

340KHz, 30V, 2A Synchronous Step-Down Converter

Features

- 2A output Current
- Automatic Pulse Skipping Mode at Light Load
- Integrated 160mΩ/110mΩ DMOS Switches
- 4.5V to 30V Input Operating Range
- Output Adjustable from 0.92V to 20V
- Up to 94% Efficiency
- 3uA Shutdown Current
- Fixed 340KHz Frequency
- Programmable Soft-Start
- Thermal Shutdown and Overcurrent Protection
- Input Supply Overvoltage and Undervoltage Lockout
- 220ns Minimum On Time
- Available in SOIC-8 Package
- RoHS Compliant and 100% Lead(pb)-Free Halogen-Free

Applications

- Distributed Power Systems
- Networking Systems
- PC Monitors
- Portable Electronics

General Description

The HCR3230 is a synchronous current mode buck regulator capable of driving 2A continuous load current with excellent line and load regulation. The HCR3230 can operate with an input range from 4.5V to 30V and the output can be externally set from 0.92V to 20V with a resistor driver.

Fault condition protection includes cycle-by-cycle current limiting and thermal shutdown, in shutdown mode the regulator draws 3uA of supply current. Programmable soft-start minimizes the inrush supply current and the output overshoot at initial startup. Automatic pulse skipping mode operation increase efficiency at light loads.

The HCR3230 require a minimum number of external components. It is available in SOIC-8 package and Operating Junction Temperature form -40°C to 125°C range



SOIC-8

Figure 1. Package Type of HCR3230

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Pin Configuration

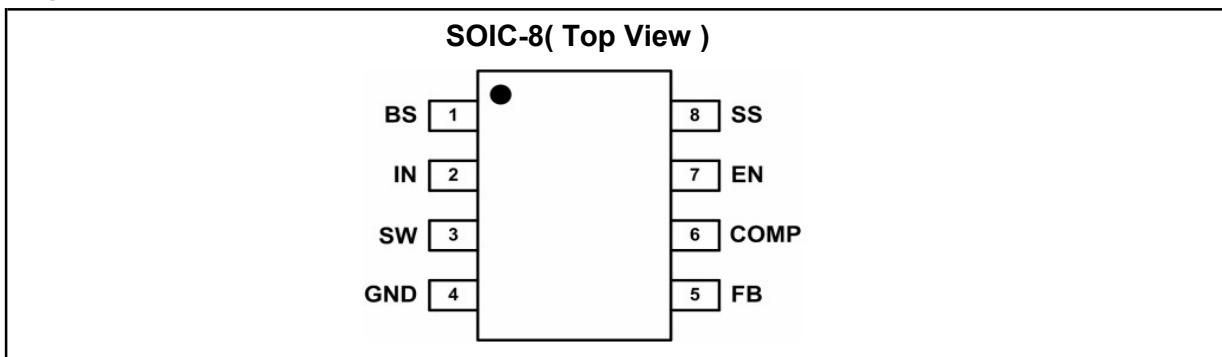
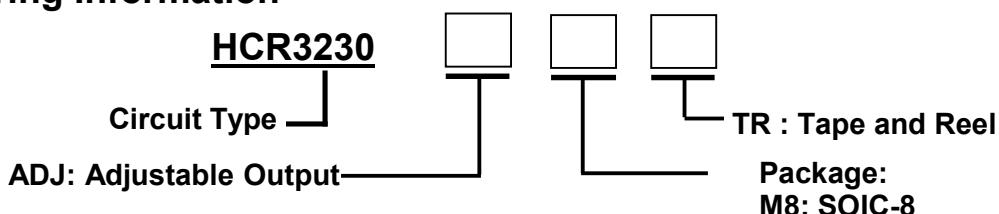


Figure 2. Pin Configuration of HCR3230 (Top View)

Pin Function Table

SOIC-8	Pin Name	Function
1	BS	High-side Gate Drive Boost Input. BS supplies the drive for the high-side N-channel DMOS switch. Connect a 0.01uF or greater capacitor from SW to BS to power the high side switch.
2	IN	Input Supply Pin. IN supplies the power to the IC, as well as the step-down converter switches. Drive IN with a 4.5V to 30V power source. Bypass IN to GND with a suitably large capacitor to minimize input ripple to the IC.
3	SW	Power Switching Output. Connect the output LC filter from SW to the output load.
4	GND	Ground
5	FB	Output Feedback Input. FB senses the output voltage and regulates it. Drive FB with a resistive voltage divider connected to it from the output voltage. The feedback threshold is 0.92V.
6	COMP	Loop compensation Input. Connect a series RC network from COMP to GND to compensate the regulation control loop.
7	EN	Enable Input. EN is a logic input that controls the regulator on or off. Drive EN high to turn on the regulator, low to turn it off. Don't leave EN pin floating. Directly connect EN to IN (or through a resistance) for automatic startup.
8	SS	Soft-start Control Input. Connect an external capacitor to program the soft-start. If unused, leave it open, which means internal soft-start function.

Ordering Information



Ordering Code

Part Number	Marking ^{note1}	Operating Junction Temperature Range	Package	Quantity per Reel
HCR3230ADJM8TR	HCR3230xx	-40°C to +125°C	SOIC-8	4000pcs/TR

Note 1. the "xx" is date code.

