider mode, DCP schemes for BC1.2, USB Type-C DFP mode and Type-A mode.

SC81532Q also integrated negative temperature coefficient (NTC) to monitor the external PCB or other components' temperatures.

Fault condition protections include hiccup current limiting, output over-voltage protection (OVP), DP/DM/CC1/CC2 short-to-battery protection, and thermal shutdown.

The SC81532Q is available in 22-pin 4mm X 4mm Wettable packages.

2 Applications

- Automotive USB Type-C Charging Ports
- Automotive USB Hubs
- Automotive USB Dedicated Charging Ports

3 Features

- AEC-Q100 qualified for automotive applications:
 - Temperature Grade 1: T_A range: -40°C to 125 °C
- Passes Apple MFI certification test
- USB-IF Type-C Certificated
- Integrates synchronous Buck converter:
 - Wide 3.9V to 36V continuous operating input range, 40V ABS voltage
 - Adjustable switching frequency from 200kHz to 2.2MHz
 - Spread Spectrum option
 - Synchronize to external clock
 - Integrates 52.5mΩ/30.5mΩ switching power FETs
 - Selectable Forced PWM Operation and Automatic PFM/FPWM operation
- Integrated multiple protocols:
 - Support DCP schemes: BC1.2 short mode, Apple 2.4A divider mode
 - Supports USB Type-C DFP mode
 - Integrates 23mΩ RDS(ON) USB Switch
 - NTC Over-Temperature detection
 - 145°C internal load shedding entry
- Line drop compensation
- Independent USB on/off control
- Hiccup current limit for Buck and USB switch
- USB_OUT, DP/DM, CC1/CC2 Pins Short to battery protection
- EN shutdown discharge function
- Fault indication for USB OCP, OVP(USB_IN), OTP, USB_OUT/DP/DM/CC1/CC2 short to battery,
- ±8kV IEC 61000-4-2 contact discharge ESD rating for CC1/CC2/DP/DM pins
- ±15kV IEC 61000-4-2 air discharge ESD rating for CC1/CC2/DP/DM pin

**4 Device Information**

ORDER NUMBER	VERSION	MODE	APPLE MODE	PACKAGE
SC81532QQFLR	DCP	Auto PFM	Apple 2.4A	4mm x 4mm x 0.9mm
SC81532AQQFLR	DCP	Forced PWM	Apple 2.4A	4mm x 4mm x 0.9mm

5 Revision History

Revision	Date	Page(s) changed	Changes Description
V1.0.5	2025/12	Page3 Page32	The recommended value for the CC capacitor has been changed from 220nF to 2.2nF
V1.0.4	2025/4	Page6	Revise certain descriptions
V1.0.3	2024/11	Page30	Revise certain descriptions
V1.0.2	2024/1	Page6	Add the application description



6 Typical Application Circuit

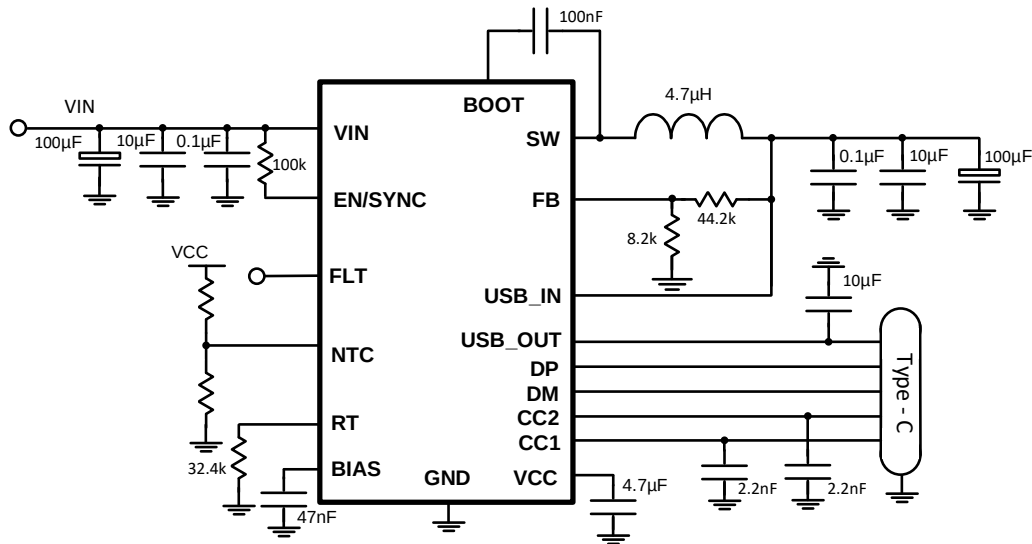
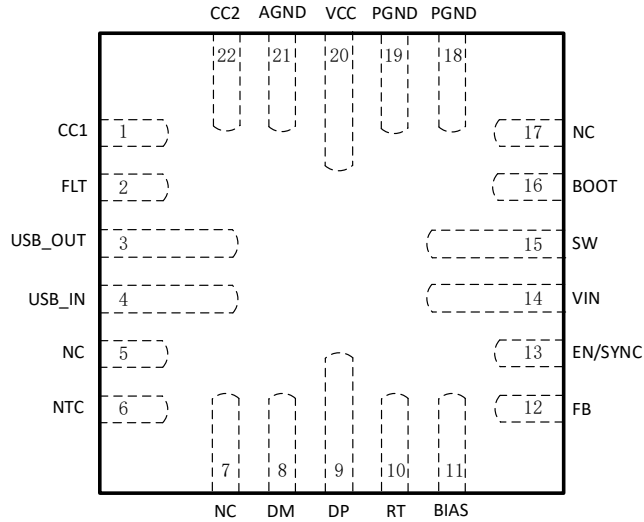


Figure 6-1. Typical Application Circuit



7 Terminal Configuration and Functions



Terminal		I/O	DESCRIPTION
NUMBER	NAME		
1	CC1	O	Type-C configure channel1. It also supports VCONN output.
2	FLT	O	This pin indicates USB OCP, USB_IN/V _{OUT} OVP, DP/DM/CC1/CC2 short to battery, and thermal shutdown. FLT is an open drain under normal conditions. FLT is pulled low during any of aforementioned fault conditions.
3	USB_OUT	O	USB bus voltage output.
4	USB_IN	I	USB bus voltage input.
5	NC	-	Not connected.
6	NTC	I	Thermistor input. Connect a thermistor from NTC to VCC, and a fixed resistor from NTC to GND. By default, NTC is pulled low by an internal 1MΩ resistor. Connect NTC to GND or float NTC to disable the thermal sense functions.
7	NC	-	This pin could be left floating or connected to FB pin.
8	DM	I	DM is the input/output used to handshake with portable devices.
9	DP	I	DP is the input/output used to handshake with portable devices.
10	RT	I	Connect this pin to ground through a resistor to set switching frequency between 200 kHz and 2200 kHz.
11	BIAS	O	Internal power supply pin.
12	FB	I	Connect to the tap of an external resistor divider from the output to GND to set the output voltage.
13	EN/SYNC	I	Apply an external CLK on this pin to sync the switching frequency to the external clock.
14	VIN	I	Input power supply for the IC.
15	SW	O	Switching node pin of the buck side. It is connected to the drain of the internal low-side power MOSFET and the source of external high-side power MOSFET.
16	BOOT	O	Connect a 100nF capacitor between BOOT and SW to provide bias voltage for MOSFET drive on Buck controller.
17	NC	-	Can be floating or connected to USB_IN pin.



18, 19	PGND	-	Power Ground.
20	VCC	O	Internal 5V LDO regulator output. Decouple with a 4.7μF capacitor.
21	AGND	-	Analog Ground.
22	CC2	O	Type-C configure channel2. It also supports VCONN output.



8 Specifications

8.1 Absolute Maximum Ratings

Over the recommended operating junction temperature range of -40°C ~ 150°C (unless otherwise noted). ⁽¹⁾

		MIN	MAX	UNIT
Voltage range at terminals ⁽²⁾	VIN, EN/SYNC, SW	-0.3	40	V
	BOOT	-0.3	45.5	V
	USB_IN, USB_OUT	-0.3	24	V
	CC1, CC2, DP, DM, BIAS	-0.3	18	V
	Others	-0.3	5.5	V
Power supply transient voltage ramp	VIN		2	V/μs
TJ	IC operating junction temperature range	-40	150	°C
Tstg	IC storage temperature range	-65	150	°C

- (1) Stresses beyond those listed under *absolute maximum ratings* may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *recommended operating conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
- (2) All voltage values are with respect to network ground terminal.

8.2 Thermal Information

THERMAL RESISTANCE ⁽¹⁾		QFN-22 (4x4)	UNIT
Θ _{JA}	Junction to ambient thermal resistance (SC81532QEVM) ⁽¹⁾	34	°C/W
Θ _{JA}	Junction to ambient thermal resistance (JESD 51-7) ⁽²⁾	45	°C/W
Θ _{JC (top)}	Junction to case (top) resistance ⁽²⁾	5	°C/W

- (1) Measured on SC81532QEVM. 4-layer, 2-oz Cu per top and bottom layer and 1-oz Cu per inner layer, evaluation board.
- (2) Measured on JE5D51-7, 4-layer PCB;

8.3 Handling Ratings

PARAMETER	DEFINITION	MIN	MAX	UNIT
ESD ⁽¹⁾	Human Body Model (HBM) ⁽²⁾	-2	2	kV
	Charged Device Model (CDM) ⁽³⁾	-750	750	V

- (1) Electrostatic discharge (ESD) to measure device sensitivity and immunity to damage caused by assembly line electrostatic discharges into the device.
- (2) Level listed above is the passing level per ANSI, ESDA, and JEDEC JS-001. JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
- (3) Level listed above is the passing level per EIA-JEDEC JESD22-C101. JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

**8.4 Recommended Operating Conditions**

		MIN	TYP	MAX	UNIT
V_{IN}	Input voltage range	3.4		36	V
V_{USB_IN}	Output voltage range	3.3		20	V
L	Inductance	2.2	4.7	22	μ H
F_{SW}	Buck switching frequency range	200		2200	kHz
T_J	Operating junction temperature	-40		150	$^{\circ}$ C
T_A	Operating ambient temperature range	-40		125	$^{\circ}$ C



8.5 Electrical Characteristic

$T_J = -40^{\circ}\text{C}$ to 150°C , $V_{IN} = 12\text{V}$ and $V_{EN} = 5\text{V}$. Typical value is tested at $T_J = +25^{\circ}\text{C}$, unless otherwise noted.

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
SUPPLY VOLTAGE						
V _{IN}	Input voltage range		3.4		36	V
V _{IN_UVLO}	V _{IN} rising threshold		3.7	3.9		V
	V _{IN} falling threshold		3.3	3.5		V
I _Q	Overall quiescent current	CC1 connected to ground with a 5.1kΩ resistor, V _{FB} pull high	820	950		μA
I _{SD}	Shutdown current into the V _{IN} pin	IC disabled, V _{EN} =0V		18		μA
V _{CC}	V _{CC} regulator voltage		4.8	5	5.2	V
V _{CC_LIM}	Internal LDO limit		70			mA
EN/SYNC						
V _{EN_H}	EN input level to start switching	Rising threshold	1.21	1.28	1.35	V
V _{EN_H}	EN input level to stop switching	Falling threshold	0.94	1	1.06	V
t _B	Blanking of EN after rising or falling edges		50			μs
t _{SYNC_EDGE}	Enable sync signal hold time after edge for edge recognition		120			ns
V _{EN_SYNC}	Edge height necessary to sync using EN/SYNC pin		4.5			V
POWER MOSFET						
R _{DS(ON)_HS}	High side switch on resistance		52	90		mΩ
R _{DS(ON)_LS}	Low side switch on resistance		31	55		mΩ
V _{BOOT_UVLO}	Voltage on BOOT pin compared to SW which will turn off high-side switch		2.4			V
OUTPUT DISCHARGE						
I _{DIS_OVP}	Output discharge current when V _{OUT} OVP happened		0.3	0.4	0.7	mA
REFERENCE VOLTAGE						
V _{FB2}	Feedback voltage	V _{OUT} =5.15V	794	806	818	mV
OSCILATOR						
f _{ADJ}	Minimum adjustable frequency by RT or SYNC	RT = 66.5 kΩ	0.18	0.2	0.22	MHz
	Adjustable frequency by RT or SYNC	RT = 32.4 kΩ	0.36	0.4	0.44	MHz
	Maximum adjustable frequency by RT or SYNC	RT = 5.2 kΩ	1.98	2.2	2.42	MHz
f _{Mod}	Spread Spectrum Modulation Frequency		1/256			F _{sw}
f _{ss}	Frequency spread spectrum span		6			%
TIMING						



t_{ON_MAX}	Maximum HS switch on time		8	us
t_{ON_MIN}	Minimum HS switch on time		150	ns
t_{OFF_MIN}	Minimum LS switch on time		150	ns
t_{SS}	Soft-start time	Output from 10% to 90%, $V_{OUT}=5.15V$	2.9	ms
HICCUP				
V_{HICCUP}	Hiccup Voltage Threshold		40	%
t_{HIC_ON}	On time of hiccup mode		38	ms
t_{HIC_OFF}	Off time of hiccup mode		460	ms
CURRENT LIMIT				
I_{PEAK}	High-side peak current limit		6.4 7.7 9	A
I_{VALLEY}	Low-side valley current limit		4.2 5.6 6.7	A
I_{LSNEG}	Low-side negative current limit		-3	A
OVP Protection				
V_{OVP1}	Output OVP		117 120 123	%
V_{OVP1_R}	Output OVP recovery		107 110 113	%
t_{FAULT_OVP}	OVP deglitch to assert fault pin		1	ms
$t_{FAULT_OVP_Recovery1}$	OVP deglitch to de-assert fault pin		1	ms
USB SWITCH				
V_{USB_UVR}	Under-voltage lockout rising threshold		4.3 4.5	V
V_{USB_UVHYS}	Under-voltage lockout threshold hysteresis		150	mV
$R_{DS(ON)_SW}$	Switch on resistance		23 46	mΩ
$R_{DIS_USB_IN}$	Input discharge resistance	$V_{OUT}=12V$	550	Ω
		$V_{OUT}=5.15V$	230	Ω
I_{LIMIT}	USB Switch current limit	Type-A/C mode	3.1 3.55 3.9	A
t_{HICP_DEG}	Deglitch time before hiccup mode		2	ms
t_{HICP_ON}	V_{BUS} enter hiccup hold time		2	ms
t_{HICP_OFF}	Hiccup mode off time		2	s
t_{USB_SS}	USB_OUT soft-start time	$V_{BUS}=5.15V$, from 10% to 90%	0.4	ms
t_{FLT_DEG}	Fault deglitch time		2	ms
$V_{OV_DM_DP}$	DM, DP pins OVP rising		3.8 4 4.2	V
$V_{OV_DM_DP_HYS}$	DM, DP pins OVP rising hysteresis		200	mV
G_{ADJ_SINK}	Line drop compensation gain		2	μA/A
V_{FLT_L}	FLT output low voltage		0.05	V
USB TYPE-C 5V @ 3A MODE – CC1, CC2				
R_A	CC resistor to disable Type-C mode		100	kΩ



