SQ76002B/SQ76002C

High Efficiency, 2A, 2.5V- 5.5V Input Synchronous Step Down DC/DC converter

General Description

The SQ76002B and SQ76002C belong to the same series of high efficiency 2.2MHz synchronous step down DC/DC converter module, which have capability of delivering up to 2A output current. That can operate over a wide input voltage range from 2.5V to 5.5V. The SQ76002B and SQ76002C integrate main switch, synchronous switch and inductor inside to minimize the conduction loss.

This device series are in a space saving, low profile MDFN1.9×1.75-6 package. Only input capacitors, output capacitor and FB resistor divider are needed to complete the design.

Applications

- Portable Electronic
- Industrial PC
- Smart Phone
- Optical Module
- Space-Constraint Systems

Features

- 2.5 to 5.5V Input Voltage Range
- Capable of 2A constant output current
- Compact Package: MDFN1.9×1.75-6 (Height:1.08mm max)
- Accurate ±1.5% Output Voltage Accuracy (Full Temperature Range)
- PFM/FCCM under light load condition:
  - SQ76002BAEE: PFM
  - SQ76002CAEE: FCCM
- Internal Soft-start Limits the Inrush Current
- 100% Duty Cycle Operation
- Output Auto Discharge Function
- Power Good Indicator
- Reliable Protection Mode:
  - Auto-retry Mode for OVP, UVLO and OTP.
  - Hiccup Mode for OCP
- RoHS Compliant and Halogen Free

Typical Applications

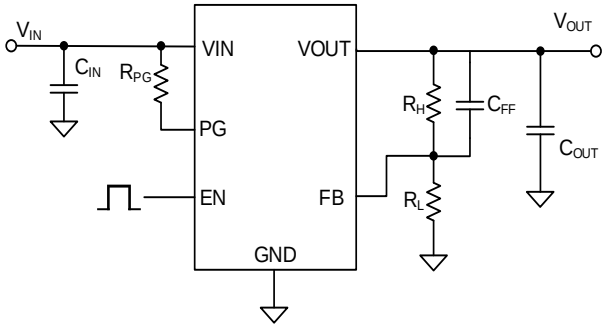

Figure 1. Schematic Diagram

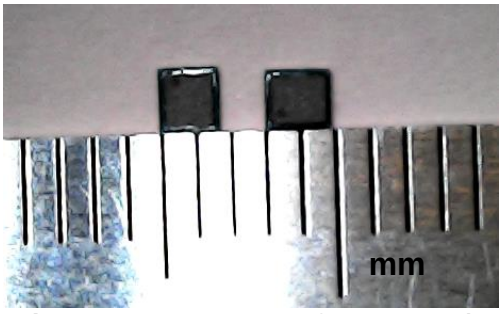

Figure 2. Appearance Of SQ76002B/C

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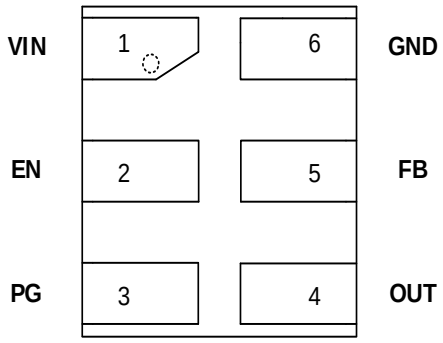
Ordering Information

Ordering Number	Operating Mode Under Light Load	Package Type
SQ76002BAEE	PFM	MDFN1.9×1.75-6
SQ76002CAEE	FCCM	

Pinout (top view)



Pin Name	Pin Number	Pin Description
VIN	1	Power supply input. Connect a minimum of 10μF ceramic capacitor from VIN to GND.
EN	2	Enable control. Pull high to enable the device, pull low to disable the device. Do not leave this pin floating.
PG	3	Power good indicator. Open drain output. Low if the V_{FB} < 92% or the V_{FB}>108.5% of V_{REF}; high otherwise. Connect a pull-up resistor to the input.
OUT	4	Output pin. Decouple this pin to the GND pin with at least a 22 μF ceramic capacitor
FB	5	Output feedback pin. Connect to the center point of resistor divider.
GND	6	Ground pin.

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Block Diagram

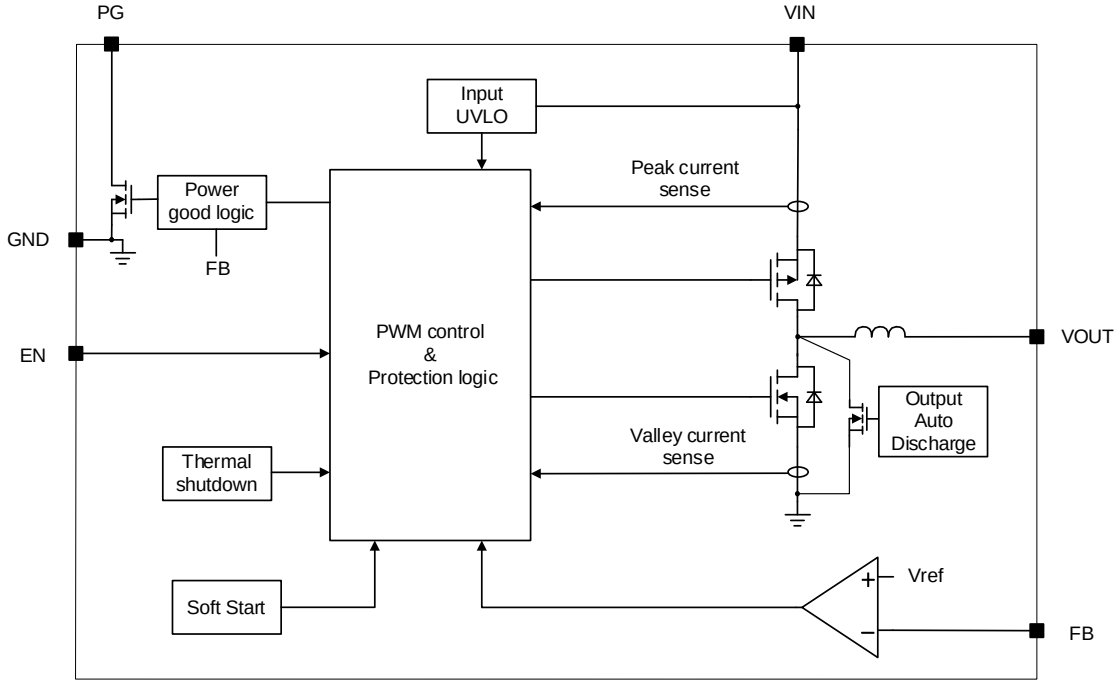

Figure 3.block diagram

Absolute Maximum Ratings (Note 1)

Parameter (Note 1)	Min	Max	Unit
VIN	-0.3	6	V
EN, PG, FB	-0.3	VIN + 0.6	
Junction Temperature, Operating	-40	125	°C
Lead Temperature (Soldering,10sec.)		260	
Storage Temperature	-55	125	

Thermal Information

Parameter (Note 2)	Typ	Unit
θ_{JA} Junction-to-Ambient Thermal Resistance	46.5	°C/W
Ψ_{JB} Junction-to-Board Thermal Resistance	35.7	
P_D Power Dissipation T_A = 25°C	1.93	W

Recommended Operating Conditions

Parameter (Note 3)	Min	Max	Unit
Supply Input Voltage	2.5	5.5	V
Output Voltage	0.6	VIN	
Output Current (Note 4)	0	2	A

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Electrical Characteristics

(V_{IN} =3.3V, V_{OUT} = 1.8V, I_{OUT}=2A, C_{OUT} = 22μF, Typical value correspond to T_J=25°C, unless otherwise specified (Note 5))

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Input Specifications						
Input Voltage Range	V_{IN}		2.5		5.5	V
Input UVLO Threshold (rising)	V_{UVLO}		2.2	2.35	2.5	V
Input UVLO Hysteresis	V_{HYS}			0.16		V
Input Current With No Load(Note 6)	I_{IN}	SQ76002C， I_{OUT}=0A		17	23	mA
Shutdown Current	I_{SHDN}	V_{EN}=0V,T_A=25°C		0.05	0.5	μA
Quiescent Current	I_Q	V_{FB}=V_{REF}x105%, V_{EN}=2V,V_{OUT}=1.3V		21		μA
Output Specifications						
Feedback Reference Voltage	V_{REF}	T_J= 25°C, CCM	0.594	0.6	0.606	V
		T_J = -40~125°C, CCM	0.591	0.6	0.609	V
Load Regulation(Note 6)		V_{IN}=3.3V,T_A=25°C, I_{OUT}=1-2A			±1	%
Line Regulation(Note 6)		V_{IN}=2.5-5V,T_A=25°C, I_{OUT}=1A			±1	%
Temperature Regulation (Note 6)		V_{IN}=3.3V, T_A=-40°C to 85°C, I_{OUT}=1A			±2	%
Bottom MOSFET Current Limit	I_{LIMT}		2.5			A
Bottom MOSFET Negative Current Limit	I_{NEG}			1.1		A
Soft Start Time	t_{SS}	From 10% to 95% of Output Set-Point	0.5	1.1	2	ms
General Specifications						
Switching Frequency	f_{SW}	I_{OUT}=2A,CCM	1.6	2.2	2.7	MHz
Thermal Shutdown Temperature	T_{SD}	OTP mode: Auto recovery		150		°C
Thermal Shutdown Hysteresis	T_{HYS}			20		°C
Minimum ON Time (Note 6)	$t_{ON,MIN}$			50		ns
Maximum Duty Cycle (Note 6)	D_{MAX}		100			%
Signal Specifications						
EN Input Voltage High	$V_{EN,H}$		1			V
EN Input Voltage Low	$V_{EN,L}$				0.4	V
Power Good Thresold	V_{PG}	V_{FB} rising, PG from low to high	92.5	95.5	99	%VREF
		V_{FB} rising, PG from high to low	105	108.5	112	%VREF
		V_{FB} falling, PG from low to high	101	104	107	%VREF
		V_{FB} falling, PG from high to low	88	92	94	%VREF

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Power Good Delay	$t_{PG,R}$	Low to High		100		μs
	$t_{PG,F}$	High to Low		20		μs
Power Good Output Low	$V_{PG,L}$	I_{PG}=10mA			0.4	V
PG High Leakage Current	$I_{PG,LKG}$	V_{PG}=5.5V		0.01	1	μA

Note 1: Stresses beyond the “Absolute Maximum Ratings” may cause permanent damage to the device. These are stress ratings only. Functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Note 2: θ_{JA} and Ψ_{JB} are based on a four-layer Silergy Evaluation Board (1.6mm thickness, 2OZ copper, 95% copper coverage) in the natural convection at T_A = 25°C. Ambient temperature (T_A) refers to the air temperature 0.5 inch above IC. Junction temperature (T_J) refers to the hottest device, which is inductor temperature and case temperature (T_C) as well for this product. Board temperature (T_B) refers to the PCB point to the hottest IC pin with a 1mm distance on the same PCB surface layer.

