1.1MHz 40V, 1A Synchronous Step-Down Converter

Features

- 4.7V to 40V operating input voltage range
- 1.1MHz Switching Frequency
- Up to 93% efficiency
- 1A output current
- FCC at light load
- Internal Soft-Start
- Input under voltage lockout
- Current run-away protection
- Short circuit protection
- Thermal protection
- Available in SOT23-6L package

Applications

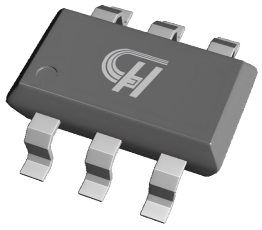
- Distributed Power Systems
- Automotive Systems
- High Voltage Power Conversion
- Industrial Power Systems
- Battery Powered Systems

General Description

The HCR3316 is a current mode monolithic buck switching regulator. Operating with an input range of 4.7V~40V, the HCR3316 delivers 1A of continuous output current with two integrated N-Channel MOSFETs. The internal synchronous power switches provide high efficiency without the use of of an external Schottky diode. At light loads, the regulator operates in continual conduction mode to maintain low output ripple. Current mode control provides tight load transient response and cycle-by -cycle current limit.

The HCR3316 guarantees robustness with short-circuit protection, thermal protection, current run-away protection, and input under voltage lockout.

The HCR3316 is available in SOT23-6L package, which provides a compact solution with minimal external components.



SOT23-6L

Figure 1. Package Type of HCR3316

1.1MHz 40V, 1A Synchronous Step-Down Converter

Pin Configuration

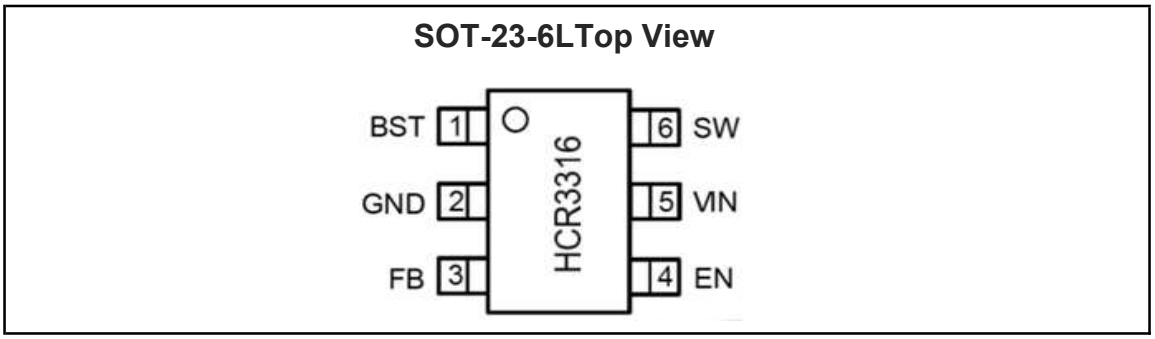
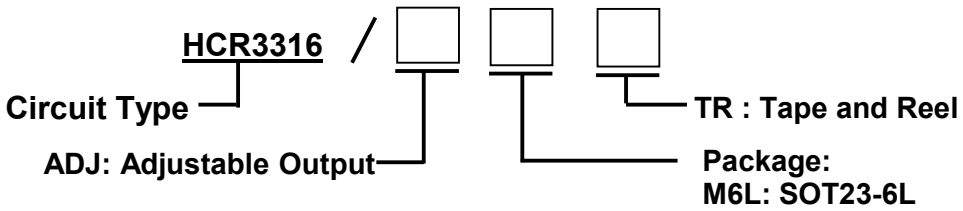


Figure 2. Pin Configuration of HCR3316 (Top View)

Pin Function Table

Pin Number	Pin Name	Function
1	BST	Bootstrap pin for top switch. A 0.1uF or larger capacitor should be connected between this pin and the SW pin to supply current to the top switch and top switch driver.
2	GND	Ground Pin
3	FB	Output feedback pin. FB senses the output voltage and is regulated by the control loop to 800mV. Connect a resistive divider at FB.
4	EN	Drive EN pin high to turn on the regulator and low to turn off the regulator.
5	VIN	Input voltage pin. VIN supplies power to the IC. Connect a 4.7V to 40V supply to VIN and bypass VIN to GND with a suitably large capacitor to eliminate noise on the input to the IC.
6	SW	SW is the switching node that supplies power to the output. Connect the output LC filter from SW to the output load.

Ordering Information



Ordering Code

Part Number	Marking ID[note2]	Temperature Range	Package	Quantity per Reel
HCR3316/ADJM6LTR	*WBHXX	-40'C to +125'C	SOT23-6L	3000pcs Tape&Reel

Note 2: the "XX" is Inside code.