I_{PLL}	CC pull-up current to detect Type-A mode		10	μA
$R_{p_80\mu A}$	CC Rp pull up 80 μA capability		80	μA
$R_{p_180\mu A}$	CC Rp pull up 180 μA capability		180	μA
$R_{p_330\mu A}$	CC Rp pull up 330 μA capability		330	μA
V_{CC_RD}	CC voltage with 5.1k Ω R_D	CC pin connected to 5.1k Ω pull-down resistor	1.3 1.68 2.0	V
V_{OPEN}	CC detach threshold		2.7	V
$t_{CC_DEBOUNCE}$	CC voltage falling debounce timer		150	ms
$t_{PD_DEBOUNCE}$	CC voltage rising debounce timer		10	ms
I_{VCONN_OCP}	VCONN over current threshold		39	mA
V_{CCOVP_TH}	CC OVP rising threshold		5.7 6 6.3	V
V_{CCOVP_HYST}	CC OVP hysteresis		0.26	V
NTC TEMPERATURE SENSING				
V_{LS_HIGH}	Load-shedding entry threshold		50%	V_{CC}
V_{LS_LOW}	Load-shedding exit threshold		25%	V_{CC}
V_{TSD_HIGH}	FLT entry threshold		70%	V_{CC}
V_{TSD_LOW}	FLT exit threshold		60%	V_{CC}
BC1.2 DCP MODE				
R_{DP/DM_SHORT}	DP and DM short resistance	$V_{DP} = 0.8V$, $I_{DM} = 1mA$, $T_J = -40^{\circ}C$ to $+150^{\circ}C$	40	Ω
2.4A DIVIDER MODE				
$V_{DP_DIVIDER}$	DP output voltage	$V_{OUT}=5.15V$	2.6 2.7 2.8	V
$R_{DP_DIVIDER}$	DP output impedance		32	k Ω
$V_{DM_DIVIDER}$	DM output voltage	$V_{OUT}=5.15V$	2.6 2.7 2.8	V
$R_{DM_DIVIDER}$	DM output impedance		32	k Ω
THERMAL SHUTDOWN ⁽¹⁾				
T_{SD}	Thermal shutdown threshold		165	$^{\circ}C$
T_{SD_HYS}	Thermal shutdown hysteresis		20	$^{\circ}C$

(1) Guarantee by Design



8.6 Typical Characteristics

$V_{IN}=13.5V$, $V_{BUS}=5.15V$, $L=4.7\mu H$, $F_{SW}=400kHz$, mode=PFM with spread spectrum, CC1 connected to ground with a 5.1k Ω resistor, $C_{OUT}=100\mu F/35V$, $T_A=25^\circ C$, unless otherwise noted.

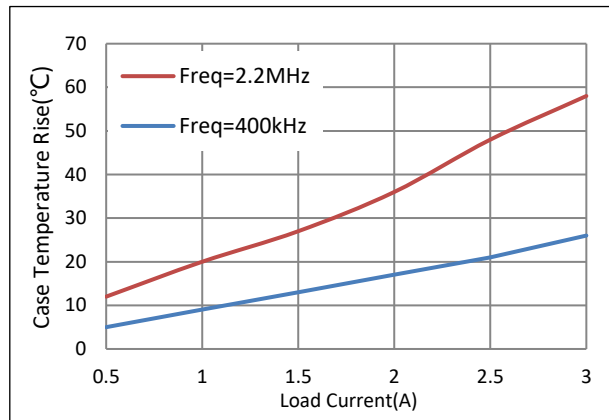


Figure 8-1. Case Temperature Rise

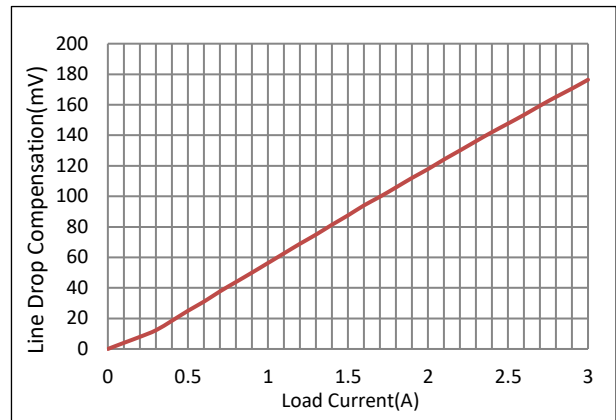


Figure 8-2. Line Drop Compensation

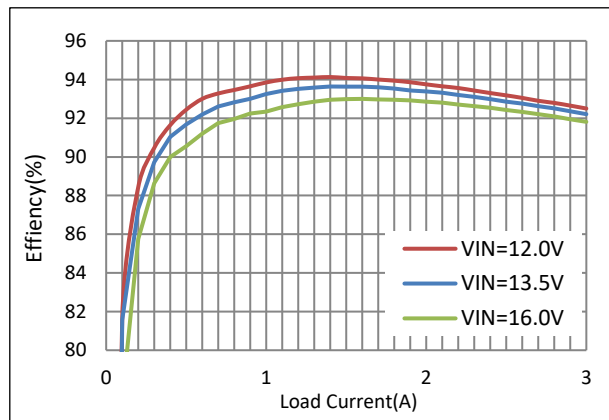


Figure 8-3. Efficiency, PFM, $F_{SW}=400kHz$, measured on USB_OUT, $C_{OUT}=4*22\mu F$, $DCR=15mR$

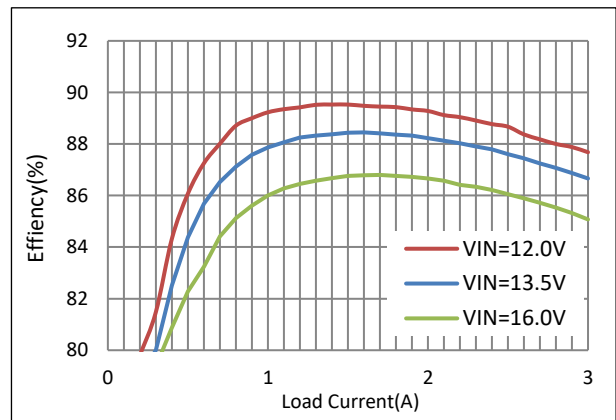


Figure 8-4. Efficiency, PFM, $F_{SW}=2.2MHz$, measured on USB_OUT, $C_{OUT}=2*22\mu F$, $DCR=6mR$

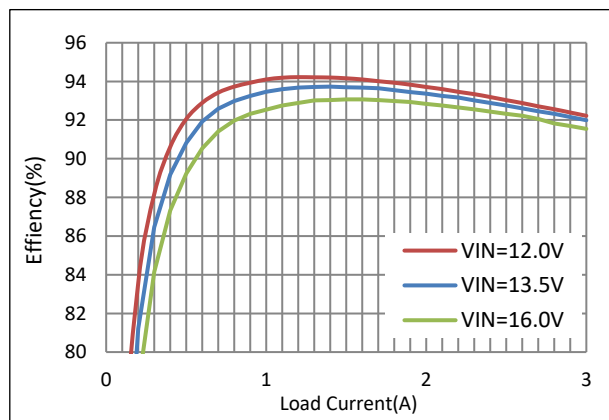


Figure 8-5. Efficiency, FPWM, $F_{SW}=400kHz$, measured on USB_OUT, $C_{OUT}=4*22\mu F$, $DCR=15mR$

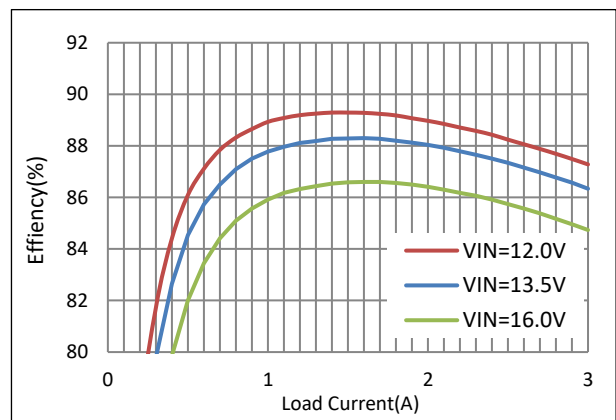


Figure 8-6. Efficiency, FPWM, $F_{SW}=2.2MHz$, measured on USB_OUT, $C_{OUT}=2*22\mu F$, $DCR=6mR$