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Functional Block Diagram

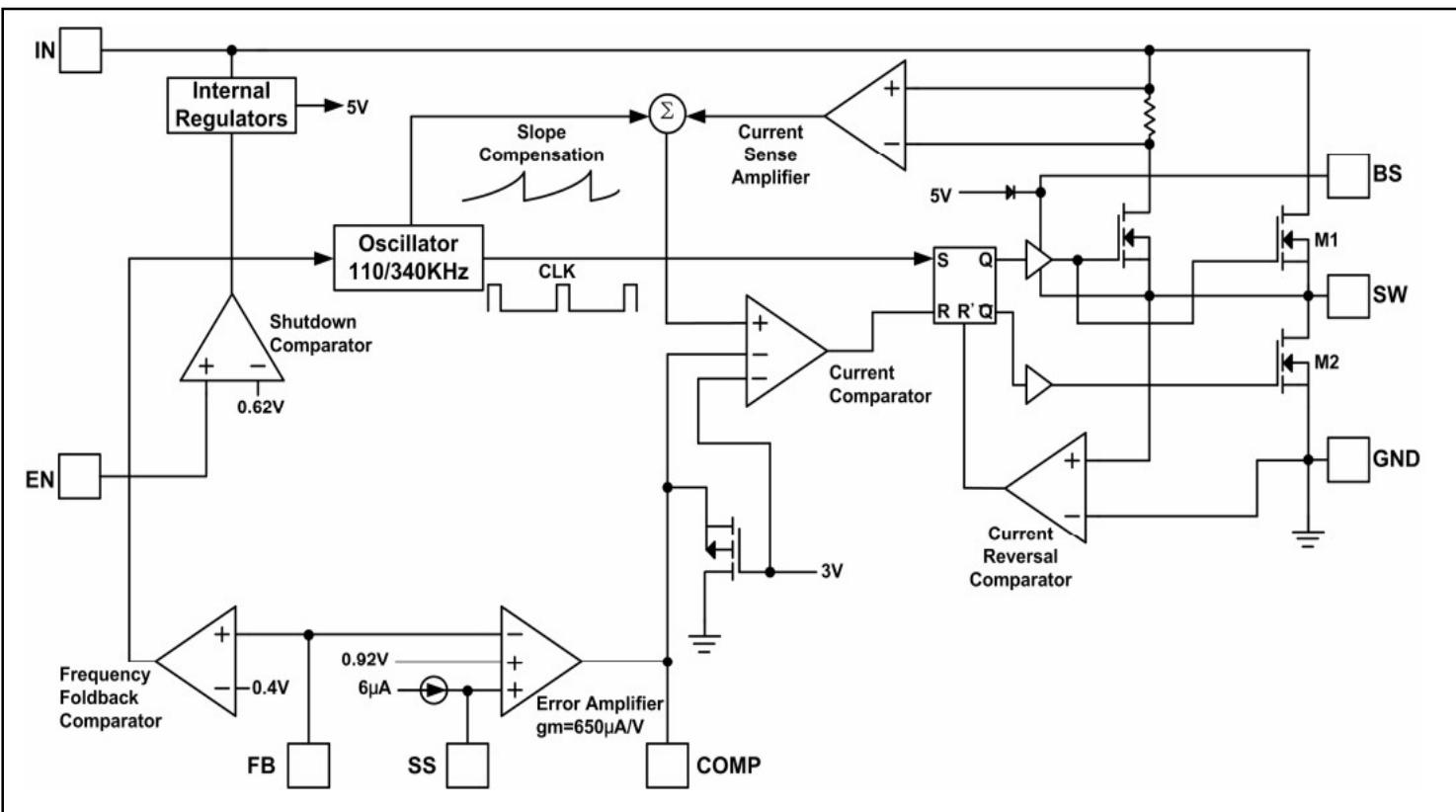


Figure 3. Functional Block Diagram of HCR3230

Application Circuit-1

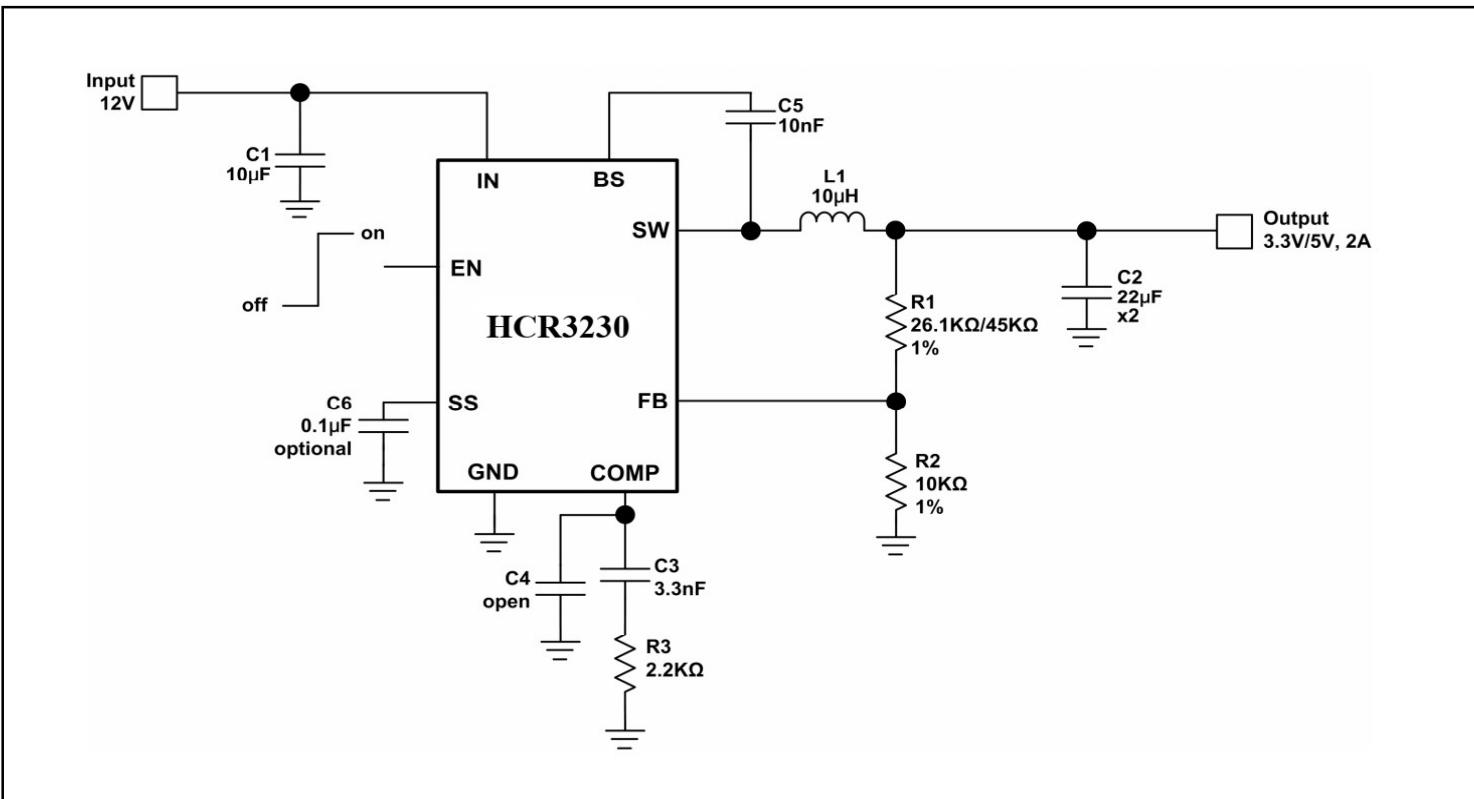


Figure 4. Application Circuit of HCR3230

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Absolute Maximum Ratings ^{Note 1}