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Functional Block Diagram

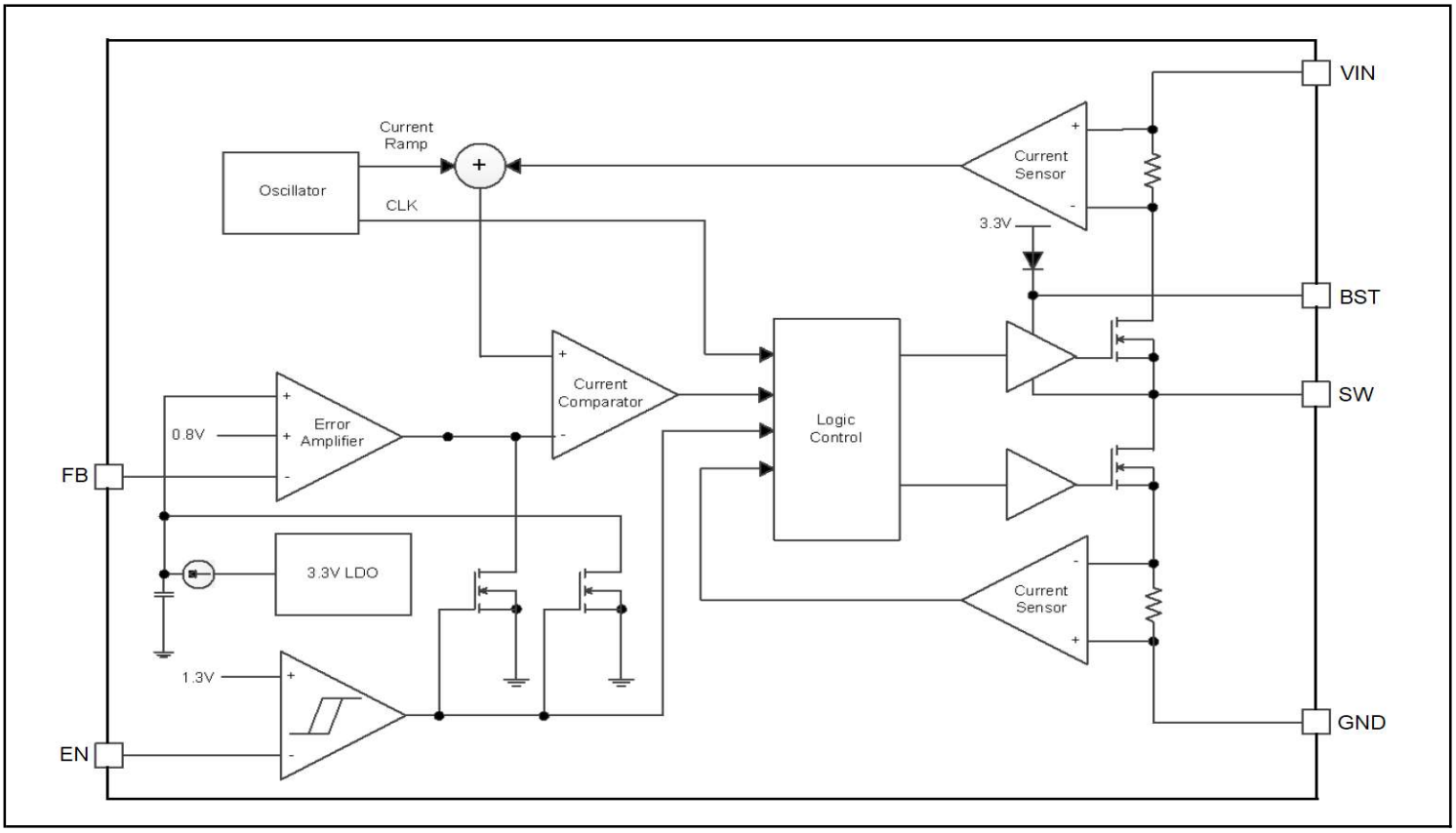


Figure 3. Functional Block Diagram of HCR3316

Typical Application Circuit

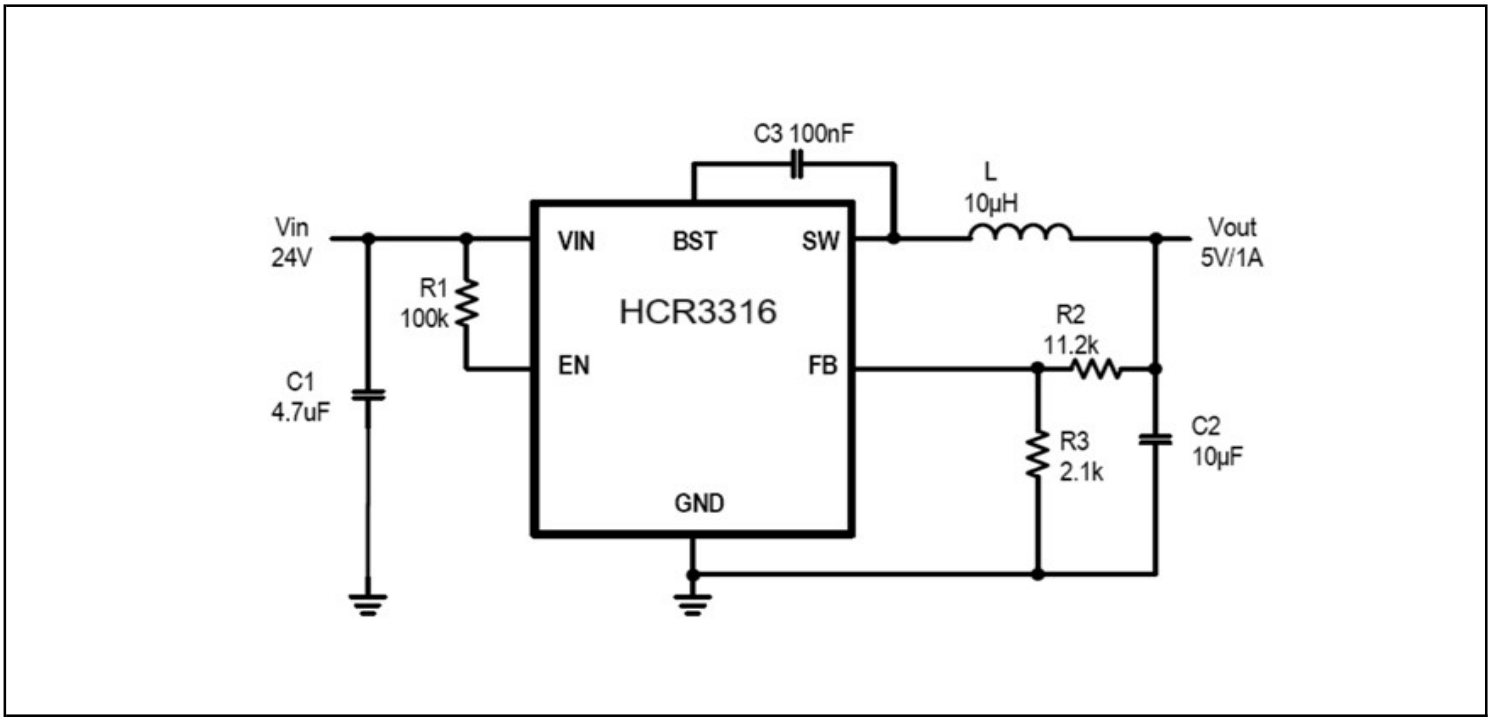


Figure 4. 5V/1A Step Down Regulators of HCR3316

Absolute Maximum Ratings Note 1

Parameter	Symbol	Value	Unit
Input Supply Voltage Range	V_{IN}	-0.3 to +44.0	V
SW Voltage Range	V_{SW}	-0.3(-7 for 5ns) to +44(45 for 5ns)	V
SW, EN Voltage Range	V_{SW}, V_{EN}	-0.3 to +44.0	V
BST Voltage Range	V_{BST}	V_{SW}-0.3 to V_{SW}+5.0	V
All other Pins	V*	-0.3 to +6.0	V
Power Dissipation	P_D	920	mW
Thermal Resistance Junction to Ambient note3	$R_{\theta JA}$	220	'C/W
Thermal Resistance Junction to Case note 3	$R_{\theta JC}$	130	'C/W
Storage Temperature Range	T_{STG}	-65 to +150	'C
Operating Junction Temperature	T_J	-40 to +125	'C
Lead Temperature (Soldering, 10s)	T_{LEAD}	260	'C

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.

3: Measured on 2OZ two-layer HCR3316 Evaluation Board at T_A=25'C

Recommended Operating Conditions

Parameter	Symbol	Test Condition	Min	Type	Max	Unit
Input Voltage Range	V_{IN}		4.7	-	40	V
Output Voltage	V_{OUT}		0.8	-	V_{IN}-3V	V
Operating Junction Temperature Range	T_J		-40	-	125	'C