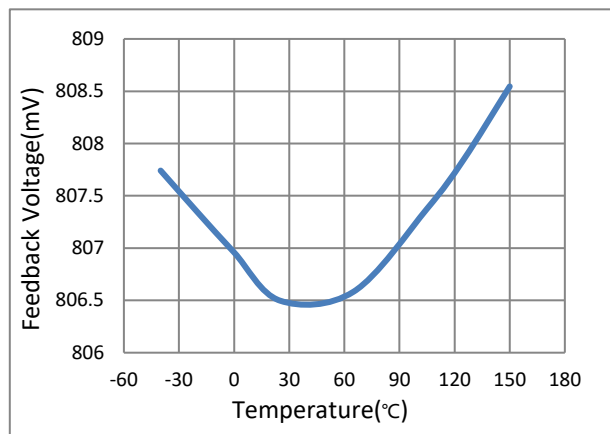


Figure 8-7. Feedback Voltage

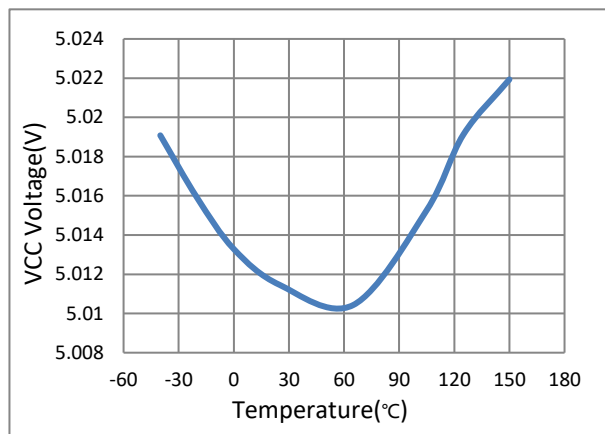


Figure 8-8. VCC Voltage

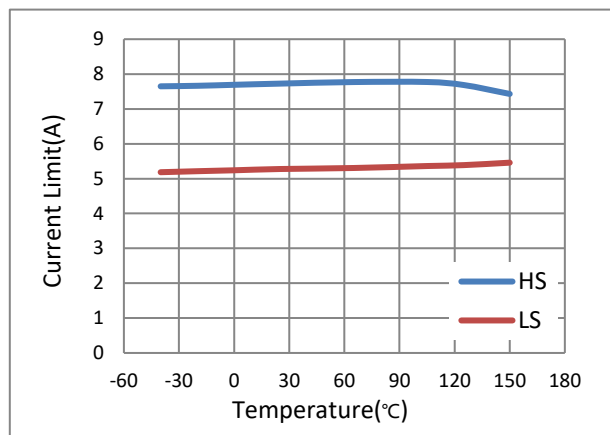


Figure 8-9. High-side and Low-side Current Limits

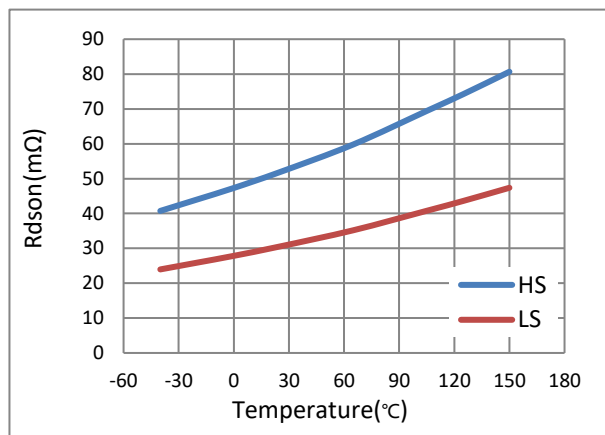


Figure 8-10. High-side and Low-side on resistor

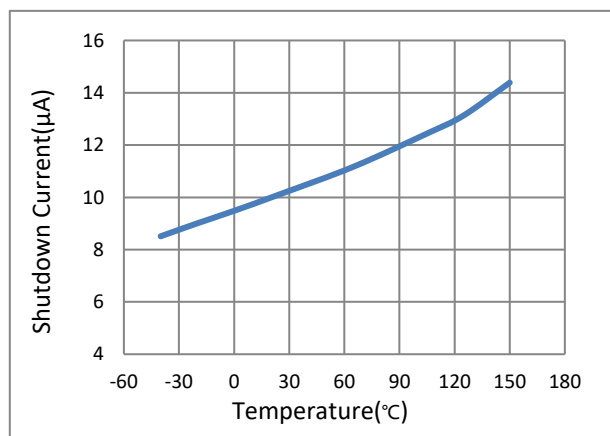


Figure 8-11. Shutdown Current

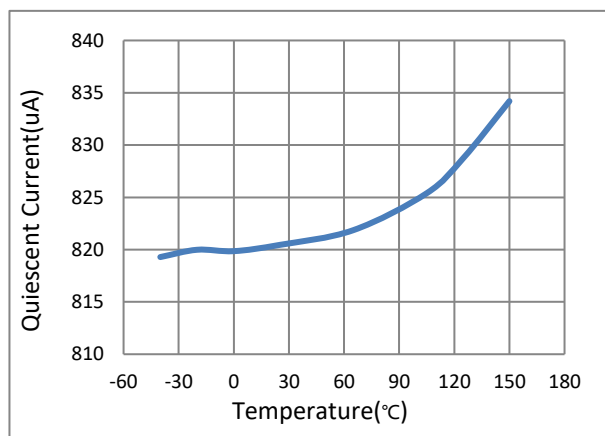


Figure 8-12. Non-Switching Input Supply Current

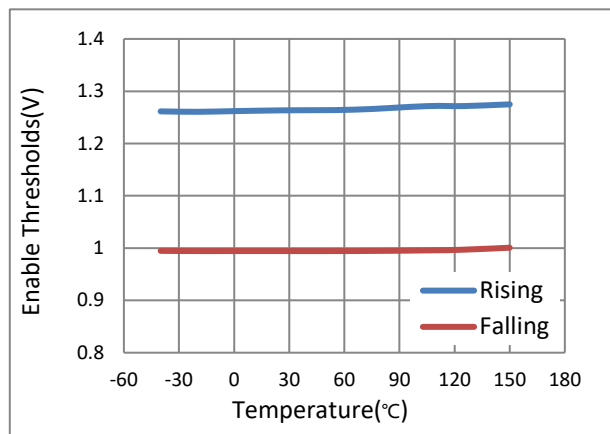


Figure 8-13. Enable Thresholds

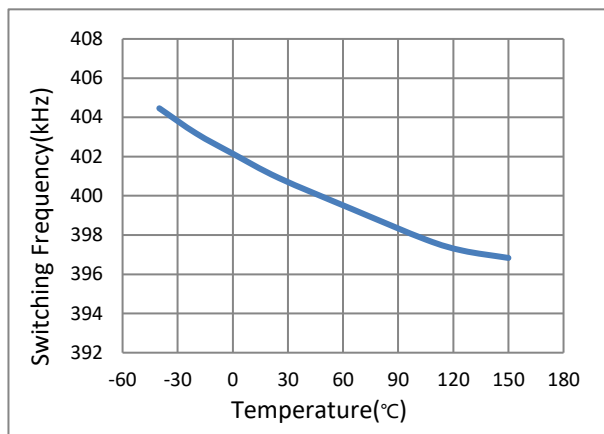


Figure 8-14. Switching Frequency

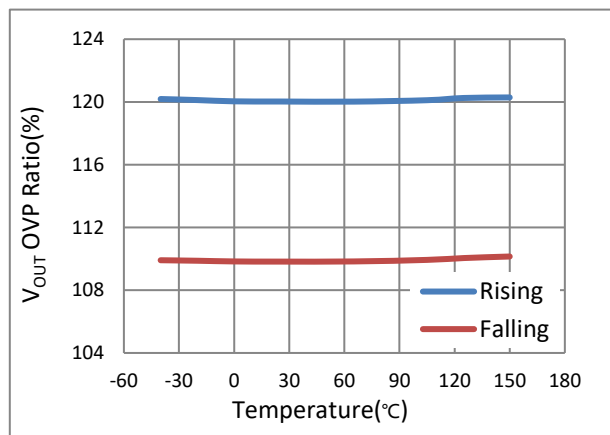


Figure 8-15. Output Over Voltage Protection Ratio

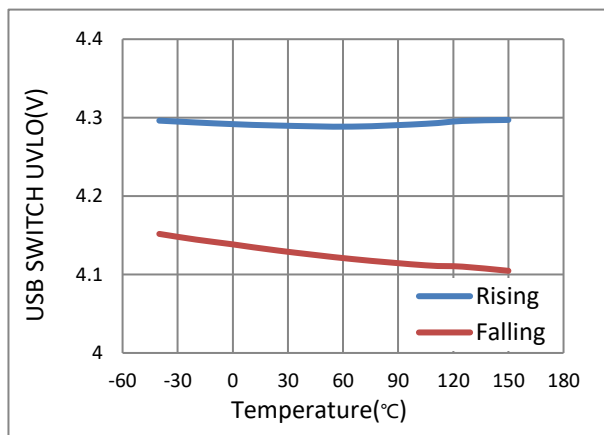


Figure 8-16. USB_SWITCH UVLO

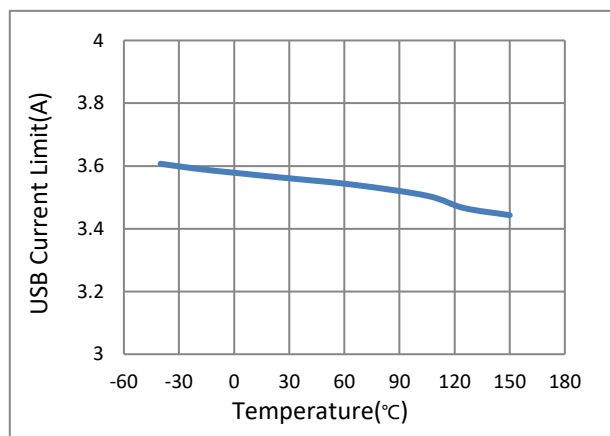


Figure 8-17. USB_SWITCH Current Limit

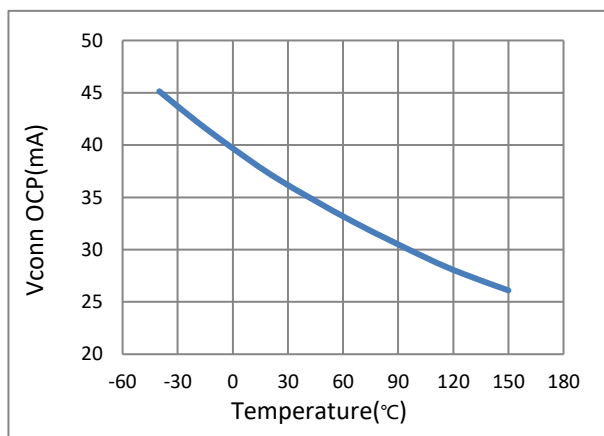


Figure 8-18. Vconn Over Current Protection

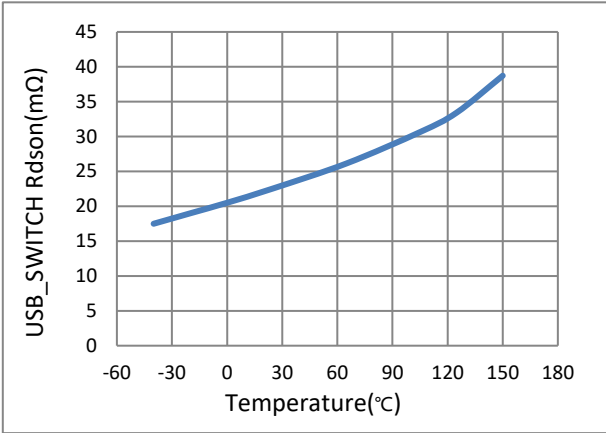


Figure 8-19. USB_SWITCH On Resistor

8.7 Typical Performance Characteristics

$V_{IN}=13.5V$, $V_{BUS}=5.15V$, $L=4.7\mu H$, $F_{SW}=400kHz$, mode=PFM with spread spectrum, CC1 connected to ground with a $5.1k\Omega$ resistor, $C_{OUT}=100\mu F/35V$, $T_A=25^\circ C$, unless otherwise noted.

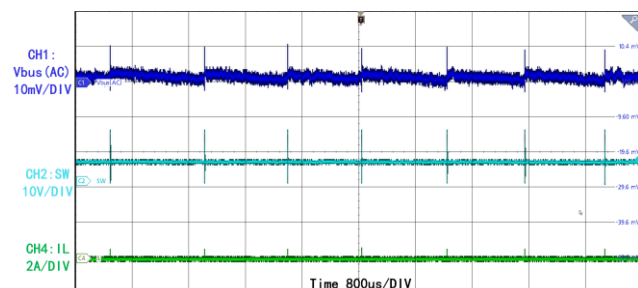


Figure 8-20. Steady State $I_{OUT}=0A$

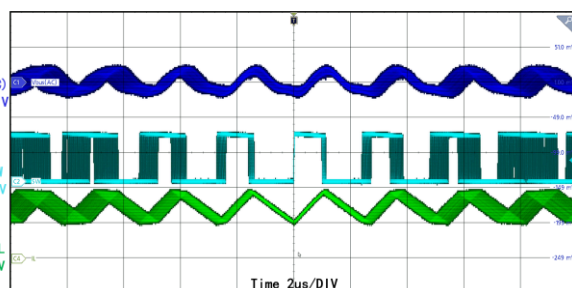


Figure 8-21. Steady State $I_{OUT}=3A$

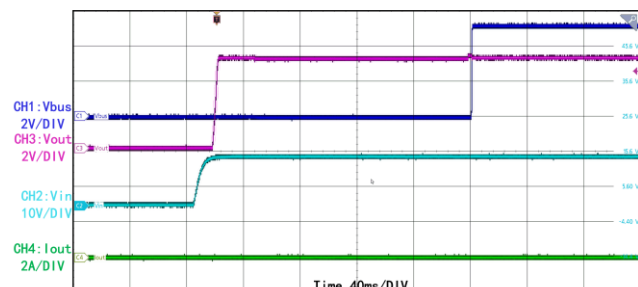


Figure 8-22. Start up Through V_{in} ; $I_{OUT}=0A$

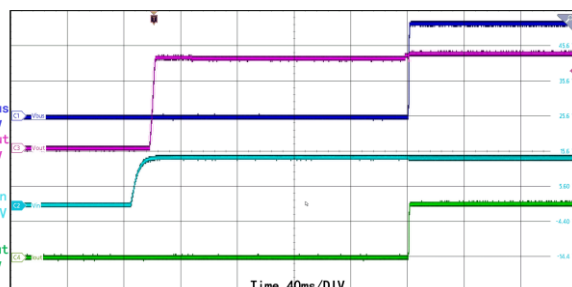


Figure 8-23. Start up Through V_{in} ; $I_{OUT}=3A$

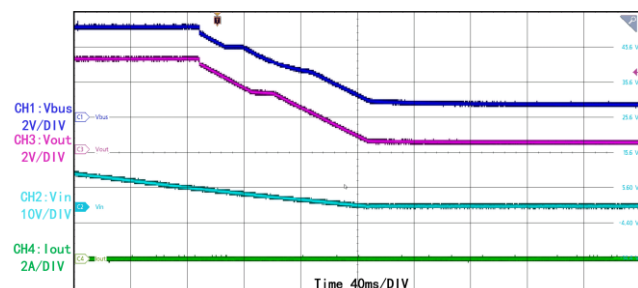


Figure 8-24. Shut Down Through V_{in} ; $I_{OUT}=0A$

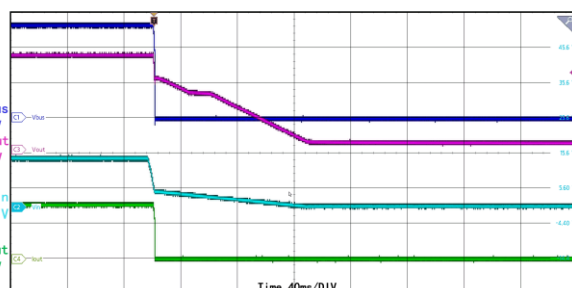


Figure 8-25. Shut Down Through V_{in} ; $I_{OUT}=3A$



$V_{IN}=13.5V$, $V_{BUS}=5.15V$, $L=4.7\mu H$, $F_{SW}=400kHz$, mode=PFM with spread spectrum, CC1 connected to ground with a $5.1k\Omega$ resistor, $C_{OUT}=100\mu F/35V$, $T_A=25^\circ C$, unless otherwise noted.