Note 3: The device is not guaranteed to function outside its operating conditions.

Note 4: Please refer to the Thermal Derating Curve to get the maximum output current under different ambient temperatures.

Note 5: Production testing is performed at 25˚C; limits at -40°C to +125°C are guaranteed by design, test or statistical correlation.

Note 6: The values are guaranteed by design, no production tested.

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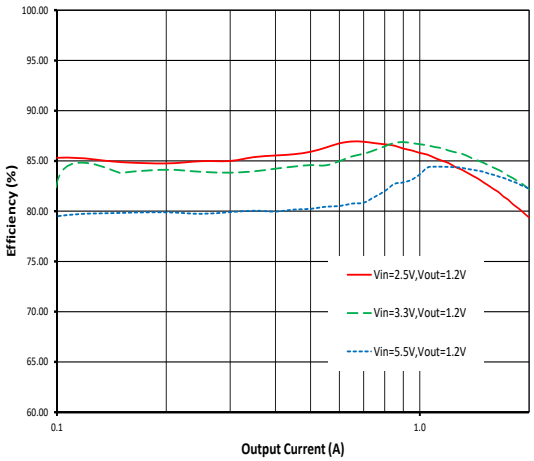
Typical Performance Characteristics

(T_A=25℃, C_{OUT}=22μF, resistor tolerance is ±1%, unless otherwise specified.)

SQ76002B

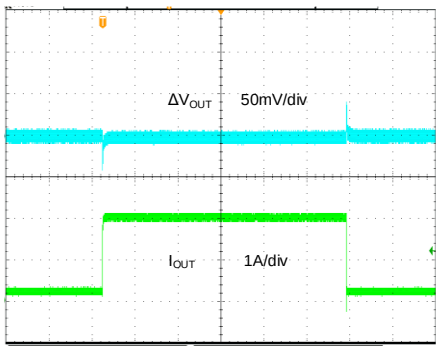
V_{OUT}=1.2V

Efficiency vs Output Current



Load Transient

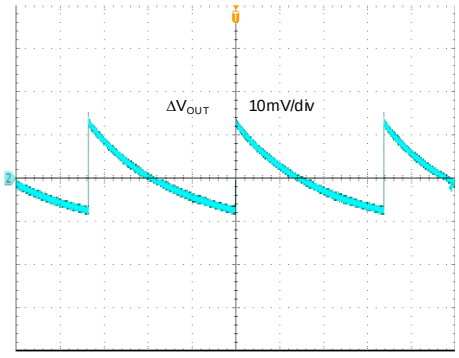
(V_{IN}=3.3V, V_{OUT}=1.2V, I_{LOAD}=0.2A~2A)



Time (400μs/div)

Output Ripple

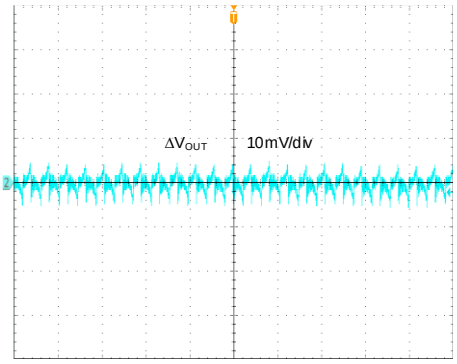
(V_{IN}=3.3V, V_{OUT}=1.2V, I_{OUT}=0A)



Time (10ms/div)

Output Ripple

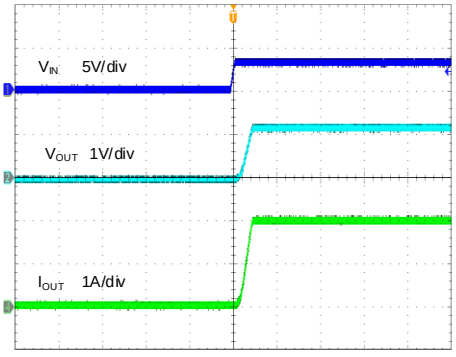
(V_{IN}=3.3V, V_{OUT}=1.2V, I_{OUT}=2A)



Time (1μs/div)

Startup from V_{IN}

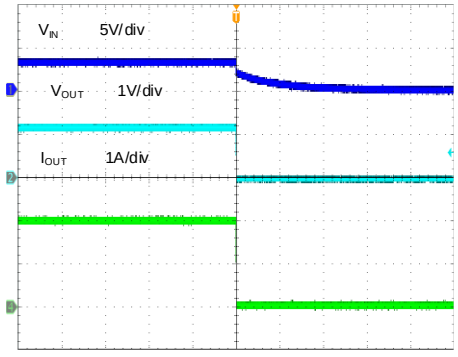
(V_{IN}=3.3V, V_{OUT}=1.2V, I_{OUT}=2A)



Time (4ms/div)

Shutdown from V_{IN}

(V_{IN}=3.3V, V_{OUT}=1.2V, I_{OUT}=2A)



Time (10ms/div)

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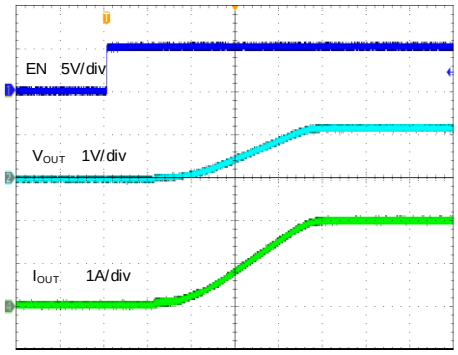
Startup from EN

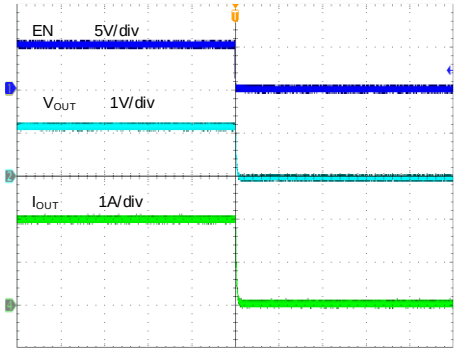
(V_{IN}=3.3V, V_{OUT}=1.2V, I_{OUT}=2A)



Time (400μs/div)

Shutdown from EN

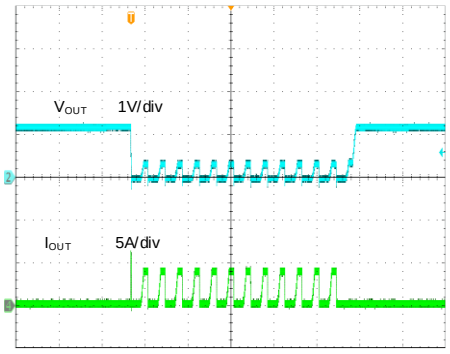
(V_{IN}=3.3V, V_{OUT}=1.2V, I_{OUT}=2A)



Time (400μs/div)

Short Circuit Protection

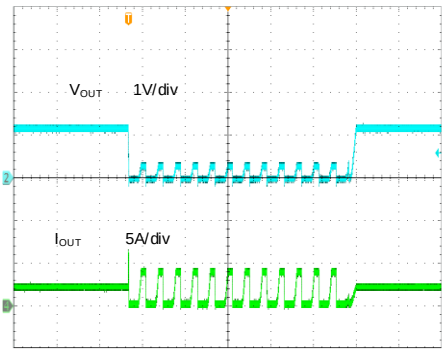
(V_{IN}=3.3V, V_{OUT}=1.2V, I_{OUT}=0A-Short)



Time (10ms/div)

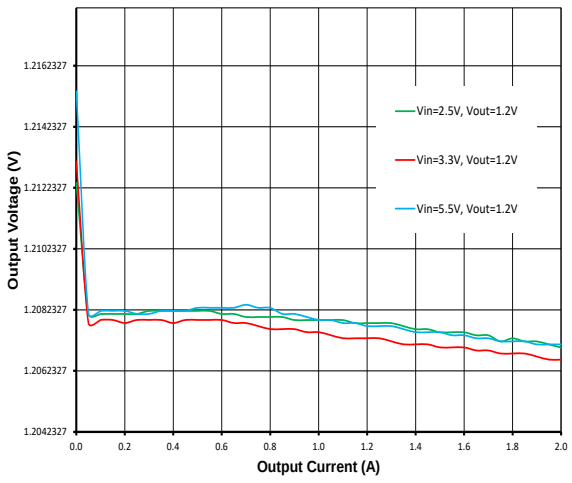
Short Circuit Protection

(V_{IN}=3.3V, V_{OUT}=1.2V, I_{OUT}=2A-Short)