Electrical Characteristics

(VIN=12V TA=25'C, unless otherwise noted.)

Parameter	Symbol	Test Condition	Min	Type	Max	Unit
VIN Under voltage lockout Threshold	VIN_MIN	VIN rising	4.0	4.3	4.6	V
VIN Under voltage lockout Hysteresis	VIN_MIN_HYST		140	250	360	mV
Quiescent Current	IQ	VEN=5.0V, VFB=1.2V	-	40	60	uA
Shutdown Supply Current	ISD	VEN=0V	-	0.1	1.0	uA
Feedback Voltage	VFB	4.7V<VIN<40V	780	800	820	mV
High-Side Switch On Resistance	RDS(ON)1		-	500	600	mΩ
Low-Side Switch On Resistance	RDS(ON)2		-	220	264	mΩ
Top Switch Leakage Current	ILEAK_TOP	VIN=40V, VEN=0V, VSW=0V	-	-	1.0	uA
Bottom Switch Leakage Current	ILEAK_BOT	VIN=40V, VEN=0V, VSW=40V	-	-	1.0	uA
Top Switch Current Limit	ILIM_TOP	Minimum Duty Cycle	-	1.7	2.04	A
Negative Current Limit	ILIM_Neg	ILIM_NEG	-	0.38	-	A
Oscillation Frequency	FOSC		0.75	1.1	1.25	MHz
Maximum Duty Cycle	η	VFB=0.8V	-	93	-	%
EN shut down threshold voltage	VEN-TH	VEN rising, FB=0V	1.18	1.3	1.42	V
EN shut down hysteresis	VEN-HYST		80	120	180	mV
Minimum On-Time	TON_MIN		-	80	96	nS
Minimum Off-Time	Toff_MIN	VFB=0V	-	100	120	nS
Thermal Shutdown note3	TSHDN		120	135	150	'C
Thermal Hysteresis note3	THYTS		-	15	-	'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.)