Parameter	Symbol	Value	Unit
Supply Voltage	V _{IN}	-0.3 to +34	V
Enable Voltage	V _{EN}	-0.3 to +34	V
Switch Voltage	V _{SW}	-1 to V _{IN} +0.3	V
Boot Voltage	V _{BS}	V _{SW} -0.3 to V _{SW} +6	V
All Other Pins	-	-0.3 to +6	V
Adjustable Output Voltage Range	V _{OUT}	0.92 to 20	V
Thermal Resistance Junction to Ambient	R _{θJA}	125	'C/W
Thermal Resistance Junction to Case	R _{θJC}	55	'C/W
Storage Temperature Range	T _{STG}	-65 to 150	'C
Operating Junction Temperature	T _J	-40 to 150	'C
Lead Temperature (Soldering, 10s)	T _{LEAD}	260	'C

Recommend Operating Conditions ^{note2}

Input Voltage	V _{IN}	4.5 to 30	V
Ambient Operating Temp	T _A	-40 to +85	'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.

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Electrical Characteristics

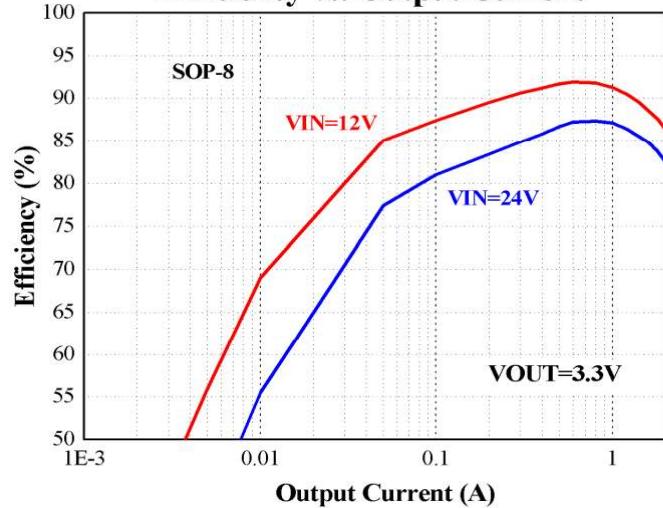
The specifications which apply over the full operating temperature range, otherwise specification are $V_{IN}=12V$, ($T_a=25^{\circ}C$; unless otherwise specified)

Parameter	Symbol	Test Condition	Min	Type	Max	Unit
Input Operation Voltage	V_{IN}		4.5	-	30	V
Shutdown Supply Current	I_{STBY}	$V_{EN}=0V$	-	3	5	uA
Quiescent Supply Current	I_q	$V_{FB}=1V$	-	1	1.4	mA
Feedback Voltage	V_{FB}	$4.5V \leq V_{IN} \leq 30V$	0.902	0.92	0.938	V
Error Amplifier Voltage Gain			-	800	-	V/V
Error Amplifier Transconductance		$\Delta I_c=+/-10uA$	-	650	-	uA/V
High-side Switch On-Resistance	R_{HS}		-	160	-	mΩ
Low-side Switch On-Resistance	R_{LS}		-	110	-	mΩ
High-side Switch Leakage Current	$I_{leakage}$		-	-	5	uA
Upper Switch Current Limit	I_{LH}	Minimum Duty Cycle	3.5	5.0	-	A
Lower Switch Current Limit	I_{LO}	From Drain to source	-	0	-	A
COMP to Current Sense Transconductance	-	-	-	4.5	-	A/V
Oscillator Frequency	F_{OSC}		300	340	380	KHz
Short Circuit Oscillator Frequency	F_{SHT}	$V_{FB}=0V$	-	110	-	KHz
Maximum Duty Cycle	D_{MAX}	$V_{FB}=0.7V$	-	96	-	%
Minimum On Time	T_{on}		-	220	-	ns
EN Input Voltage	V_{EN}	EN High Threshold	2.0	-	-	V
		EN Low Threshold	-	-	0.4	
Input Under Voltage Lockout Threshold	V_{LK}	V_{IN} Rising	3.8	4.1	4.4	V
Soft-start Charge Current	I_{start}	$V_{SS}=0V$	-	6	-	uA
Thermal Shutdown	T_{stdn}		-	160	-	°C

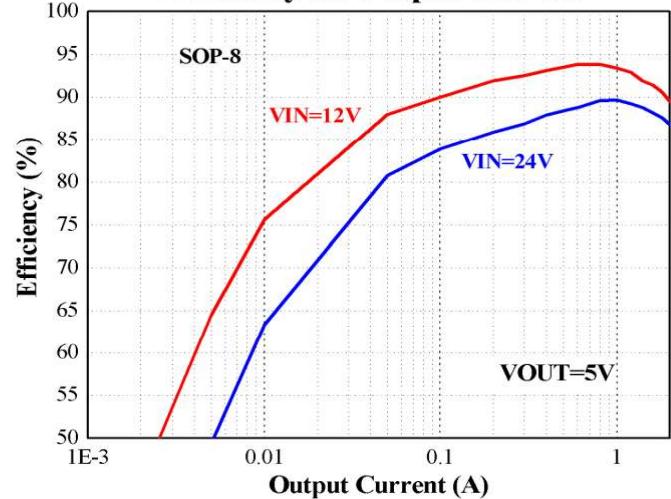
340KHz, 30V, 2A Synchronous Step-Down Converter