Time (10ms/div)

Load Regulation



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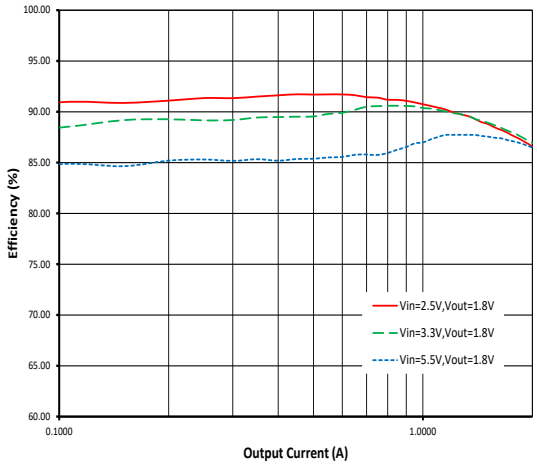
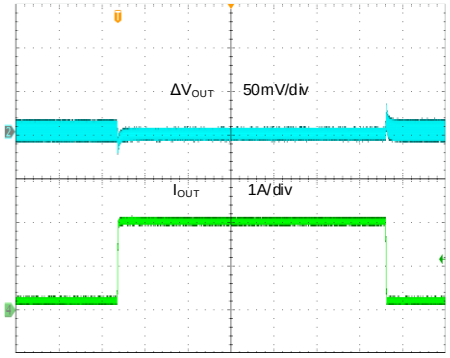
V_{OUT}=1.8V

Efficiency vs Output Current



Load Transient

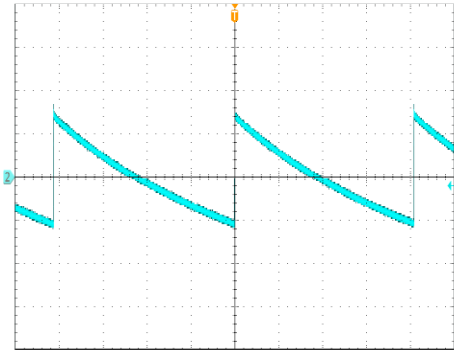
(V_{IN}=3.3V, V_{OUT}=1.8V, I_{LOAD}=0.2A~2A)



Time (400μs/div)

Output Ripple

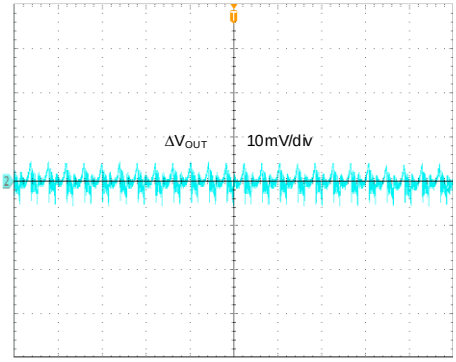
(V_{IN}=3.3V, V_{OUT}=1.8V, I_{OUT}=0A)



Time (4ms/div)

Output Ripple

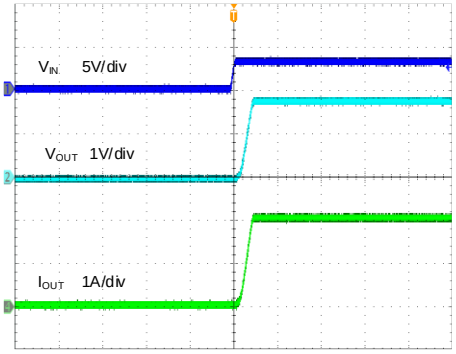
(V_{IN}=3.3V, V_{OUT}=1.8V, I_{OUT}=2A)



Time (1μs/div)

Startup from V_{IN}

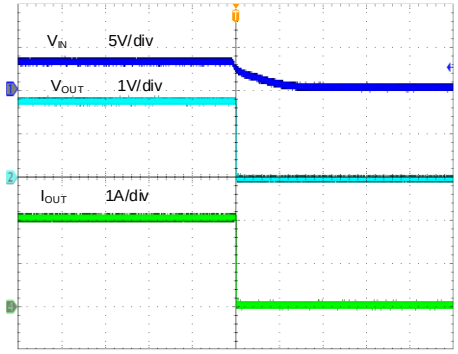
(V_{IN}=3.3V, V_{OUT}=1.8V, I_{OUT}=2A)



Time (4ms/div)

Shutdown from V_{IN}

(V_{IN}=3.3V, V_{OUT}=1.8V, I_{OUT}=2A)



Time (10ms/div)

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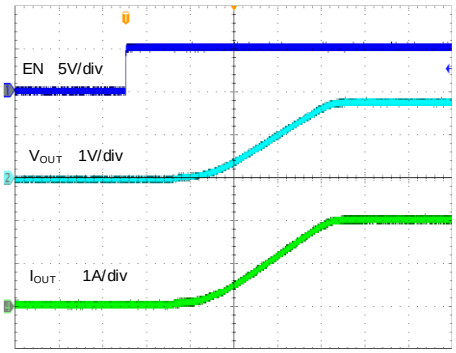
Startup from EN

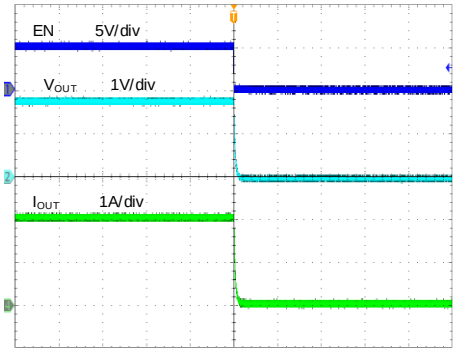
(V_{IN}=3.3V, V_{OUT}=1.8V, I_{OUT}=2A)



Time (400μs/div)

Shutdown from EN

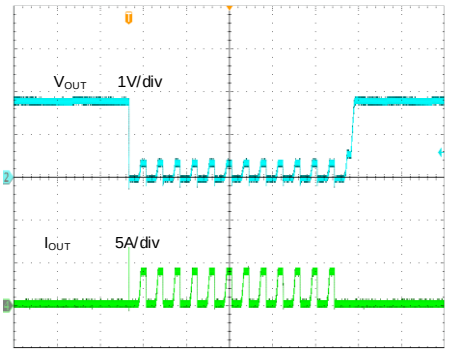
(V_{IN}=3.3V, V_{OUT}=1.8V, I_{OUT}=2A)



Time (400μs/div)

Short Circuit Protection

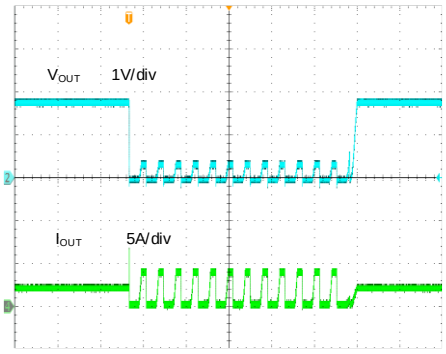
(V_{IN}=3.3V, V_{OUT}=1.8V, I_{OUT}=0A-Short)



Time (10ms/div)

Short Circuit Protection

(V_{IN}=3.3V, V_{OUT}=1.8V, I_{OUT}=2A-Short)



Time (10ms/div)

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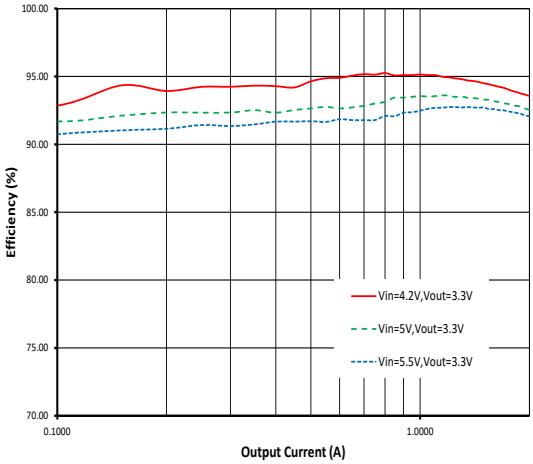
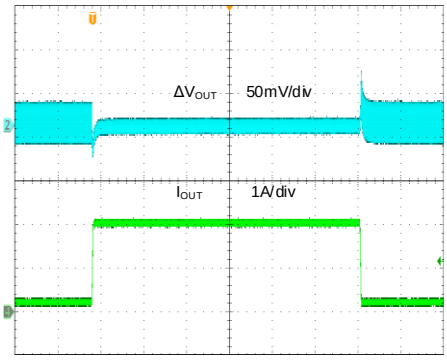
V_{OUT}=3.3V

Efficiency vs Output Current



Load Transient

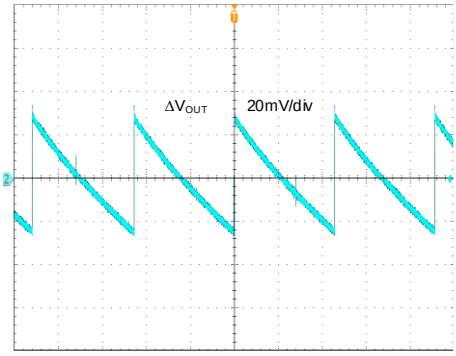
(V_{IN}=5V, V_{OUT}=3.3V, I_{LOAD}=0.2A~2A)



Time (400μs/div)

Output Ripple

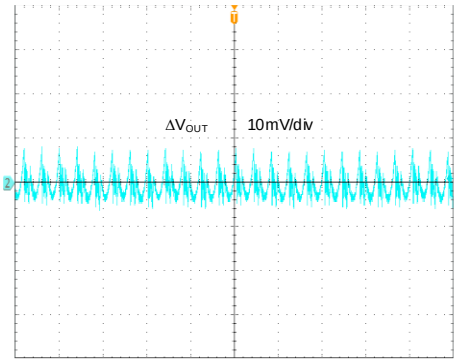
(V_{IN}=5V, V_{OUT}=3.3V, I_{OUT}=0A)