(VIN=12V, VOUT=5V, Iout=1A)

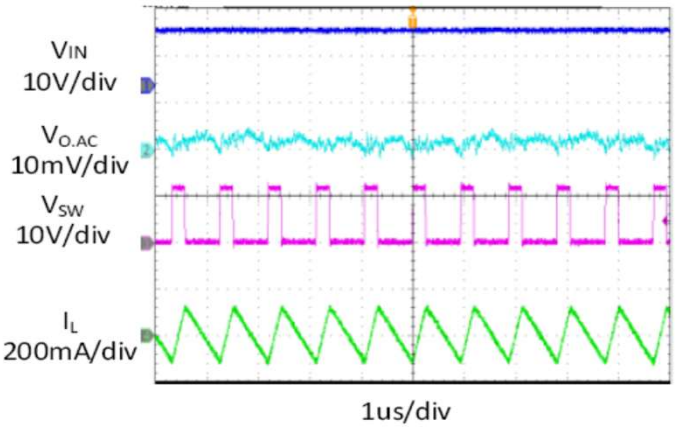


Figure 5. Steady State Test

(VIN=12V, VOUT=5V, Iout=1A (Resistive load))

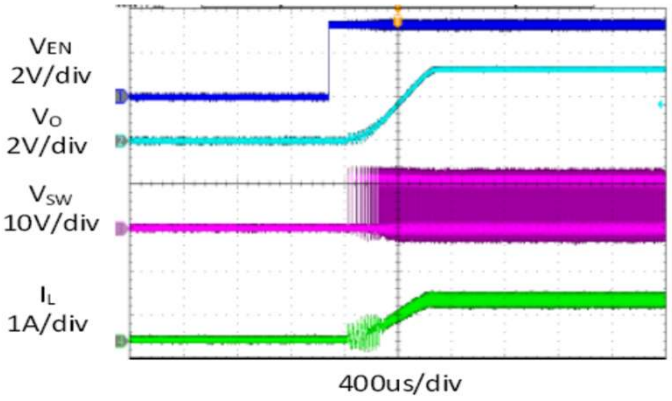


Figure 6. Startup through Enable

(VIN=12V, VOUT=5V, Iout=1A (Resistive load))

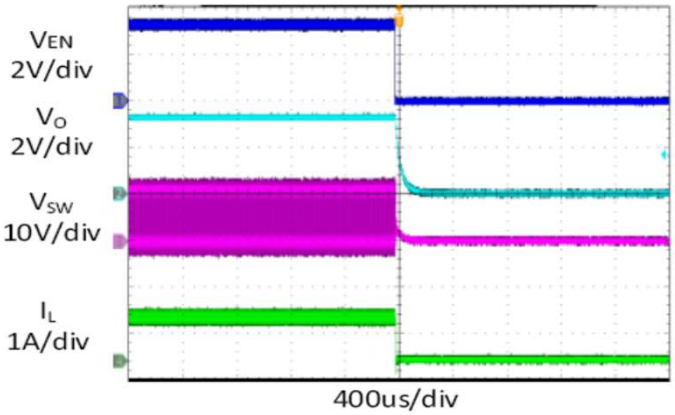


Figure 7. Shutdown through Enable

1A LOAD

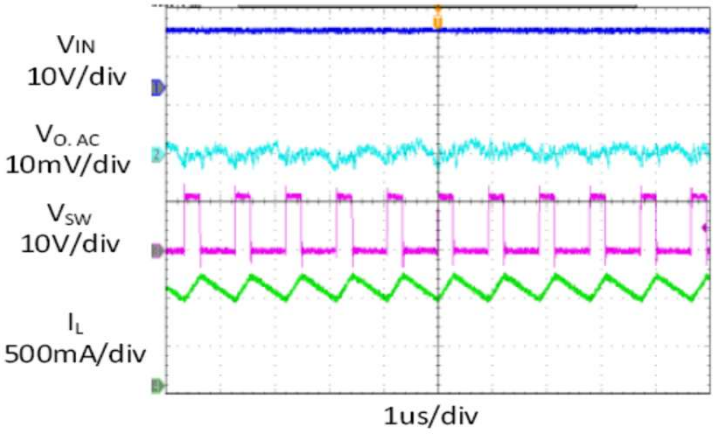


Figure 8. Heavy Load Operation

500mA LOAD

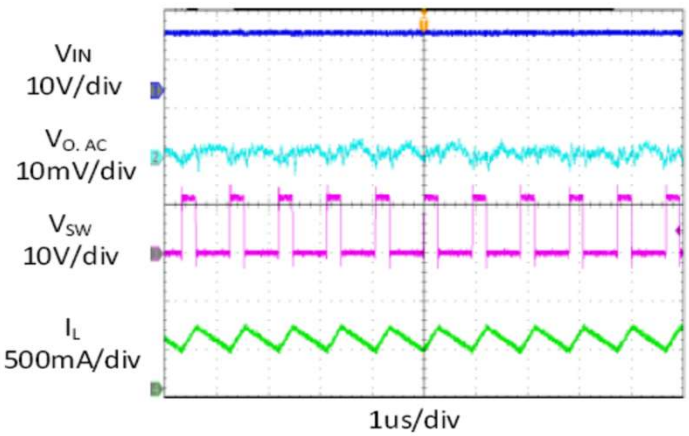


Figure 9. Medium Load Operation

0A LOAD

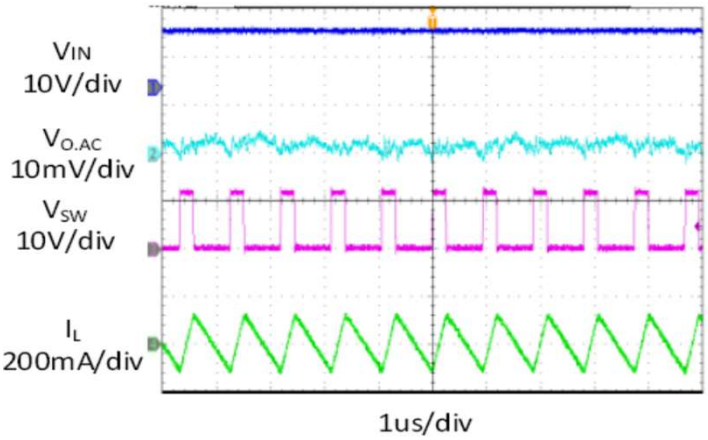


Figure 10. Light Load Operation

1.1MHz 40V, 1A Synchronous Step-Down Converter

Typical Performance Characteristics(Con.)

