500KHz, 32V, 2A Synchronous Step-Down Converter with EMI Reduction

Features

- EMI Reduction with Switching Node Ringing-Free
- 500KHz Switching Frequency With ±6% FSS
- 2.0A Output Current
- PSM mode with 20uA Quiescent Current
- 3.8V to 32V Input Voltage Range
- 0.8V±1% Reference
- 1uA Shut-down Current
- 80nS Minimum On-time
- Programmable UVLO Threshold and Hysteresis
- Low Drop out(LDO) Mode Operation
- 4ms Built-in Soft Start Time
- Output Over Voltage Protection
- Thermal Shutdown Protection at 160'C

Applications

- White Goods, Home Appliance
- Surveillance
- Audio, WiFi Speaker
- Printer, Charging Station
- DTV, STB, Monitor/LCD Display

Pacakage

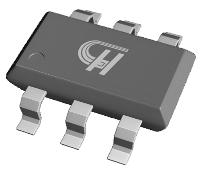
- TSOT23-6L(TSOP-6)

General Description

The HCR3231 is 2A synchronous buck converters with up to 32V wide input voltage range, which fully intergrates an 130mΩ high-side MOSFET and a 70mΩ low-side MOSFET to provide high efficiency step-down DC/DC conversion. The HCR3231 adopts peak current mode control with the integrated compensation network, which makes HCR3231 easily to be used by minimizing the off-chip component count. The HCR3231 supports the Pulse Skipping Modulation(PSM) with typical 20uA Ultra-Low Quiescent and achieves more than 80% efficient at 1mA and 88% at 5mA light load conditions.

The HCR3231 is an Electromagnetic Interference (EMI) friendly buck converter with implementing optimized design for EMI reduction.The HCR3231 features Frequency Spread Spectrum FSS with ±6% jittering span of the 500KHz switching frequency and modulation rate 1/512 of switching frequency to reduce the conducted EMI. The converter has proprietary designed gate driver scheme to resist switching node ringing without sacrificing MOSFET turn-on and turn-off time, which further erases high frequency radiation EMI noise caused by the MOSFETs hard switching.

The HCR3231 offers output over-voltage protection, cycle-by-cycle peak current limit, and thermal shutdown protection. The device is available in a low-profile SOT23-6L(TSOP-6) package.



SOT23-6L(TSOP-6)

Figure 1. Package Type of HCR3231

Pin Configuration

TSOP-6 (SOT23-6L) Top View

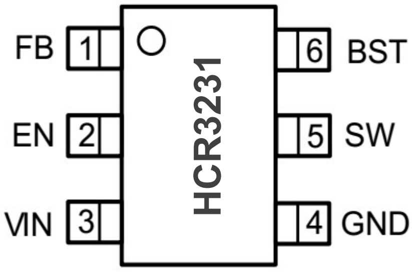
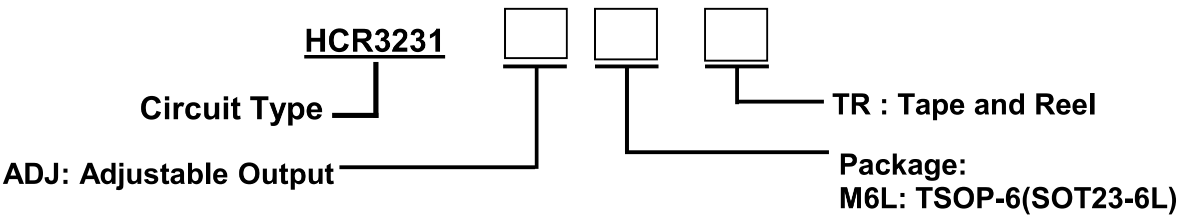


Figure 2. Pin Configuration of HCR3231 (Top View)

Pin Function Table

Pin Number	Pin Name	Function
1	FB	Output Voltage Feedback Pin. Connect FB to the center point of the external resistor divider. The FB voltage is 0.8V as reference
2	EN	Enable logic Pin. Floating the pin enables the device. This pin supports high voltage input up to VIN supply to be connected VIN directly to enable the device automatically. The device has precision enable thresholds 1.18V rising /1.1V falling for programmable UVLO threshold and hysteresis.
3	VIN	Power Supply input pin. Must be loaclly bypassed.
4	GND	Power Ground. Must be soldered directly to ground plane.
5	SW	Switching node of the buck converter.
6	BST	Power supply for the high-side power MOSFET gate driver. Must connect a 0.1uF or greater ceramic capacitor between BST pin and SW node.

Ordering Information



Ordering Code

Part Number	Marking ID note2	Temperature Junction Range	Package	Quantity per Reel
HCR3231ADJM6LTR	2320XXX	-40'C to +125'C	TSOP-6 (SOT23-6L)	3000pcs/TR

Note 2: "2320" is device code and "XXX" is Inside code.