Time (4ms/div)

Output Ripple

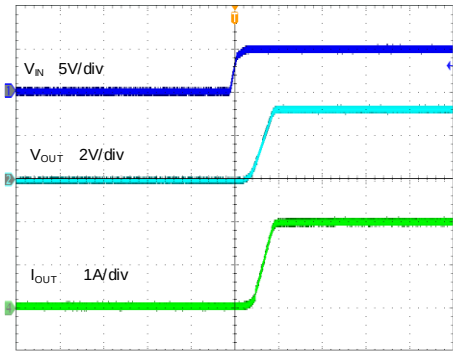
(V_{IN}=5V, V_{OUT}=3.3V, I_{OUT}=2A)



Time (1μs/div)

Startup from V_{IN}

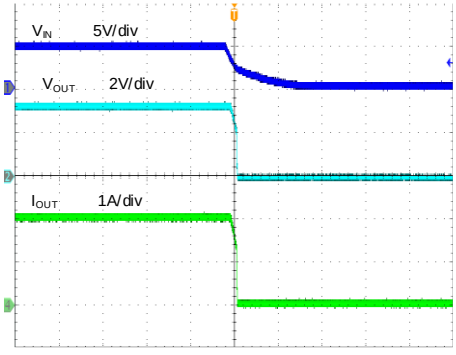
(V_{IN}=5V, V_{OUT}=3.3V, I_{OUT}=2A)



Time (2ms/div)

Shutdown from V_{IN}

(V_{IN}=5V, V_{OUT}=3.3V, I_{OUT}=2A)



Time (10ms/div)

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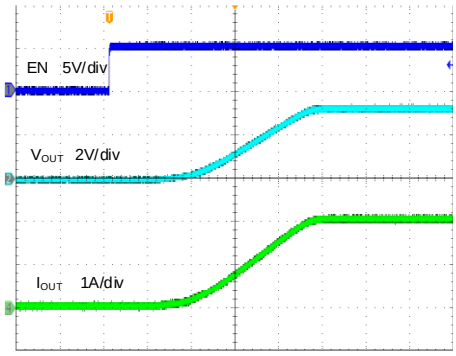
Startup from EN

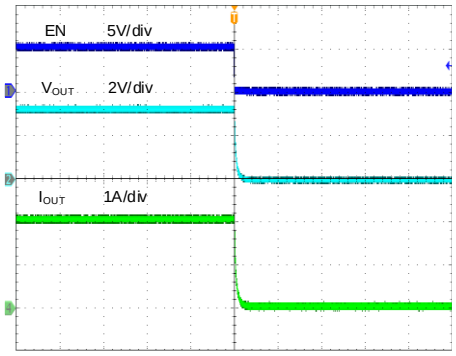
(V_{IN}=5V, V_{OUT}=3.3V, I_{OUT}=2A)



Time (400μs/div)

Shutdown from EN

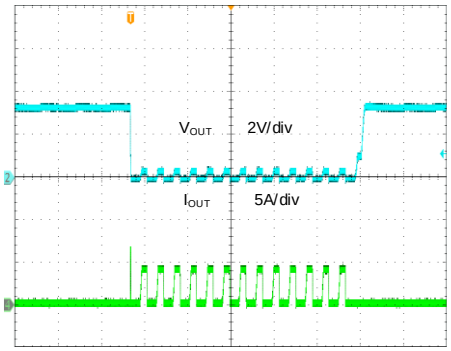
(V_{IN}=5V, V_{OUT}=3.3V, I_{OUT}=2A)



Time (400μs/div)

Short Circuit Protection

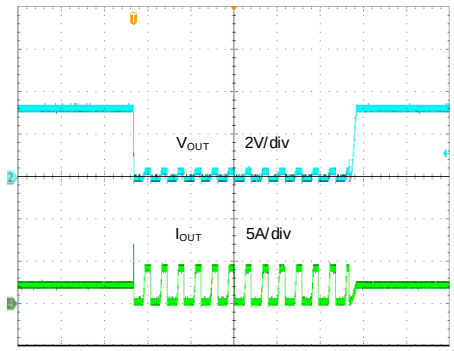
(V_{IN}=5V, V_{OUT}=3.3V, I_{OUT}=0A-Short)



Time (10ms/div)

Short Circuit Protection

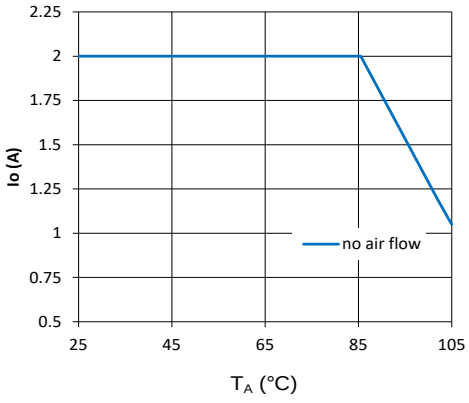
(V_{IN}=5V, V_{OUT}=3.3V, I_{OUT}=2A-Short)



Time (10ms/div)

Thermal Derating

Curve@V_{IN}=3.3V,V_{OUT}=1.8V



1) T_A: Air temperature, 0.5 inch above IC.

2) Based on a four-layer 8cm × 8cm Silergy Evaluation Board in the natural convection. Board thickness:1.6mm, copper thickness:2oz, copper coverage:95%.

3) The inductor surface temperature is not beyond 115℃ under this TD curve.

4) For customer's specific application, the recommended inductor surface temperature limitation is 115℃.

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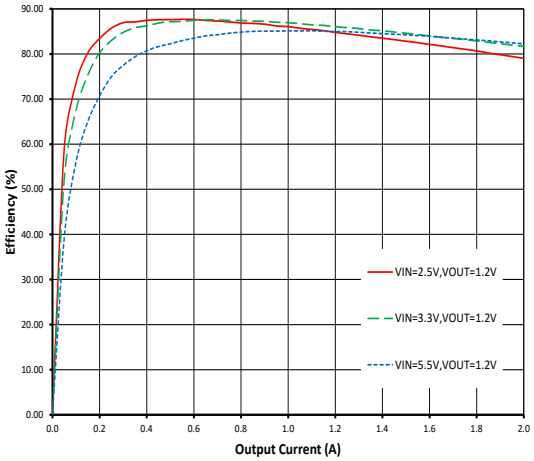
SQ76002C

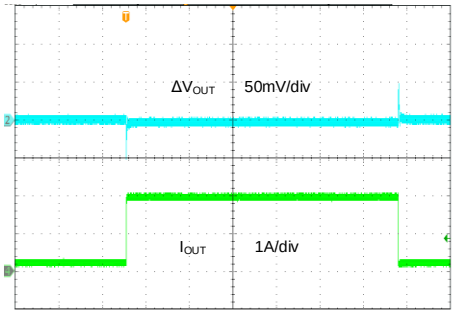
V_{OUT}=1.2V

Efficiency vs Output Current



Load Transient

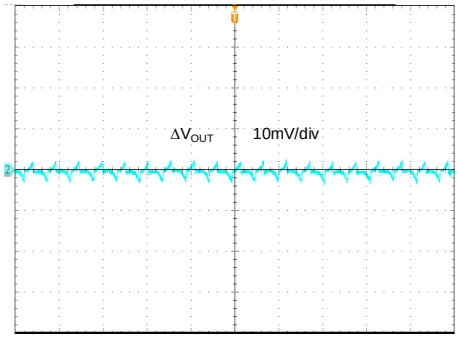
(V_{IN}=3.3V, V_{OUT}=1.2V, I_{LOAD}=0.2A~2A)



Time (400μs/div)

Output Ripple

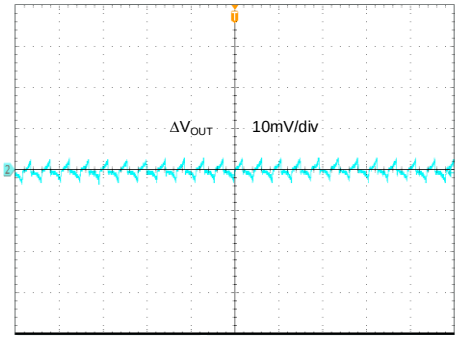
(V_{IN}=3.3V, V_{OUT}=1.2V, I_{OUT}=0A)



Time (1μs/div)

Output Ripple

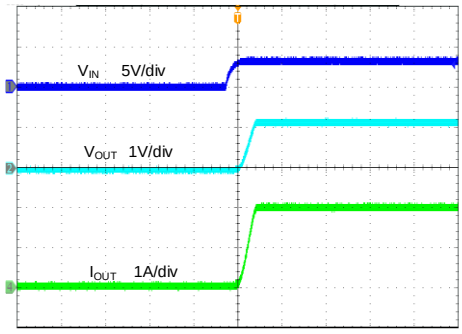
(V_{IN}=3.3V, V_{OUT}=1.2V, I_{OUT}=2A)



Time (1μs/div)

Startup from V_{IN}

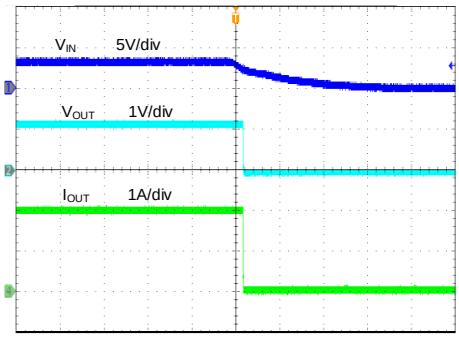
(V_{IN}=3.3V, V_{OUT}=1.2V, I_{OUT}=2A)



Time (4ms/div)