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

(VIN=12V, VOUT=5V, Iout=1A-Short)

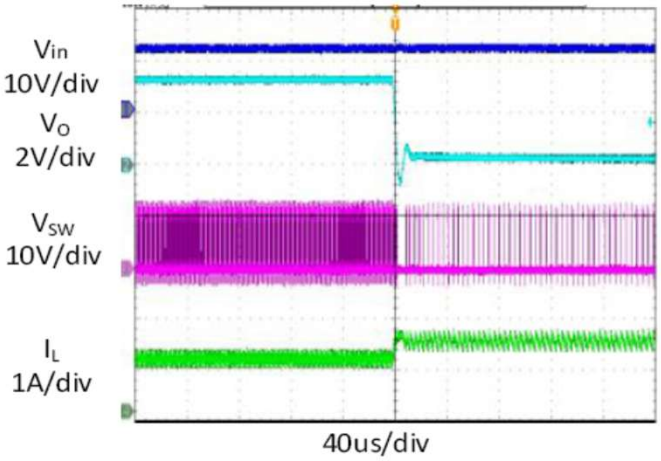


Figure 11. Short Circuit Protection

(VIN=12V, VOUT=5V, Iout=1A-Short)

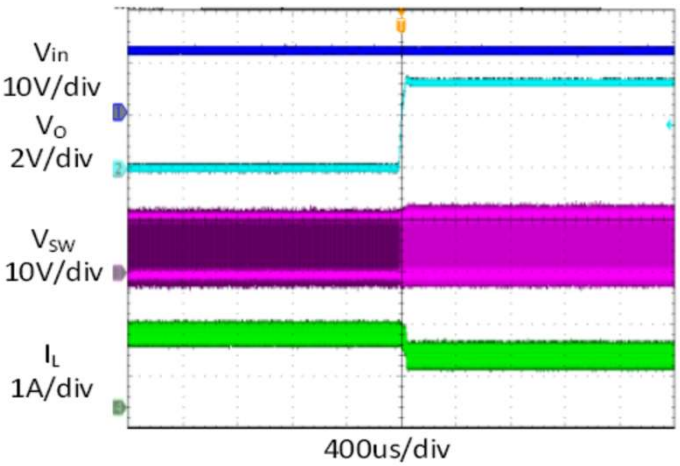


Figure 12. Short Circuit Recovery

(500mA LOAD->1A LOAD
->500mA LOAD)

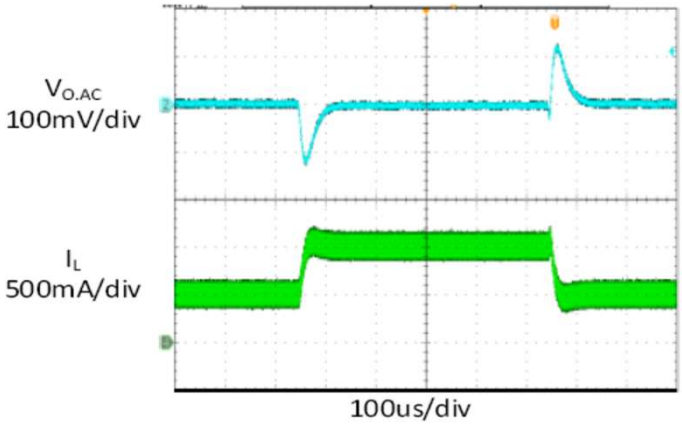


Figure 13. Load Transient

FUNCTIONAL DESCRIPTION

The HCR3316 is a synchronous, current-mode step-down regulator. It regulates input voltages from 4.7V to 40V down to an output voltage as low as 0.8V, and is capable of supplying up to 1A of load current.

Current-Mode Control

The HCR3316 utilizes current-mode control to regulate the output voltage. The output voltage is measured at the FB pin through a resistive voltage divider and the error is amplified by the internal transconductance error amplifier.

Output of the internal error amplifier is compared with the switch current measured internally to control the output current.

Continuous Conduction Mode

The HCR3316 operates in continuous conduction mode, At light load, the inductor current will reach negative current to keep the fixed frequency.

Shut-Down Mode

The HCR3316 shuts down when voltage at EN pin is below 0.3V. The entire regulator is off and the supply current consumed by the HCR3316 drops below 0.1uA.

Power Switch

The N-Channel MOSFET switches are integrated on the HCR3316 to down convert the input voltage to the regulated output voltage. Since the top MOSFET needs a gate voltage great than the input voltage, a boost capacitor connected between BST and SW pins is required to drive the gate of the top switch. The boost capacitor is charged by the internal 3.3V rail when SW is low.