Functional Block Diagram

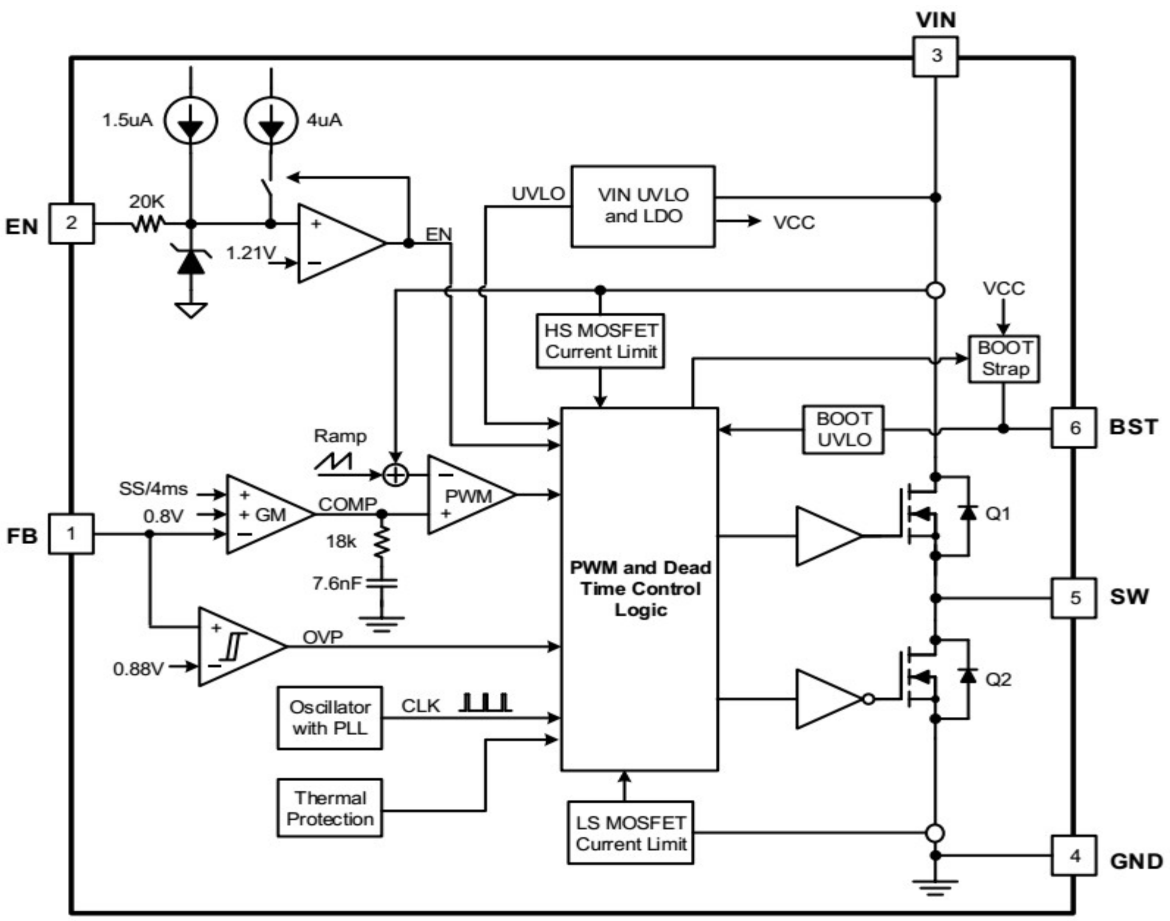
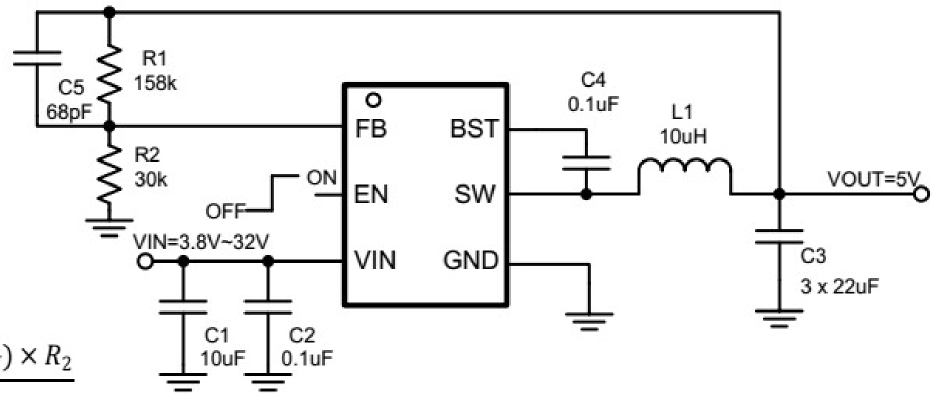


Figure 3. Functional Block Diagram of HCR3231

Typical Application Circuit



$$R_1 = \frac{(V_{OUT} - V_{ref}) \times R_2}{V_{ref}}$$

Note: if R3=2KΩ, R2=30KΩ, Vref=0.8V, So the R1 should be selected from 88KΩ to 500KΩ

Figure 4. Typical Application Circuit of HCR3231

Absolute Maximum Ratings Note 1

Parameter	Symbol	Value	Unit
BST Voltage Range	VBST	-0.3 to +40.0	V
Input Supply Voltage Range	VIN	-0.3 to +34.0	V
SW Voltage Range	VSW	-0.3 to +34.0	V
EN Voltage Range	VEN	-0.3 to +34.0	V
VS, FB Voltage Range	VVS, VFB	-0.3 to +5.5	V
Power Dissipation	PO	550	mW
Thermal Resistance Junction to Ambient	RθJA	89.0	'C/W
Thermal Resistance Junction to Case	RθJC	39.0	'C/W
Storage Temperature Range	TSTG	-65 to 150	'C
Operating Junction Temperature	TJ	-40 to +125	'C
Lead Temperature (Soldering, 10s)	TLEAD	260	'C
Human Body Model for all pins	VESD_HBM	±2000	V
Charge Device Model for all pins	VESD_CDM	±500	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	VIN		3.8	-	32	V
Operating Junction Temperature Range	TJ		-40	-	125	'C

Electrical Characteristics

(VIN=VEN=12V, TJ=-40'C~125'C, typical values are tested under 25'C, unless otherwise noted.)