Typical Performance Characteristics

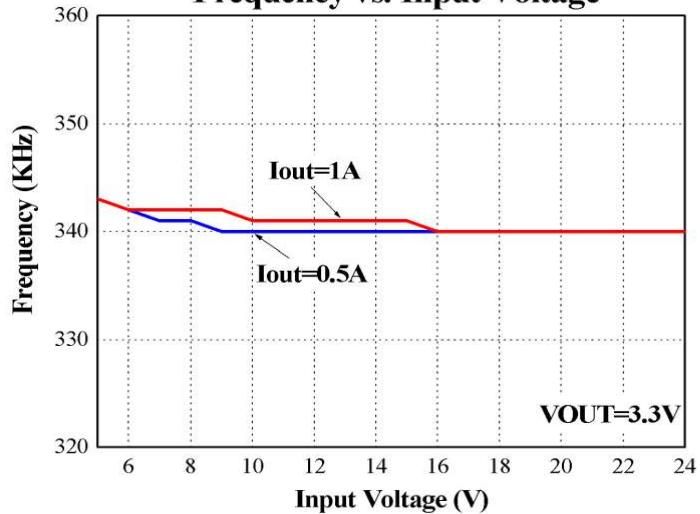
Efficiency vs. Output Current



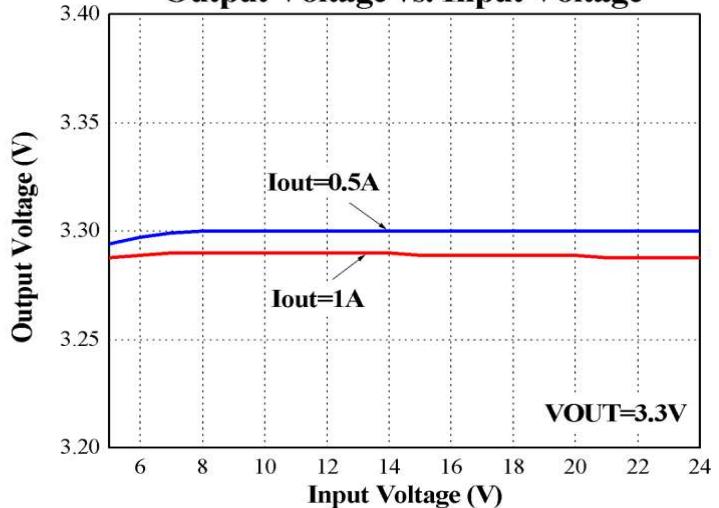
Efficiency vs. Output Current



Frequency vs. Input Voltage

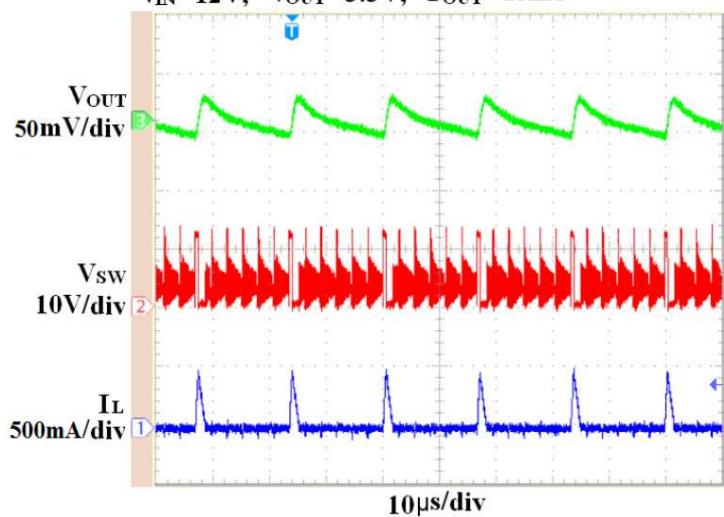


Output Voltage vs. Input Voltage



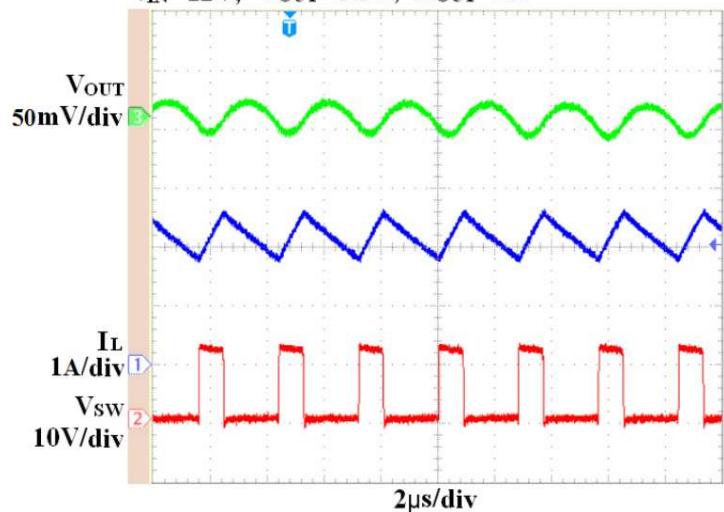
Steady State Test

V_{IN}=12V, V_{OUT}=3.3V, I_{OUT}=25mA



Steady State Test

V_{IN}=12V, V_{OUT}=3.3V, I_{OUT}=2A

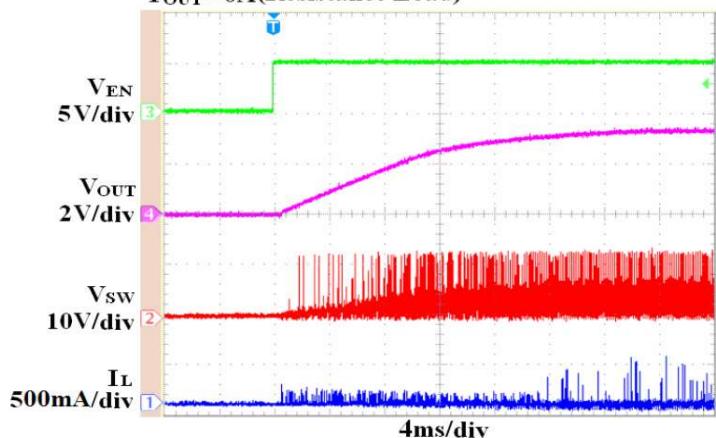


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Typical Performance Characteristics (continued)