VIN Under-Voltage Protection

A resistive divider can be connected between VIN and GND, with the central tap connected to EN, so that when VIN drops to the pre-set value, EN drops below 1.2V to trigger input under voltage lockout protection.

Output Current Run-Away Protection

At start-up,due to the high voltage at input and low voltage at output, current inertia of the output inductance can be easily built up, resulting in a large start-up output current. A valley current limit is designed in the HCR3316 so that only when output current drops below the valley current limit can the top power switch be turned on. By such control mechanism, the output current at start-up is well controlled.

Output Short Protection

When output is shorted to ground, output current reaches its peak current limit and the top power switch rapidly is turned off. Right after the top power switch is turned off, the bottom power switch is turned on and stay on until the output current falls below the valley current limit. When output current is below the valley current limit, the top power switch will be turned on again and if the output short is still present, the top power switch is turned off when the peak current limit is reached and the bottom power switch is turned on. This cycle goes on until the output short is removed and the regulator comes into normal operation again.

Thermal Protection

When the temperature of the HCR3316 rises above 135'C, It is forced into thermal shut-down.

Only when core temperature drops below 120'C can the regulator becomes active again.

APPLICATION INFORMATION

Output Voltage Set

The output voltage is determined by the resistor divider connected at the FB pin, and the voltage ratio is:

$$V_{FB} = V_{OUT} \cdot \frac{R_3}{R_2 + R_3}$$

where VFB is the feedback voltage and VOUT is the output voltage.

Choose R3 around 2.1kΩ, and then R2 can be calculated by: $R_2 = R_3 \cdot \left(\frac{V_{OUT}}{0.8V} - 1 \right)$

The following table lists the recommended values.

VOUT(V)	R3(KΩ)	R2(KΩ)
2.5	4.99	11
3.3	2.4	7.5
5.0	2.1	11.2

Input Capacitor

The input capacitor is used to supply the AC input current to the step-down converter and maintaining the DC input voltage. The ripple current through the input capacitor can be calculated by:

$$I_{C1} = I_{LOAD} \cdot \sqrt{\frac{V_{OUT}}{V_{IN}} \cdot \left(1 - \frac{V_{OUT}}{V_{IN}} \right)}$$

where ILOAD is the load current, VOUT is the output voltage, VIN is the input voltage.

Thus the input capacitor can be calculated by the following equation when the input ripple voltage is determined. $C_1 = \frac{I_{LOAD}}{f_s \cdot \Delta V_{IN}} \cdot \frac{V_{OUT}}{V_{IN}} \cdot \left(1 - \frac{V_{OUT}}{V_{IN}} \right)$

where C1 is the input capacitance value, fs is the switching frequency, △VIN is the input ripple current.

The input capacitor can be electrolytic, tantalum or ceramic. To minimizing the potential noise, a small X5R or X7R ceramic capacitor, i.e. 0.1uF, should be placed as close to the IC as possible when using electrolytic capacitors.

Input Capacitor(con.)

A 4.7uF ceramic capacitor is recommended in typical application, and an extra 47uF electrolytic capacitor is needed if hot-plug is required.

Output Capacitor

The output capacitor is required to maintain the DC output voltage, and the capacitance value determines the output ripple voltage. The output voltage ripple can be calculated by:

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_s \cdot L} \cdot \left(1 - \frac{V_{OUT}}{V_{IN}} \right) \cdot \left(R_{ESR} + \frac{1}{8 \cdot f_s \cdot C_2} \right)$$

where C2 is the output capacitance value and RESR is the equivalent series resistance value of the output capacitor.

The output capacitor can be low ESR electrolytic, tantalum or ceramic, which lower ESR capacitors get lower output ripple voltage.

The output capacitors also affect the system stability and transient response, and a 10uF ceramic capacitor is recommended in typical application.

Inductor

The inductor is used to supply constant current to the output load, and the value determines the ripple current which affect the efficiency and the output voltage ripple. The ripple current is typically allowed to be 30% of the maximum switch current limit, thus the inductance value can be calculated by:

$$L = \frac{V_{OUT}}{f_s \cdot \Delta I_L} \cdot \left(1 - \frac{V_{OUT}}{V_{IN}} \right)$$

where VIN is the input voltage, VOUT is the output voltage, fs is the switching frequency, and △IL is the peak-to-peak inductor ripple current.

APPLICATION INFORMATION(con.)

External Boostrap Capacitor

A boostrap capacitor is required to supply voltage to the top switch driver. A 0.1uF low ESR ceramic capacitor is recommended to connected to the BST pin and SW pin.

PCB Layout Note

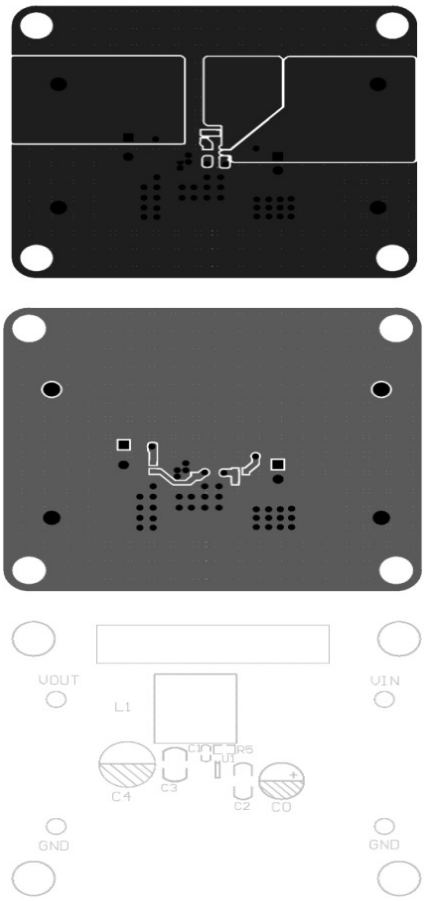
For minimum noise problem and best operating performance, the PCB is preferred to following the guidelines as reference.