Parameter	Symbol	Test Condition	Min	Type	Max	Unit
Input Voltage Range	V_{IN}		3.8	-	32	V
Input UVLO Threshold	V_{UVLO}	Vin rising	-	3.5	3.7	V
Input UVLO Hysteresis	$V_{UVLO-HYS}$		-	420	-	mV
Quiescent Current	I_Q	V_{EN}=floating, No load, No switching. VIN=12V. BST-SW=5V.	-	20	-	uA
Shutdown Current	I_{SD}	V_{EN}=0V, No load, VIN=12V	-	1	3	uA
Regulated Feedback Voltage Accuracy	V_{REF}		0.792	0.800	0.808	V
High-Side Switch On Resistance	$R_{DS(ON)\_H}$		-	130	-	mΩ
Low-Side Switch On Resistance	$R_{DS(ON)\_L}$		-	70	-	mΩ
HSD Peak Current Limit	I_{LIM_HSD}		2.5	2.8	3.1	A
LSD Valley Current Limit	I_{LIM_LSD}		2.8	3.2	3.6	A
Switching Frequency	F_{SW}	V_{IN}=12V, V_{OUT}=5V	450	500	550	KHz
Minimum On-time	t_{ON_MIN}	-	-	80	-	ns
FSS Jittering Span	F_{JITTER}	-	-	±6	-	%
Enable High Threshold	V_{EN-H}		-	1.18	1.25	V
Enable Low Threshold	V_{EN-L}		1.03	1.1	-	V
Enable Pin Input Current	I_{EN}	EN=1V	1.0	1.5	2.0	uA
Enable Pin Hysteresis Current	I_{EN_HYS}	EN=1.5V	-	4.0	-	uA
Internal Soft-Start Time	T_{SS}		-	4	-	ms
Output OVP Threshold	V_{OVP}	V_{OUT} Rising	-	110	-	%
Output OVP Hysteresis	V_{OVP_HYS}		-	5	-	%
OCP Hiccup Wait Time	T_{HIC_W}		-	512	-	Cycles
OCP Hiccup Restart Time	T_{HIC_R}		-	8192	-	Cycles
Thermal Shutdown [note3]	T_{SD}		-	160	-	'C
Thermal Hysteresis[note3]	T_{SD_HYS}		-	25	-	'C

Note 3. Thermal shutdown threshold and hysteresis are guaranteed by design.

Typical Performance Characteristics

(Test condition: VIN=12V, VOUT=5V, L=10uH, TA=25'C, unless otherwise noted.)