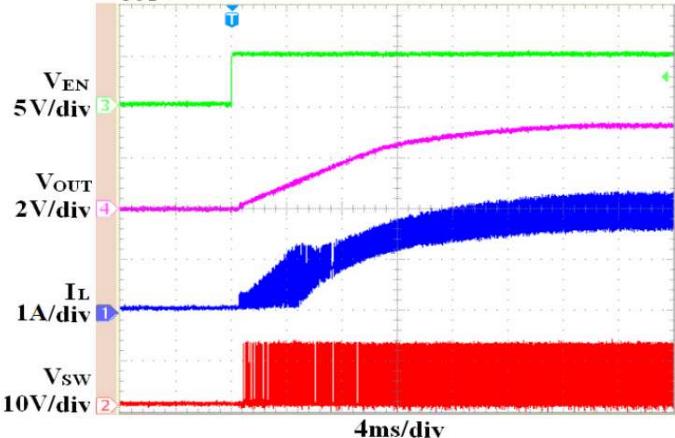
Startup through Enable

$V_{IN}=12V$, $V_{OUT}=3.3V$, $C_6=0.1\mu F$
 $I_{OUT}=0A$ (Resistance Load)



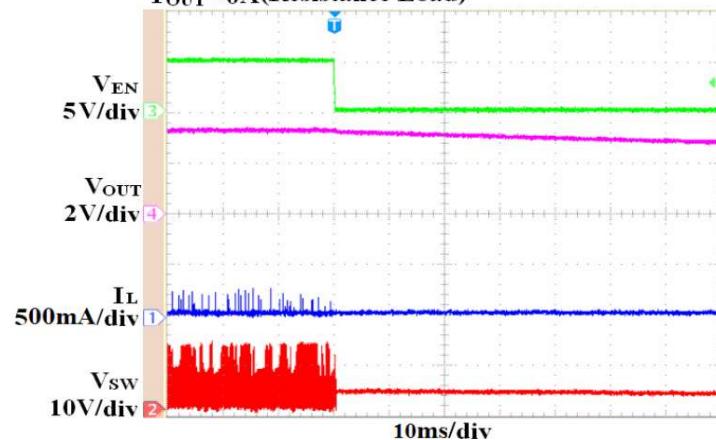
Startup through Enable

$V_{IN}=12V$, $V_{OUT}=3.3V$, $C_6=0.1\mu F$
 $I_{OUT}=2A$ (Resistance Load)



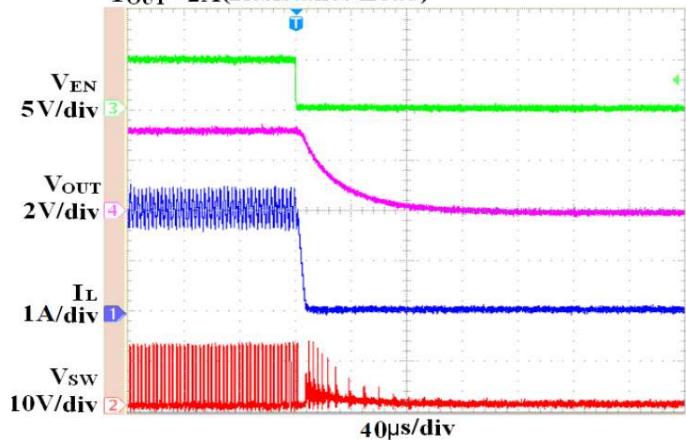
Shutdown through Enable

$V_{IN}=12V$, $V_{OUT}=3.3V$,
 $I_{OUT}=0A$ (Resistance Load)



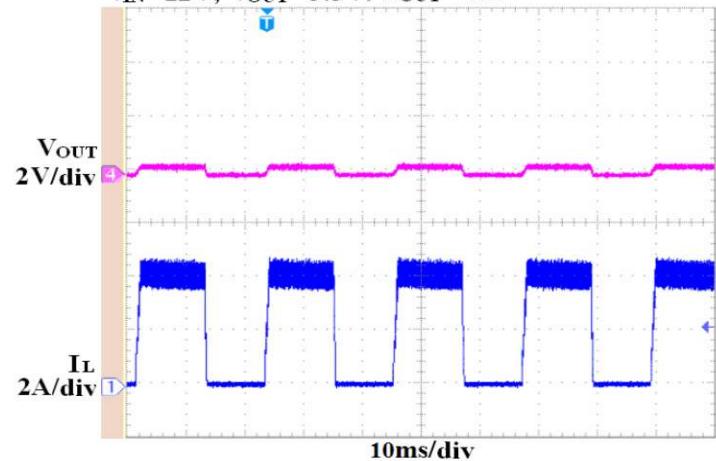
Shutdown through Enable

$V_{IN}=12V$, $V_{OUT}=3.3V$,
 $I_{OUT}=2A$ (Resistance Load)



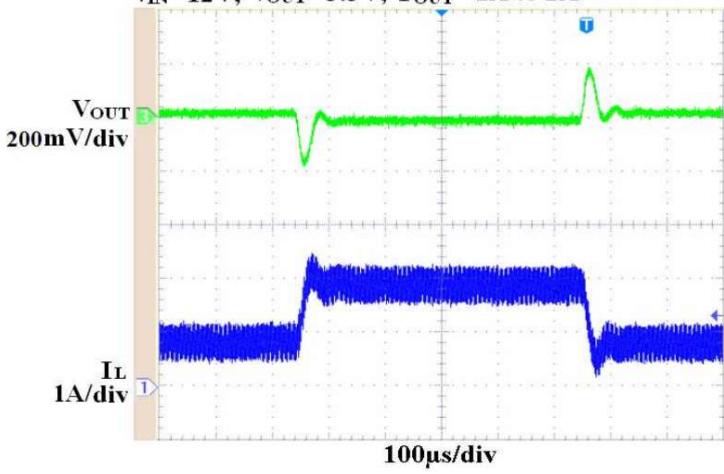
Short Circuit (Hiccup Mode)

