700KHz, 28V, 3A Synchronous Step-Down Converter

Features

- 4.5V to 28V Operating Input Voltage Range
- 700KHz Switching Frequency
- 0.6V to 7V Output Voltage Range
- 3.0A Continuous Output Current
- Integrated 62mΩ/32mΩ Power MOSFETs
- Low Quiescent Current: 40uA(TYP)
- Shutdown Current: 3uA(TYP)
- 5ms Internal Soft-Star Time
- Up to 94% efficiency
- Adaptive Constant On-Time Mode Control
- Hiccup Current-Protection Mode
- Output Over-Voltage Protection
- Adjustable Input Under-Voltage Lockout
- Thermal Shutdown with Auto Recovery
- Available in a Green SOT23-6L package

Applications

- 12V Distributed Power Supply Buses
- Industrial and Consumer Applications
- White Goods & Audio Equipment
- Set Top Boxes
- Digital Television Printers

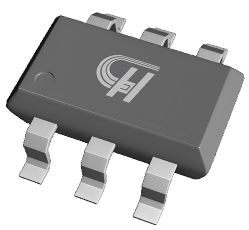
General Description

The HCR3229 is an adaptive constant on-time control (ACOT) synchronous Buck converter with a wide input voltage range of 4.5V to 28V. This device has 3A output current capability and operates at pseudo-fixed frequency. It is an easy-to-use device with power switches and internal compensation circuit, which supports are all integrated in a small 6-pin package, and low-equivalent series resistance (ESR) output capacitors. A typical 5ms soft-start ramp is also included to minimize the inrush current.

Protection features include cycle-by-cycle current limit, hiccup current-protection mode, output over-voltage protection and thermal shutdown in case of excessive power dissipation.

The HCR3229A enters in pulse-skip mode (PSM) to improve efficiency during light load operation, while the HCR3229B works in continuous current mode (CCM) to achieve low output ripple and good regulation.

The HCR3229 is available in a Green SOT23-6L package.



SOT23-6L

Figure 1. Package Type of HCR3229

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Pin Configuration

SOT23-6L Top View

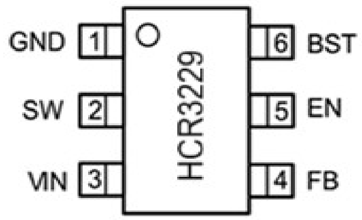
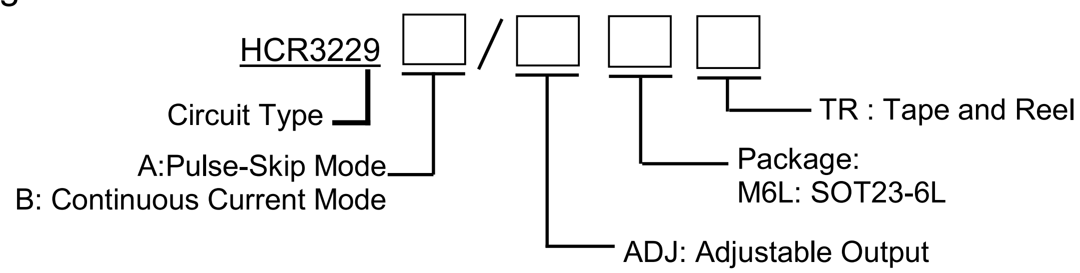


Figure 2. Pin Configuration of HCR3229 (Top View)

Pin Function Table

Pin Number	Pin Name	Function
1	GND	Power Ground. Must be soldered directly to ground plane.
2	SW	Switching Node. Connection point of the internal converter lower and upper power MOSFETs. Connect this pin to the output inductor and the bootstrap capacitor
3	VIN	Supply Input. Connect VIN to a power source with 4.5V to 28V output voltage range. Decouple VIN to GND as close as possible with a high frequency, low ESR ceramic capacitor (X5R or higher grade is recommended).
4	FB	Feedback Pin for Setting the Output Voltage. Tap an output feedback resistor divider to this pin.
5	EN	Active High Enable Input. Float the EN pin to enable the device. Input UVLO level can be programmed using a resistor divider from VIN pin.
6	BST	Bootstrap Pin. Bootstrap supply for high-side driver. Connect a 0.1μF ceramic capacitor between BOOT and SW pins

Ordering Information



Ordering Code

Part Number	Marking ID note2	Temperature Junction Range	Package	Quantity per Reel
HCR3229A/ADJM6LTR	06DYY	-40'C to +125'C	SOT23-6L	3000, Tape&Reel
HCR3229B/ADJM6LTR	06EYY	-40'C to +125'C	SOT23-6L	3000, Tape&Reel

Note 2: the "YY" is Inside code.

Functional Block Diagram

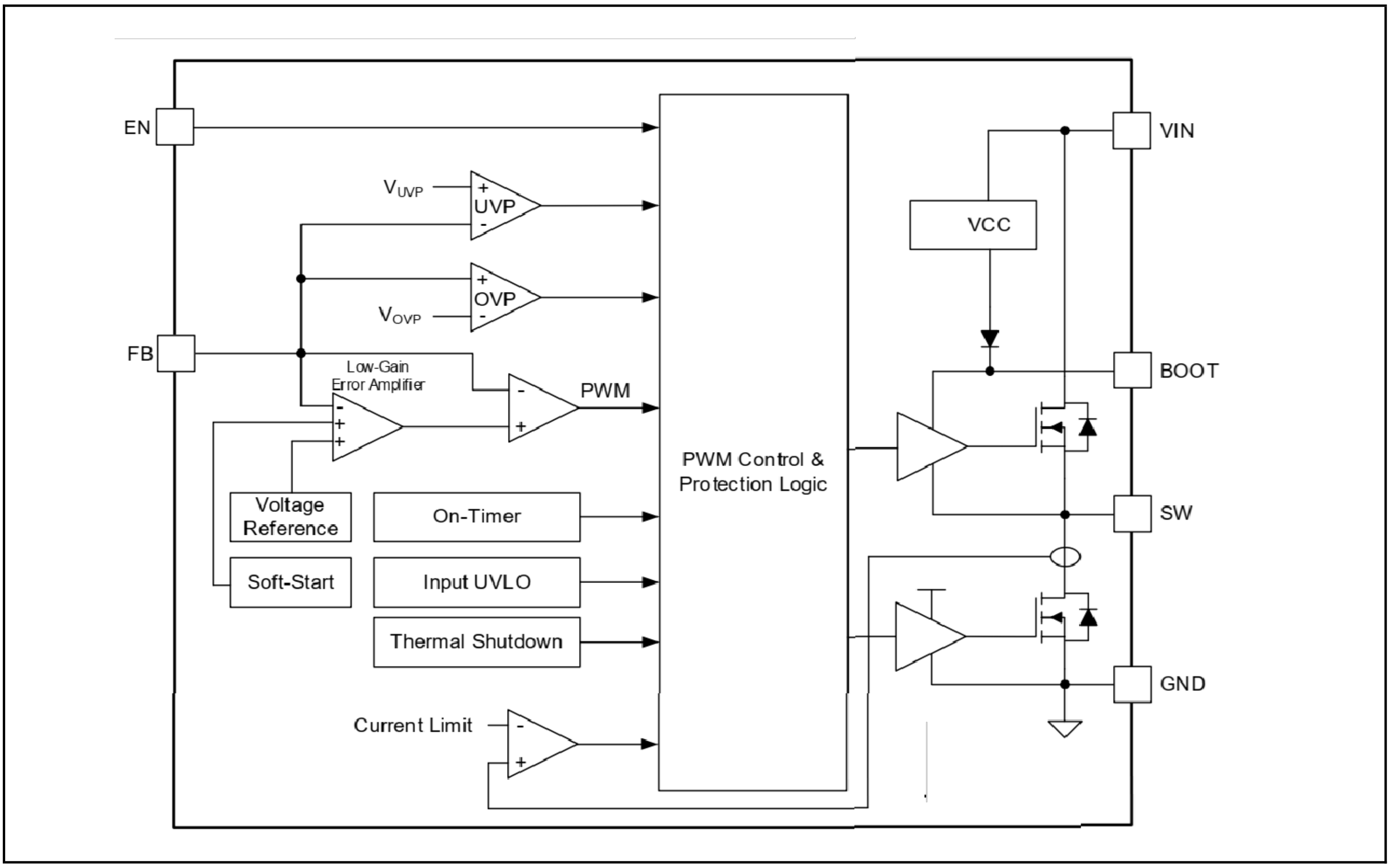


Figure 3. Functional Block Diagram of HCR3229

Typical Application Circuit

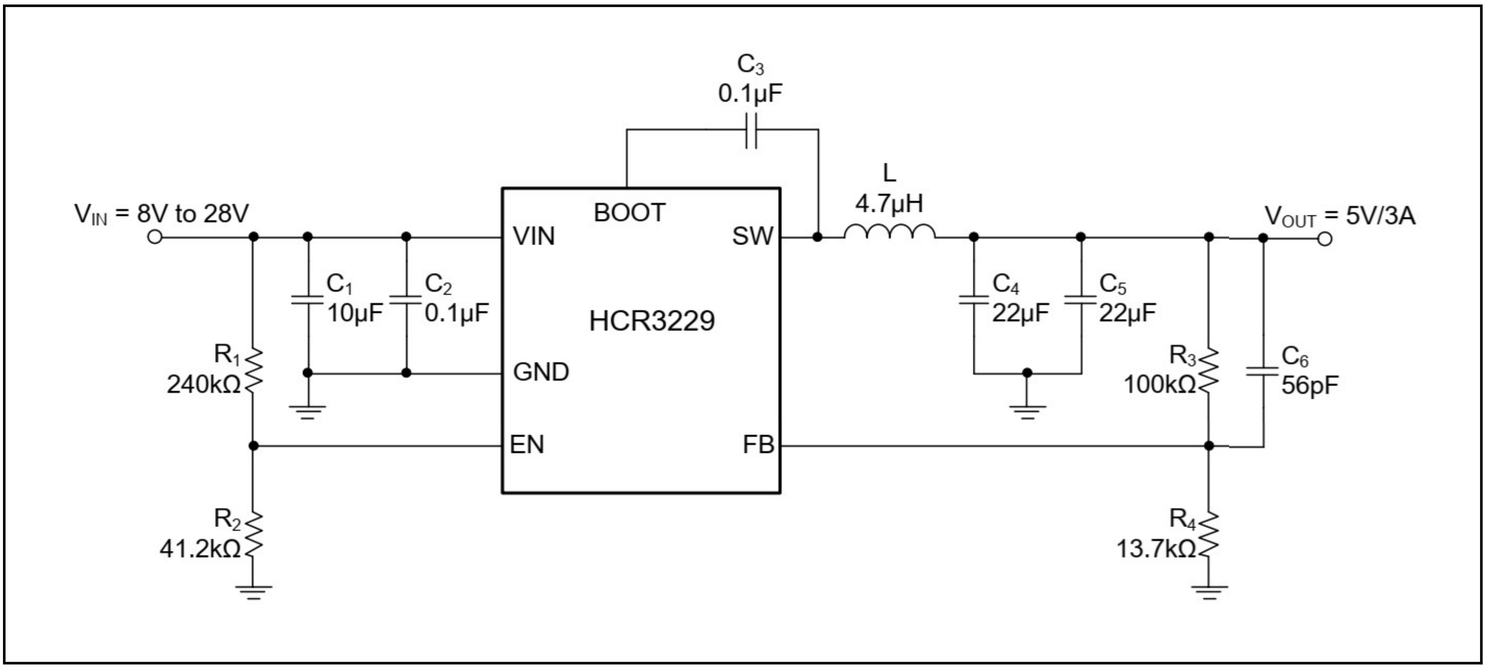


Figure 4. Typical Application Circuit of HCR3229

Absolute Maximum Ratings Note 1

Parameter	Symbol	Value	Unit
Input Supply Voltage Range	V_{IN}	-0.3 to +30.0	V
SW Voltage Range	V_{SW}	-0.3(-5V for 20nS) to +30.0	V
BST Voltage Range	V_{BST}	-0.3 to +6.0	V
EN Voltage Range	V_{EN}	-0.3 to +6.0	V
FB Voltage Range	V_{FB}	-0.3 to +3.5	V
Power Dissipation	P_O	550	mW
Thermal Resistance Junction to Ambient	$R_{\theta JA}$	95	'C/W
Thermal Resistance Junction to Case	$R_{\theta JC}$	48	'C/W
Storage Temperature Range	T_{STG}	-65 to +150	'C
Junction Temperature	T_J	+150	'C
Lead Temperature (Soldering, 10s)	T_{LEAD}	260	'C
Human Body Model for EN Pin	VESD_HBM	2000	V
Human Body Model for all pins	VESD_HBM	4000	V
Charge Device Model for all pins	VESD_CDM	1000	V

Note 1: Stresses beyond those listed under"Absolute maximum Ratings" may damage the device.