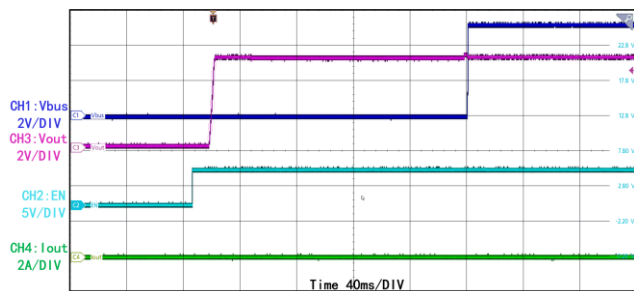


Figure 8-26. Start up Through EN; $I_{OUT}=0A$

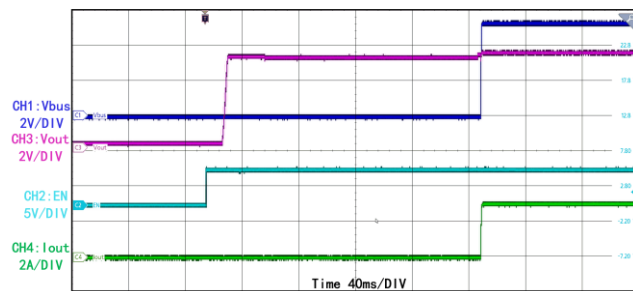


Figure 8-27. Start up Through EN; $I_{OUT}=3A$

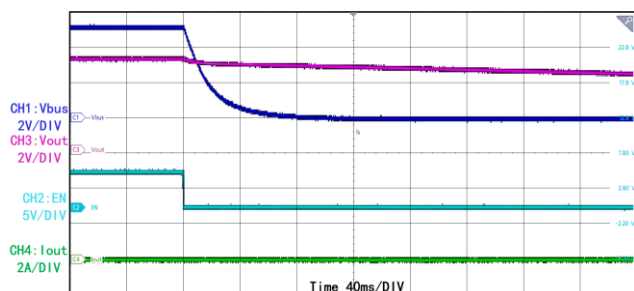


Figure 8-28. Shut Down Through EN; $I_{OUT}=0A$

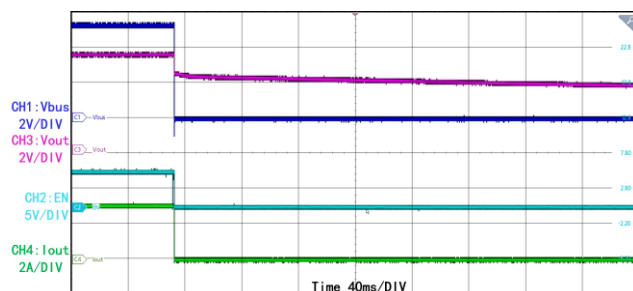


Figure 8-29. Shut Down Through EN; $I_{OUT}=3A$

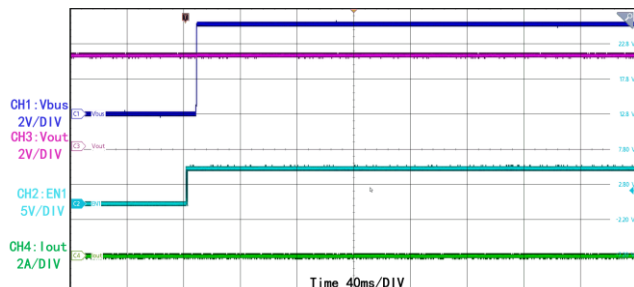


Figure 8-30. Start up Through EN1; $I_{OUT}=0A$; Type-A mode

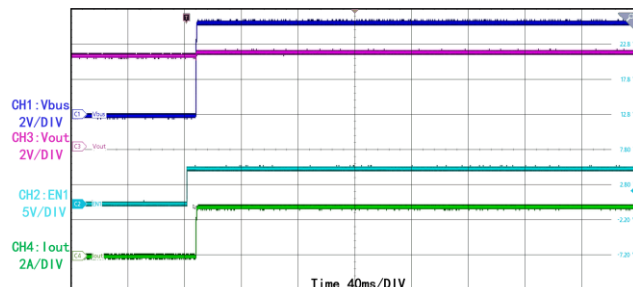


Figure 8-31. Start up Through EN1; $I_{OUT}=2.8A$; Type-A mode



$V_{IN}=13.5V$, $V_{BUS}=5.15V$, $L=4.7\mu H$, $F_{SW}=400kHz$, mode=PFM with spread spectrum, CC1 connected to ground with a $5.1k\Omega$ resistor, $C_{OUT}=100\mu F/35V$, $T_A=25^\circ C$, unless otherwise noted.

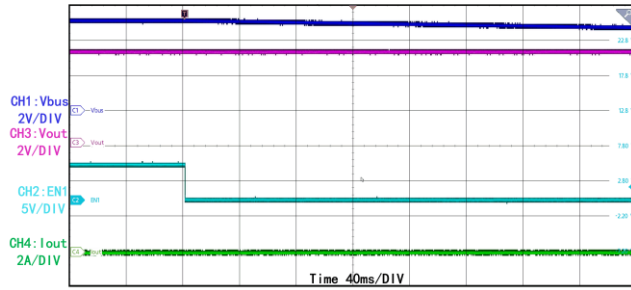


Figure 8-32. Shut Down Through EN1; $I_{OUT}=0A$

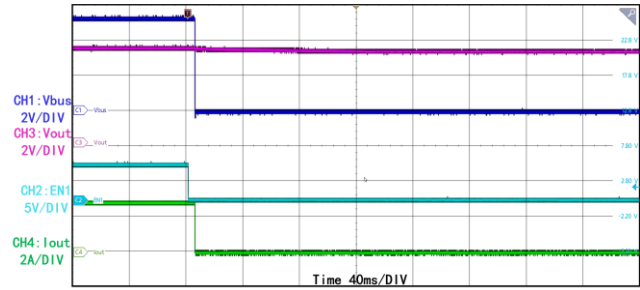


Figure 8-33. Shut Down Through EN1; $I_{OUT}=2.8A$

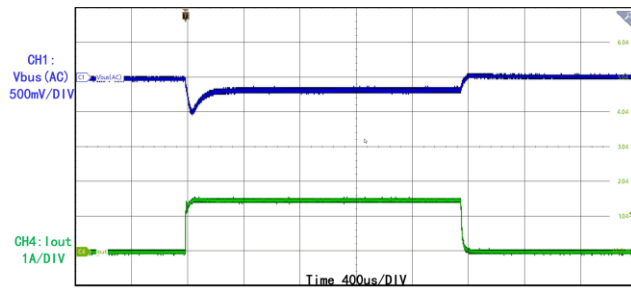


Figure 8-34. Load Transient I_{OUT} : $0A \rightarrow 1.5A \rightarrow 0A$

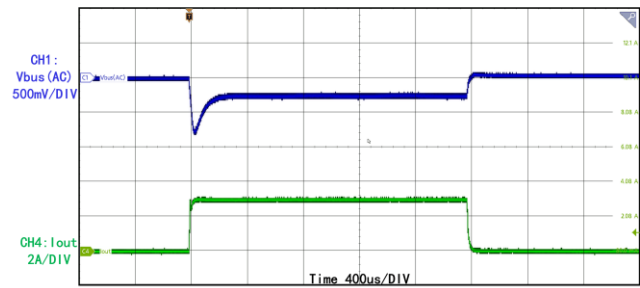


Figure 8-35. Load Transient I_{OUT} : $0A \rightarrow 3A \rightarrow 0A$

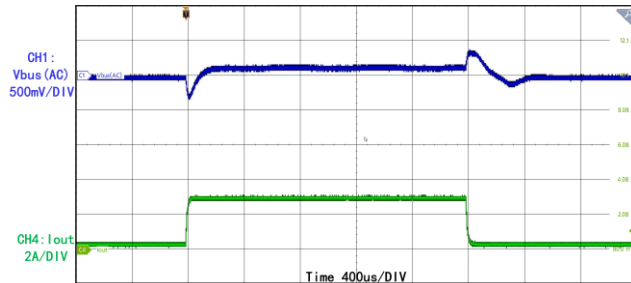


Figure 8-36. Load Transient I_{OUT} : $0.3A \rightarrow 3A \rightarrow 0.3A$

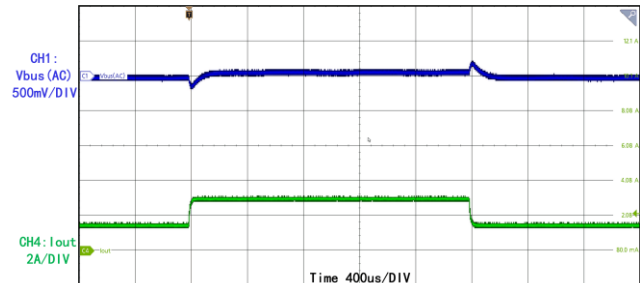


Figure 8-37. Load Transient I_{OUT} : $1.5A \rightarrow 3A \rightarrow 1.5A$



$V_{IN}=13.5V$, $V_{BUS}=5.15V$, $L=4.7\mu H$, $F_{SW}=400kHz$, mode=PFM with spread spectrum, CC1 connected to ground with a $5.1k\Omega$ resistor, $C_{OUT}=100\mu F/35V$, $T_A=25^\circ C$, unless otherwise noted.

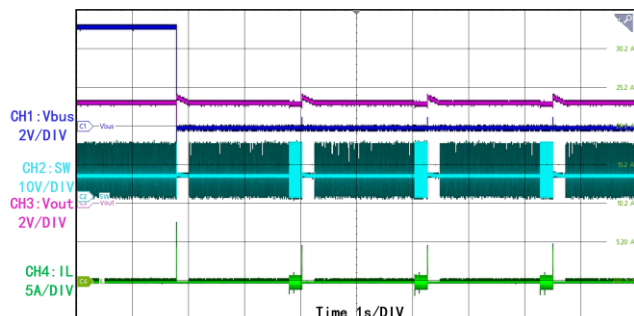


Figure 8-38. USB_OUT Short-to-GND Entry, $I_{OUT}=0A \rightarrow$ Short

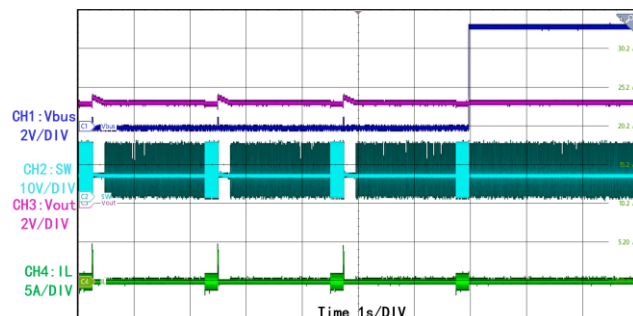


Figure 8-39. USB_OUT Short-to-GND Recovery, $I_{OUT}=Short \rightarrow 0A$

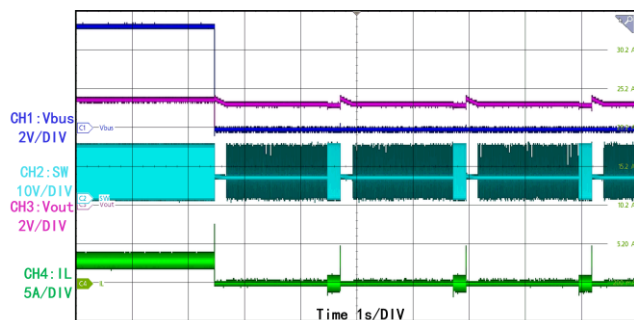


Figure 8-40. USB_OUT Short-to-GND Entry, $I_{OUT}=3A \rightarrow$ Short

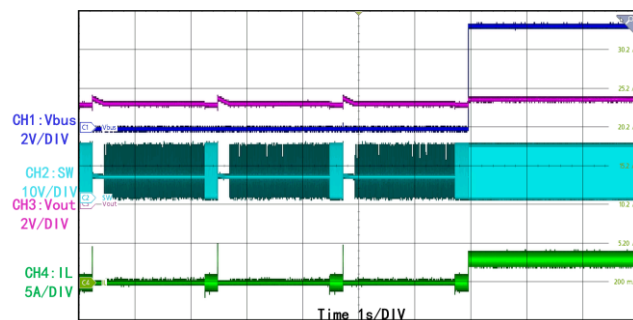


Figure 8-41. USB_OUT Short-to-GND Recovery, $I_{OUT}=Short \rightarrow 3A$

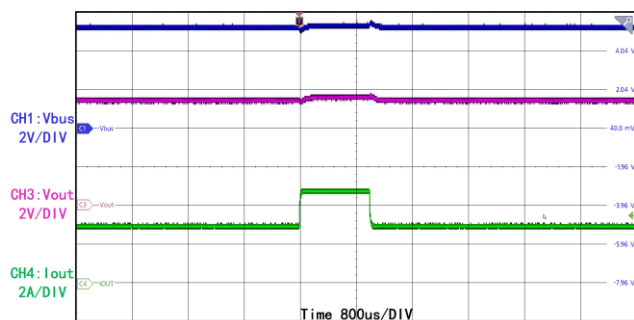


Figure 8-42. MFI Test Type-C mode, $I_{OUT}= 3A$ to $4.8A$, 1ms hold time

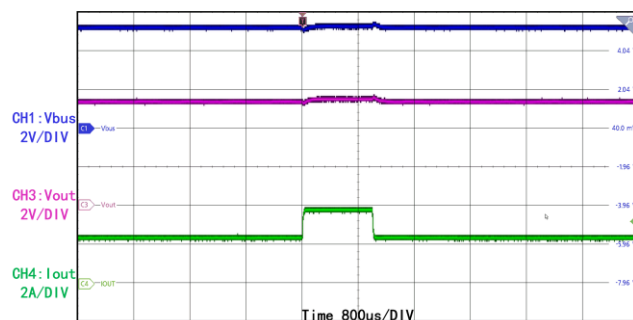


Figure 8-43. MFI Test Type-A mode, $I_{OUT}= 2.4A$ to $3.84A$, 1ms hold time



$V_{IN}=13.5V$, $V_{BUS}=5.15V$, $L=4.7\mu H$, $F_{SW}=400kHz$, mode=PFM with spread spectrum, CC1 connected to ground with a $5.1k\Omega$ resistor, $C_{OUT}=100\mu F/35V$, $T_A=25^\circ C$, unless otherwise noted.