$V_{IN}=12V$, $V_{OUT}=3.3V$, $I_{OUT}=0A$



Load Transient Response

$V_{IN}=12V$, $V_{OUT}=3.3V$, $I_{OUT}=1A$ to $2A$



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Typical Application Circuit

Input Voltage 12V to 3.3V or 5.0V / 2A Application Circuit

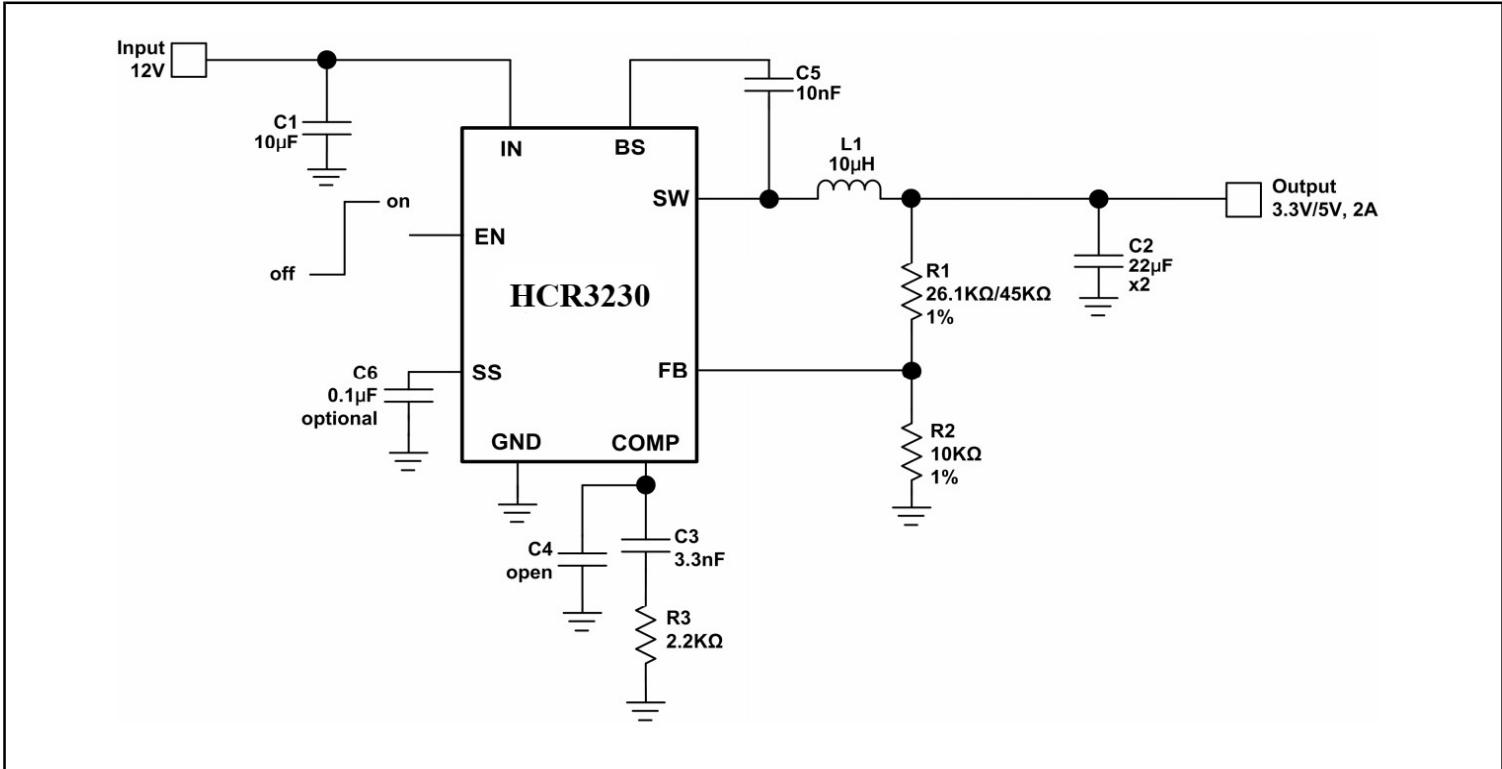


Figure 5. Adjustable Output Voltage of HCR3230

Input Voltage 30V to 3.3V or 5.0V / 2A Application Circuit

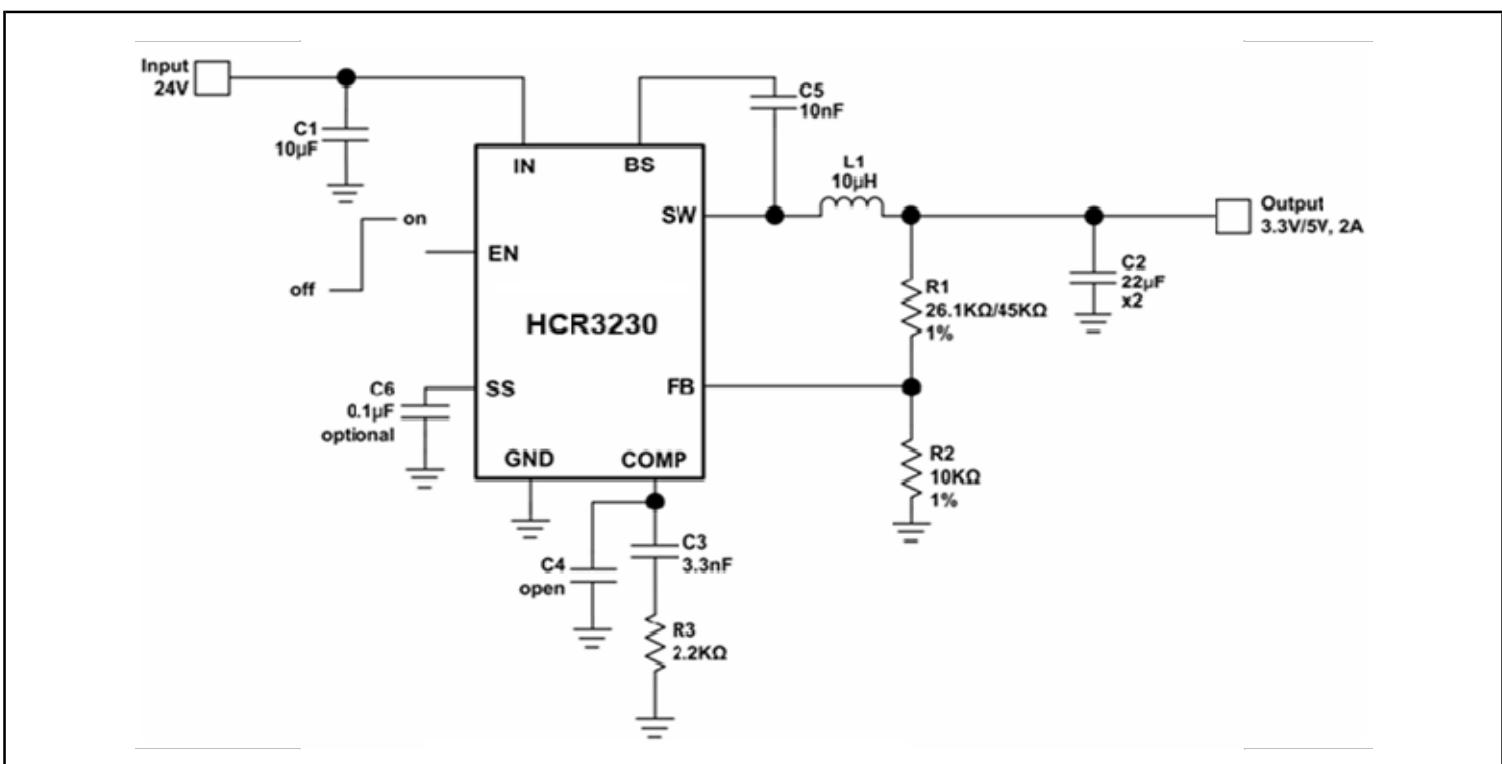


Figure 6. 30V to 3.3V or 5V Application Circuit of HCR3230

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Function Description

The HCR3230 regulates input voltages from 4.5V to 30V down to an output voltage as low as 0.92V, and supplies up to 2A of load current.

The HCR3230 uses current-mode control to regulate the output voltage. The output voltage is measured at FB through a resistive voltage divider and amplified through the internal transconductance error amplifier. The voltage at the COMP pin is compared to the switch current (measured internally) to control the output voltage.

The converter uses internal N-Channel MOSFET switch to step-down the input voltage to the regulated output voltage. Since the high side MOSFET requires a gate voltage greater than the input voltage, a boost capacitor

connected between SW and BS is needed to drive the high side gate. The boost capacitor is charged from the internal 5V rail when SW is low.

At light loads, the inductor current may reach Zero or reverse on each pulse. The bottom DMOS is turned off by the current reversal comparator and the switch voltage will ring. This is discontinuous mode operation, and is normal behavior for the switching regulator. At light load, the HCR3230 will automatically skip pulses in pulse skipping mode operation to maintain output regulation and increase efficiency.

When the FB pin voltage exceeds 13% of the nominal regulation value of 0.92V, the over voltage comparator is tripped and forcing the high-side switch off.

Application Information

Setting the Output Voltage

The output voltage is set using a resistive voltage divider connected from the output voltage to FB. The voltage divider divides the output voltage down to the feedback voltage by the ratio:

$$V_{FB} = V_{OUT} \frac{R_2}{R_1 + R_2}$$

Thus the output voltage is :

$$V_{OUT} = 0.92 * \frac{R_1 + R_2}{R_2}$$

R2 can be as high as 100KΩ, but a typical value is 10KΩ

Using the typical value for R2, R1 is determined by:

$$R_1 = 10.83 * (V_{OUT} - 0.92) \text{ (kΩ)}$$