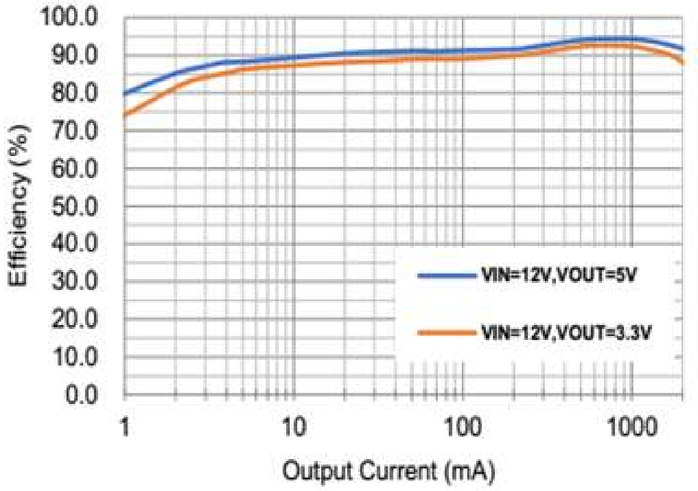


Figure 5. Efficiency, Vin=12V

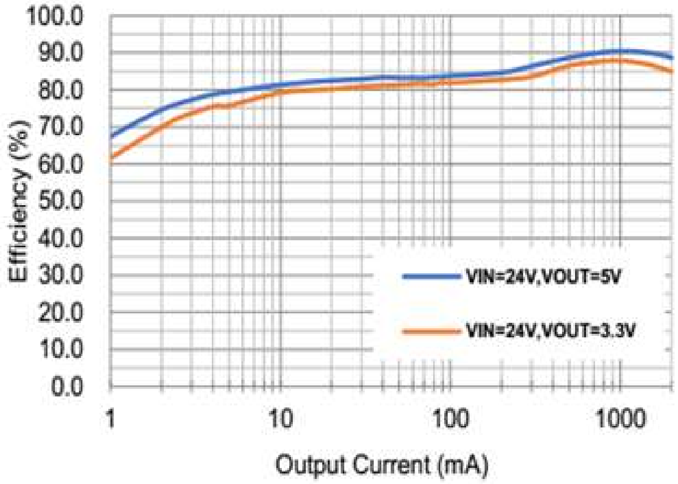


Figure 6. Efficiency, Vin=24V

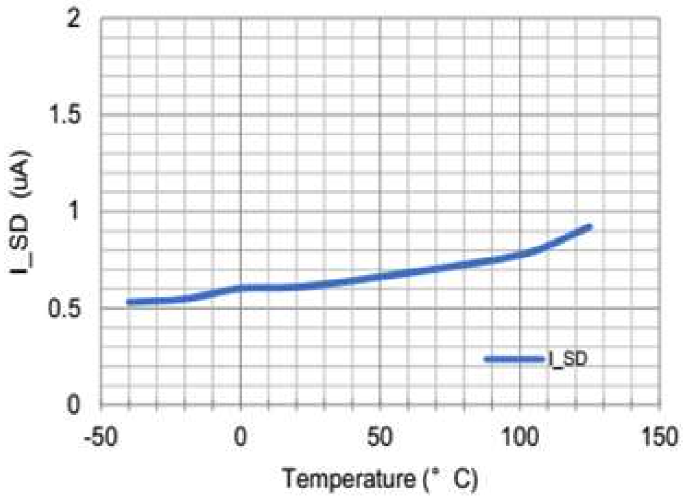


Figure 7. Shut-down Current vs Temperature

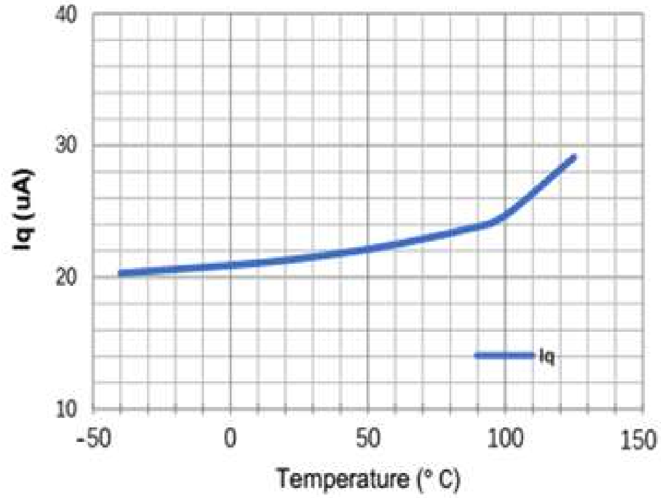


Figure 8. Quiescent Current vs Temperature

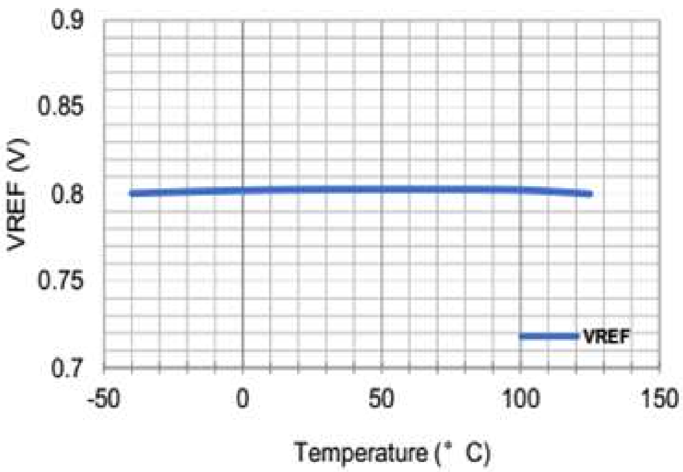


Figure 9. Reference Voltage vs Temperature

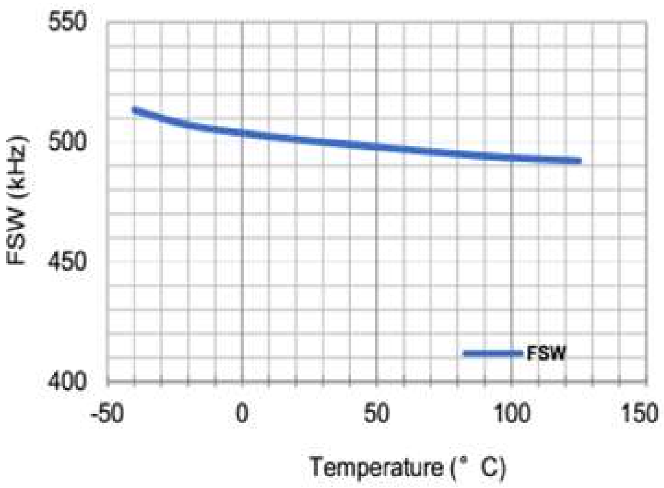


Figure 10. Center Switching Frequency vs Temperature

500KHz, 32V, 2A Synchronous Step-Down Converter with EMI Reduction

Typical Performance Characteristics(Con.)

(Test condition: VIN=12V, VOUT=5V, L=10uH, TA=25'C, unless otherwise noted.)