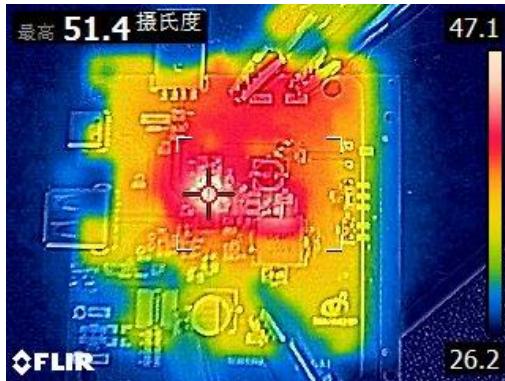


Figure 8-44. Thermal Test

$I_{OUT}=3A$, Frequency=400kHz, measured on 4-layer PCB,
Top/Bottom layer: 2oz, middle layers: 1oz

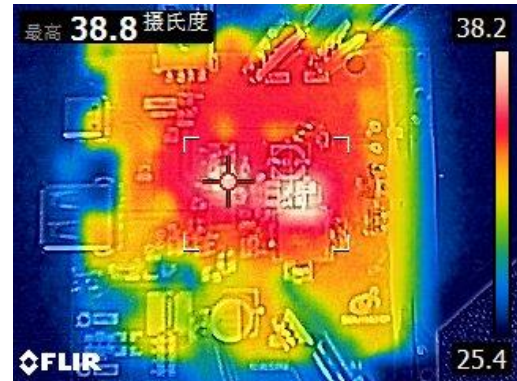


Figure 8-45. Thermal Test

$I_{OUT}=3A$, Frequency=2.2MHz, measured on 4-layer PCB,
Top/Bottom layer: 2oz, middle layers: 1oz



9 Functional Block Diagram

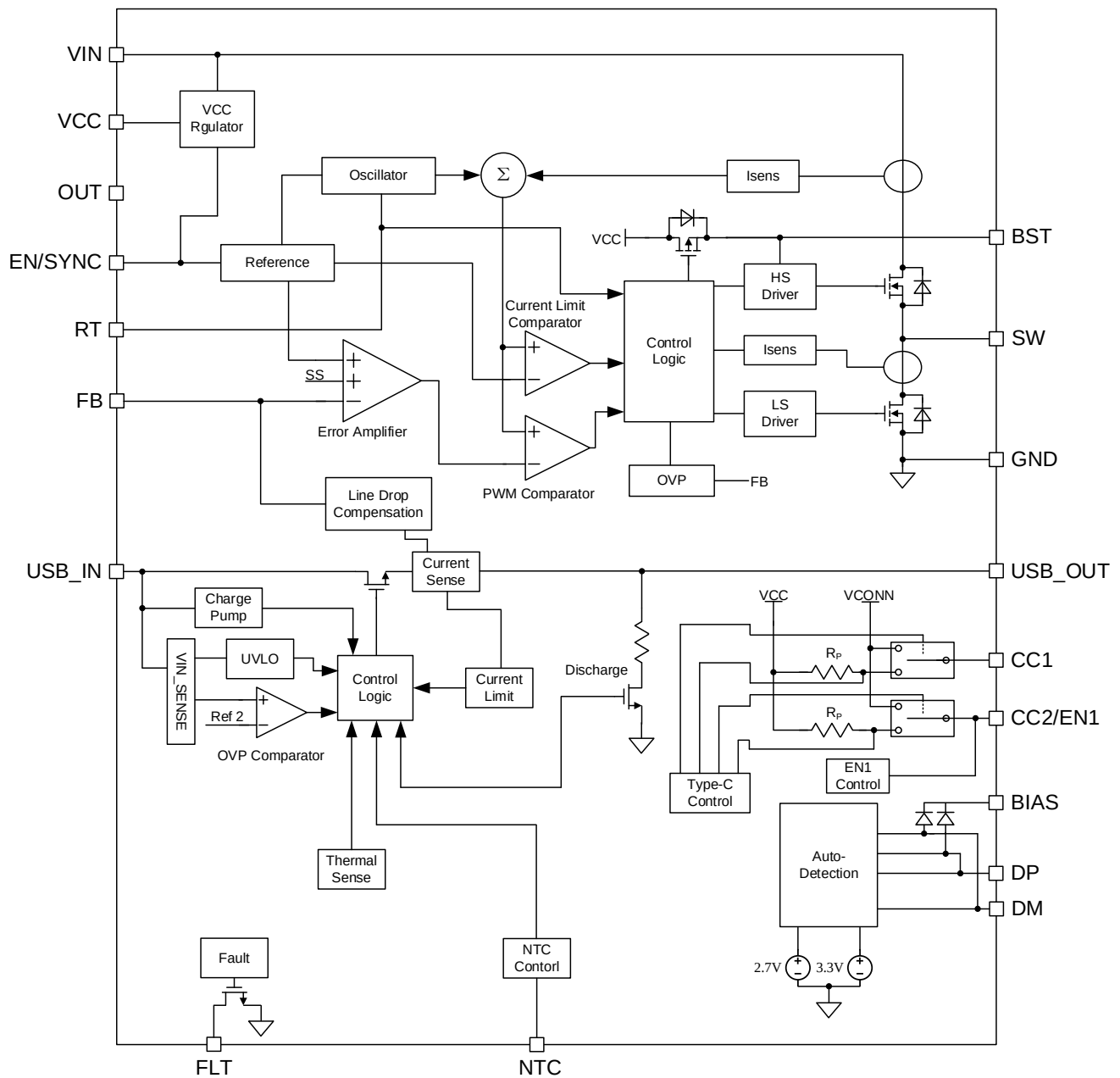


Figure 9-1. Function Block



10 Feature Description

10.1 Overview

SC81532Q is a synchronous buck converter with a USB current-limit switch and BC1.2 charging port controller Integrated. It provides a compact solution to achieve 3A of continuous output current across a wide V_{IN} range. Implementing peak-current and valley-current mode, SC81532Q is able to provide excellent line and load transient performance.

SC81532Q could be configured at different frequency from 200kHz to 2.2MHz by RT pin resistor, as well as synchronize to external clock. It operates in Auto PFM in light condition to achieve higher efficiency. SC81532AQ is Forced PWM version, it can operate fixed frequency even in light load to get a small output ripple during all load range.

SC81532Q integrates spread spectrum feature to optimize the EMI performance. SC81532Q includes high bandwidth analog switches, short to battery protection on USB_OUT/DP/DM/CC1/CC2 pins.

10.2 Buck Converter

SC81532Q integrates a synchronous buck converter with high-side and low-side switches inside. It regulates the output voltage by adjusting the duty cycle of HS switch and LS switch. When the high-side switch is ON, the inductor current i_L increase with linear slope $(V_{IN} - V_{OUT}) / L$. The low-side switch is turned on after HS switch is turned off and dead time.

10.3 VCC Power Supply

The SC81532Q integrates an internal LDO to generate VCC for control circuitry and power stage's drivers. The nominal voltage for VCC is 5V. The LDO charges BOOT capacitor when low side MOSFET is ON. A high-quality ceramic capacitor with a value of 4.7 μ F, 10 V or higher rated voltage should be placed as close as possible to VCC and grounded to the AGND pin. When V_{IN} is higher than 6V, the internal LDO is fully regulated and the VCC voltage is 5V. When EN logic is low and VCC is lower than 4.3V, an additional discharge path will be open to discharge the output voltage of V_{BUS} .

10.4 Input Under Voltage Lockout

When the input voltage is above than 3.8V, the SC81532Q can be enabled by pulling EN pin to a high voltage above 1.3V, but the USB_SWITCH won't turn on until the USB_IN voltage is higher than 4.3V and a valid USB connection is monitored. After the DCDC starts switching, it won't turn off until the V_{IN} falls to 3.4V.

10.5 EN/SYNC for Enable and Precise Input UVLO

EN/SYNC pin is multiplexed to be either precise enable or external clock synchronization. When it is used as precise enable, start-up and shutdown sequence can be controlled by pulling this pin high or low. Furthermore, precise enable threshold can help build user programmable input UVLO.

The EN/SYNC pin must be properly terminated and cannot be floating. EN/SYNC can be directly connected to V_{IN} for self-start-up for the simplest design. As shown in **Figure 10-1**, in order to build power up sequence and use programmable input UVLO, resistor dividers can be used to set appropriate threshold on EN/SYNC pin. The EN/SYNC has 300mV (typ.) hysteresis to help build robust enable or disable function. The EN/SYNC pin can also connect to an external I/O pin for systematical power sequence management.

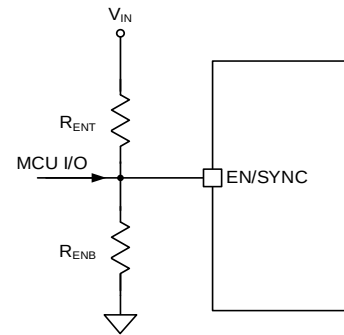


Figure 10-1. EN/SYNC Configuration for Precise Enable

$$R_{ENB} = R_{ENT} \cdot \frac{V_{EN_H}}{V_{IN_R} - V_{EN_H}} \quad (1)$$

$$V_{IN_HYS} = V_{EN_HYS} \cdot \frac{R_{ENT} + R_{ENB}}{R_{ENB}} \quad (2)$$

Equation (1) can be used to calculate resistor values and **Equation (2)** can be used to calculate hysteresis after resistors are selected. V_{IN_R} is the input rising voltage for start-up and V_{IN_HYS} is the hysteresis.

10.6 EN/SYNC for Synchronization

The EN/SYNC pin can be used to synchronize internal oscillator to an external clock. As shown in **Figure 10-2**, internal oscillator is synchronized to the positive clock edge through C_{SYNC} AC coupling. This will prevent external clock when it is in idle state from interfering input UVLO.

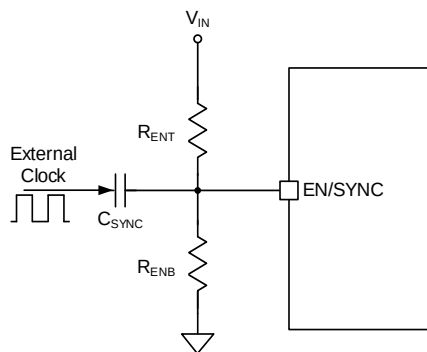


Figure 10-2 EN/SYNC Configuration for Clock Synchronization

The C_{SYNC} , R_{ENT} and R_{ENB} forms a high-pass filter in frequency domain seen from EN/SYNC pin. From demonstration of **Figure 10-3**, the cross-over frequency is determined by time constant τ , which is the product of C_{SYNC} and parallel resistance R_{ENT}/R_{ENB} . The cross-over frequency of the high-pass filter must be much lower than the external clock frequency. The recommended parallel resistance R_{ENT}/R_{ENB} is 100k Ω . The AC coupling capacitor, C_{SYNC} , can be 1nF.

The device's synchronization frequency range is 200kHz to 2.2MHz. When synchronizing external clock, it should be noted that the RT resistor needs to set free-run switching frequency equal or below the lowest synchronization clock frequency, as slope compensation is determined by the RT value.

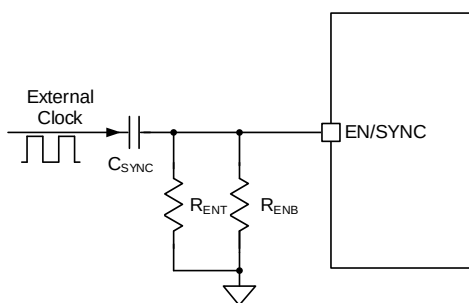


Figure 10-3 EN/SYNC High-pass Filter Demonstration

The amplitude of external clock needs to be higher than V_{EN_SYNC} to trigger internal synchronization pulse detector. An external clock with 5V amplitude can be used on EN/SYNC pin. Moreover, the minimum EN/SYNC rising pulse and falling pulse duration should be longer than t_{SYNC_EDGE} , as what has been shown in **Figure 10-4**. Note that it is recommended to control rise/fall time of clock edge to be less than 30ns. Exerting external clock without meeting the requirements could deteriorate synchronization performance.

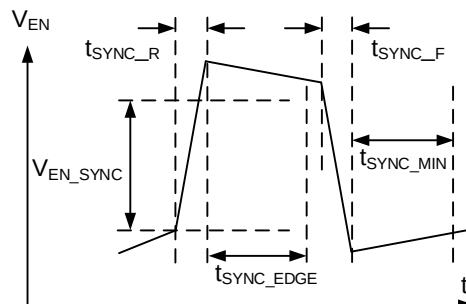


Figure 10-4 Typical EN/SYNC Waveform with External Clock

In order to prevent external clock from interfering the normal start-up, the clock must be off before start-up to allow proper sequencing.

10.7 Internal Soft Start

The Integrated soft-start circuit prevents input inrush current and the input power supply. Soft start is achieved by slowly ramping up the internal reference voltage when the device is first enabled or powered up. If the output of SC81532Q is pre-biased to a certain voltage during start-up, the IC disables the switching of both the high-side and low-side switches until the voltage on the internal SS capacitor exceeds the internal feedback voltage. In order to prevent negative inductor current from pulling output voltage down at start-up, the device is automatically operating in diode emulation mode.

10.8 Over Current Limit and Short Circuit Protection

The SC81532Q has a cycle-by-cycle peak and valley overcurrent limit. If the inductor peak or valley current exceeds the current-limit threshold, and the FB voltage drops below the 40% of the reference, SC81532Q enters hiccup mode to restart the part periodically. It works on current limit for 38ms and then turns off for 480ms to reduce the thermal temperature. This protection mode is especially useful when the output is dead shorted to ground. The SC81532Q exits hiccup mode once the FB voltage is higher than 50% of the reference.

10.9 Over Voltage Protection

SC81532Q has output overvoltage protection. When the output voltage is higher than 120% of V_{REF} , the SC81532Q turns off both high-side switches and low-side switches. The discharge path from USB_OUT pin to ground will turn on. If the FB voltage drops to 110% of V_{REF} , the device will return to normal operation. There is 1ms deglitch for entering or recovery from OVP condition.



10.10 RT and Switching Frequency

A resistor from RT to AGND is needed to set target switching frequency. **Equation (3)** and **Figure 10-5** can be used to determine the resistance. If synchronization to an external clock is needed, do not apply the signal to RT pin. Instead, EN/SYNC can be used for external clock synchronization.

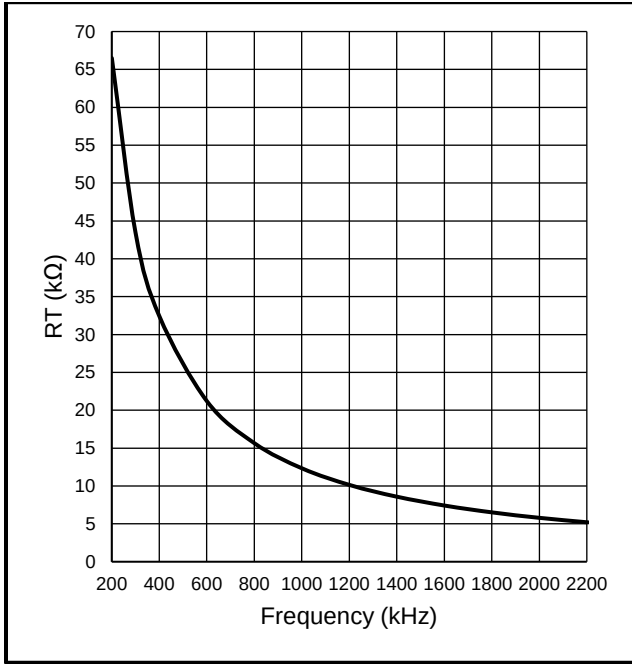


Figure 10-5 RT and Switching Frequency Relationship

$$R_T(k\Omega) = 1.8711 \times 10^4 \times F_{SW}(kHz)^{-1.062} \quad (3)$$

10.11 Spread Spectrum

Spread spectrum is a factory option for applications sensitive to EMI. Through implementing triangular spread spectrum, SC81532Q is able to evenly distribute fundamental frequency and its harmonics. Therefore, peak emissions can be eliminated. The switching frequency is changed per 8 internal oscillator cycles over a $\pm 10\%$ window with total 32 steps. The steps are dependent to nominal setting frequency to optimize the EMI performance.