a1. Place the input decoupling capacitor as close to (VIN pin and PGND) as possible to eliminate noise at the input pin. The loop area formed by input capacitor and GND must be minimized.

a2. Put the feedback trace as far away from the inductor and noisy power traces as possible.

a3. The ground plane on the PCB should be as large as possible for better heat dissipation.

PCB Layout Designning as reference picture.



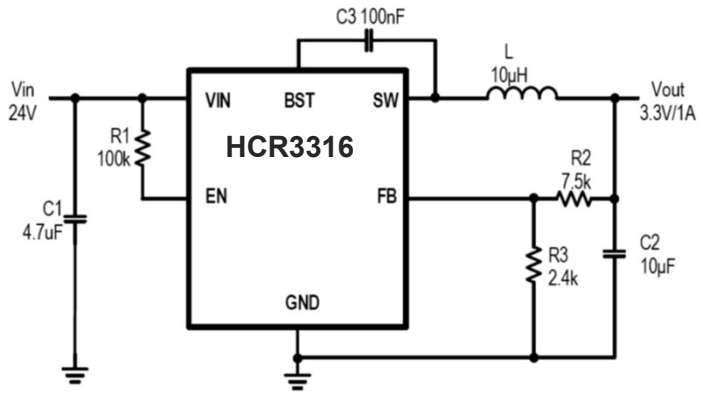
REFERENCE DESIGN

Reference-1

VIN: 24V

VOUT: 3.3V

IOUT: 0~1A



Reference-2

VIN: 24V

VOUT: 5.0V

IOUT: 0~1A

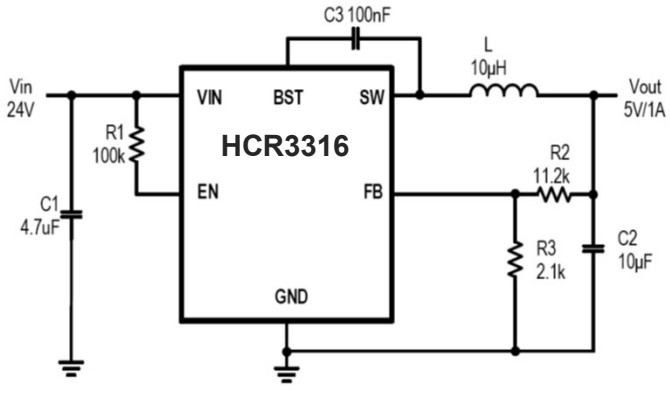


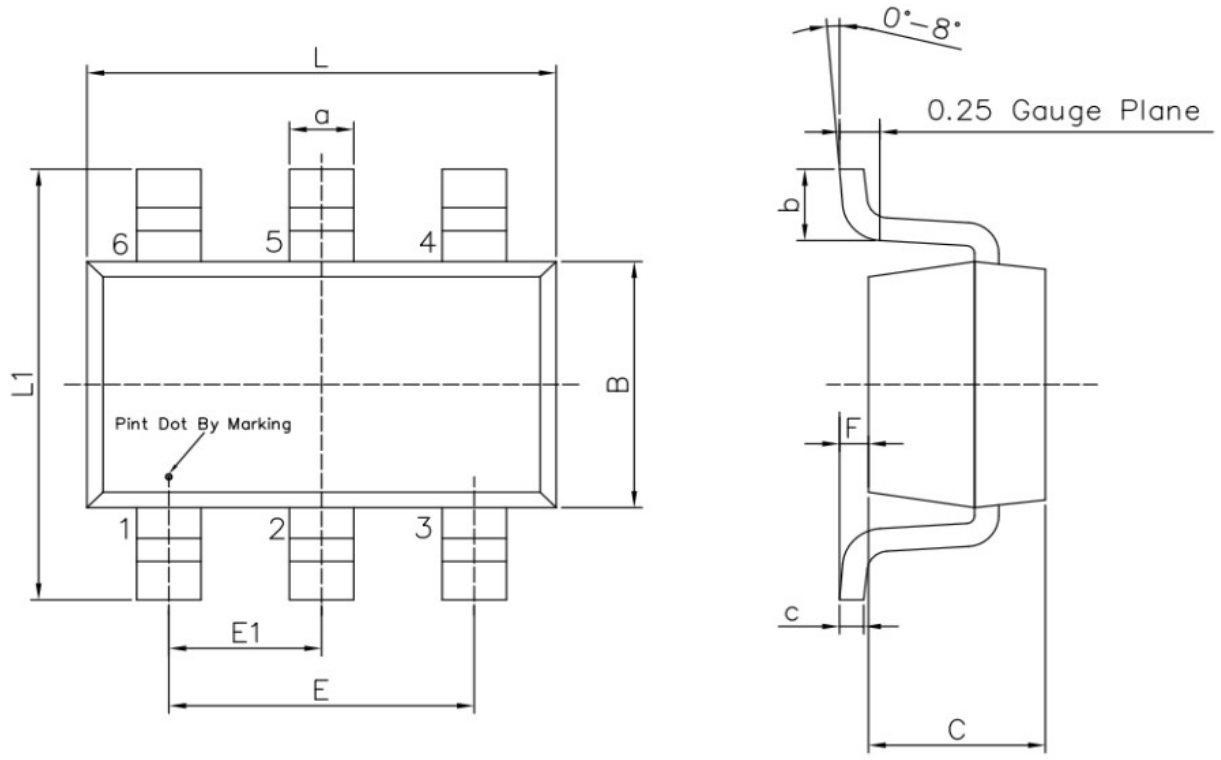
Figure 14. Output 3.3V/1A and 5V/1A Schematic Diagram of HCR3316