2: The device is not guaranteed to function outside the recommended operating conditions.

Recommended Operating Conditions

Parameter	Symbol	Test Condition	Min	Type	Max	Unit
Input Voltage Range	V_{IN}		4.5	-	28	V
EN and BST Voltages	V_{EN}, V_{BST}		-0.1	-	5.5	V
SW Voltage	V_{SW}		-0.1	-	28	V
FB Voltage	V_{FB}		-0.1	-	3.0	V
Operating Junction Temperature Range	T_J		-40	-	+125	'C

Electrical Characteristics

(TJ=-40'C to +125'C, VIN=4.5V to 28V, all typical values are measured at TJ=+25'C, unless otherwise noted.)

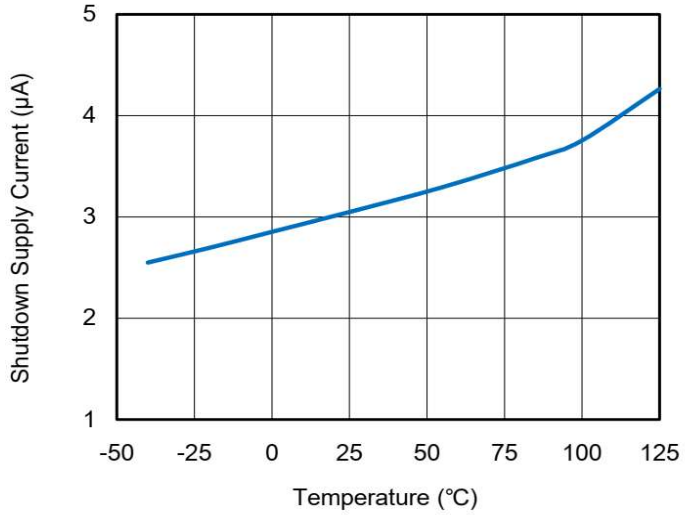
Parameter		Symbol	Test Condition	Min	Type	Max	Unit
Input Voltage Range		V_{IN}		4.5	-	28	V
Non-Switching Quiescent Current	HCR3229A	I_Q	V_{EN}=5V, V_{FB}=1V	-	45	72	uA
	HCR3229B		V_{EN}=5V, V_{FB}=1V	-	630	880	uA
Shutdown Supply Current		I_{SD}	V_{EN}=GND	-	3	8.1	uA
EN Terminal Input Threshold		$V_{EN\text{-}H}$	V_{EN} Rising	-	1.20	1.25	V
		$V_{EN\text{-}L}$	V_{EN} falling	1.02	1.09	-	
EN Terminal Leakage Current		$I_{EN\text{-}H}$	V_{EN} =1.5V	-	1.45	-	uA
		$I_{EN\text{-}L}$	V_{EN} =0.5V	-	0.4	-	
Feedback							
Feedback Reference Voltage		V_{REF}		0.582	0.594	0.606	V
Power Stage							
High-Side Switch On Resistance		$R_{DS(ON)\_H}$	V_{BST}-V_{SW}=5V	-	62	103	mΩ
Low-Side Switch On Resistance		$R_{DS(ON)\_L}$		-	32	54	mΩ
Current Limit							
Low-side Current Limit		I_{LIM_LS}	VOUT=5V, L=4.7uH, TJ=+25'C, close-loop	3.4	4.4	5.5	A
Input Under-Voltage Lockout							
UVLO Threshold Voltage		V_{UVLO}	Rising VIN	-	4.07	4.21	V
			Falling VIN	3.61	3.75	-	
UVLO Hysteresis		V_{UVLO_HYS}	-	-	320	-	mV
Over-Temperature Protection							
Thermal Shutdown[1]		T_{SHDN}	Rising temperature	-	170	-	'C
Thermal Shutdown Hysteresis[1]		T_{HYS}	-	-	30	-	'C
Frequency							
Switching Frequency		f_{SW}	V_{IN}=12V, V_{OUT}=5V, Continuous current mode	-	700	-	KHz
Timing Requirements							
Soft-Start Time		T_{SS}		-	5	-	ms
On-Time Timer Control							
Minimum Off Time[1]		t_{OFF_MIN}		-	170	-	ns
Output Under-Voltage and Over-Voltage Protection							
Output OVP Threshold		V_{OVP}	OVP detect	-	108%x V_{REF}	-	V
Output UVP Threshold		V_{UVP}	Hiccup detect	-	50%xV_{REF}	-	V
Hiccup Wait Time		N_{OC}		-	512	-	Cycles
Hiccup Time before Restart		t_{OC}		-	7	-	ms

Note 1. Not production tested

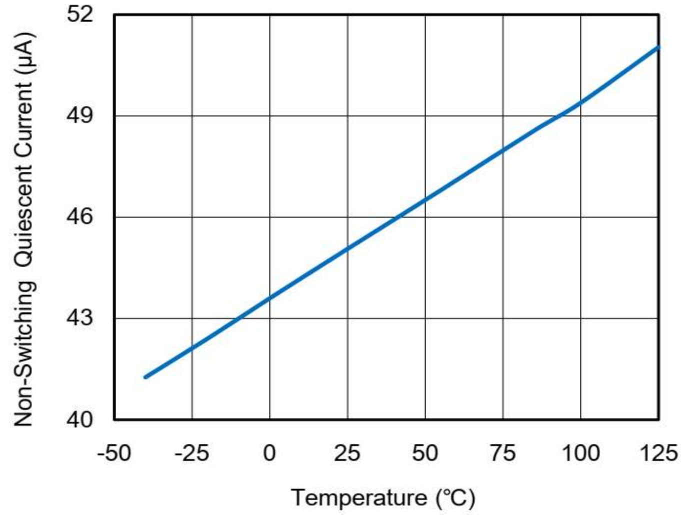
Typical Performance Characteristics

(TA = +25°C, VIN = 12V, VOUT = 5V, L = 4.7μH and COUT = 22μF × 2, unless otherwise noted.)

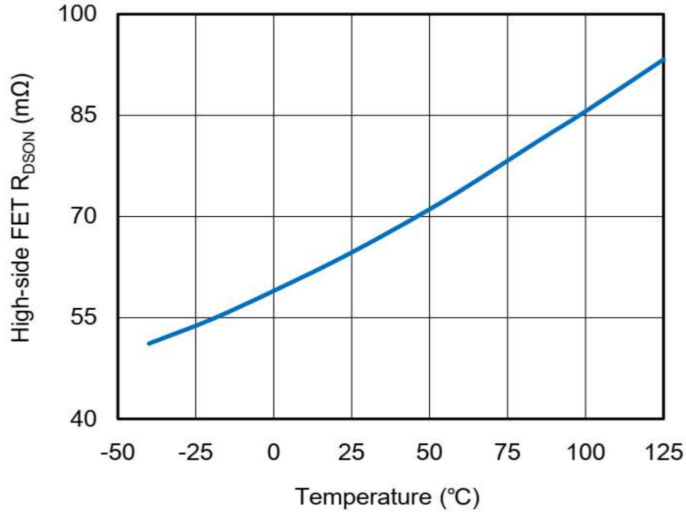
Shutdown Supply Current vs. Junction Temperature



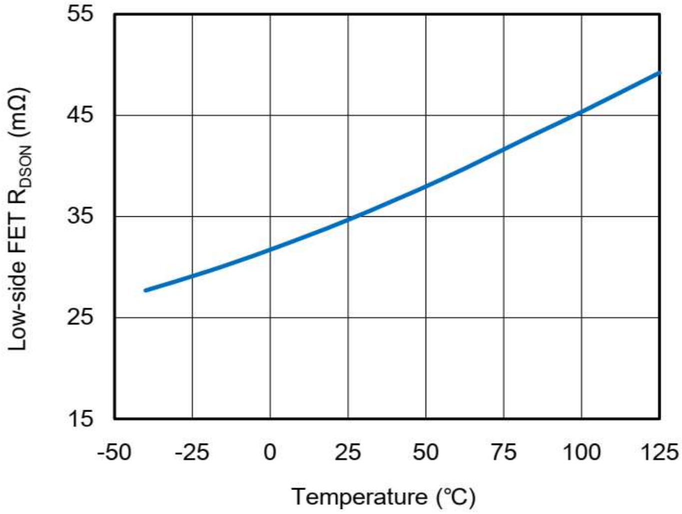
Non-Switching Quiescent Current vs. Junction Temperature (HCR3229A)



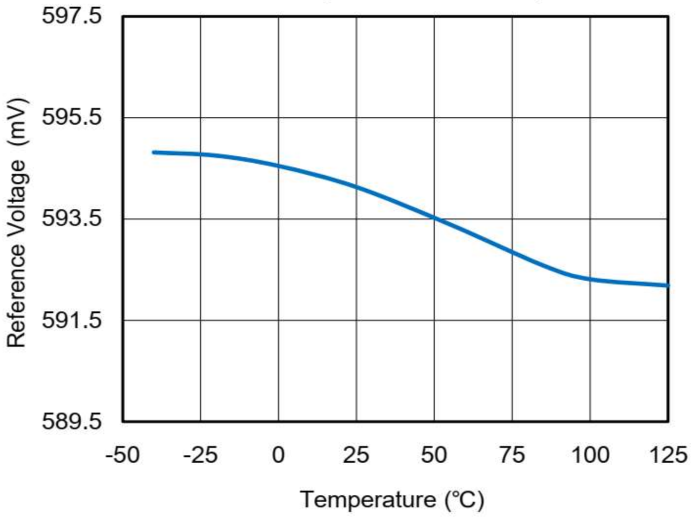
High-side Resistance vs. Junction Temperature



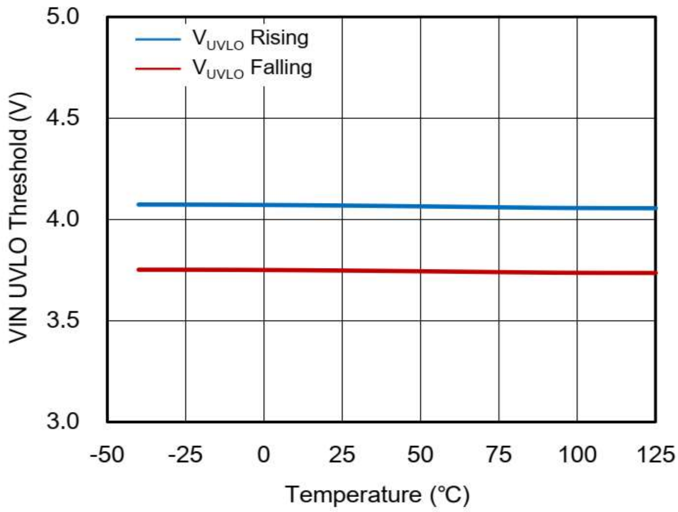
Low-side Resistance vs. Junction Temperature



Reference Voltage vs. Junction Temperature



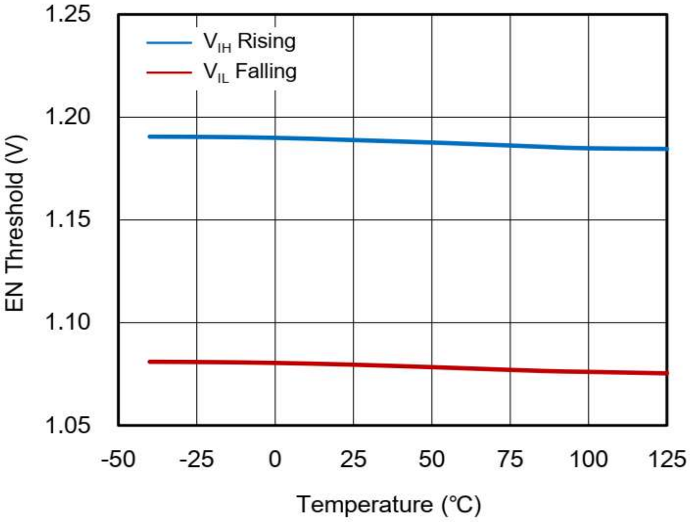
VIN UVLO Threshold vs. Junction Temperature



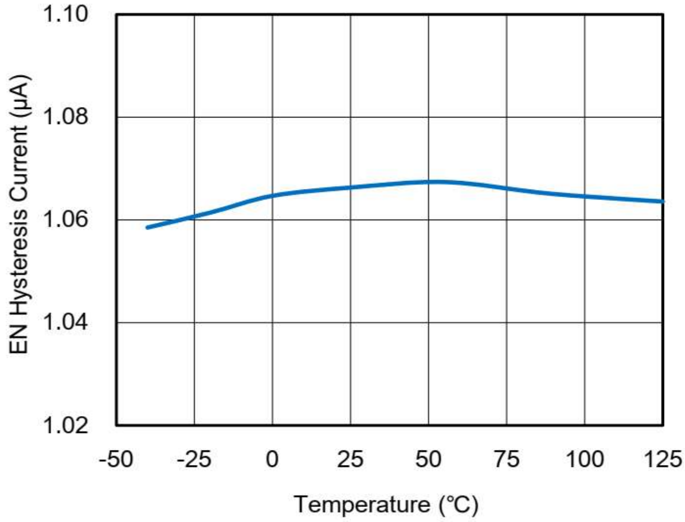
Typical Performance Characteristics(Con.)