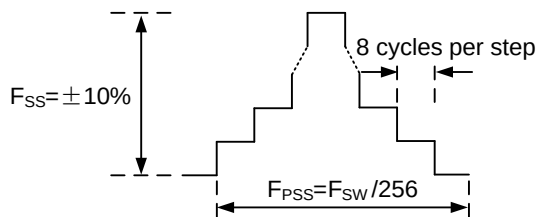


Figure 10-6 Spread-spectrum Mechanism

10.12 Line Drop Compensation

SC81532Q is capable of compensating an output voltage drop, which is helpful when there is high impedance at the output side. The compensated voltage is impacted the output current, upper feedback resistors.

$$V_{BUS} = \left(\frac{R_{up}}{R_{dn}} + 1 \right) \cdot V_{ref} + R_{up} \cdot G_{ADJ} \cdot I_{OUT} \quad (4)$$

Where G_{ADJ} is $2\mu A/A$.

If additional line drop compensation is required, a resistor can be connected in series between the FB pin and the voltage divider network, as shown in Figure 10-7.

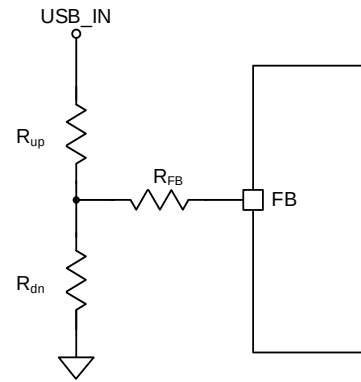


Figure 10-7. Additional Line Drop Compensation

If additional line drop compensation is applied, V_{BUS} is calculated by **Equation (5)**:

$$V_{BUS} = \left(\frac{R_{up}}{R_{dn}} + 1 \right) \cdot V_{ref} + (R_{up} + R_{FB} \cdot \frac{R_{up} + R_{dn}}{R_{dn}}) \cdot G_{ADJ} \cdot I_{OUT} \quad (5)$$

10.13 Over Current Protection

SC81532Q integrates a precise current limit in USB Switch to protect the USB port from extreme overload condition. According to different I_{BUS} and the duration time, the behavior of SC81532Q is different.

- If $I_{LIMIT1} < I_{BUS} < 1.6 \cdot I_{LIMIT1}$ and duration time is shorter than 1.8ms, the device doesn't have OCP behavior which helps it to pass Apple MFI test.
- If $I_{LIMIT1} < I_{BUS} < 1.6 \cdot I_{LIMIT1}$ and the duration time is longer than 1.8ms, the device will limit the I_{BUS} to I_{LIMIT1} after 1.8ms and then enters into the hiccup mode.
- If $I_{BUS} > 1.6 \cdot I_{LIMIT1}$, such as in short circuit condition, device will limit the I_{BUS} to I_{LIMIT} immediately and then enters into the hiccup mode.



10.14 Short to Battery Protection

SC81532Q provides DP/DM/CC1/CC2/USB_OUT short to battery protections to avoid the abnormal fault happen when the cable is short to battery but no device is attached.

When USB_OUT short to battery occurs, the parasitic diode will conduct and USB_IN voltage will charge high to exceed the OVP threshold, then internal DCDC converter will turn off the power stage immediately and the device will turn off the USB switch and data switch. The fault pin will be pulled down after 1ms deglitch time.

When DP/DM short to battery occurs, once the voltage on these pins exceeds 4V, the device turns off the data switch immediate to disable DP/DM output. When CC1/CC2 short to battery occurs, once the voltage on these pins exceeds 5.7V, the device will not only turn off the USB_SWITCH and data switch, but also turn off VCONN switch. Both the deglitch for DP/DM/CC1/CC2 pin is about 16us.

10.15 Type-C Mode

SC81532Q use the function of the configuration channel (CC1/CC2 pin) to detect connections and configure the interface across the USB Type-C cables. The detection concept is based on being able to detect terminations in the product. To define the functional behavior of CC, a pull-up resistor (R_P) and pull-down resistor termination model is used ad below. A pull-up termination can be replaced by a current source.

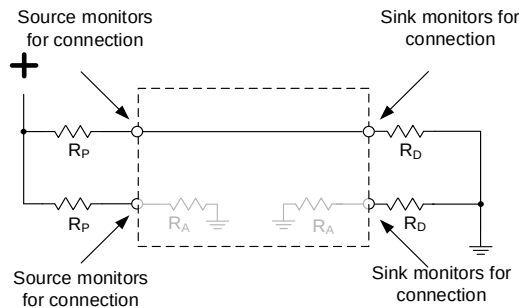


Figure 10-8 USB Type-C Connection

To prevent mistakenly entering TypeA mode, CC1 requires a parallel capacitor of at least 2.2nF.

10.16 Type-A Mode

During start up process, once VCC logic is high, SC81532Q source a 10μA current on CC1 pin for 70μS. When a 100kΩ resistor connected to CC1, an internal 1V voltage will be created and device enter into Type-A mode. In this mode, the CC attached and detach logic is disabled, the current limit changes to the Type-A specifications.

10.17 NTC

SC81532Q integrates NTC (Negative Temperature Coefficient) comparator to ensures the devices operating in a safe environment by sensing the external device's temperature.

This function is established by connecting a resistor from NTC pin to GND, then connect the thermistor from the NTC pin to VCC.

Once the NTC voltage rises to 50% of VCC during normal operation, the USB port's CC pin current capability is reduced to 180uA to indicate that the source capability has changed to 1.5A. The current limit is unchanged and line compensation is disabled in this condition. If the NTC voltage falls to 25% of VCC, the USB current capability changes to 3A and SC81532Q will resume normal operation.

Once the NTC voltage rises to 75% of VCC, SC81532Q will report a fault after 16uS deglitch, and will recovery when it falls to 60% of VCC.

10.18 Load Shedding

When the sensed temperature exceeds 145°C or the NTC voltage is higher than 50% of VCC, the USB port's CC1/CC2 pin pull-up resistor will be changed to indicate that the capability has change to 1.5A but the current limit is not changed. If the sensed temperature drops below 105°C and last for 16 seconds, the current capability will be back to 3A.

10.19 Thermal Shutdown

The device has an internal overtemperature shutdown threshold T_{SD} to protect the device from damage. If the USB switch silicon temperature exceeds 165°C, the device shuts down and recovery when the temperature falls to 145°C.



11 Application Information

11.1 Inductor Selection

The parameters for selecting the inductor are the inductance and saturation current. The inductance is based on the desired peak-to-peak ripple current and is normally chosen to be in the range of 20% to 40% of the maximum output current. Experience shows that the best value for inductor ripple current is 30% of the maximum load current for systems with a fixed input voltage and 25% for systems with a variable input voltage such as the 12V battery in a car. Note that when selecting the ripple current for applications with much smaller maximum load than the maximum available from the device, the maximum device current must still be used. **Equation 5** can be used to determine the value of inductance. The constant K is the percentage of inductor current ripple. For this example, K = 0.4 was chosen and an inductance of approximately 5.7μH was found. The next standard value of 4.7μH was selected.

$$L = \frac{V_{IN} - V_{OUT}}{F_{SW} \cdot K \cdot I_{OUT}(MAX)} \cdot \frac{V_{OUT}}{V_{IN}} \quad (5)$$

The saturation current rating of the inductor must be at least as large as the high-side switch current limit, IL-HS (see Section 8.5). This ensures that the inductor does not saturate even during a short circuit on the output. When the inductor core material saturates, the inductance falls to a very low value, causing the inductor current to rise very rapidly. Although the valley current limit, IL-LS, is designed to reduce the risk of current run-away, a saturated inductor can cause the current to rise to high values very rapidly. This can lead to component damage; do not allow the inductor to saturate. Inductors with a ferrite core material have very hard saturation characteristics, but usually have lower core losses than powdered iron cores. Powdered iron cores exhibit a soft saturation, allowing some relaxation in the current rating of the inductor. However, they have more core losses at frequencies typically above 1MHz. To avoid subharmonic oscillation, the inductance value must not be less than that given in **Equation 6**. The maximum inductance is limited by the minimum current ripple required for the current mode control to perform correctly. As a rule-of-thumb, the minimum inductor ripple current must be no less than about 10% of the device maximum rated current under nominal conditions.

$$L \geq 0.32 \cdot \frac{V_{OUT}}{F_{SW}} \quad (6)$$

Equation 6 assumes that this design must operate with input voltage near or in dropout. If minimum operating

voltage for this design is high enough to limit duty factor to below 50%, **Equation 7** can be used in place of **Equation 6**.

$$L \geq 0.2 \cdot \frac{V_{OUT}}{F_{SW}} \quad (7)$$

Note that choosing an inductor that is larger than the minimum inductance calculated using **Equation 5** through **Equation 7** results in less output capacitance being needed to limit output ripple but more output capacitance being needed to manage large load transients. See Section 11.2.

11.2 Output Capacitor Selection

The value of the output capacitor and its ESR determine the output voltage ripple, control loop stability and load transient performance. **Table 11-1** can be used to find the output capacitor for a few common applications. In this example, improved control loop stability and transient performance is desired giving 4* 22μF ceramic as the output capacitor and 33pF as C_{FF} (Feedforward Capacitor).

Table 11-1. Recommended Output Capacitors

F _{SW}	Recommendation 1	Recommendation 2
400kHz	4X22μF+0.1μF MLCC	100μF (Electrolytic capacitor, ESR<50mΩ) +10μF+0.1μF MLCC
2.2MHz	2X22μF+0.1μF MLCC	NA

Most ceramic capacitors deliver far less capacitance than the rating of the capacitor indicates. Be sure to check any capacitor selected for initial accuracy, temperature derating, and voltage derating. **Table 11-1** have been generated assuming typical derating for 16V, X7R, automotive grade capacitors. If lower voltage, non-automotive grade, or lower temperature rated capacitors are used, more capacitors than listed are likely to be needed.

11.3 Input Capacitor Selection

The ceramic input capacitors provide a low impedance source to the converter to supply the ripple current and isolate switching noise from other circuits. A minimum of 10μF of ceramic capacitance is required on the input of the device. This must be rated for at least the maximum input voltage that the application requires; preferably twice the maximum input voltage. This capacitance can be increased to help reduce input voltage ripple and maintain the input voltage during load transients. In addition, a small case size 100nF ceramic capacitor must be used at input/ground pin pair, immediately adjacent to the converter. This provides a



high-frequency bypass for the control circuits internal to the device. These capacitors also suppress SW node ringing, which reduces the maximum voltage present on the SW node and EMI. The 100nF must also be rated at 50V with an X7R or better dielectric.

Many times, it is desirable and necessary to use an electrolytic capacitor on the input in parallel with the ceramics. This is especially true if long leads or traces are used to connect the input supply to the converter. The moderate ESR of this capacitor can help damp any ringing on the input supply caused by the long power leads. The use of this additional capacitor also helps with momentary voltage dips caused by input supplies with unusually high impedance.

Most of the input switching current passes through the input ceramic capacitors. The approximate worst-case RMS value of this current can be calculated from **Equation 8** and must be checked against the manufacturers' maximum ratings.

$$I_{RMS} \approx \frac{I_{OUT}}{2} \quad (8)$$

11.4 BOOT Capacitor Selection

The SC81532Q requires a bootstrap capacitor connected between the BOOT pin and the SW pin. This capacitor stores energy that is used to supply the gate drivers for the high-side power MOSFET. A high-quality (X7R) ceramic capacitor of 100nF and at least 10V is required.

11.5 BOOT Resistor Selection

A BOOT resistor and capacitor can be connected in series between the BOOT and SW pins. Unless EMI for the application being designed is critical, R_{BOOT} can be shorted. To maximize efficiency, 0Ω is chosen for this example. Under most circumstances, selecting an R_{BOOT} resistor value above 100Ω is undesirable since the resulting small improvement in EMI is not enough to justify further decreased efficiency.

11.6 VCC

The VCC pin is the output of the internal LDO used to supply the control circuits of the converter. This output requires a 4.7μF, 16V ceramic capacitor connected from VCC to GND for proper operation. In general, avoid loading this output with any external circuitry. However, this output can be used to supply the pullup (FLT or NTC function) or logic level (CC2 logic high). A pullup resistor with a value of 10kΩ is a good choice in this case.

11.7 External UVLO

In some cases, an input UVLO level different than that provided internal to the device is needed. This can be accomplished by using the circuit shown in **Figure 11-1**. First, a value for R_{ENB} is chosen in the range of 10kΩ to 100kΩ, then **Equation 9 and 10** is used to calculate R_{ENT} and V_{OFF} :

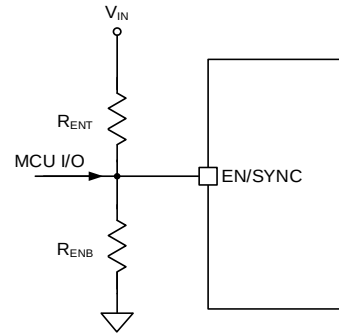


Figure 11-1. EN/SYNC Configuration for Precise Enable

$$R_{ENB} = R_{ENT} \cdot \frac{V_{EN_H}}{V_{IN_R} - V_{EN_H}} \quad (9)$$

$$V_{IN_HYS} = V_{EN_HYS} \cdot \frac{R_{ENT} + R_{ENB}}{R_{ENB}} \quad (10)$$

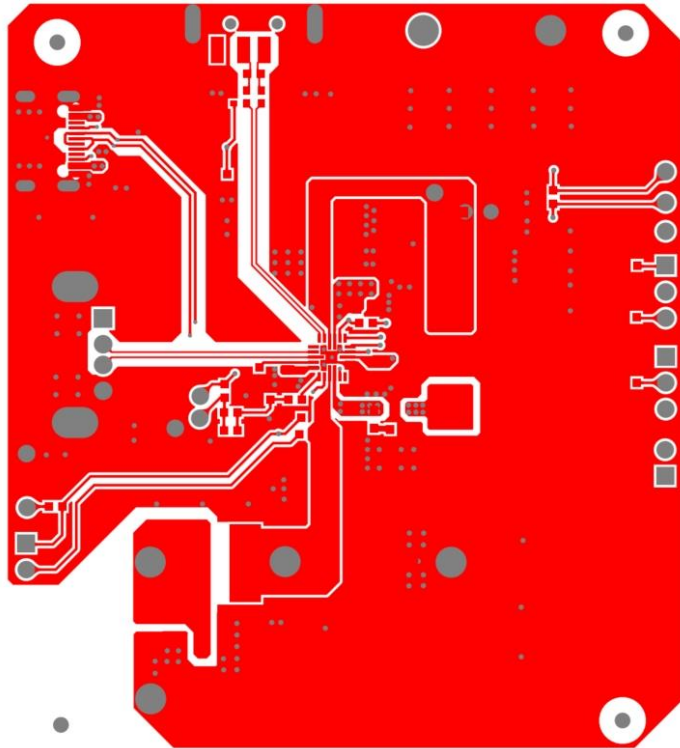
Equation (9) can be used to calculate resistor values and **Equation (10)** can be used to calculate hysteresis after resistors are selected. V_{IN_R} is the input rising voltage for start-up and V_{IN_HYS} is the hysteresis.