For example, for a 3.3V output voltage, R2 is 10KΩ and R1 is 26.1KΩ.

Inductor

The inductor is required to supply constant current to the load while being driven by the switched input voltage. A larger value inductor will result in less ripple current that will in turn result in lower output ripple voltage. However, the larger value inductor will have a large physical size, higher series resistance, and/or lower saturation current. A good rule for determining inductance is to allow the peak-to-peak ripple current to be approximately 30% of the maximum switch current limit. Also, make sure that the peak inductor

Inductor(con.)

current is below the maximum switch current limit. The inductance value can be calculated by:

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

Where VOUT is the output voltage, VIN is the input voltage, fs is the switching frequency, and ΔIL is the peak-to-peak inductor ripple current.

Choose an inductor peak current, calculated by:

$$I_{LP} = I_{LOAD} + \frac{V_{OUT}}{2 * f_S * L} * \left(1 - \frac{V_{OUT}}{V_{IN}} \right)$$

Where ILOAD is the load current.

The choice of which style inductor to use mainly depends on the price vs.size requirements and any EMI constraints.

Optional Schottky Diode

During the transition between the high-side switch and low-side switch, the body diode of the low-side power MOSFET conducts the inductor current. The forward voltage of this body diode may be high and cause efficiency loss. An optional small 1A Schottky diode B130 in parallel with low-side switch is recommended to improve overall efficiency when input voltage is higher.

Input Capacitor

The input current to the step-down converter is discontinuous, therefore a capacitor is required to

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Application Information(Con.)

Input Capacitor(con.)

supply the AC current while maintaining the DC input voltage. Use low ESR capacitors for the best performance. Ceramic capacitors are preferred, but tantalum or low-ESR electrolytic capacitors will also suffice. Choose X5R or X7R dielectrics when using ceramic capacitors.

Since the input capacitor (C1) absorbs the input switching current, it requires an adequate ripple current rating. The RMS current in the input capacitor can be estimated by:

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

The worst-case condition occurs at $V_{IN}=2V_{OUT}$, where $I_{C1}=I_{LOAD}/2$. For simplification, use an input capacitor with a RMS current rating greater than half of the maximum load current.