(TA = +25°C, VIN = 12V, VOUT = 5V, L = 4.7μH and COUT = 22μF × 2, unless otherwise noted.)

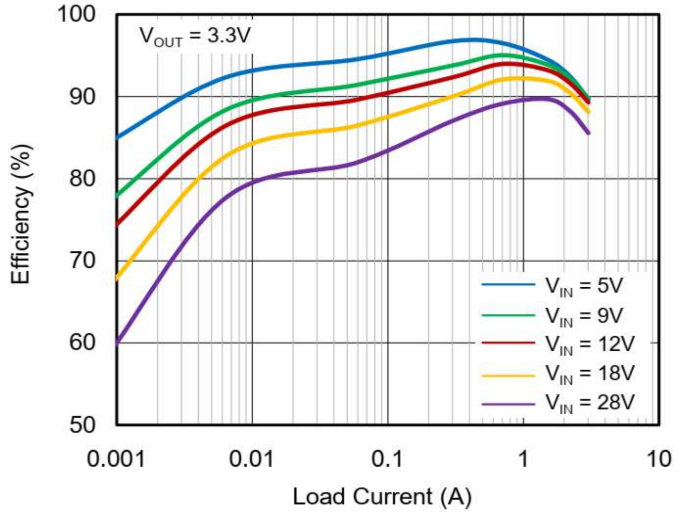
EN Threshold vs. Junction Temperature



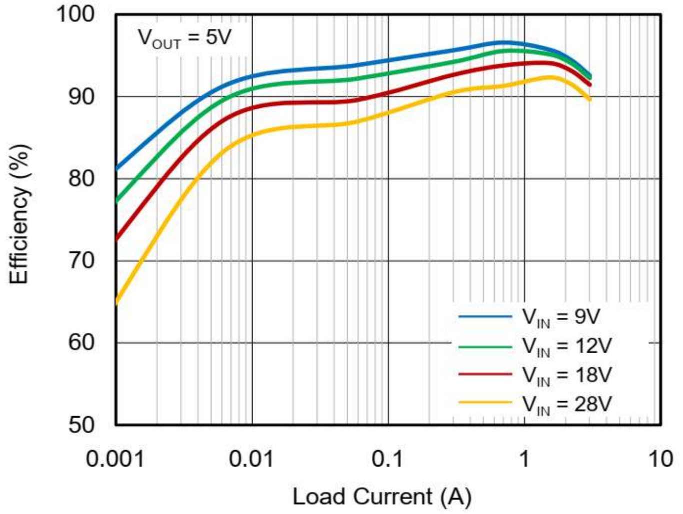
EN Hysteresis Current vs. Junction Temperature



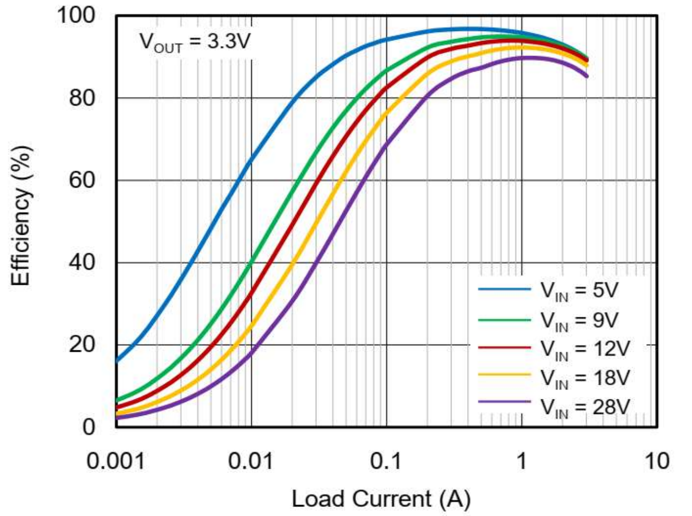
Efficiency vs. Load Current (HCR3229A)



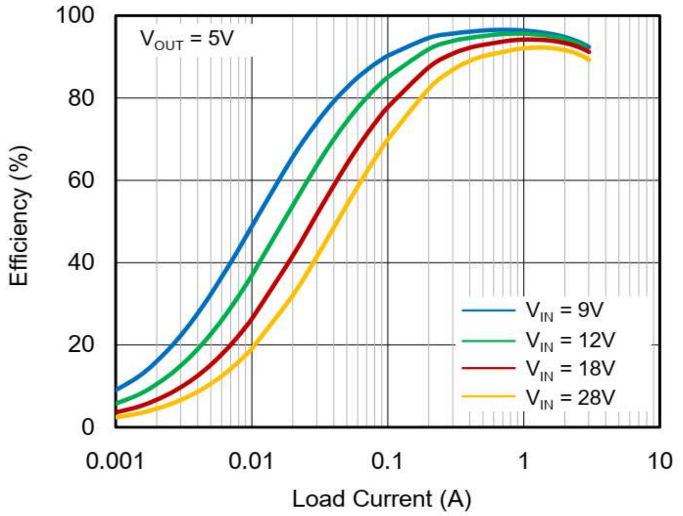
Efficiency vs. Load Current (HCR3229A)



Efficiency vs. Load Current (HCR3229B)

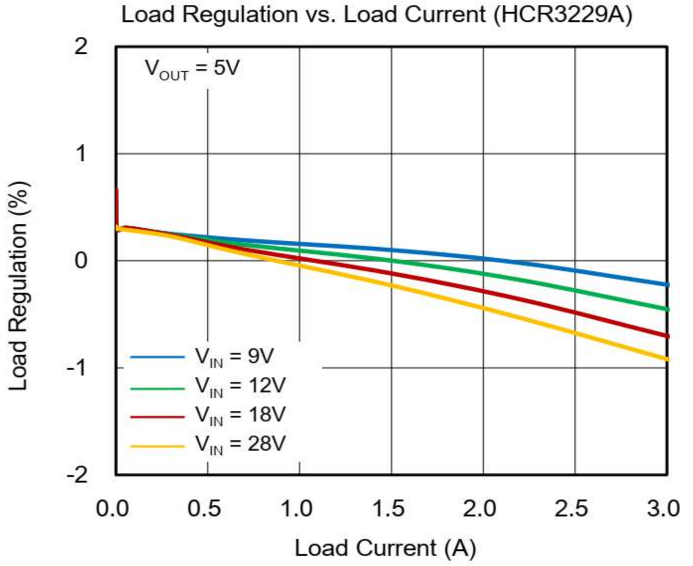


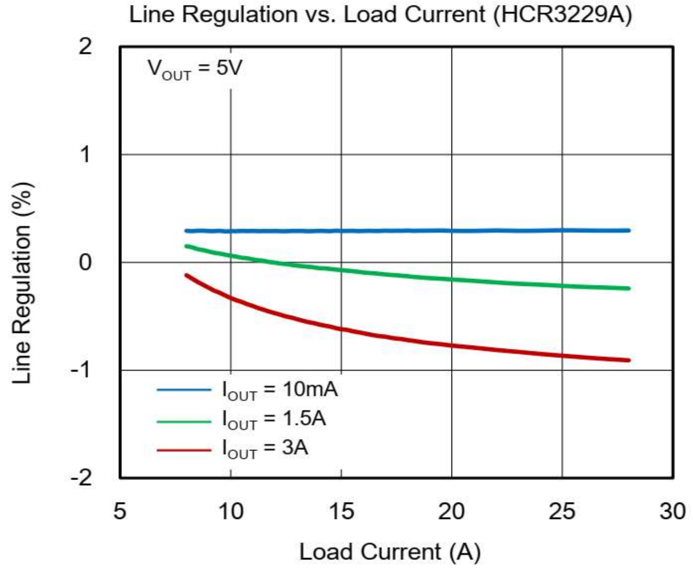
Efficiency vs. Load Current (HCR3229B)

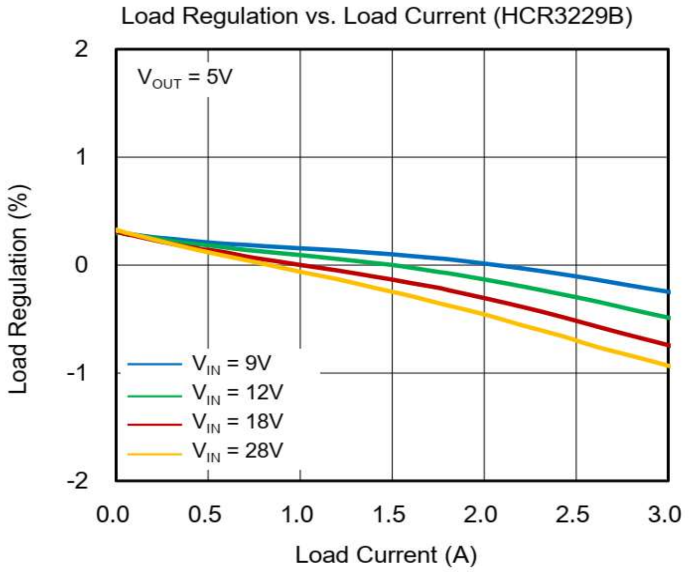


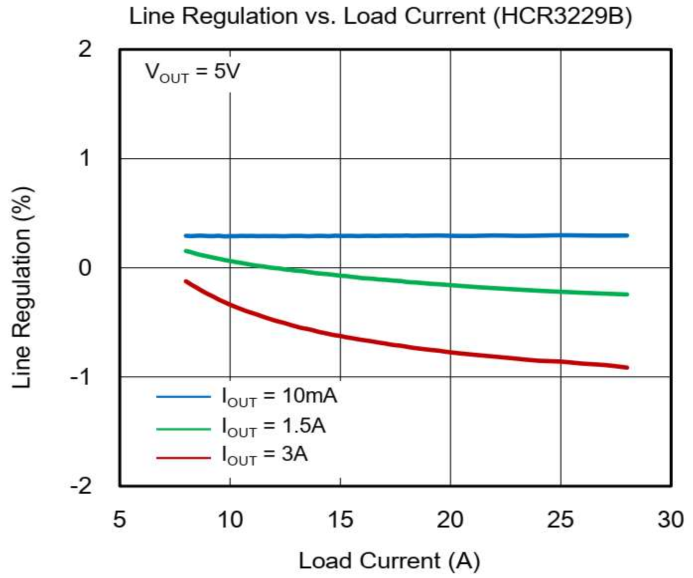
Typical Performance Characteristics(Con.)

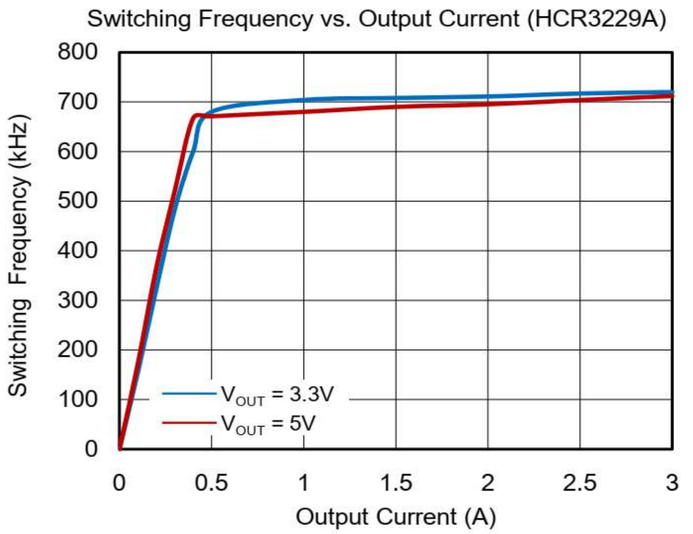
(TA = +25°C, VIN = 12V, VOUT = 5V, L = 4.7μH and COUT = 22μF × 2, unless otherwise noted.)