Shutdown from V_{IN}

(V_{IN}=3.3V, V_{OUT}=1.2V, I_{OUT}=2A)



Time (4ms/div)

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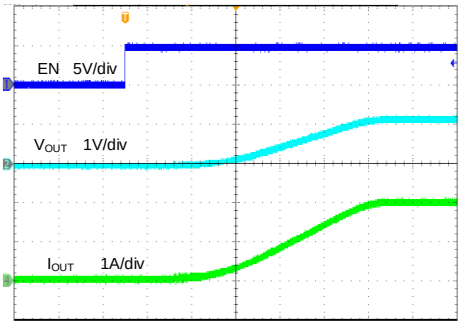
Startup from EN

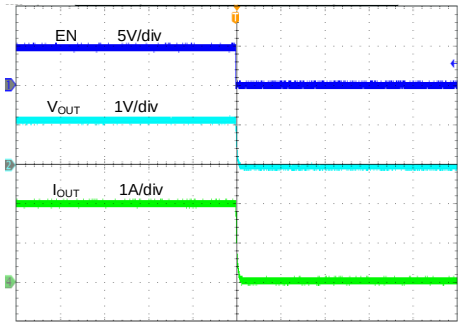
(V_{IN}=3.3V, V_{OUT}=1.2V, I_{OUT}=2A)



Time (400μs/div)

Shutdown from EN

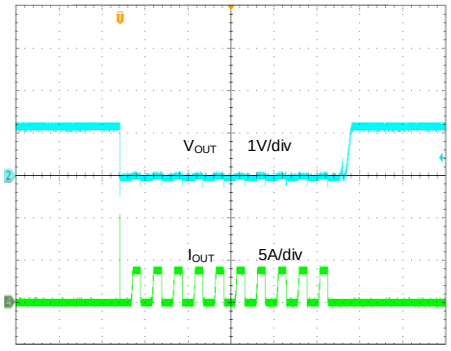
(V_{IN}=3.3V, V_{OUT}=1.2V, I_{OUT}=2A)



Time (400μs/div)

Short Circuit Protection

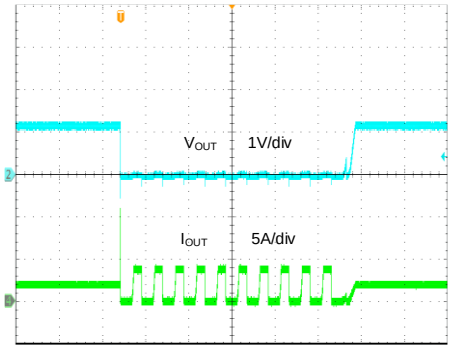
(V_{IN}=3.3V, V_{OUT}=1.2V, I_{OUT}=0A-Short)



Time (10ms/div)

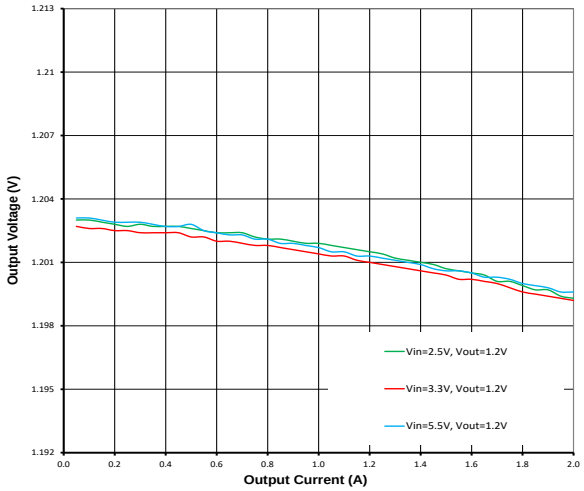
Short Circuit Protection

(V_{IN}=3.3V, V_{OUT}=1.2V, I_{OUT}=2A-Short)



Time (10ms/div)

Load Regulation



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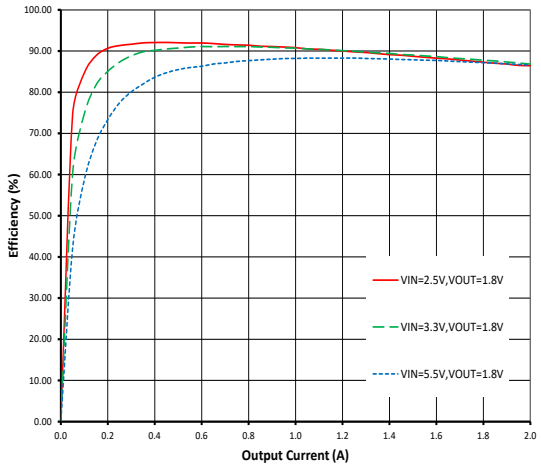
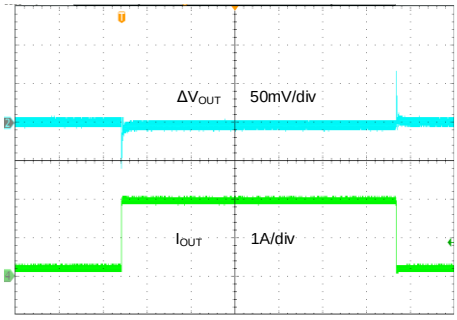
V_{OUT}=1.8V

Efficiency vs Output Current



Load Transient

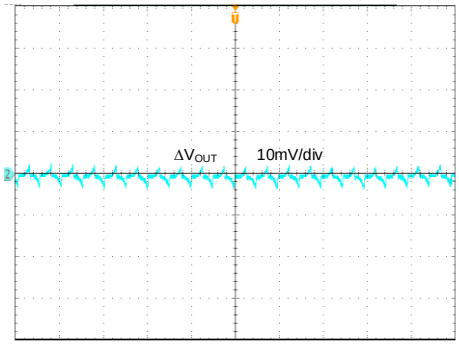
(V_{IN}=3.3V, V_{OUT}=1.8V, I_{LOAD}=0.2A~2A)



Time (400μs/div)

Output Ripple

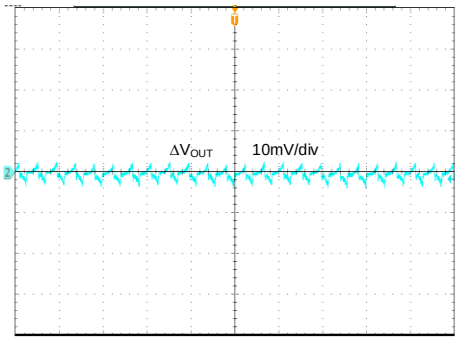
(V_{IN}=3.3V, V_{OUT}=1.8V, I_{OUT}=0A)



Time (1μs/div)

Output Ripple

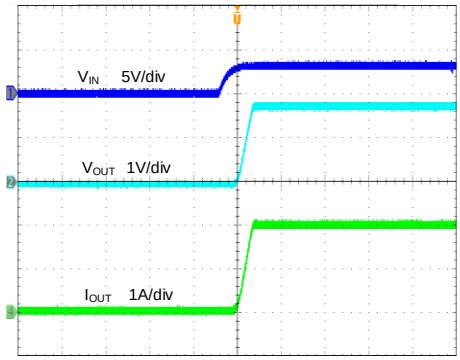
(V_{IN}=3.3V, V_{OUT}=1.8V, I_{OUT}=2A)



Time (1μs/div)

Startup from V_{IN}

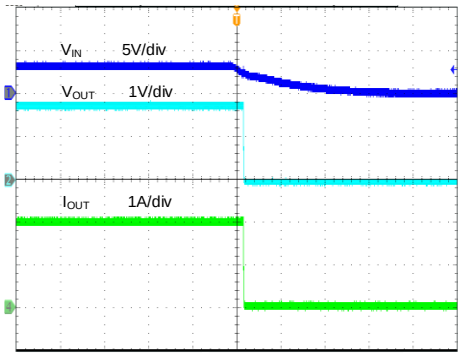
(V_{IN}=3.3V, V_{OUT}=1.8V, I_{OUT}=2A)



Time (4ms/div)

Shutdown from V_{IN}

(V_{IN}=3.3V, V_{OUT}=1.8V, I_{OUT}=2A)



Time (4ms/div)

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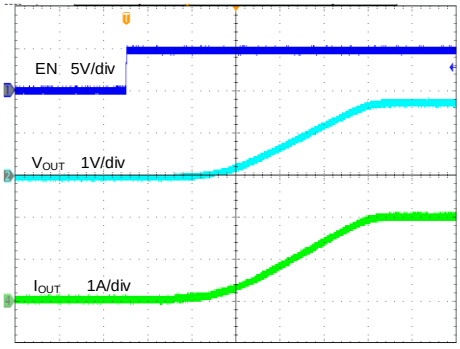
Startup from EN

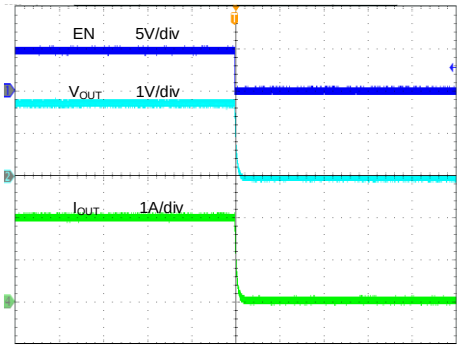
(V_{IN}=3.3V, V_{OUT}=1.8V, I_{OUT}=2A)



Time (400μs/div)

Shutdown from EN

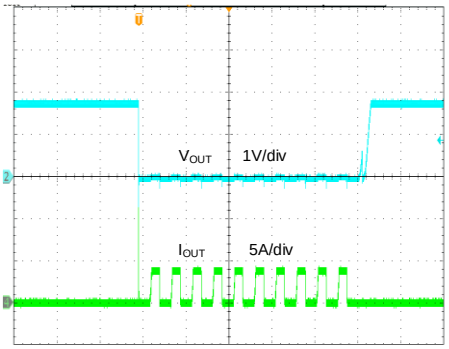
(V_{IN}=3.3V, V_{OUT}=1.8V, I_{OUT}=2A)