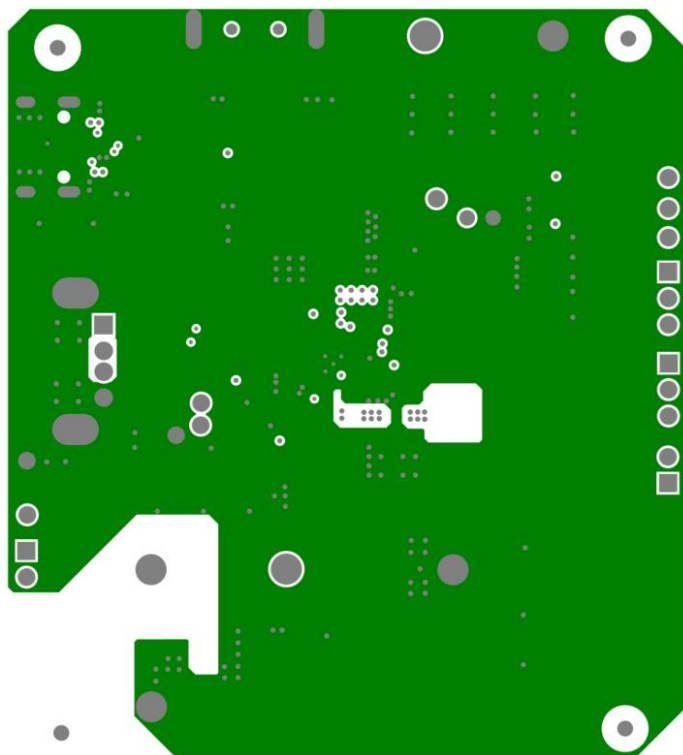
12 Layout Guide

The PCB layout is critical to get the optimal performance and thermal dissipation. For SC81532Q, the loop consisting of VIN-SW-GND and VIN-SW-USB_IN is the most important. Poor layout means larger parasitic parameters and noise. Generally, to reduce the PCB inductance, the area of this loop must be small, and the trace must be wide. **Figure 12-1** shows a recommended layout.

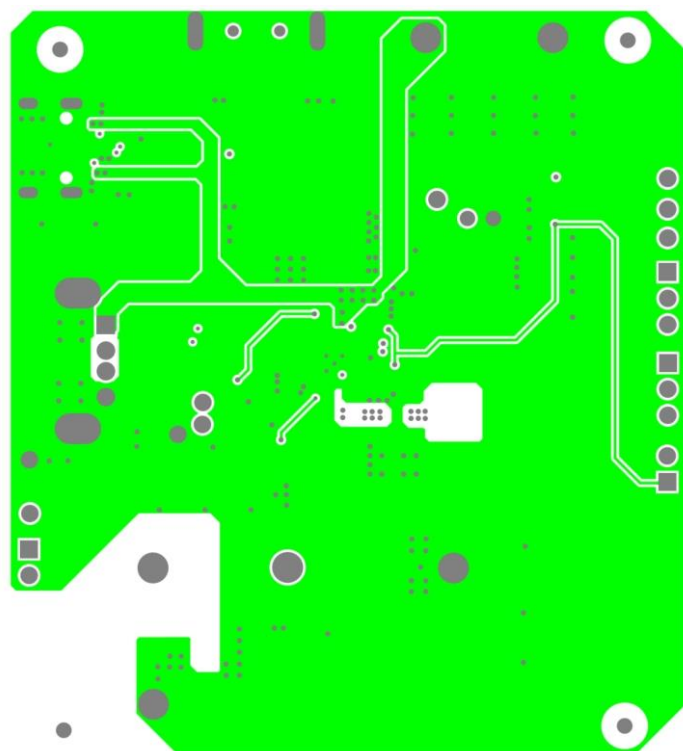
1. Place the ceramic input capacitors as close to VIN pin and GND as possible, especially the small package size (recommend 0603) input bypass capacitor.
2. The VIN, USB_IN and GND paths must be wide and short enough to reduce any voltage drops on the input or output paths of the converter.
3. Place the VCC/BIAS capacitor as close to the VCC/BIAS pin.
4. The VCC/BIAS and GND paths must be as wide and short as possible. More vias should be placed near GND of C_{VCC}/C_{BIAS} .
5. Recommend to connect a large ground plane to GND on all layers. Add vias near GND if there are several ground planes on different layers.
6. Place SW and BOOT away from sensitive analog areas, such as FB.
7. The area of SW and BOOT should be small to reduce EMC noise.
8. If an R_{BOOT} resistor is used, place it as close as possible to BOOT pins. If high efficiency is desired, R_{BOOT} can be shorted.



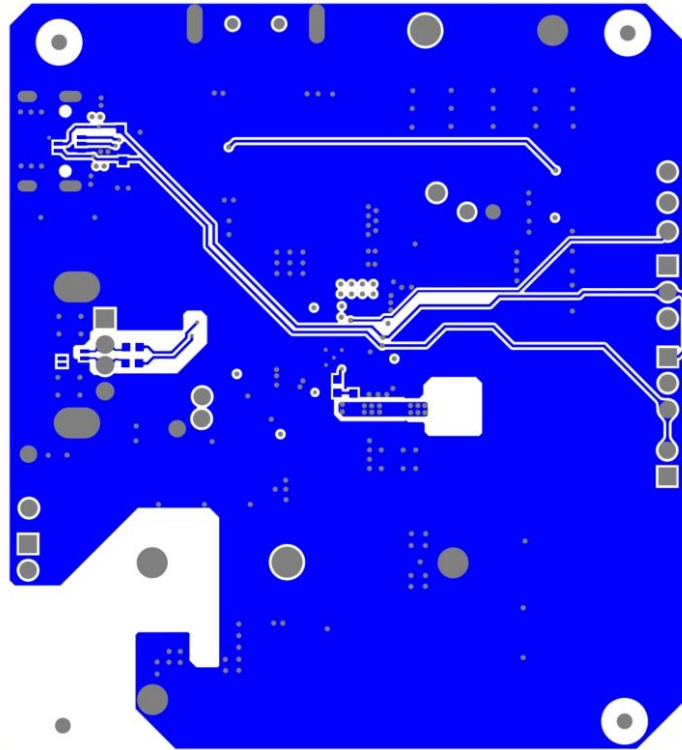
(a) Top Layer



(b) GND1 Layer



(c) GND2 Layer

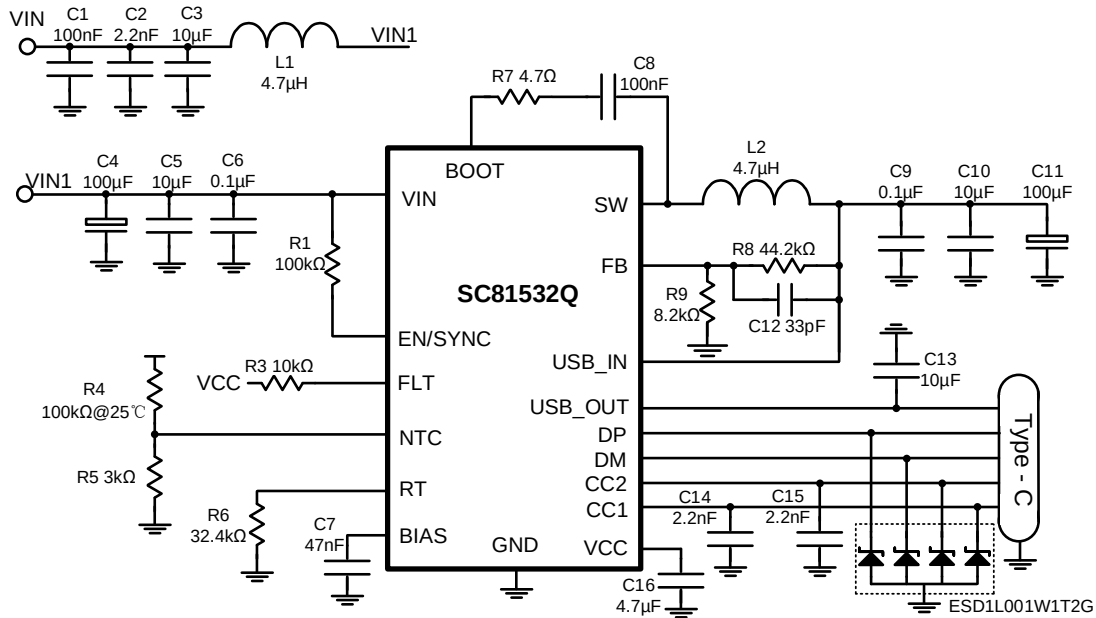
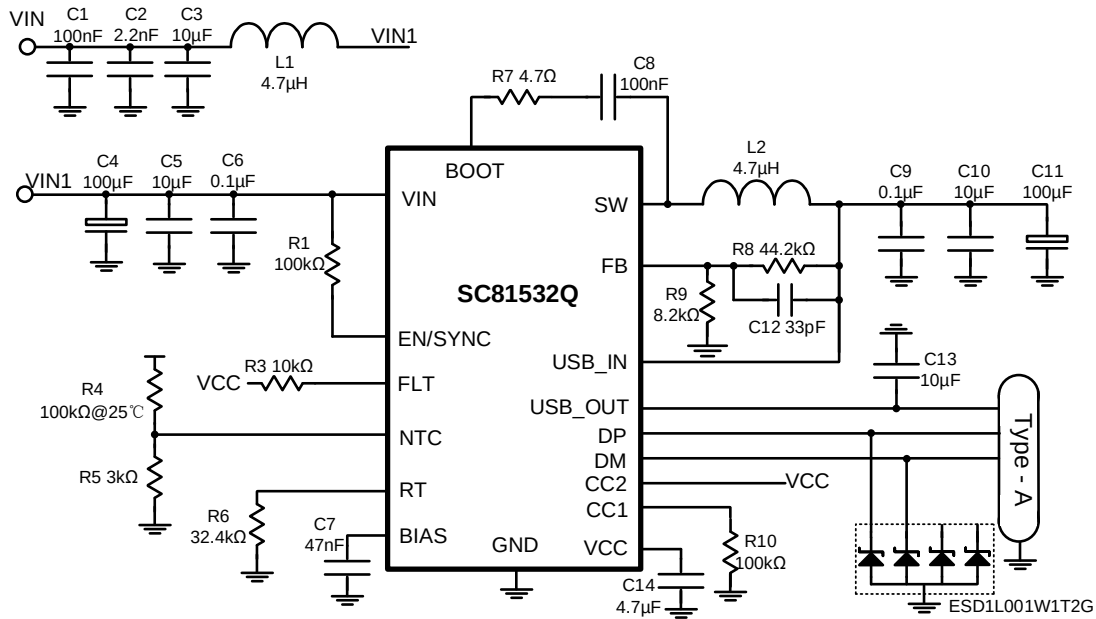


(d) Bottom Layer

Figure 12-1 Layout Example



13 Typical Application Circuits

Figure 13-1 $V_{IN}=12V$, $V_{OUT}=5V$, $I_{OUT}=3A$, $F_{SW}=400KHz$, Type-C DFP ModeFigure 13-2 $V_{IN}=12V$, $V_{OUT}=5V$, $I_{OUT}=2.4A$, $F_{SW}=400KHz$, Type-A DFP Mode

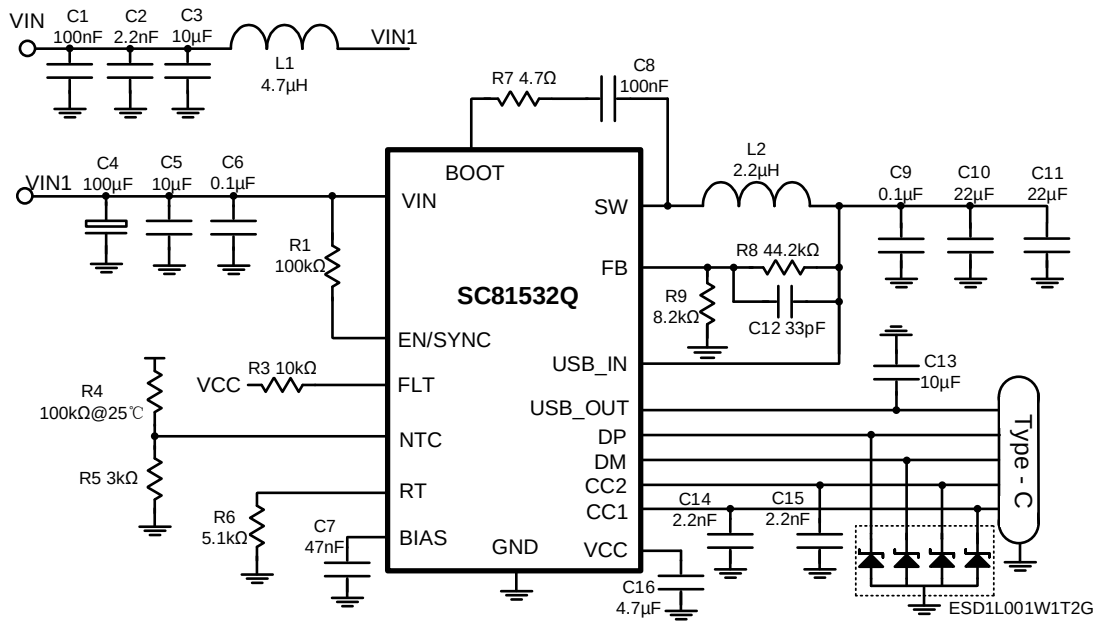


Figure 13-3 $V_{IN}=12V$, $V_{OUT}=5V$, $I_{OUT}=3A$, $F_{SW}=2.2MHz$, Type-C DFP Mode