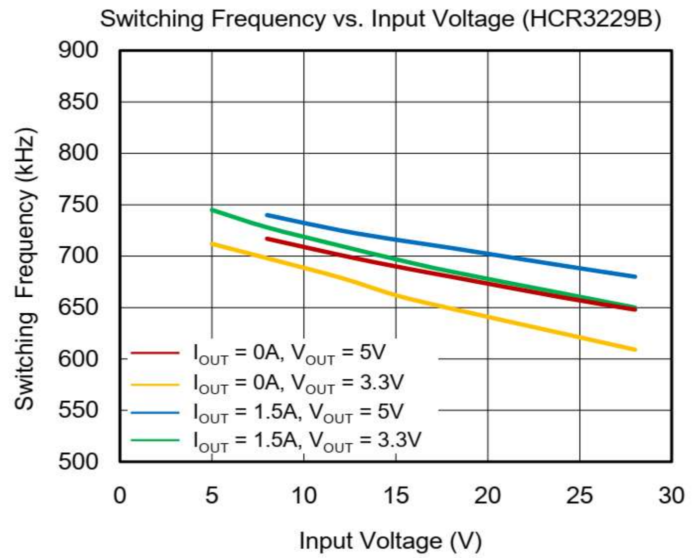








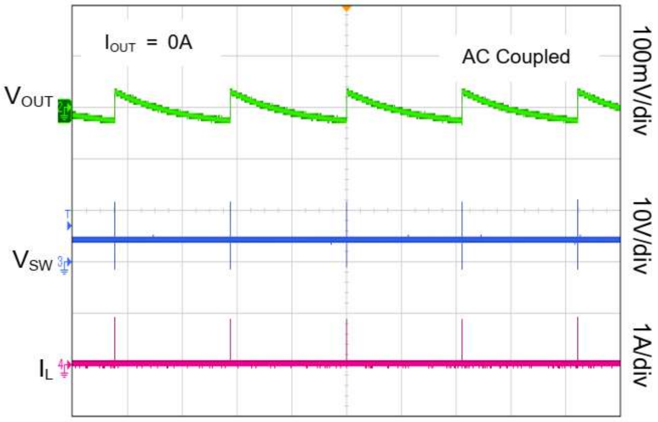




Typical Performance Characteristics(Con.)

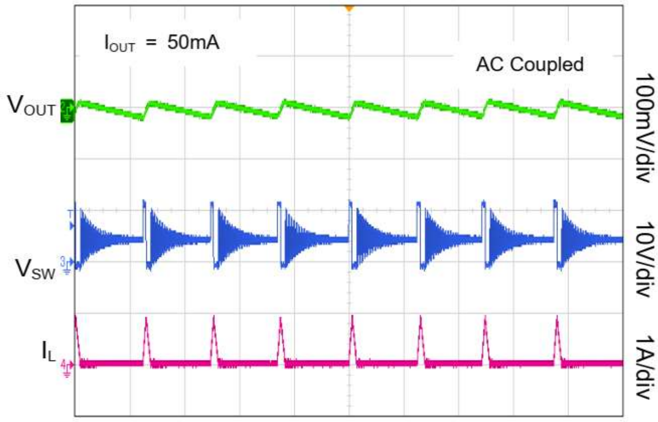
(TA = +25°C, VIN = 12V, VOUT = 5V, L = 4.7μH and COUT = 22μF × 2, unless otherwise noted.)

Output Voltage Ripple (HCR3229A)



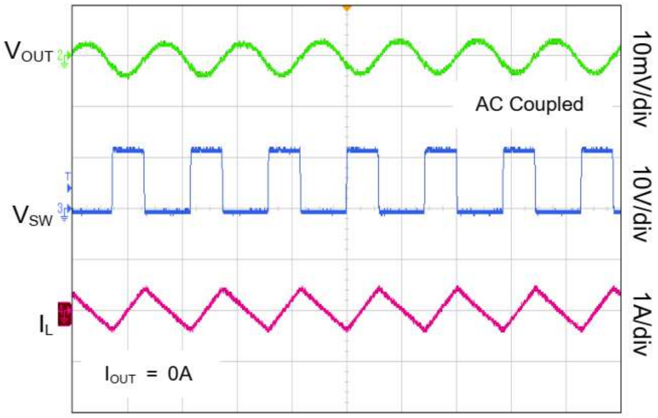
Time (10ms/div)

Output Voltage Ripple (HCR3229A)



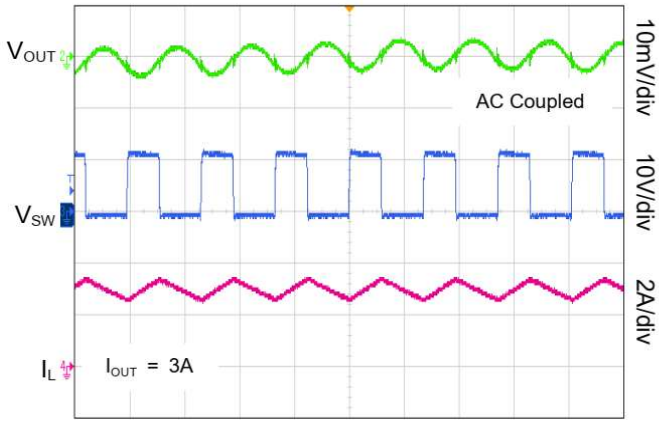
Time (10μs/div)

Output Voltage Ripple (HCR3229B)



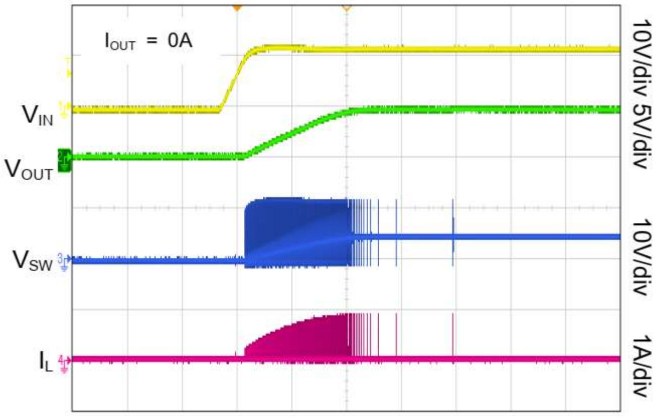
Time (1μs/div)

Output Voltage Ripple



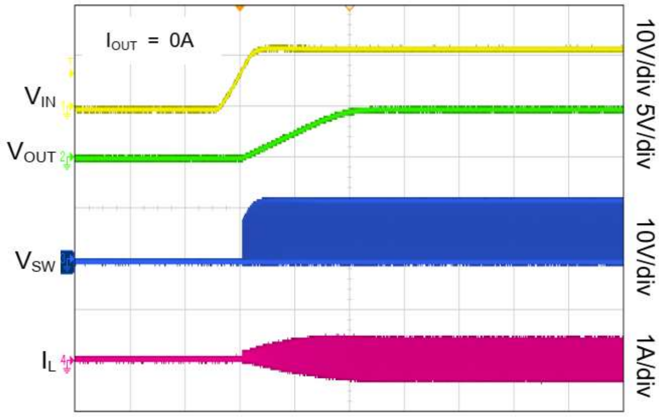
Time (1μs/div)

Startup by VIN (HCR3229A)



Time (4ms/div)

Startup by VIN (HCR3229B)

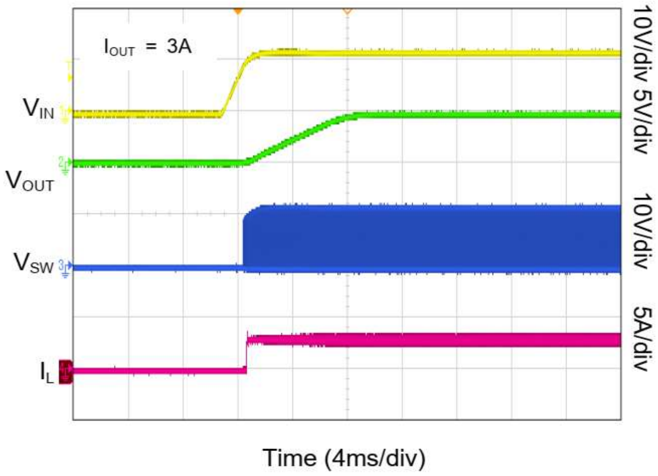


Time (4ms/div)

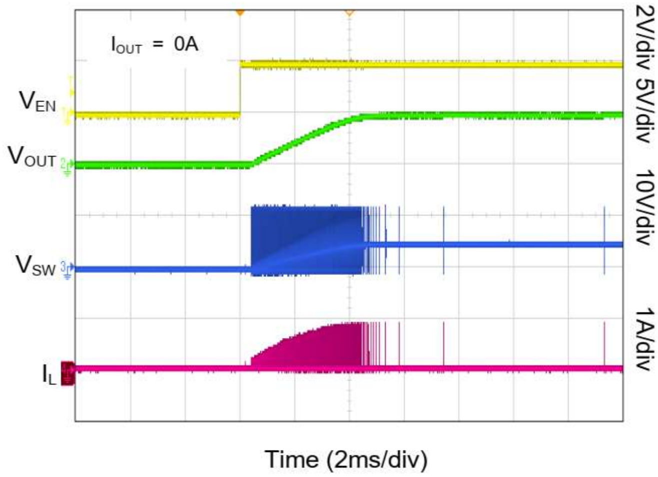
Typical Performance Characteristics(Con.)

(TA = +25°C, VIN = 12V, VOUT = 5V, L = 4.7μH and COUT = 22μF × 2, unless otherwise noted.)

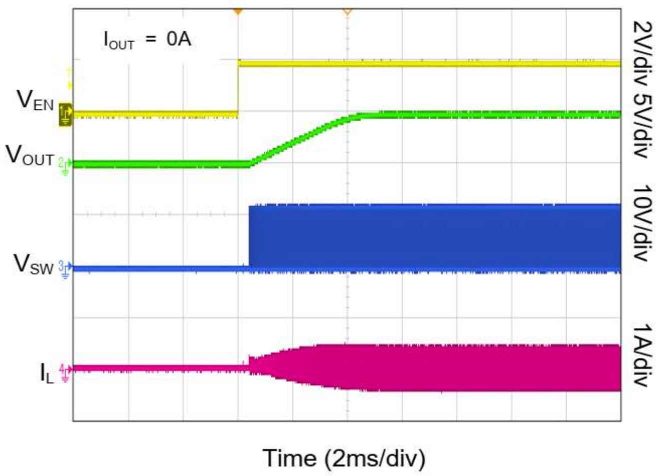
Startup by VIN



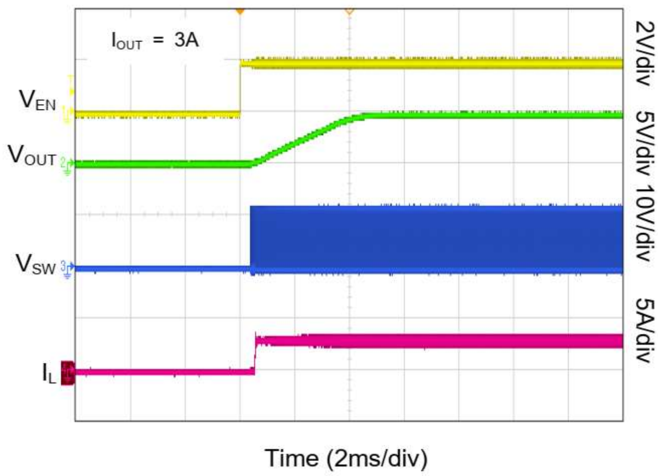
Startup by EN (HCR3229A)



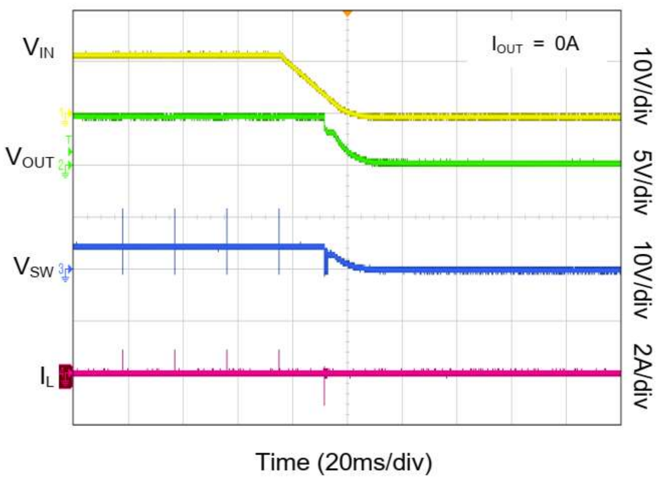
Startup by EN (HCR3229B)



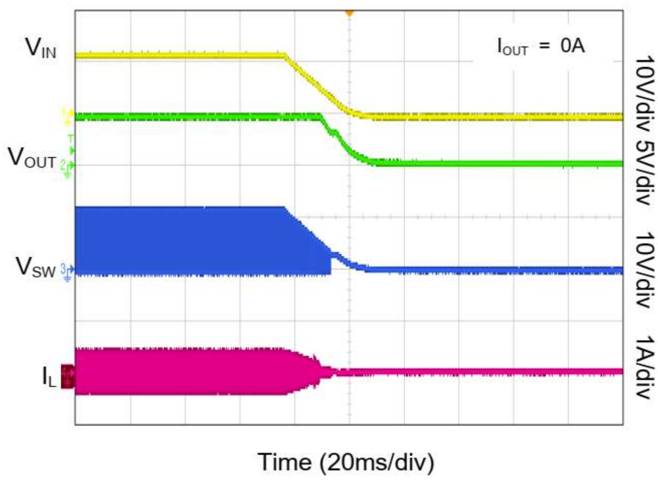
Startup by EN



Shutdown by VIN (HCR3229A)



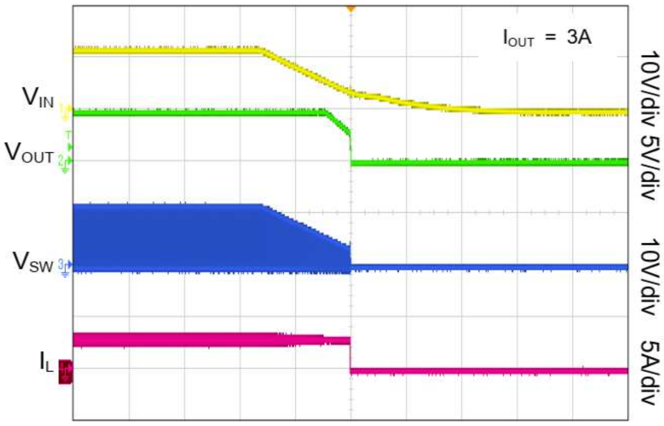
Shutdown by VIN (HCR3229B)



Typical Performance Characteristics(Con.)