Time (400μs/div)

Short Circuit Protection

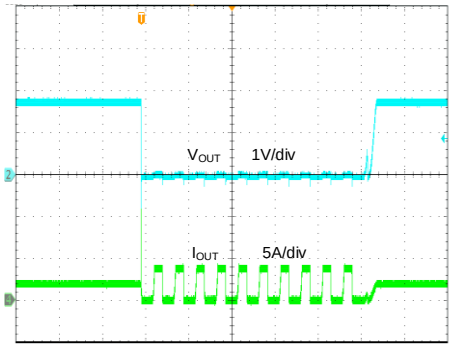
(V_{IN}=3.3V, V_{OUT}=1.8V, I_{OUT}=0A-Short)



Time (10ms/div)

Short Circuit Protection

(V_{IN}=3.3V, V_{OUT}=1.8V, I_{OUT}=2A-Short)



Time (10ms/div)

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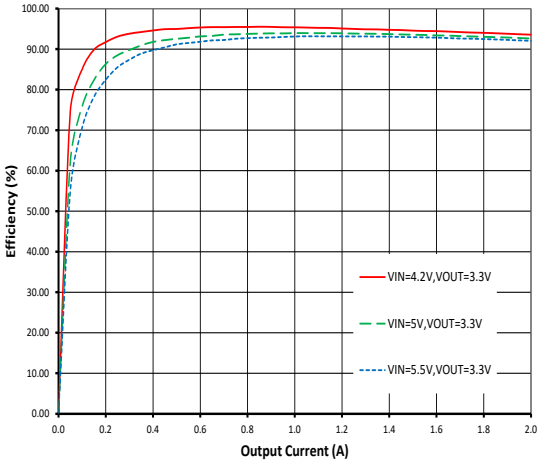
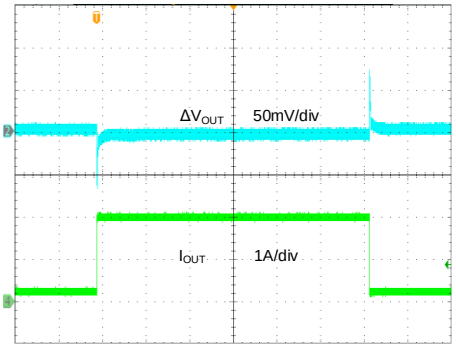
V_{OUT}=3.3V

Efficiency vs Output Current



Load Transient

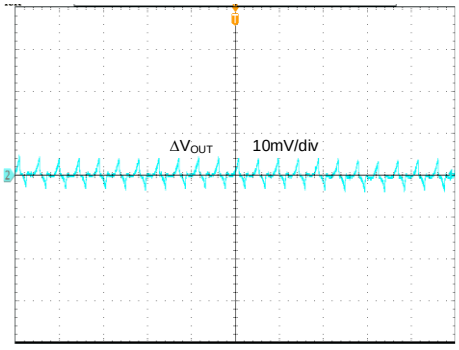
(V_{IN}=5V, V_{OUT}=3.3V, I_{LOAD}=0.2A~2A)



Time (400μs/div)

Output Ripple

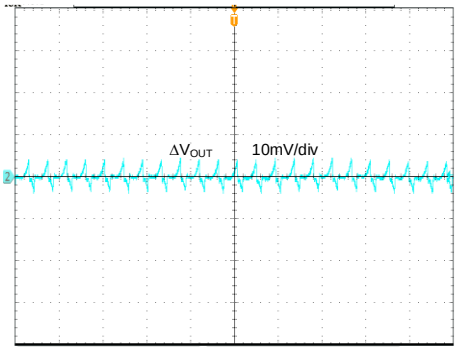
(V_{IN}=5V, V_{OUT}=3.3V, I_{OUT}=0A)



Time (1μs/div)

Output Ripple

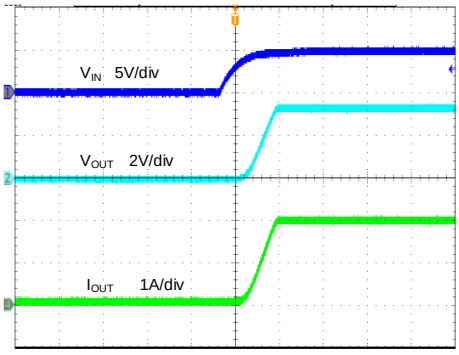
(V_{IN}=5V, V_{OUT}=3.3V, I_{OUT}=2A)



Time (1μs/div)

Startup from V_{IN}

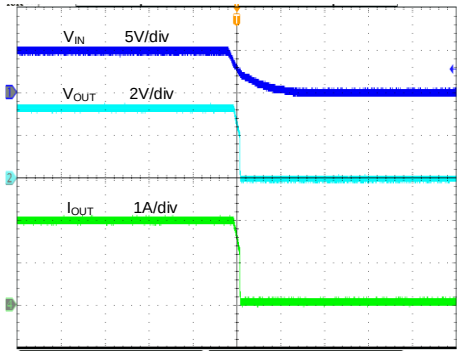
(V_{IN}=5V, V_{OUT}=3.3V, I_{OUT}=2A)



Time (2ms/div)

Shutdown from V_{IN}

(V_{IN}=5V, V_{OUT}=3.3V, I_{OUT}=2A)



Time (10ms/div)

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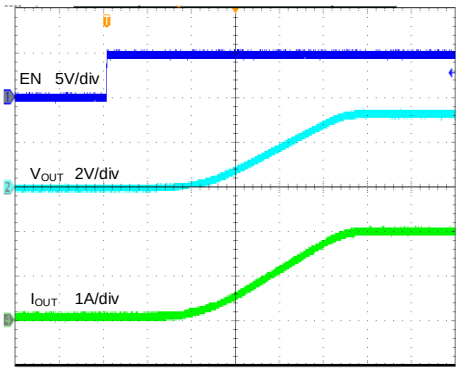
Startup from EN

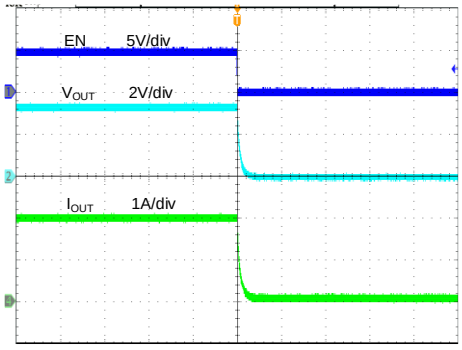
(V_{IN}=5V, V_{OUT}=3.3V, I_{OUT}=2A)



Time (400μs/div)

Shutdown from EN

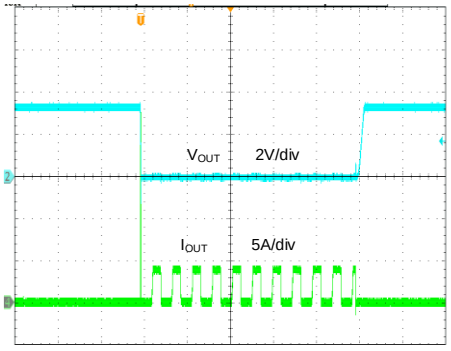
(V_{IN}=5V, V_{OUT}=3.3V, I_{OUT}=2A)



Time (400μs/div)

Short Circuit Protection

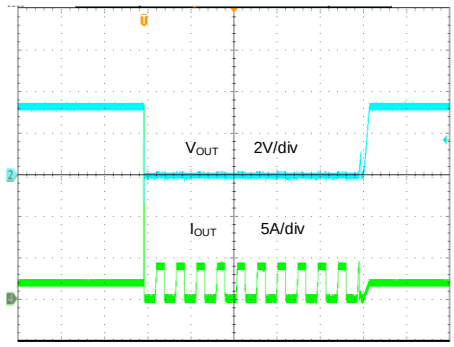
(V_{IN}=5V, V_{OUT}=3.3V, I_{OUT}=0A-Short)



Time (10ms/div)

Short Circuit Protection

(V_{IN}=5V, V_{OUT}=3.3V, I_{OUT}=2A-Short)



Time (10ms/div)

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Applications Information

Feedback Resistor Dividers R_H and R_L

Choose R_H and R_L to program the proper output voltage. To minimize the power consumption under light loads, it is desirable to choose large resistance values for both R_H and R_L. A value of between 10kΩ and 1MΩ is highly recommended for both resistors. If R_H is chosen, then R_L can be calculated to be:

$$R_L = \frac{0.6 \times R_H}{V_{OUT} - 0.6}$$

A feedforward capacitor (C_{FF}) could be placed paralleling to R_H to improve the transient response. Please refer to the EVB document for the C_{FF} recommendation.

Input Capacitor C_{IN}

A ceramic capacitor whose capacitance is greater than 10μF is recommended. The component should be placed as close as possible to the module, while also minimizing the loop area formed by C_{IN} and the IN/GND pins. When selecting an input capacitor ensure that its voltage rating is at least 20% greater than the maximum voltage of the input supply. X6R or X7R dielectric types are the most often selected due to their small size, low cost, surge current capability and high RMS current rating over a wide temperature and voltage range.

In situations where the input rail is supplied through long wires it is recommended adding some bulk capacitance like electrolytic, tantalum or polymer type capacitors to reduce the overshoot and ringing caused by the added parasitic inductance.