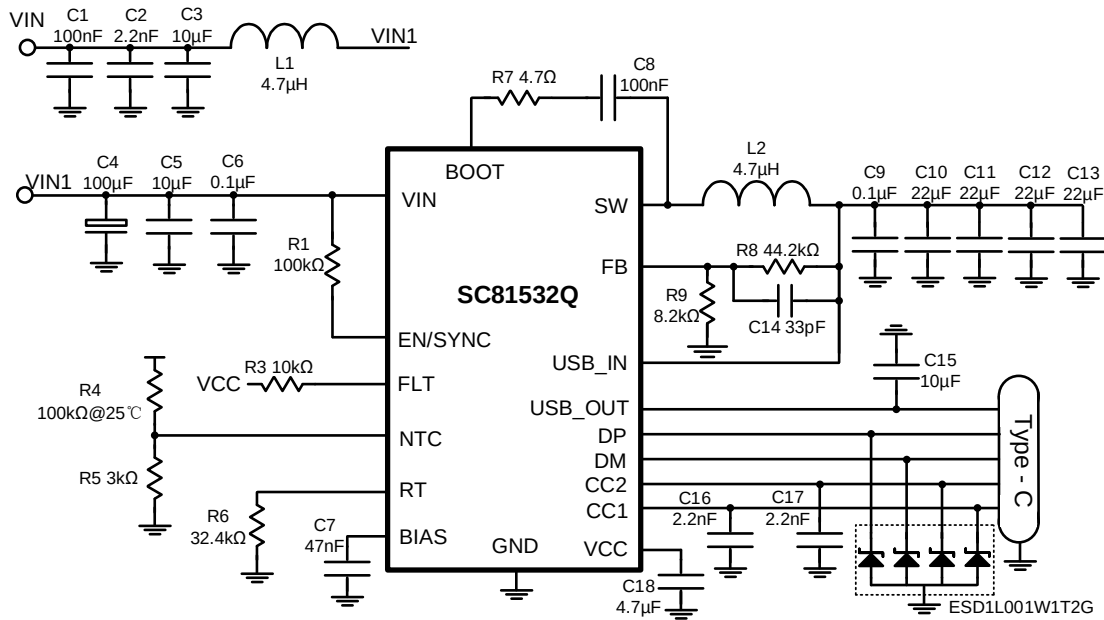
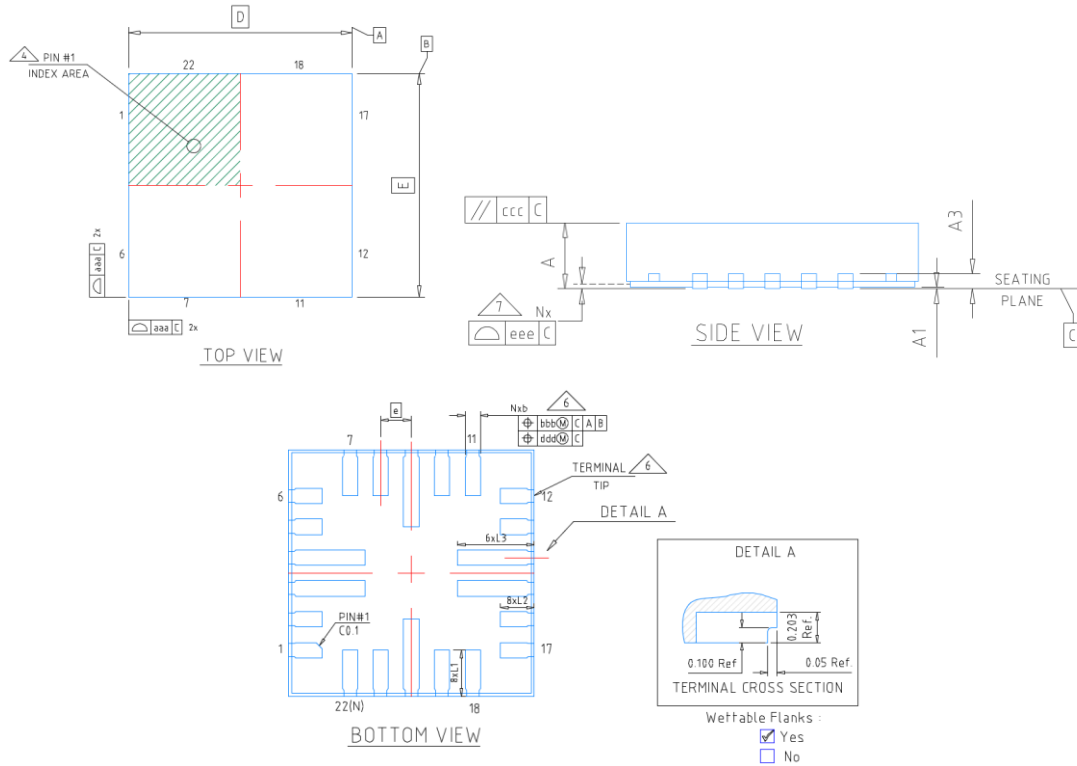


Figure 13-4 $V_{IN}=12V$, $V_{OUT}=5V$, $I_{OUT}=3A$, $F_{SW}=400KHz$, Type-C DFP Mode (with 22μF MLCC)



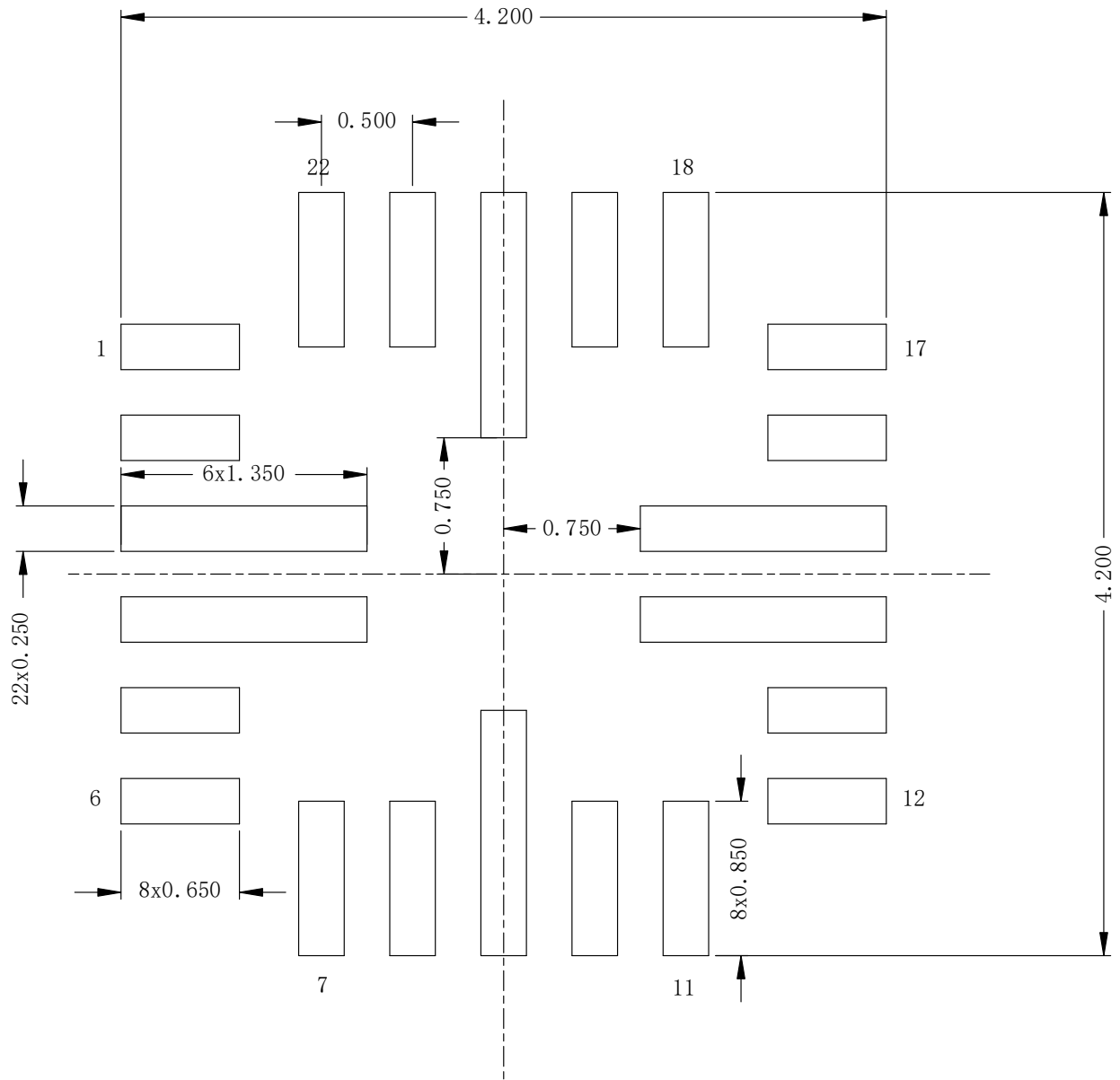
MECHANICAL DATA



Dimension Table			
Thickness Symbol	V		
	MINIMUM	NOMINAL	MAXIMUM
A	0.80	0.90	1.00
A1	0.00	0.02	0.05
A3	---	0.203 Ref.	---
b	0.20	0.25	0.30
D	3.90	4.00	4.10
E	3.90	4.00	4.10
e	0.50 BSC		
L1	0.65	0.75	0.85
L2	0.45	0.55	0.65
L3	1.15	1.25	1.35
aaa	0.05		
bbb	0.10		
ccc	0.10		
ddd	0.05		
eee	0.08		

Unit:mm

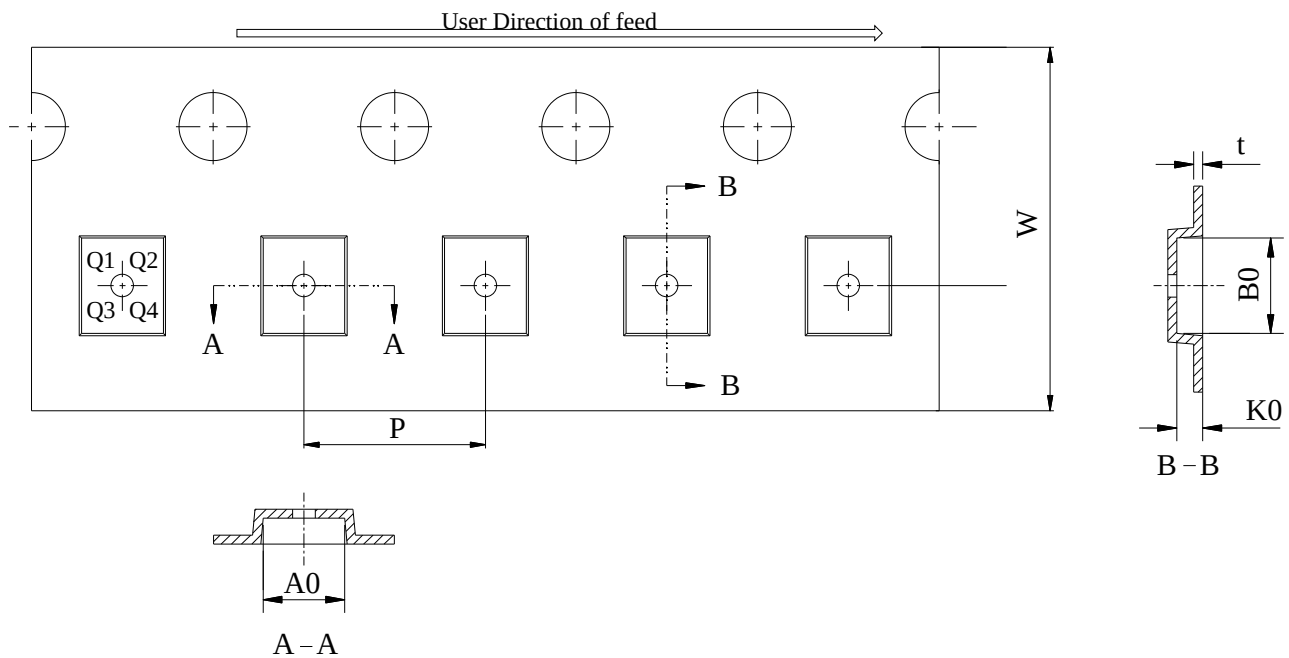
RECOMMENDED FOOTPRINT



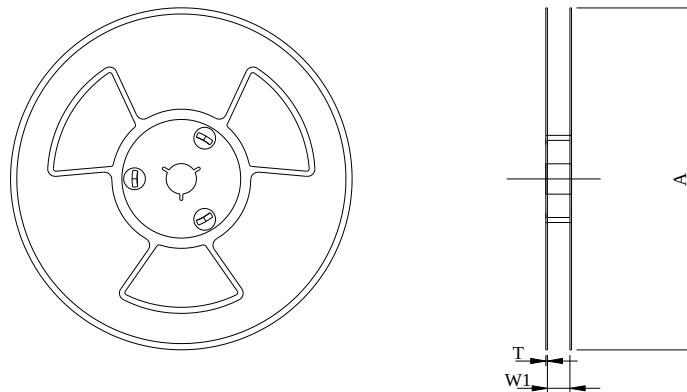
Unit:mm



TAPE AND REEL INFORMATION

Carrier Tape

Item	W	P	A0	B0	K0	t	Pin1 Quadrant
Size (mm)	12.00 +0.30/-0.10	8.00 ±0.10	4.30 ±0.10	4.30 ±0.10	1.10 ±0.10	0.30 ±0.03	Q1

REEL

Item	A	W1	T
Size (mm)	330 ±2	12.4 +2/-0	2.1 ±0.15



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