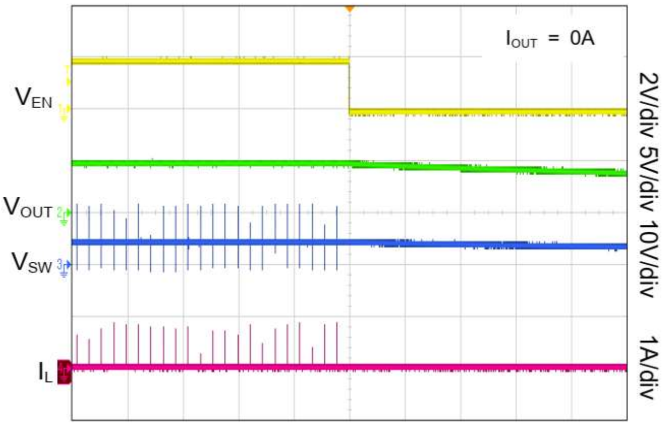
(TA = +25°C, VIN = 12V, VOUT = 5V, L = 4.7μH and COUT = 22μF × 2, unless otherwise noted.)

Shutdown by VIN



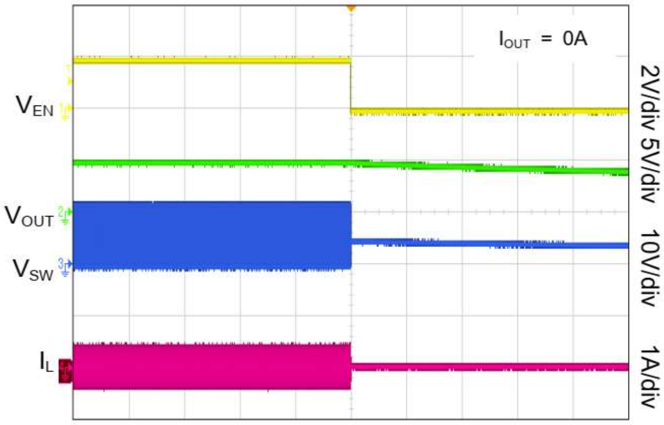
Time (5ms/div)

Shutdown by EN (HCR3229A)



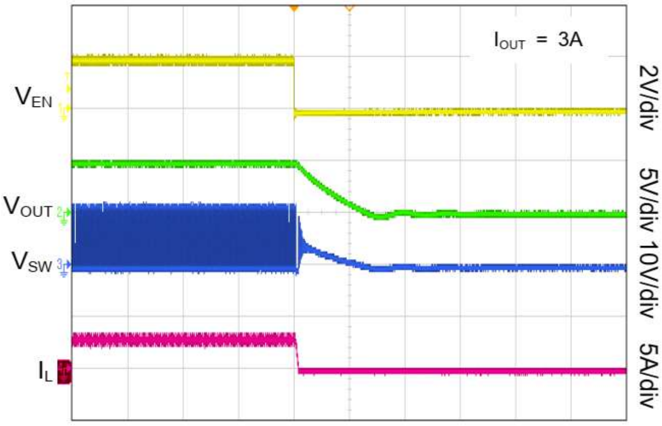
Time (100ms/div)

Shutdown by EN (HCR3229B)



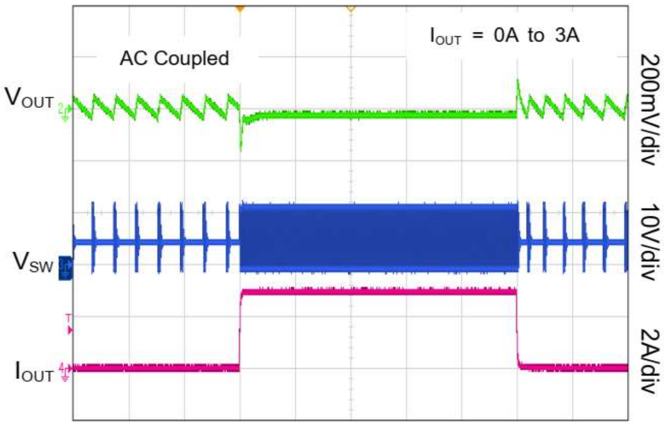
Time (100ms/div)

Shutdown by EN



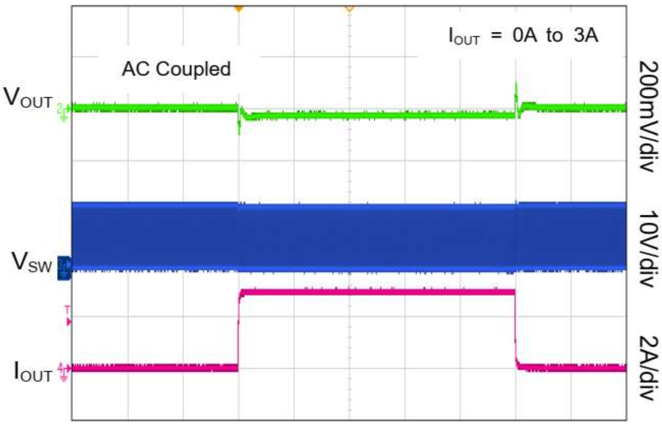
Time (50μs/div)

Load Transient (HCR3229A)



Time (200μs/div)

Load Transient (HCR3229B)

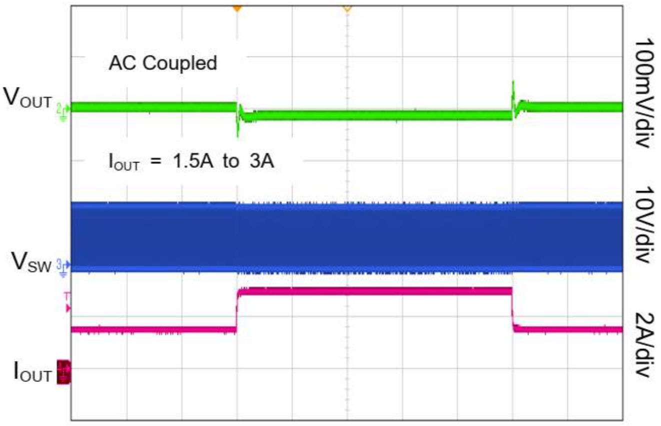


Time (400μs/div)

Typical Performance Characteristics(Con.)

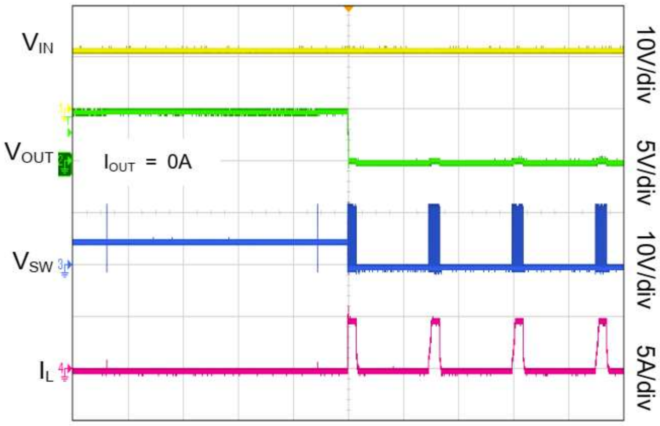
(TA = +25°C, VIN = 12V, VOUT = 5V, L = 4.7μH and COUT = 22μF × 2, unless otherwise noted.)

Load Transient



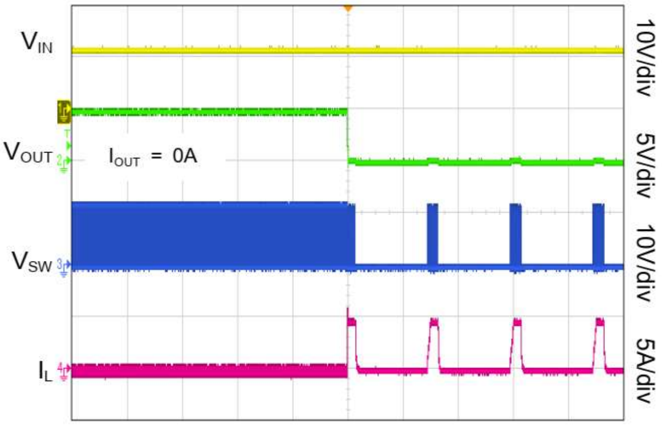
Time (200μs/div)

Short-Circuit Entry (HCR3229A)



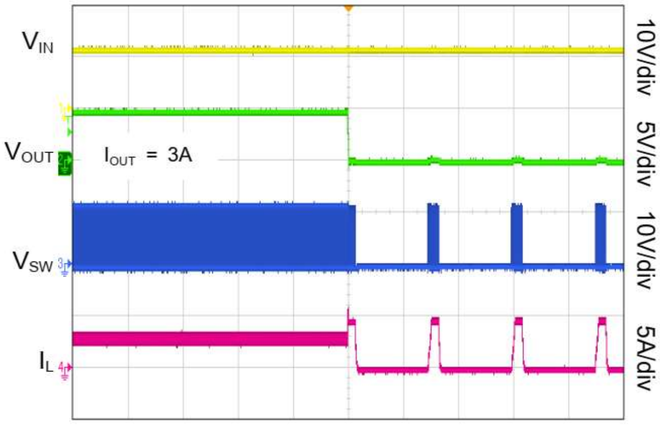
Time (5ms/div)

Short-Circuit Entry (HCR3229B)



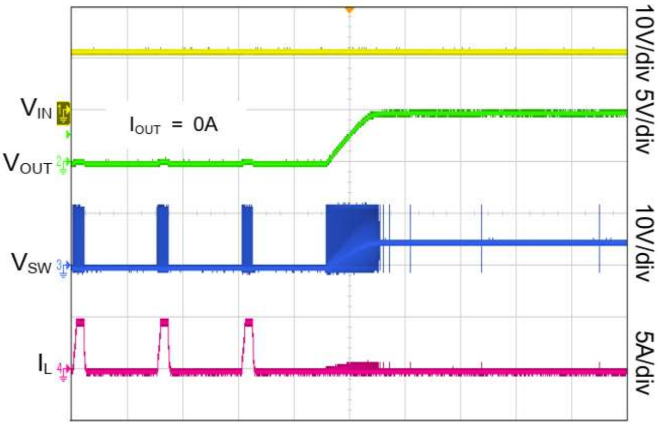
Time (5ms/div)

Short-Circuit Entry



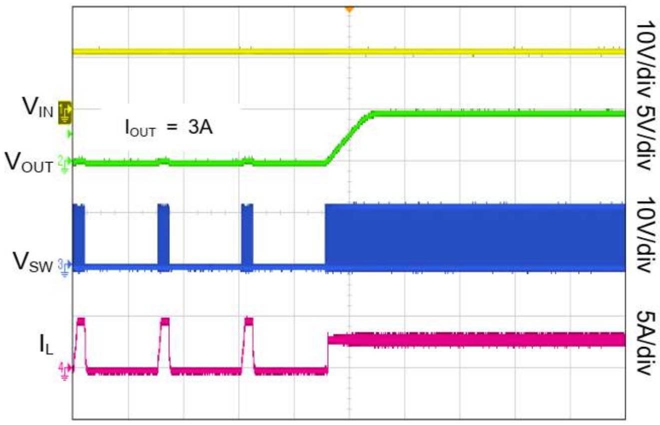
Time (5ms/div)

Short-Circuit Recovery (HCR3229A)



Time (5ms/div)

Short-Circuit Recovery



Time (5ms/div)

DETAILED DESCRIPTION

Overview

The HCR3229 is a 28V, 3A synchronous Buck converter with over-current, short-circuit and thermal shutdown with auto recovery. Figure 4 shows the simplified block diagram of the HCR3229. The two integrated MOSFET switches of the power stage(62mΩ high-side and 32mΩ low-side) can provide up to 3A of continuous current with high efficiency.