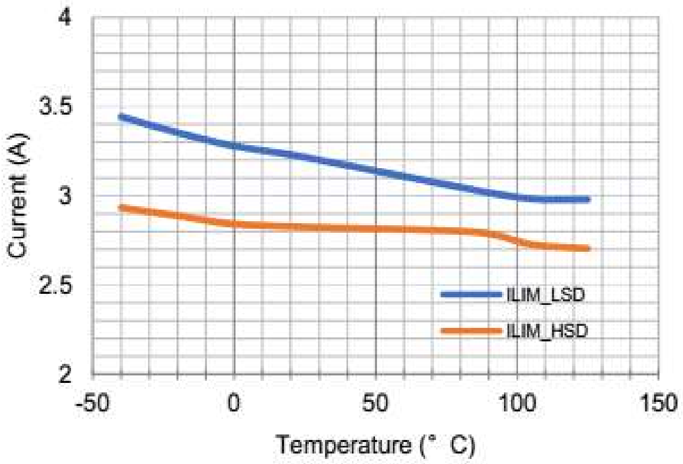


Figure 11. Peak Current Limit vs Temperature

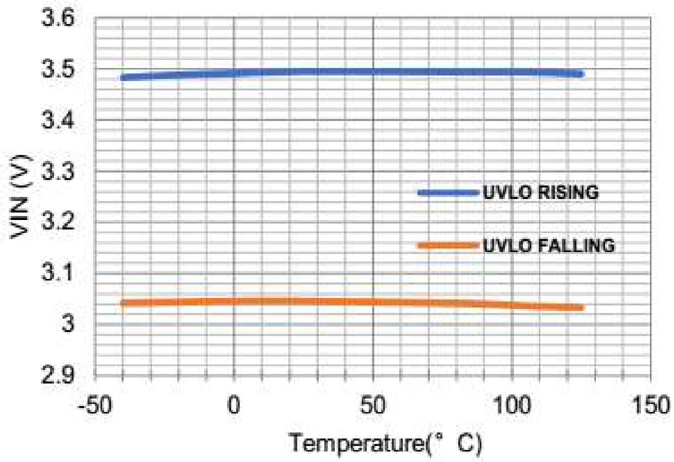


Figure 12. VIN UVLO vs Temperature

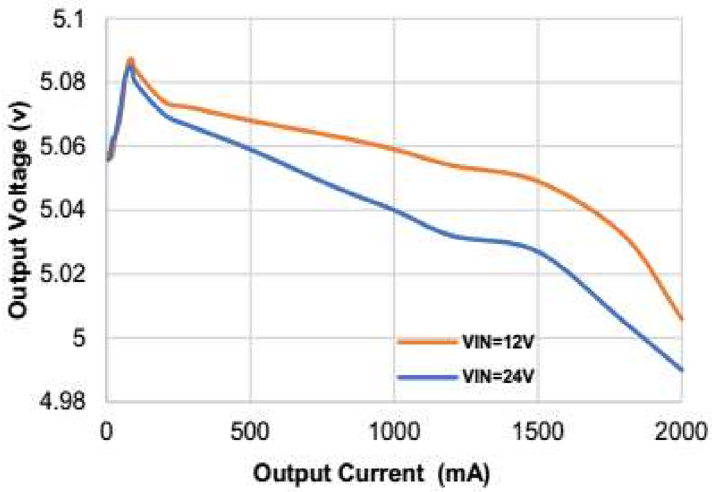


Figure 13. Load Regulation (VOUT=5V)

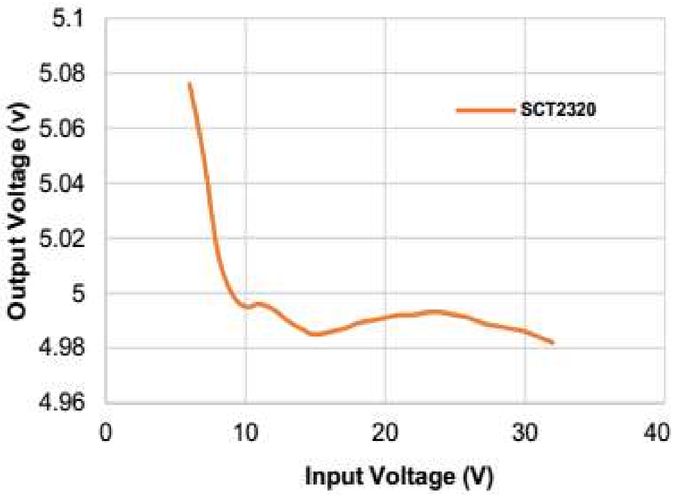
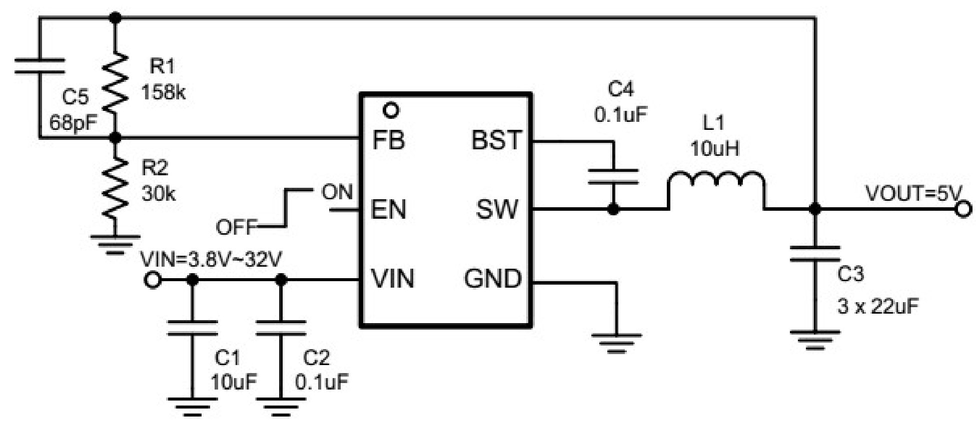


Figure 14. Line Regulation (IOUT=2A)

Application Information

Typical Application



Note: Input Voltage=24V, Output Voltage=5V, Output Current=2A, Output voltage ripple=±0.3V, F=500KHz

Figure 15. 24V Input, 5V/2A Output

Application Information (Con.)

Input Capacitor Selection

For the input voltage filtering,choose low-ESR ceramic capacitors. A ceramic capacitor 10uF is recommended For the decoupling capacitor and 0.1uF ceramic bypass capacitor is recommended to be placed as close as possible to the VIN pin of the HCR3231.

Use Equation (3) to calculate the input voltage ripple:

$$\Delta V_{IN} = \frac{I_{OUT}}{C_{IN} \times f_{SW}} \times \frac{V_{OUT}}{V_{IN}} \times (1 - \frac{V_{OUT}}{V_{IN}}) \qquad (3)$$

Where:
- C_{IN} is the input capacitor value
- f_{SW} is the converter switching frequency
- I_{OUT} is the maximum load current

Due to the inductor current ripple, the input voltage changes if there is parasitic inductance and resistance batween the power supply and the VIN pin. It is recom -mended to have enough input capacitance to make the input voltage ripple less than 100mV. Generally, a input 35V/10uF ceramic capacitor is recommended for most of applications, Choose the right capacitor value carefully with considering high-capacitance ceramic capacitors DC bias effect, which has a strong influence on the final effective capacitance.