Consider the RMS current rating of the input capacitor, paralleling additional capacitors if required to meet the calculated RMS ripple current.

$$I_{CIN_RMS} = I_{OUT} \times \sqrt{D \times (1-D)}$$

The worst-case condition occurs at D = 0.5, then

$$I_{CIN_RMS,MAX} = \frac{I_{OUT}}{2}$$

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

The input capacitor value determines the input voltage ripple of the converter. If there is a voltage ripple requirement in the system, choose an appropriate input capacitor that meets the specification.

Given the very low ESR and ESL of ceramic capacitors, the input voltage ripple can be estimated using the formula:

$$V_{CIN_RIPPLE,CAP} = \frac{I_{OUT}}{f_{SW} \times C_{IN}} \times D \times (1\text{-}D)$$

The worst-case condition occurs at D = 0.5, then

$$V_{CIN_RIPPLE,CAP,MAX} = \frac{I_{OUT}}{4 \times f_{SW} \times C_{IN}}$$

The capacitance value is less important than the RMS current rating. In most applications a single 10 uF X7R capacitor is sufficient.

External Capacitor Recommendation

	Description	Vendor	PN
C_{IN}	10μF/10V/X7T, 0603	Murata	GRM188D71A106KA73#

Output Capacitor C_{OUT}

The output capacitor is selected to handle the output ripple noise requirements. Both steady state ripple and transient requirements must be taken into consideration when selecting this capacitor. For the best performance, it is recommended to use X7R or better grade ceramic capacitor greater than 22μF capacitance. Place this ceramic capacitor really close to the VOUT and GND pins to minimize the loop area formed by C_{OUT}, and the VOUT/GND pins.

External Capacitor Recommendation

	Description	Vendor	PN
C_{OUT}	22μF/6.3V/X7R, 0603	Murata	GRM188D70J226ME01#
C_{OUT}	22μF/4V/X6S, 0402	Murata	GRM158C80G226ME01#

For the application where T_A is between -10°C and 80°C, The capacitor (GRM158C80G226ME01#) with 0402 size is recommended as an output capacitor to save the PCB space.

If the output capacitance is larger than 220μF or other type of capacitor (polymer, tantalum…) is used, please contact Silergy supporting team to get more assessment.

PFM Mode

The SQ76002B uses PFM(Pulse Frequency Modulation) mode at light load operation, which can maintain the high efficiency by reducing the switching frequency.

In PFM mode, the SQ76002B operates only when actual output voltage falls below the nominal output voltage. Other times, the

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SQ76002B enters a sleep period that most of the internal circuits will be turned off to reduce quiescent current of IC. So this control method can greatly improve efficiency when SQ76002B works at light load.

FCCM Mode

The SQ76002C utilizes FCCM (Forced Continuous Inductor Current Mode) to work in a continuous conduction mode throughout full load range. Different from PFM mode, its advantage is that it can still maintain a very small output ripple even under light load.

In FCCM, the low-side synchronous MOSFET remains on until the next on time cycle, allowing continuous current flow in the inductor. The inductor current ramps below zero, recirculating current from the output to the input. This allows the device to maintain a relatively constant switching frequency over the output current range. Therefore, the SQ76002C can minimize output ripple and ensure excellent load regulation.

Minimum Duty Cycle and Maximum Duty Cycle

In the COT architecture, there is no limitation for small duty cycles, since even at very low duty cycles, the switching frequency can be reduced as needed once the on-time is close to the minimum on time, to always ensure a proper operation.

The device will enter 100% dropout mode if the output voltage is very close to the input voltage, while the top MOSFET is constantly turned on, the bottom MOSFET is turned off. When the IC works under the condition of large duty cycle before entering 100% dropout mode, off-time may be reach the minimum off time (Approximately 100ns). In this case, it will extend on-time to reduce switching frequency in order to meet the large duty cycle.

Power Good Indicator

The power good indicator is an open drain output controlled by a window comparator connected to the feedback signal. If V_{FB} is greater than V_{PG} low thresold and less than V_{OVP} for at least the power good delay time (low to high), PG will be high-impedance. Otherwise, it is pulled low. PG should be connected to VIN or another voltage source through a resistor (e.g., 10kΩ~100kΩ).

Over Current Protection

With load current increasing, as soon as the high side power MOSFET current gets higher than peak current limit threshold(~5A), the high side power MOSFET will turn off and the low side power MOSFET will keep turning on until low side power MOSFET current decrease below the valley current limit threshold(~3.5A).

If the load current continues to increase, the output voltage will drop. When the output voltage drops to below 20% of the target the output, the Under Voltage Protection (UVP) is triggered and the device stops switching for a period of 3ms (typ.). A soft-start is initiated after the hiccup time and the device will attempt to restart. Normal operation is resumed if the overcurrent condition is removed.

Over Temperature Protection

If the wafer temperature of SQ76002B is higher than the thermal shutdown temperature (typical 150℃), the IC will turn off both high side power MOSFET and low side power MOSFET, and then enters thermal shutdown protection mode. It will remain in this state until the wafer temperature decreases below 130℃. After exiting this state, the IC auto retries to normal operation.

Output Auto Discharge Function

An internal 8Ω discharge MOSFET is turned on whenever the shutdown logic is triggered, discharging the output through the inductor. The circuit is only active during the shutdown process, when it brings the output to a low-voltage state until the device is once again enabled.

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Layout Design

To achieve a higher efficiency and better noise immunity, following components should be placed close to the IC:

C_{IN} and C_{OUT}.

1) C_{IN} must be close to the pins VIN and GND. The loop area formed by C_{IN} and GND must be minimized.

2) C_{OUT} must be close to the pins VOUT and GND. The loop area formed by C_{OUT} and GND must be minimized.

3) Place the FB components (R_H, R_L, C_{FF}) as close to the FB pin as possible.

4) It is desirable to maximize the PCB copper area connecting to the GND pin to achieve the best thermal and noise performance. If the board space allowed, a ground plane is highly desirable.

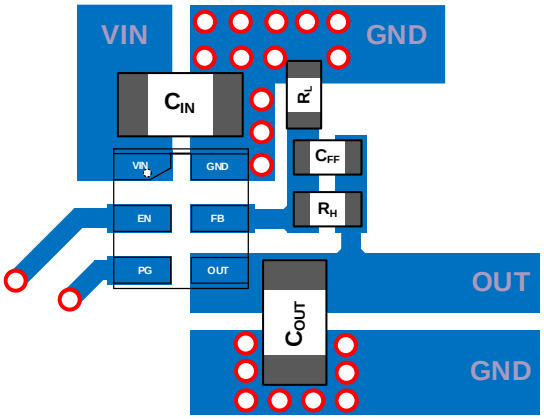

Figure4. PCB Layout Suggestion

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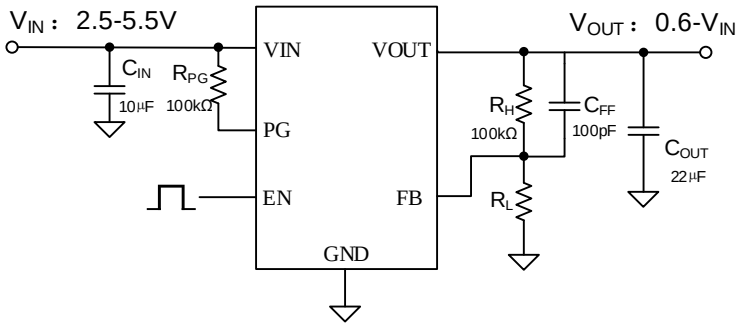
Application Schematic



BOM List

Reference Designator	Description	Part Number	Manufacturer
C_{IN}	10μF/10V/X7T,0603	GRM188D71A106KA73#	muRata
C_{FF}	100pF/50V/C0G, 0402 (for 1.2/1.8/3.3Vout)	GRM1555C1H101GA01#	muRata
C_{OUT}	22μF/6.3V/X7R,0603	GRM188D70J226ME01#	muRata
	22μF/4V/X6S,0402	GRM158C80G226ME01#	muRata
R_{PG}	100kΩ, 1%, 0402		
R_H	100kΩ, 1%, 0402		
R_L	49.9kΩ, 1%, 0402 (for 1.8Vout)		
	22.1kΩ, 1%, 0402 (for 3.3Vout)		
	100kΩ, 1%, 0402 (for 1.2Vout)		

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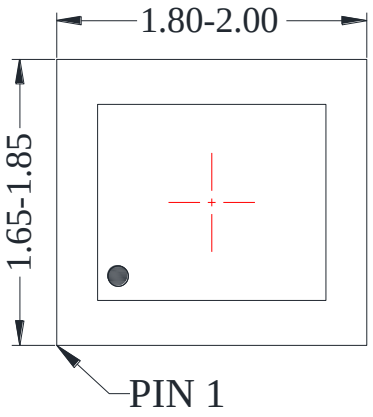
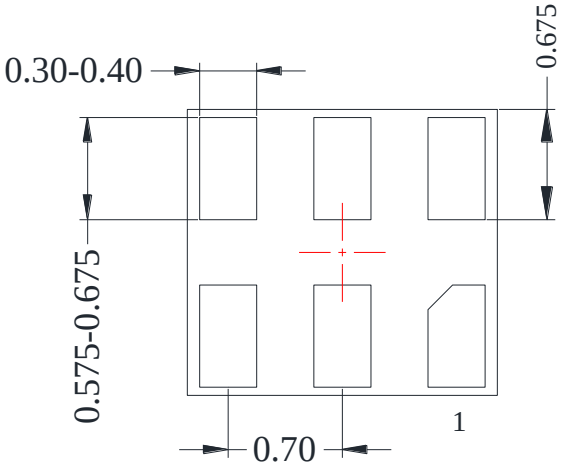
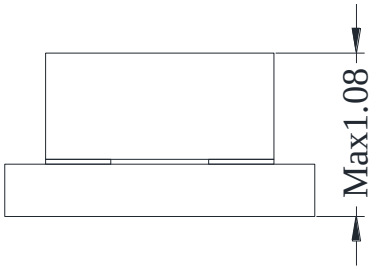
MDFN1.9X1.75-6 Package Outline Drawing



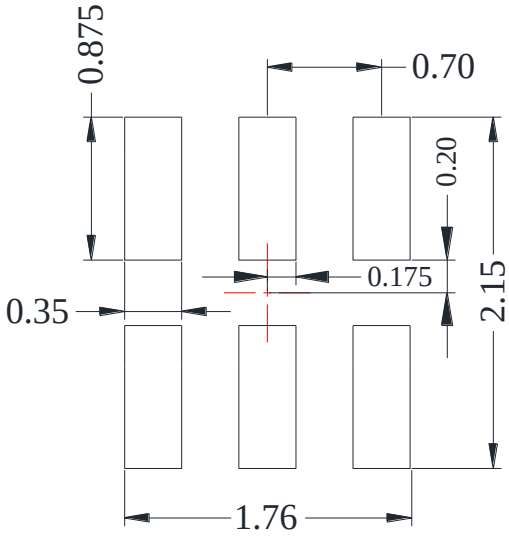
Top View



Bottom View



Front View



Recommended PCB layout
(Reference only)

Notes: 1.All dimension in millimeter and exclude mold flash & metal burr.