The device is powered up when VIN exceeds the UVLO threshold (4.07V TYP). At light load condition, the HCR3229A enters in pulse-skip mode (PSM) to improve efficiency, while the HCR3229B works in continuous current mode(CCM) to achieve low output ripple and good regulation. At no load and with no switching, the typical operating current of HCR3229A is 45μA (TYP) and when the device is disabled by EN pin, it is only 3μA (TYP). The internal ripple injection minimizes the BOM cost and simplifies the design. The inrush current is also limited by an internal 5ms soft-start ramp.

Adaptive Constant On-Time Control

In conventional voltage mode control (VMC) or current mode control (CMC) converters, a fixed frequency clock timing signal generates a saw-tooth ramp that is compared with the compensation network output to adjust the PWM duty cycle (on-time) as control variable and regulate the output voltage and/or current feedback(s) to govern the control variable and keep the output regulated with fast reaction to load or VIN variations. The existence of the compensator in VMC or CMC converter inherently introduces some delay in the loop response.

The adaptive constant on-time(ACOT) control differs from voltage mode control(VMC) or current mode control(CMC) in that it operates without clock signal and instead uses hysteretic mode control.At the start of each switching cycle, the ACOT control generates a relatively constant on-time pulse when the internal comparator detects that the output voltage has dropped below the desired level. The feedback (FB) pin senses the output voltage through a resistor divider and compares it to the internal reference voltage (V_{REF}) using a low-gain error amplifier. The amplifier output is then sent to a comparator. When the feedback voltage (VFB) falls below the amplifier output, the on-time control logic is triggered which turns on the high-side switch. ACOT control can dynamically adjust the on-time duration based on the input and output voltage, achieving a relatively constant frequency during steady-state operation and minimizing electromagnetic interference at certain frequencies. Additionally, an internal ramp is added to the reference voltage to simulate output ripple, allowing for use with low equivalent series resistance (ESR) output capacitors.

Enable Pin and UVLO Adjustment

The EN pin can be used to turn the device on and off or to change the UVLO thresholds. The device is enabled when the EN pin voltage exceeds its high threshold. A low EN voltage disables the device and brings it to the shutdown state.

The EN pin is internally pulled up by a small current source (IIL) so the device is enabled if EN pin is floated. An open-drain or open collector output can be used to control the EN pin.

V_{IN} is monitored by the internal under-voltage lockout circuit and if it is below UVLO threshold, the device is disabled. The internal UVLO has a 320mV hysteresis. If higher thresholds are needed, EN pin can be used as shown in Figure 5.

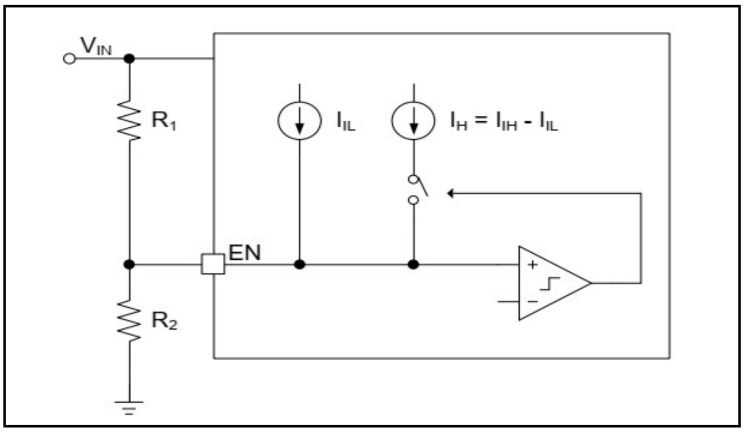


Figure 5. Adjustable VIN Under-Voltage Lockout

The EN pull-up current is used to set the hysteresis. The pull-up current is increased by IIH - IIL when the EN pin

DETAILED DESCRIPTION(Con.)

Enable Pin and UVLO Adjustment(Con.)

exceeds its high threshold. Use Equations 1 and 2 to calculate the R1 and R2 values for the desired UVLO low (VUV_L) and high (VUV_H) thresholds.

$$R_1 = \frac{V_{UV\_H} \times V_{IL} - V_{UV\_L} \times V_{IH}}{I_{IH} \times V_{IH} - I_{IL} \times V_{IL}} \quad (1)$$

$$R_2 = \frac{R_1 \times V_{IL}}{V_{UV\_L} - V_{IL} + R_1 \times I_{IH}} \quad (2)$$

where:

IIL = 0.4μA (TYP)

IIH = 1.45μA (TYP)

VIL = 1.08V (TYP)

VIH = 1.19V (TYP)

Bootstrap Voltage (BOOT)

To power the upper switch gate driver, a voltage higher than VIN is needed. Bootstrap technique is used to provide this voltage from the switching node by using a 0.1μF bootstrap capacitor between SW and BOOT pins along with an internal bootstrap diode. The voltage is internally regulated for driving the high-side switch. An X5R or X7R ceramic capacitor is recommended for CBOOT to have stable capacitance against temperature and voltage variations.

Output Voltage Programming

The output voltage is set by a resistor divider between VOUT and GND that is tapped to the FB pin. It is recommended to use 1% or higher quality resistors with low thermal tolerance for an accurate and thermally stable output voltage.

Use Equation 3 and Figure 4 to calculate the output voltage Lower divider resistor values increase loss and reduce light load efficiency. Consider larger resistors to improve efficiency at light load, and start with 100kΩ for the upper resistor (RFB1). Note that if RFB1 is too high (>1MΩ), the FB pin leakage current and other noises can easily affect the accuracy and performance of the regulator.

$$V_{OUT} = V_{REF} \times \left[\frac{R_{FB1}}{R_{FB2}} + 1\right] \quad (3)$$

Output Voltage Programming(Con.)

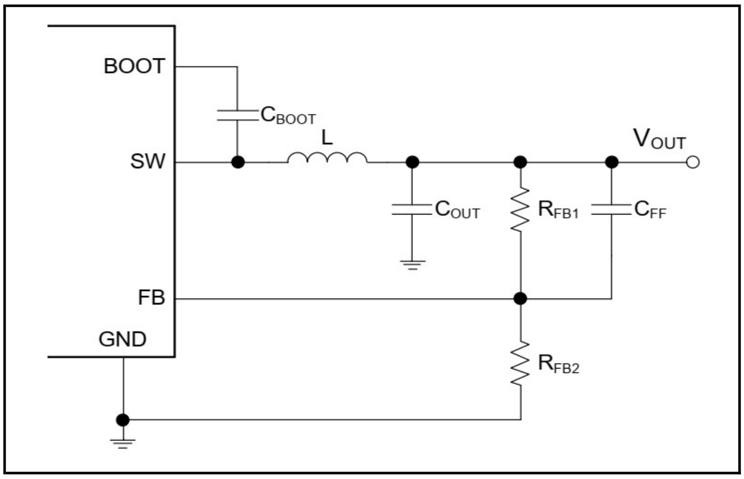


Figure 6. Adjustable Output Voltage

Internal Voltage Reference and Soft-Start

The HCR3229 device has an internal 0.594V reference (VREF) to program the output at the desired level. When the converter starts(or is enabled),an internal ramp voltage begins to rise from near 0V to slightly above 0.594V with a ramp time of 5ms. The lower of VREF and this ramp is used as reference for the error amplifier, therefore, during startup the ramp provides a soft-start for the output. The soft-start is essential to prevent high inrush currents caused by rapid increase of output voltage across output capacitors and the load.

Over-Current and Short-Circuit Protection

The HCR3229 supports overload mode. When the output current continues overload while the system power-up, the HCR3229 exports the maximize power and limits the maximum valley current of the low-side FET switch. The device keeps in cycle-by-cycle limit to meet the system’s power request. The HCR3229 does not shut down until the device heats and then goes to thermal shutdown. As the load increases continuously,the output voltage decreases. If the output voltage drops to 50% of VREF and the current of the low-side switch is higher than the low-side current limit for 512 consecutive cycles, the hiccup current-protection mode will be activated. In hiccup mode, the regulator is shut down and kept off for 7ms typically before the HCR3229 tries to start again. If over-current or a short -circuit fault condition still exists, the hiccup mode will

DETAILED DESCRIPTION(Con.)

Over-Current and Short-Circuit Protection(Con.)

repeat until the fault condition is removed. Hiccup mode can help to reduce power dissipation and prevent over-heating and potential damage to the device.

Output Over-Voltage Protection (OVP)

An over-voltage protection is included in the device to minimize the output voltage overshoots that may occur after recovery from an output fault or a large unloading transient. The FB pin voltage is compared with the OVP thresholds. If the VFB exceeds 108% of the VREF, the high-side switch is forced to turn off, and the low-side switch is turned on until zero cross current limit HCR3229A or negative current limit HCR3229B is triggered. When the VFB falls below 104% of the VREF, the high-side switch is allowed to turn on again

Light Load Operation with Pulse-Skip Mode (HCR3229A)

When HCR3229A operates in discontinuous conduction mode (DCM) with light loads, it goes into the pulse-skip mode (PSM) in which internal power dissipation is significantly reduced. Moreover, the operating frequency starts to drop depending on the load. At very light load and when the off-time exceeds 10μs, device goes to the sleep mode to lower internal dissipation.

The details are explained in Figure 7 that shows the timings of the ACOT control in DCM. Inductor current (IL) is monitored with a zero-crossing detector and when IL crosses the zero and VFB > VREF_EA (the output of the low-gain error amplifier), both high-side and low-side MOSFETs are turned off. They will not turn on again until the VFB falls below VREF_EA and triggers a new on-time pulse. During this off-time period, all non-essential circuits are shut down to minimize losses and the load is supplied by the output capacitor stored energy. The control circuitry wakes up when the new on-pulse is triggered. When the time between successive high-side pulses (t1) is longer than 10μs, the device goes into sleep mode in which the system current dissipation is only about 45μA.

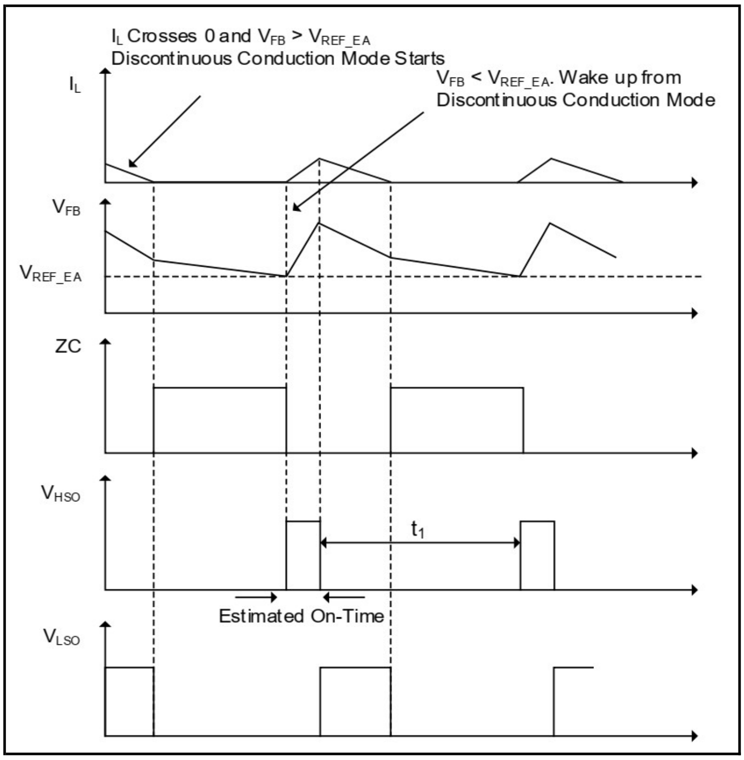


Figure 7. Pulse-Skip Mode in DCM

Light Load Operation with Continuous Current Mode (HCR3229B)

The HCR3229B is locked in continuous current mode from full load to no load. Negative inductor currents are allowed at light load to keep continuous inductor current operation. It is a tradeoff that sacrifices light load efficiency for keeping switching frequency relatively fixed, lower output ripple, and better output regulation. To avoid fatal negative current in the low-side switch, this current is limited at -1A.

Thermal Shutdown

If the junction temperature exceeds +170℃ (TYP), the device is forced to stop switching. It will recover automatically when TJ falls below the recovery threshold.