Inductor Selection

The performance of inductor affect the power supply's steady state operation,transient behavior,loop stability and buck converter efficiency. The inductor value, DC resistance(DCR), and saturation current influences both efficiency and the magnitude of the output voltage ripple. Larger inductance value reduces inductor current ripple and therefore leads to lower output voltage ripple. For a fixed DCR. A larger value inductor yields higher efficiency via reduced RMS and core losses. However, a larger inductor within a given inductor family will generally have a greater series resistance, thereby counterby counteracting this efficiency advantage.

Inductor values can have ±20% or even ±30% tolerance

Inductor Selection(con.)

with no current bias. When the inductor current approaches saturation level, its inductance can decrease 20% to 35% from the value at 0-A current depending on how the inductor vendor defines saturation. When selecting an inductor,choose its rated current especially the saturation current larger than its peak current during the operation.

To calculate the current in the worst case, use the max input voltage, minimum output voltage, maxim load current and minimum switching frequency of the application, while considering the inductance with -30% tolerance and low-power conversion efficiency.

For a buck converter, calculate the inductor minimum value as shown in equation(4).

$$L_{INDMIN} = \frac{V_{OUT} \times (V_{INMAX} - V_{OUT})}{V_{INMAX} \times K_{IND} \times I_{OUT} \times f_{SW}} \qquad (4)$$

Where:
- K_{IND} is the coefficient of inductor ripple current relative to the maximum output current.

Therefore, the peak switching current of inductor, ILPEAK, is calculated as in equation(5).

$$I_{LPEAK} = I_{OUT} + K_{IND} \times \frac{I_{OUT}}{2} \qquad (5)$$

Set the current limit of the HCR3231 higher than the peak current ILPEAK and select the inductor with the current higher than the current limit. The inductor's DC resistance(DCR) and the core loss significantly affect the efficiency of power conversion. Core loss is related to the core material and different inductors have different core loss. For a certain inductor, larger current ripple generates higher DCR and ESR conduction losses and higher core loss.

Table 1 lists recommended inductors for the HCR3231 Verify whether the recommended inductor can support the user's target application with the previous calculations and bench evaluation. In this application,

Application Information (Con.)

Inductor Selection(con.)

the inductor 10uH is used on HCR3231 evaluation board.

L(uH)	DCR Max (mΩ)	Saturation Current/Heat Rating Current(A)	Size Max (LXWXH mm)
10	33	3.5	7X7X5

Output Capacitor Selection

For buck converter,the output capacitor value determine the regulator pole, the output voltage ripple, and how the regulator responds to a large change in load current The output capacitance needs to be selected based on the most stringent of these three criteria.

For small output voltage ripple, choose a low-ESR output capacitor like a ceramic capacitor, for example, X5R and X7R family. Typically, 1~3X22uF ceramic output capacitors work for most applications. Higher capacitor values can be used to improve the load transient response. Due to a capacitor's de-rating under DC bias, the bias can significantly reduce capacitance. Ceramic capacitors can lose most of their capacitance at rated voltage. Therefore, leave margin on the voltage rating to ensure adequate effective capacitance.

From the required output voltage ripple, use the equation(6) to calculate the minimum required effective capacitance, COUT.

$$C_{OUT} = \frac{\Delta I_{LPP}}{8 \times V_{OUTRipple} \times f_{SW}} \quad (6)$$

Where: ·VOUT Ripple is output voltage ripple caused by charging and discharging of the output capacitor.

·ΔILPP is the inductor peak to peak ripple current, equal to KIND * IOUT.

·fSW is the converter switching frequency.

The allowed maximum ESR of the output capacitor is calculated by the equation(7).

$$R_{ESR} = \frac{V_{OUTRipple}}{\Delta I_{LPP}} \quad (7)$$

Output Capacitor Selection(con.)

The output capacitor affects the crossover frequency fC. Considering the loop stability and effect of the inter- -nal loop compensation parameters, choose the cross- -over frequency less than 55KHz(1/10XfSW) without considering the feed-forward capacitor. A simple estimation for the crossover frequency without feed forward capacitor is shown in equation(8), assuming COUT has small ESR.

$$C_{OUT} > \frac{18k \times G_M \times G_{MP} \times 0.8V}{2\pi \times V_{OUT} \times f_C} \quad (8)$$

Where: ·GM is the transfer conductance of the error amplifier(300uS).

·GM is the gain from internal COMP to inductor current, which is 5A/V.

·fC is the cross over frequency.

Additional capacitance de-rating for aging, temperature and DC bias should be factored in which increases this minimum value. Capacitors generally have limits to the amount of ripple current they can handle without failing or producing excess heat. An output capacitor that can support the inductor ripple current must be specified. The capacitor data sheets specify the RMS(Root Mean Square) value of the maximum ripple current. Equation (9) can be used to calculate the RMS ripple current the output capacitor needs to support.

$$I_{COUTRMS} = \frac{V_{OUT} \cdot (V_{IN} - V_{OUT})}{\sqrt{12} \cdot V_{IN} \cdot L_{IND} \cdot f_{SW}} \quad (9)$$

Output Feed-Forward Capacitor Selection

The HCR3231 has the internal integrated loop compensation as shown in the function block diagram. The compensation network includes a 18K resistor and a 7.6nF capacitor. Usually, the type || compensation network has a phase margin between 60 and 90 degree. However, if the output capacitor has ultra-low ESR, the converter results in low phase margin. To increase the converter phase margin, a feed-forward cap Cff is used

Application Information (Con.)