2.Center line on drawing refers to the chip body center.

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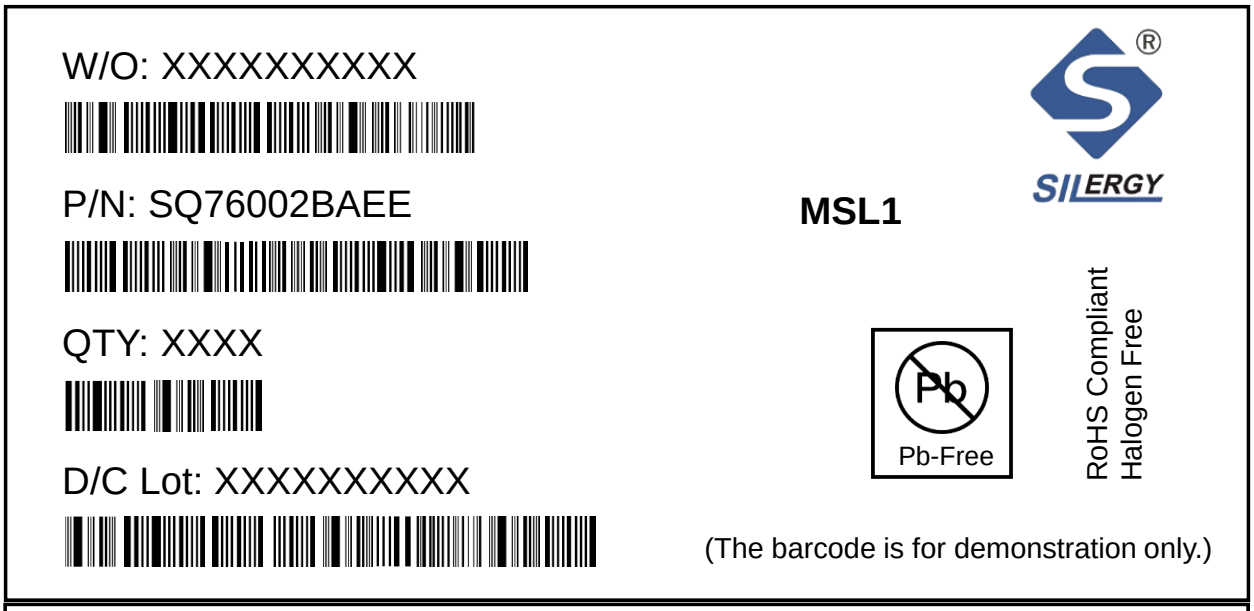
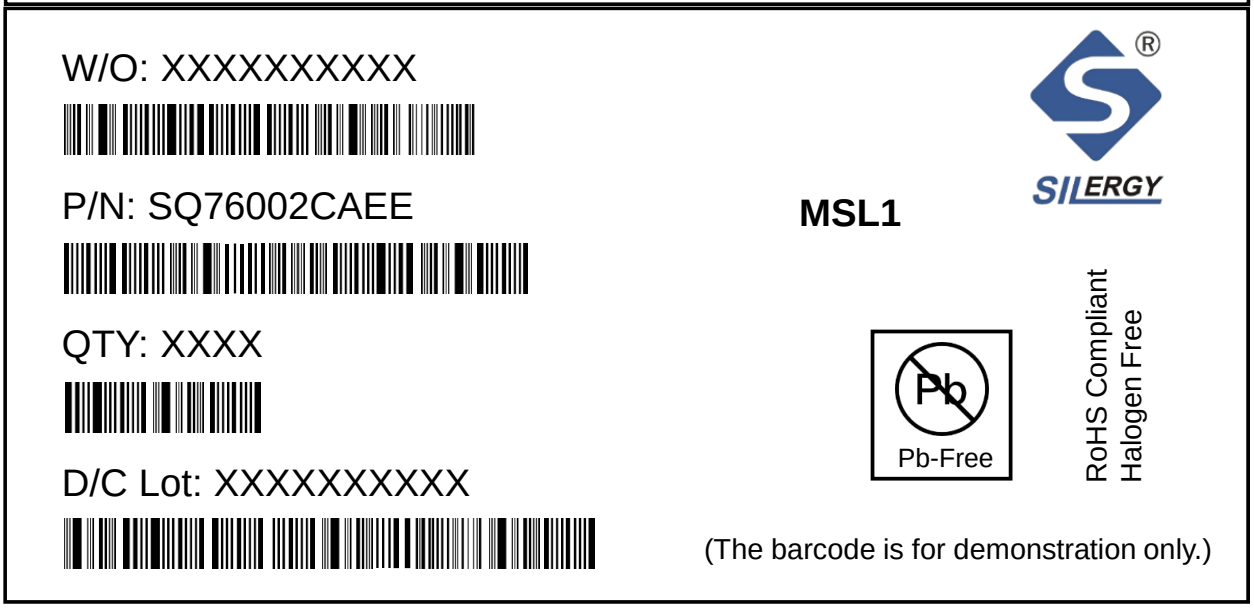
Packaging Information

Ordering Number	Device Code
SQ76002BAEE	HBT
SQ76002CAEE	HLF

Label Information





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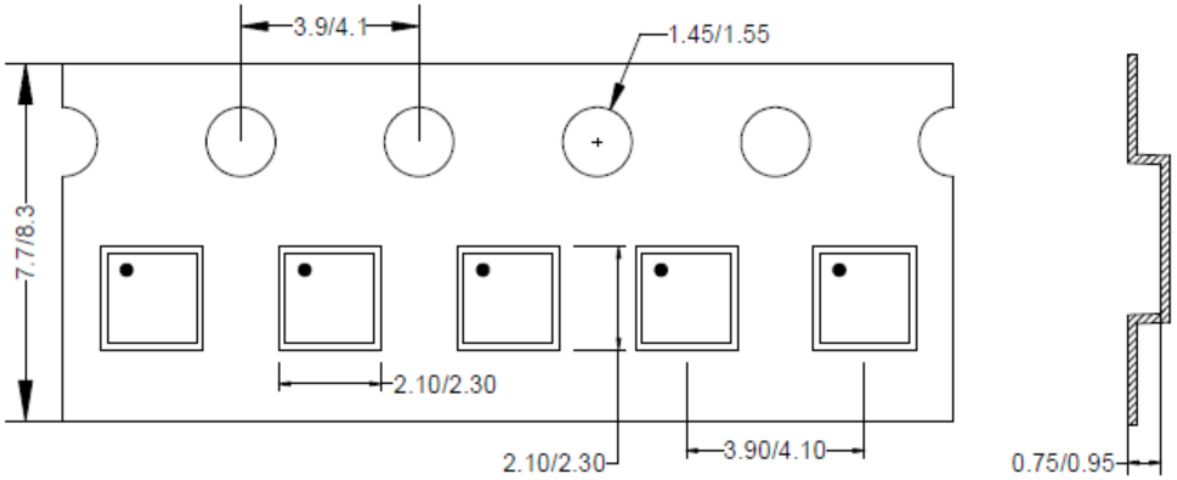
Taping & Reel Specification

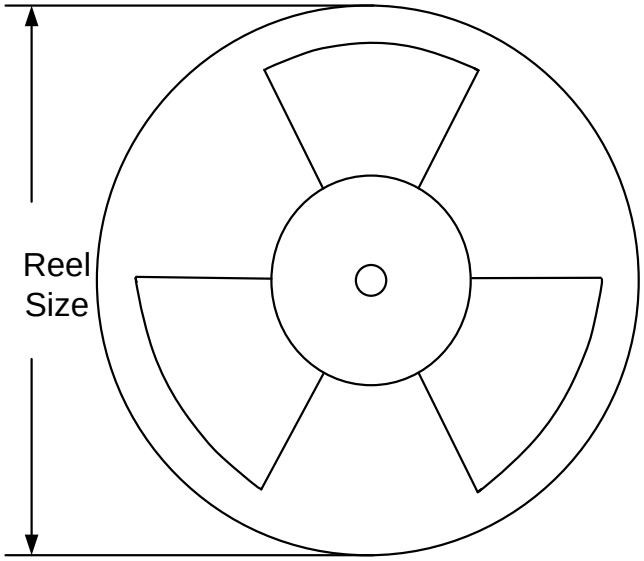
1. Taping Orientation

MDFN1.9*1.75-6



Feeding Direction ⟶

2. Carrier Tape & Reel specification for packages



Package types	Tape width (mm)	Pocket pitch(mm)	Reel size (Inch)	Trailer * length(mm)	Leader * length (mm)	Qty per reel (pcs)
MDFN1.9*1.75-6	8	4	7"	400	400	3000

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