APPLICATION INFORMATION

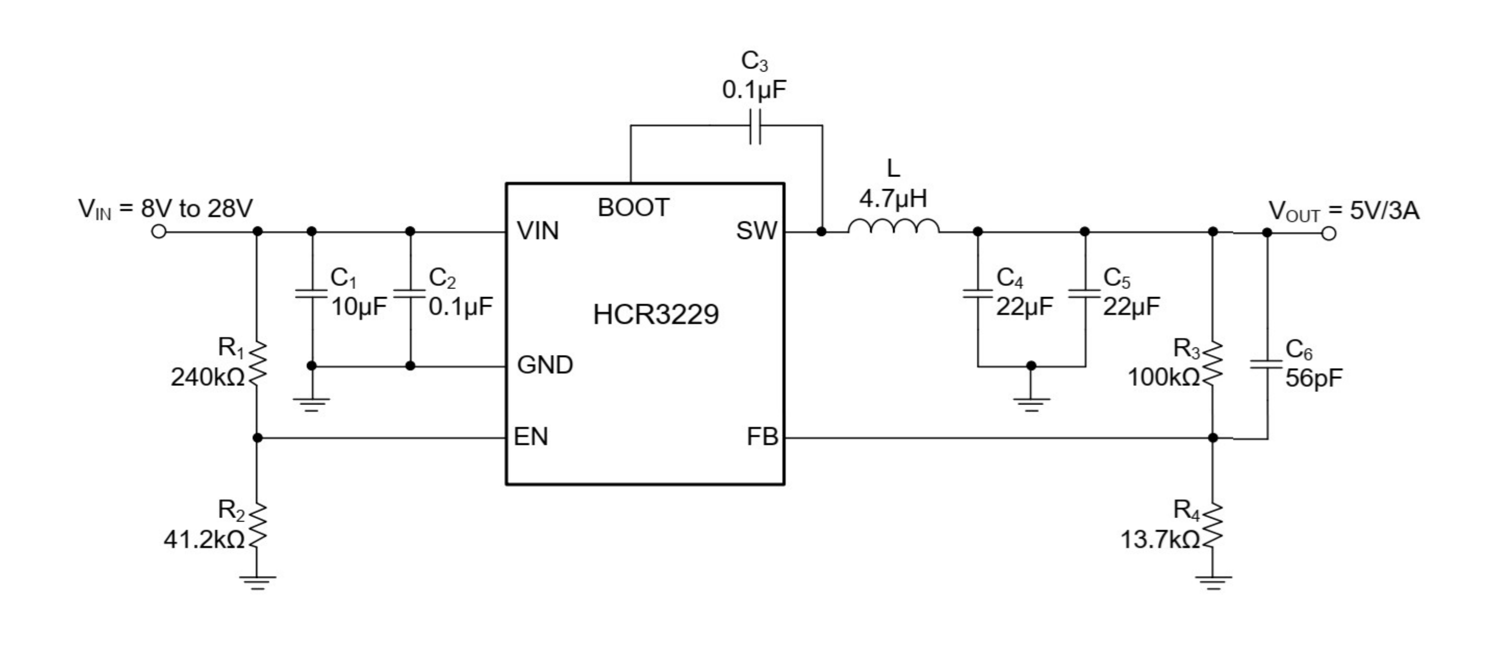


Figure 8. A Reference Design for 5V/3A Application

The design method and component selection for The HCR3229 Buck converter is explained in this section. Schematic of a basic design is shown in Figure 8. Only a few external components are needed to provide a constant output voltage from a wide input voltage range.

The external components are designed based on the application requirements and device stability. Some suitable output filters (L and COUT) along with CFF and divider resistor values are provided in Table 1 to simplify component selection.

Table 1. Recommended Component Values

VOUT(V)	L(uH)	C4+C5(uF)	R3(KΩ)	R4(KΩ)	C6(pF)
0.6	1.0	94	100	--	56
3.3	4.7	44	100	22.1	56
5.0	4.7	44	100	13.7	56
6.5	4.7	33	100	10	22

Design Requirements

A typical application circuit for the HCR3229 as a Buck converter is shown in Figure 8. It is used for converting an 8V to 28V supply voltage to a lower voltage level supply voltage (5V) suitable for the system. The design parameters given in Table 2 are used for this design example.

Table 2. Design Parameters

Design Parameters	Example Values
Input Voltage	12V (TYP), 8V to 28V
Start Input Voltage (Rising VIN)	8V
Stop Input Voltage (Falling VIN)	7V
Input Ripple Voltage	360mV, 3% of VIN_TYP
Output Voltage	5V
Output Voltage Ripple	50mV, 1% of VOUT
Output Current Rating	3A
Transient Response, 1.5A to 3A Load Step	250mV, 5% of VOUT
Operation Frequency	700kHz

Input Capacitor Selection

A high-quality ceramic capacitor (X5R or X7R or better dielectric grade) must be used for input decoupling of the HCR3229. At least 3μF of effective capacitance (after de-ratings) is needed on the VIN input. In some applications, additional bulk capacitance may also be required for the VIN input, for example, when the HCR3229 is more than 5cm away from the input source. The VIN capacitor ripple current rating must also be greater than the maximum input current ripple. The input current ripple can be calculated using Equation 4 and the maximum value occurs at 50% duty cycle. Using the design example values, IOUT = 3A, yields an RMS input ripple current of 1.5A.

APPLICATION INFORMATION(Con.)

Input Capacitor Selection(Con.)

$$I_{CIN\_RMS} = I_{OUT} \times \sqrt{\frac{V_{OUT}}{V_{IN}} \times \frac{(V_{IN} - V_{OUT})}{V_{IN}}} = I_{OUT} \times \sqrt{D \times (1-D)} \quad (4)$$

For this design, a ceramic capacitor with at least 50V voltage rating is required to support the maximum input voltage. So, a 10µF/50V capacitor is selected for VIN to cover all DC bias, thermal and aging de-ratings. The input capacitance determines the regulator input voltage ripple. This ripple can be calculated from Equation 5. In this example, the total effective capacitance of the 10µF/50V capacitor is around 4µF at 12V input and the input voltage ripple is 260mV.

$$\Delta V_{IN} = \frac{I_{OUT} \times D \times (1-D)}{C_{IN} \times f_{SW}} \quad (5)$$

It recommended placing an additional small size 0.1µF ceramic capacitor right beside VIN and GND pins for high frequency filtering.

Inductor Selection

Equation 6 is conventionally used to calculate the output inductance of a Buck converter. The ratio of inductor current ripple (ΔIL) to the maximum output current (IOUT) is represented as KIND factor (ΔIL/IOUT). The inductor ripple current is bypassed and filtered by the output capacitor and the inductor DC current is passed to the output. Inductor ripple is selected based on a few considerations. The peak inductor current (IOUT + ΔIL/2) must have a safe margin from the saturation current of the inductor in the worst-case conditions especially if a hard-saturation core type inductor (such as ferrite) is chosen. The ripple current also affects the selection of the output capacitor. COUT RMS current rating must be higher than the inductor RMS ripple.Typically,a 40% ripple is selected (KIND = 0.4).

$$L = \frac{V_{IN\_MAX} - V_{OUT}}{I_{OUT} \times K_{IND}} \times \frac{V_{OUT}}{V_{IN\_MAX} \times f_{SW}} \quad (6)$$

In this example, the calculated inductance will be 4.9µH with KIND = 0.4, so the nearest inductance of 4.7µH is selected. The ripple, RMS and peak inductor current calculations are summarized in Equations 7, 8 and 9 respectively.

Inductor Selection (Con.)

$$\Delta I_L = \frac{V_{IN\_MAX} - V_{OUT}}{L} \times \frac{V_{OUT}}{V_{IN\_MAX} \times f_{SW}} \quad (7)$$

$$I_{L\_RMS} = \sqrt{I_{OUT}^2 + \frac{\Delta I_L^2}{12}} \quad (8)$$

$$I_{L\_PEAK} = I_{OUT} + \frac{\Delta I_L}{2} \quad (9)$$

Note that during startup, load transients or fault conditions, the peak inductor current may exceed the calculated IL_PEAK.Therefore, it is always safer to choose the inductor saturation current higher than the switch current limit.

Output Capacitor Selection

The output capacitors and inductor filter the AC part of the PWM switching voltage and provide an acceptable level of output voltage ripple superimposed on the desired output DC voltage. Additionally, the capacitors store energy to assist in maintaining output voltage regulation during load transient. The output voltage ripple (ΔVOUT) depends on the output capacitor value at the operating voltage, temperature (°C) and its parasitic parameters (ESR and ESL):

$$\Delta V_{OUT} = \Delta I_L \times ESR + \frac{V_{IN} - V_{OUT}}{L} \times ESL + \frac{\Delta I_L}{8 \times f_{SW} \times C_{OUT}} \quad (10)$$

The voltage rating of the output capacitors should be selected with enough margins to ensure that capacitance drop (voltage and temperature de-rating) is not significant. The type of output capacitors will determine which terms of Equation 10 are dominant.For ceramic output capacitors, the ESR and ESL are virtually zero, so the output voltage ripple will be dominated by the capacitive term.

To reduce the voltage ripple, either inductance or the total capacitance is increased. For electrolytic output capacitors, the value of capacitance is relatively high, and compared with ESR and ESL terms, the third term in Equation 10 can be ignored:

Higher quality capacitors, larger inductance or using parallel capacitors can help reduce the output ripple in a design using electrolytic output capacitors.

The ESR of some commercial electrolytic capacitors can be quite high, and it is recommended using quality capacitors with the ESR or the total impedance clearly

APPLICATION INFORMATION(Con.)

Output Capacitor Selection(Con.)

documented in the datasheet. ESR of an electrolytic capacitor may increase significantly at cold ambient temperatures with a factor of 10 or so, which increases the ripple and can deteriorate the regulator stability.

The transient response of the regulator also depends on the quantity and type of output capacitors. In general, reducing the ESR of the output capacitance will lead to a better transient response. The ESR can be minimized by simply adding more capacitors in parallel or by using higher quality capacitors. When a fast load transient of magnitude ΔIL and rate of di/dt occurs, the output voltage will jump or dip by a transient magnitude of ΔV_{OUT}:

$$\Delta V_{OUT} = \Delta I_L \times ESR + \frac{di}{dt} \times ESL \qquad (11)$$

Right after the transient, the inductor current remains almost constant especially for larger inductors and the transient current is carried by the capacitor. The output voltage will deviate from its nominal value for a short time depending on the system bandwidth, the inductor and the output capacitance. Eventually, the error amplifier and feedback bring the output voltage back to its nominal value. A higher bandwidth is usually preferred to get shorter settling time, however, it may be more difficult to get acceptable gain and phase margins. In this example, according to Table 1, 2×22μF/16Vx5R ceramic capacitors with 2mΩ of ESR can meet the above conditions.

Bootstrap Capacitor Selection

Use a 0.1μF high-quality ceramic capacitor (X5R or X7R) with 10V or higher voltage rating for the bootstrap capacitor (C3).

VIN UVLO Setting

The input UVLO can be programmed by using an external voltage divider on the EN pin of the HCR3229. In this design, R1 is connected between VIN pin and EN pin and R2 is connected between EN pin and GND (see Figure 6). The UVLO has two thresholds (hysteresis), one for power -up (turn-on) when the input voltage is rising and one for

VIN UVLO Setting (Con.)

power-down (turn-off) when the voltage is falling. In this design, the turn-on(enable to start switching) occurs when VIN rises above 8V (UVLO rising threshold). When the regulator is working, it will not stop switching (disabled) until the input falls below 7V (UVLO falling threshold). Equations 1 and 2 are provided to calculate the resistors. For this example, the nearest standard resistor values are R1 = 240kΩ and R2 = 41.2kΩ.

Output Voltage Setting

Use an external resistor divider (R3 and R4) to set the output voltage using Equation 14:

$$R_4 = R_3 \times \left(\frac{V_{REF}}{V_{OUT} - V_{REF}} \right) \qquad (12)$$

where V_{REF}=0.594V is the internal reference. For example, by choosing R3 = 100kΩ, the R4 value for 5V output will be calculated as 13.7kΩ.

Feed-Forward Capacitor Selection

The HCR3229 contains an internal compensation circuit, an internal ramp is added to reference voltage to simulate output ripple. For ultra-low output capacitance ESR (ceramic capacitor) applications, it is recommended adding a 56pF feed-forward capacitor (C6) to provide a low-impedance path for output voltage ripple and ensure minimal phase shift of the voltage ripple at the feedback node while maintaining acceptable transient response.

Layout Guide

PCB is an essential element of any switching power supply. The converter operation can be significantly disturbed due to the existence of the large and fast rising/falling voltages that can couple through stray capacitances to other signal paths and also due to the large and fast changing currents that can interact through parasitic magnetic couplings, unless those interferences are minimized and properly managed in the layout design. Insufficient conductance in copper traces for the high current paths results in high resistive losses in the power paths and voltage errors. The following guidelines provided here are necessary to

APPLICATION INFORMATION(Con.)