Output Feed-Forward Capacitor Selection(con.)

to boost the phase margin at the converter cross-over frequency fC. Equation(10) is used to calculate the feed -forward capacitor.

$$C_{ff} = \frac{1}{2\pi \cdot f_C \times R_1} \qquad (10)$$

Output Feedback Resistor Divider Selection

A HCR3231 features external programmable output voltage by using a resistor divider network R1 and R2 as shown in the typical application circuit Figure 17. Use equation(11) to calculate the resistor divider values

$$R_1 = \frac{(V_{OUT} - V_{ref}) \times R_2}{V_{ref}} \qquad (11)$$

Set the resistor R2 value to be approximately 20K. Slightly increasing or decreasing R1 can result in closer output voltage matching when using standard value resistors.

Thermal Considerations

The maximum IC junction temperature should be restricted to 125'C under normal operating conditions. Calculate the maximum allowable dissipation, PD(max), and keep the actual power dissipation less than or equal to PD(max), The maximum-power-dissipation limit is determined using Equation(12)

$$P_{D(MAX)} = \frac{125 - TC_A}{R_{\theta JA}} \qquad (12)$$

Where:

- ·TA is the maximum ambient temperature for the application.
- ·RθJA is the junction-to-ambient thermal resistance given in the Thermal Information table.

The real junction-to-ambient thermal resistance RθJA of the package greatly depends on the PCB type, layout, thermal pad connection and environmental factor. Using thick PCB copper and soldering the GND to a

Thermal Considerations(con.)

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

Layout Guideline

The regulator could suffer from instability and noise problems without carefully layout of PCB. Radiation of high-frequency noise induces EMI, So proper layout of the high-frequency switching path is essential. Minimize the length and area of all traces connected to the SW pin, and always use a ground plane under the switching regulator to minimize coupling. The input capacitor needs to be very close to the VIN pin and GND pin to reduce the input supply ripple. Place the capacitor as close to VIN pin as possible to reduce high frequency ringing voltage on SW pin as well. Figure 16 is the recommended PCB layout of HCR3231.
The layout needs be done with well consideration of the thermal. A large top layer ground plate using multiple thermal vias is used to improve the thermal dissipation. The bottom layer is a large ground plane connected to the top layer ground by vias.

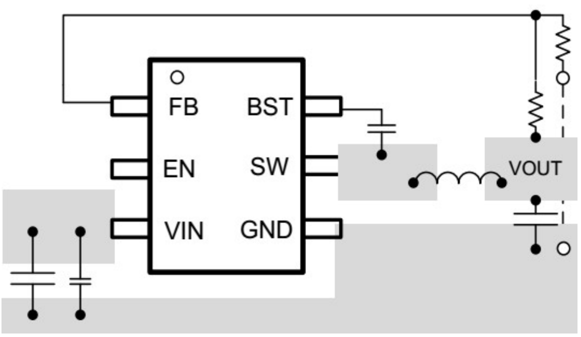
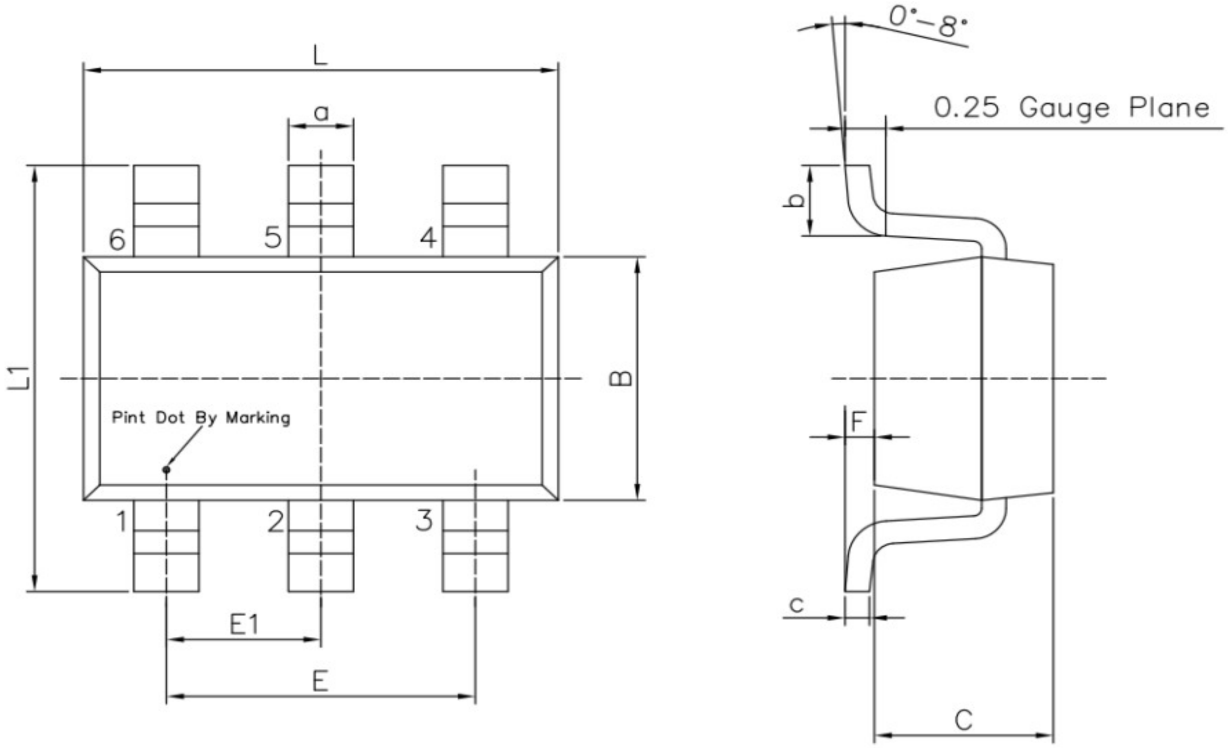