1.1MHz 40V, 1A Synchronous Step-Down Converter

Mechanical Dimensions

M6L PKG: SOT-23-6L

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.

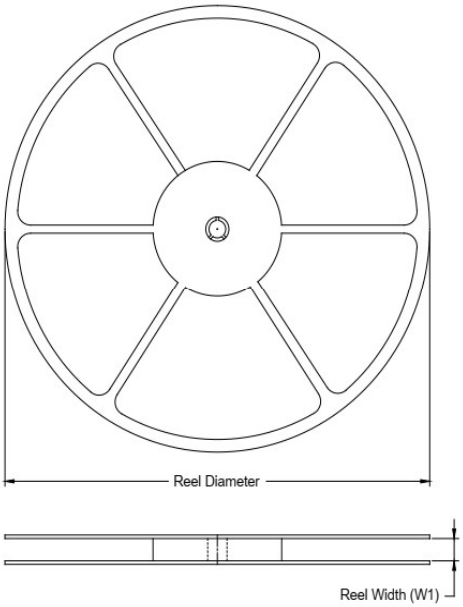
3) Package width does not include inter lead flash or protrusion.

4) Lead popularity (bottom of leads after forming) shall be 0.10 millimeters max.

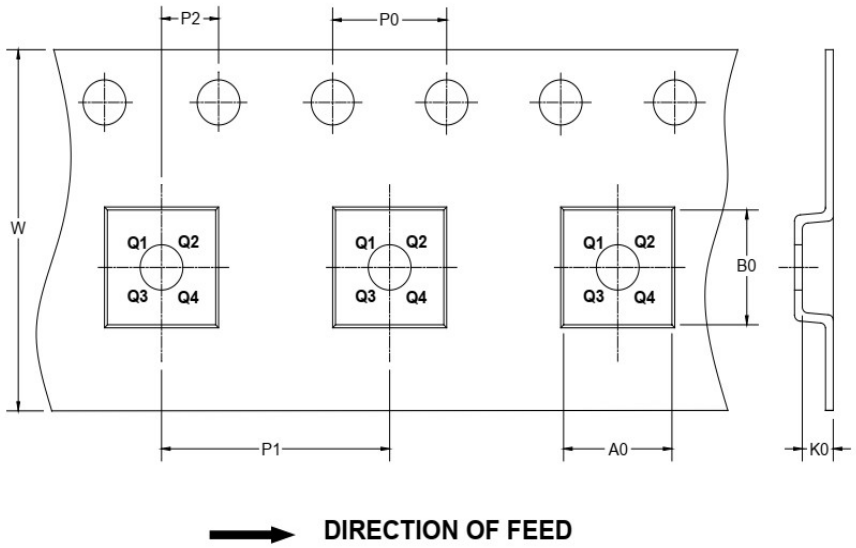
5) Pin 1 is lower left pin when reading top mark from left to right.

TAPE AND REEL INFORMATION

REEL DIMENSIONS



TAPE DIMENSIONS

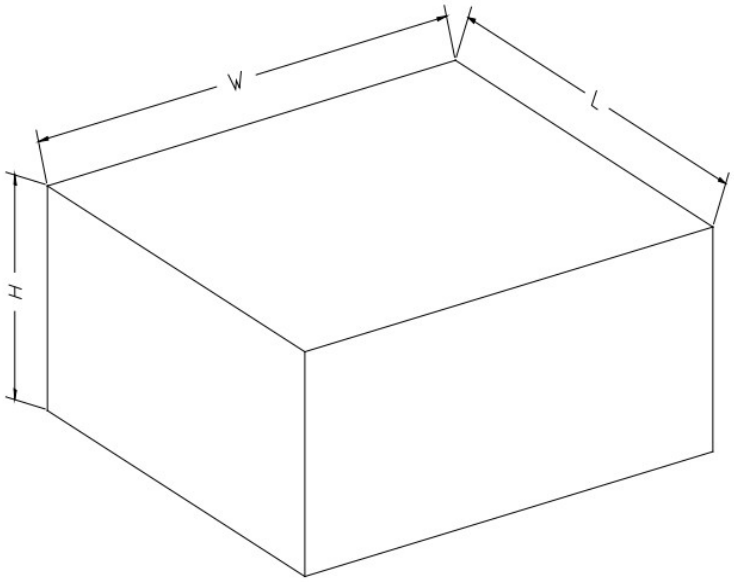


NOTE: The picture is only for reference. Please make the object as the standard.

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
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