Layout Guide(Con.)

design a good layout:

- Bypass VIN pin to GND pin with low-ESR ceramic capacitors (X5R or X7R better dielectric) placed as close as possible to VIN pin.
- Use short, wide and direct traces for high-current connections (IN, SW and GND).

Layout Guide(Con.)

- Keep the BOOT-SW voltage path as short as possible.
- Place the feedback resistors as close as possible to the FB pin that is sensitive to noise.
- Minimize the area and path length of the loop formed by VIN pin, bypass capacitors connections and SW pin.

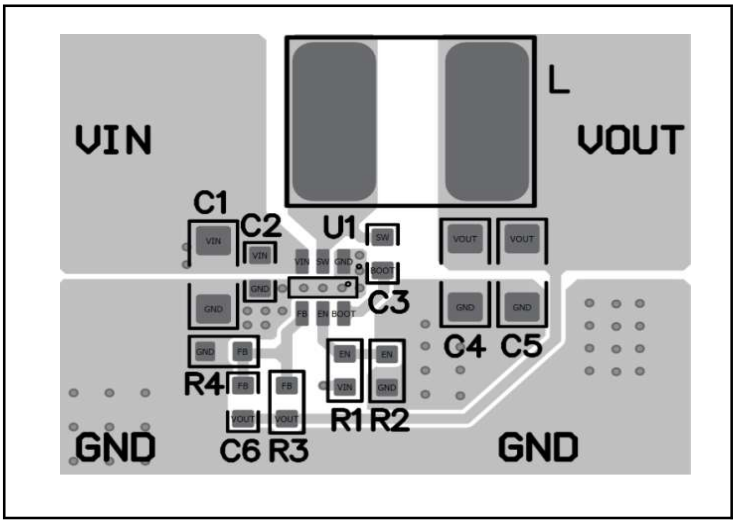


Figure 9. PCB Top Layer

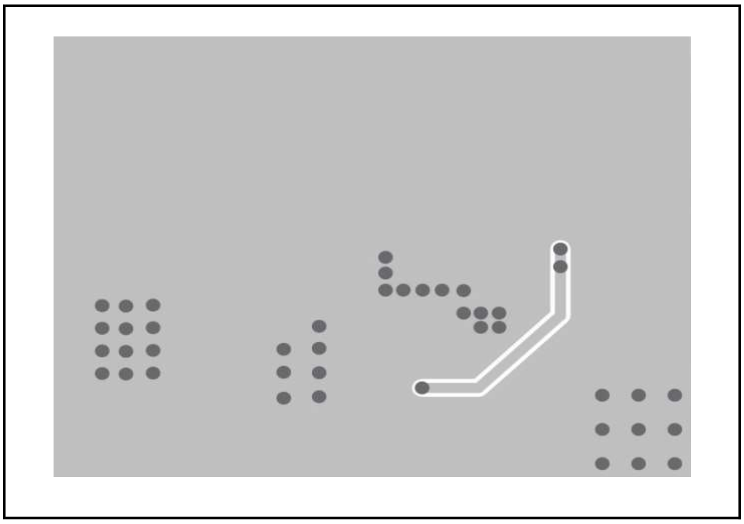


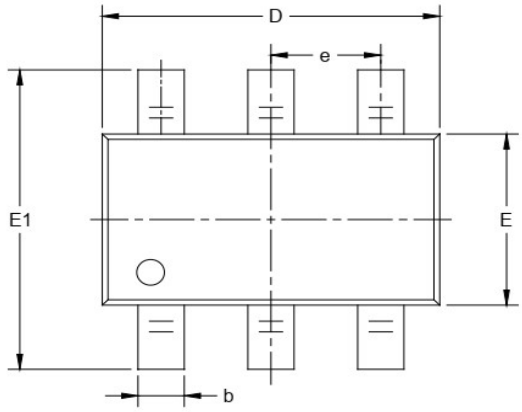
Figure 10. PCB Bottom Layer

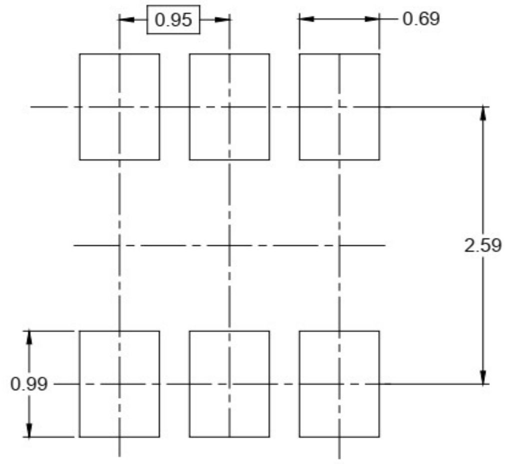
700KHz, 28V, 3A Synchronous Step-Down Converter

Mechanical Dimensions

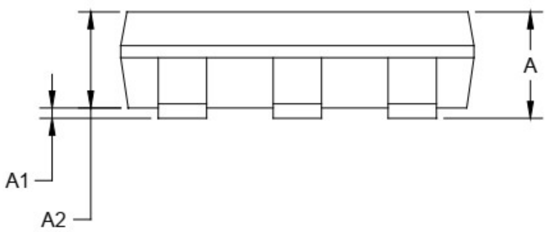
M6L PKG: TSOP-6 (SOT23-6L)

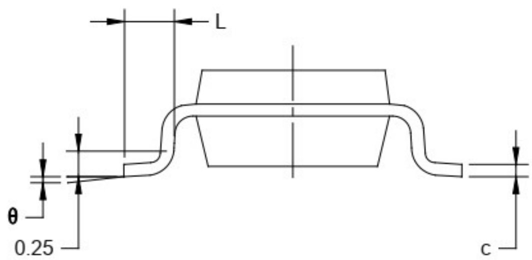
Unit: mm





RECOMMENDED LAND PATTERN





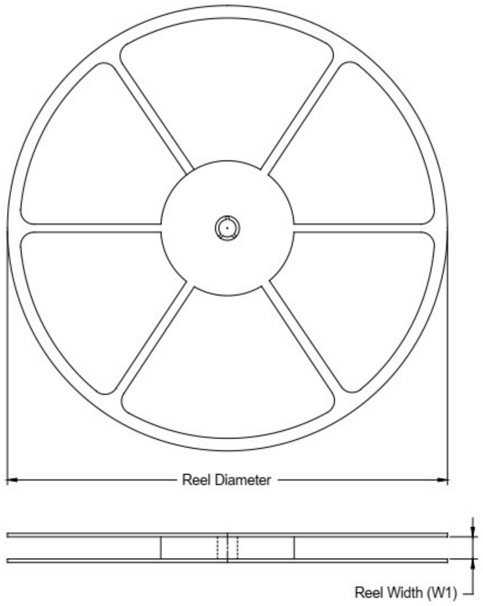
Symbol	Dimensions In Millimeters		
	MIN	MOD	MAX
A	-	-	1.100
A1	0.000	-	0.100
A2	0.700	-	1.000
b	0.300	-	0.500
c	0.080	-	0.200
D	2.820	-	3.050
E	1.550	-	1.700
E1	2.650	-	2.950
e	0.950 BSC		
L	0.300	-	0.600
θ	0°	-	8°

NOTES:

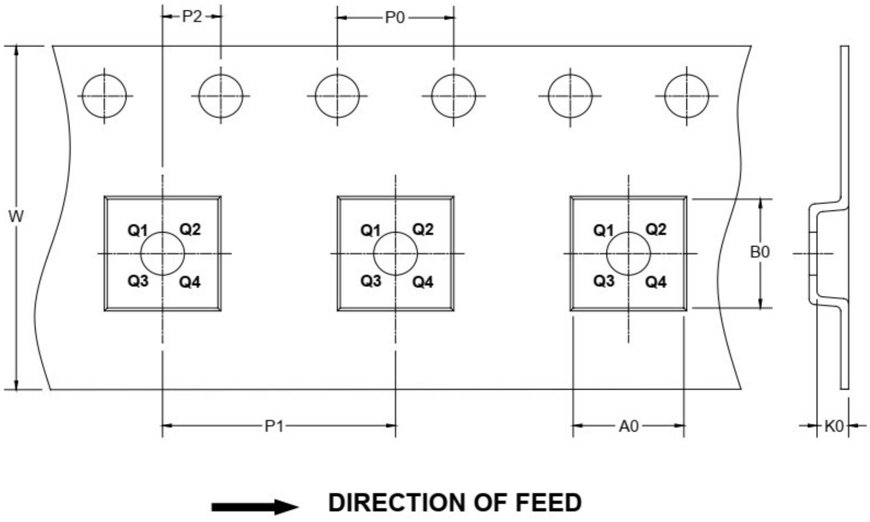
1. Body dimensions do not include mode flash or protrusion.
2. This drawing is subject to change without notice.

Tape and Reel Information

REEL DIMENSIONS



TAPE DIMENSIONS



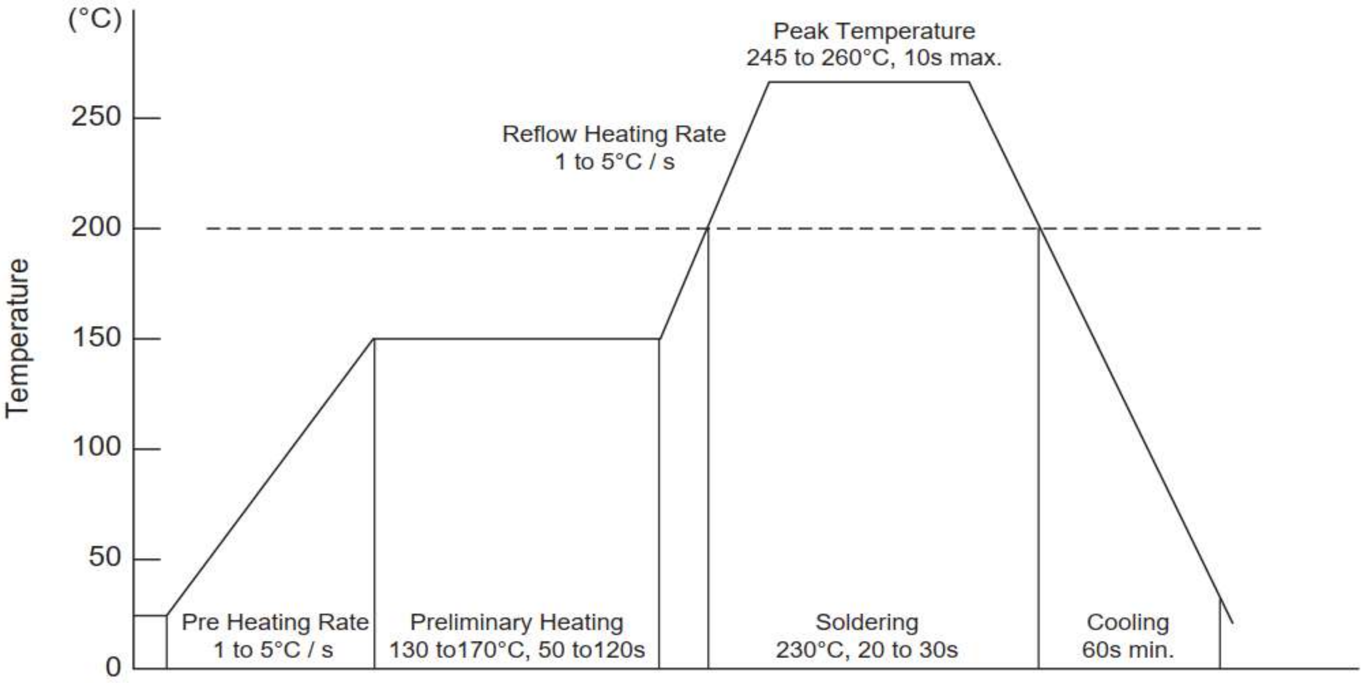
NOTE: The picture is only for reference. Please make the object as the standard.

Key Parameter List of Tape and Reel

Package Type	Reel Diameter	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	P1 (mm)	P2 (mm)	W (mm)	Pin1 Quadrant
SOT23-6L	7"	9.5	3.20	3.20	1.40	4.0	4.0	2.0	8.0	Q3

Conditins of Soldering and Storage

* Recommended condition of reflow soldering



Recommended peak temperature is over 245'C, if peak temperature is below 245'C, you may adjust the following parameters:

* Time length of peak temperature (longer)
* Time length of soldering (longer)
* Thickness of solder paste (thicker)

* Conditions of hand soldering
  * Temperature : 300'C
  * Time : 3s max
  * Times : one time

* Storage conditions
  * Temperature
    5 to 40'C
  * Humidity
    30 to 80% RH
  * Recommended period
    One year after manufacturing