Figure 16. PCB Layout Example

Mechanical Dimensions

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

Unit: mm



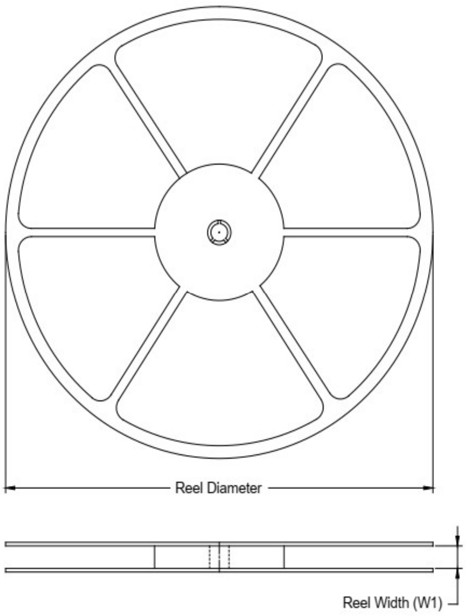
Symbol	Dimensions In Millimeters		Symbol	Dimensions In Millimeters	
	Min	Max		Min	Max
L	2.82	3.02	E1	0.85	1.05
B	1.50	1.70	a	0.35	0.50
C	0.90	1.30	c	0.10	0.20
L1	2.60	3.00	b	0.35	0.55
E	1.80	2.00	F	0	0.15

Note:

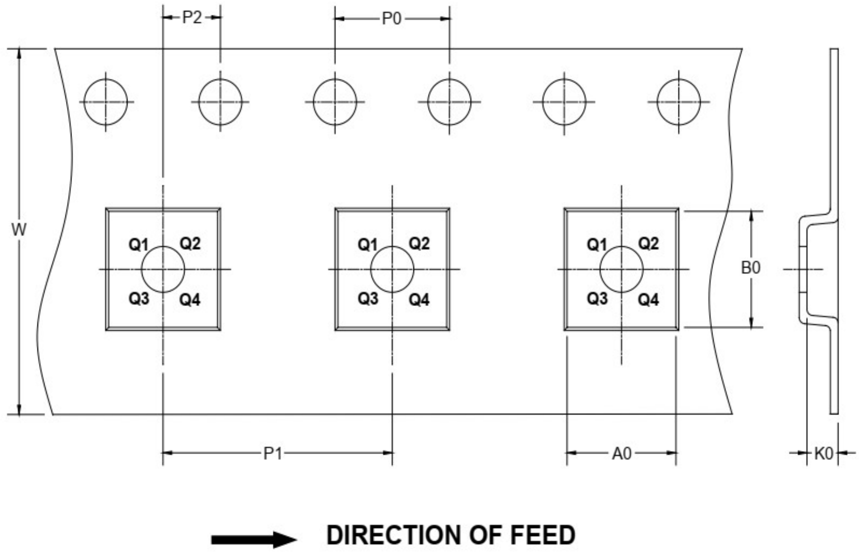
1) All dimensions are in millimeters.
2) Package length does not include mold flash, protrusion or gate burr.
3) Package width does not include inter lead flash or protrusion.
4) Lead popularity (bottom of leads after forming) shall be 0.10 millimeters max.
5) Pin 1 is lower left pin when reading top mark from left to right.

TAPE AND REEL INFORMATION

REEL DIMENSIONS



TAPE DIMENSIONS

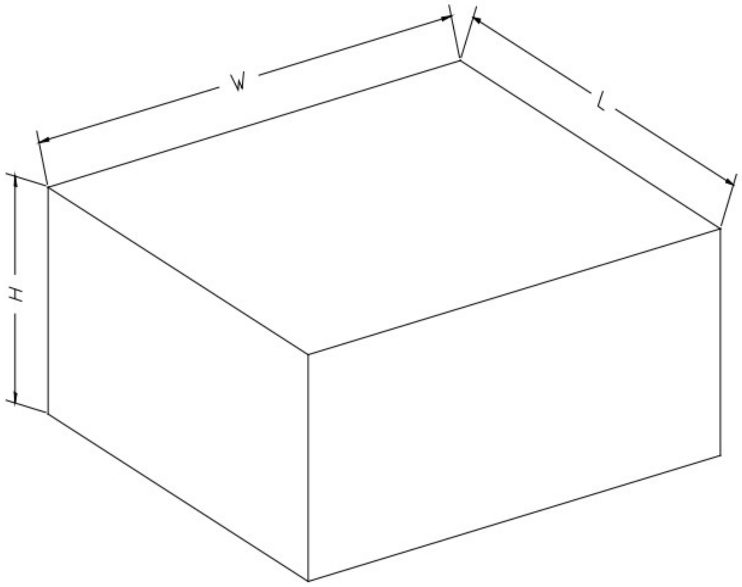


NOTE: The picture is only for reference. Please make the object as the standard.

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
TSOP-6 (SOT23-6L)	7"	9.5	3.20	3.20	1.40	4.0	4.0	2.0	8.0	Q3

CARTON BOX DIMENSIONS



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

KEY PARAMETER LIST OF CARTON BOX

Reel Type	Length (mm)	Width (mm)	Height (mm)	Pizza/Carton
7″	442	410	224	18