The input capacitor can be electrolytic, tantalum or ceramic. When using electrolytic or tantalum capacitors, a small, high quality ceramic capacitor, i.e. 0.1uF, should be placed as close to the IC as possible. When using ceramic capacitors, make sure that they have enough capacitance to provide sufficient charge to prevent excessive voltage ripple at input. The input voltage ripple for low ESR capacitors can be estimated by:

$$\Delta V_{IN} = \frac{I_{LOAD}}{C1 * f_S} * \frac{V_{OUT}}{V_{IN}} * \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

Where C1 is the input capacitance value.

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

Output Capacitor

The output capacitor(C2) is required to maintain the DC output voltage. Ceramic, tantalum, or low ESR electrolytic capacitors are recommended. Low ESR capacitors are preferred to keep the output voltage ripple low.

The output voltage ripple can be estimated

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_S * L} * \left(1 - \frac{V_{OUT}}{V_{IN}}\right) * \left(R_{ESR} + \frac{1}{8 * f_S * C2}\right)$$

Output Capacitor(con.)

Where C2 is the output capacitance value and RESR is the equivalent series resistance (ESR) value of the output capacitor.

When using ceramic capacitors, the impedance at the switching frequency is dominated by the capacitance which is the main cause for the output voltage ripple. For simplification, the output voltage ripple can be estimated by:

$$\Delta V_{OUT} = \frac{V_{OUT}}{8 * f_S^2 * L * C2} * \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

When using tantalum or electrolytic capacitors, the ESR dominates the impedance at the switching frequency. For simplification, the output ripple can be approximated to:

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_S * L} * \left(1 - \frac{V_{OUT}}{V_{IN}}\right) * R_{ESR}$$

The characteristics of the output capacitor also affect the stability of the regulation system. The HCR3230 can be optimized for a wide range of capacitance and ESR values.

Compensation Components

The HCR3230 employs current mode control for easy compensation and fast transient response. The system stability and transient response are controlled through the COMP pin. COMP is the output of the internal transconductance error amplifier. A series capacitor-resistor combination sets a pole-zero combination to govern the characteristics of the control system.

The DC gain of the voltage feedback loop is given by:

$$A_{VDC} = R_{LOAD} * G_{CS} * A_{VEA} * \frac{V_{FB}}{V_{OUT}}$$

Where VFB is the feedback voltage (0.92V), AVEA is the error amplifier voltage gain, GCS is the current sense transconductance and RLOAD is the load resistor value. The system has two poles of importance. One is due to the compensation capacitor(C3) and the output resistor of the error amplifier, and the other is due to output capacitor and the load resistor. These poles are

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Application Information(Con.)

Compensation Components(con.)

located at:

$$f_{P1} = \frac{G_{EA}}{2\pi * C3 * A_{VEA}}$$

$$f_{P2} = \frac{1}{2\pi * C2 * R_{LOAD}}$$

Where GEA is the error amplifier transconductance. the system has one zero of importance, due to the compensation capacitor (C3) and the compensation resistor (R3). This zero is located at:

$$f_{Z1} = \frac{1}{2\pi * C3 * R3}$$

The system may have another zero of importance, if the output capacitor has a large capacitance and/or a high ESR value. The zero, due to the ESR and capacitance of the output capacitor, is located at:

$$f_{ESR} = \frac{1}{2\pi * C2 * R_{ESR}}$$

In this case, a third pole set by the compensation capacitor (C4) and the compensation resistor (R3) is used to compensate the effect of the ESR zero on the loop gain. This pole is located at:

$$f_{P3} = \frac{1}{2\pi * C4 * R3}$$

The goal of compensation design is to shape the converter transfer function to get a desired loop gain. the system crossover frequency where the feedback loop has the unity gain is important. Lower crossover frequencies result in slower line and load transient responses, while higher crossover frequencies could cause the system instability. A good standard is to set the crossover frequency below one-tenth of the switching frequency.

To optimize the compensation components, the following procedure can be used:

1.1 Choose the compensation resistor(R3) to set the desired crossover frequency.

Determine R3 by the following equation:

$$R3 = \frac{2\pi * C2 * f_C}{G_{EA} * G_{CS}} * \frac{V_{OUT}}{V_{FB}}$$

$$< \frac{2\pi * C2 * 0.1 * f_S}{G_{EA} * G_{CS}} * \frac{V_{OUT}}{V_{FB}}$$

Where fC is the desired crossover frequency, which is typically below one tenth of the switching frequency.

1.2 Choose the compensation capacitor(C3) to achieve the desired phase margin. For applications with typical inductor values, setting the compensation zero (fZ1) below one-fourth of the crossover frequency provides sufficient phase margin.

Determine C3 by the following equation:

$$C3 > \frac{4}{2\pi * R3 * f_C}$$

Where R3 is the compensation resistor.

1.3 Determine if the second compensation capacitor (C4) is required. It is required if the ESR zero of the output capacitor is located at less than half of the switching frequency, or the following relationship is valid:

$$\frac{1}{2\pi * C2 * R_{ESR}} < \frac{f_S}{2}$$

If this is the case, then add the second compensation capacitor (C4) to set the pole fP3 at the location of the ESR zero. Determine C4 by the equation:

$$C4 = \frac{C2 * R_{ESR}}{R3}$$

To simplify design efforts using the HCR3230, the typical design for common application are listed in Table 1.

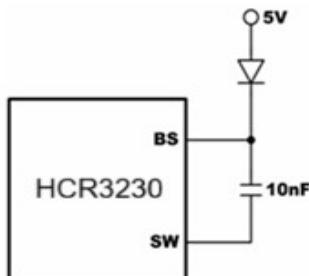
External Bootstrap Diode

It is recommended that an external bootstrap diode be added when the system has a 5V fixed input or the power supply generates a 5V output. This helps improve the efficiency of the regulator.

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Application Information(Con.,)

External Bootstrap Diode(con.)



This diode is also recommended for high duty cycle operation (When $V_{OUT}/V_{IN} > 65\%$) and high output Voltage ($V_{OUT} > 12V$) applications.

Figure 7. Add optional External Bootstrap

Diode to Enhance

Table 1. External Components for Typical Designs

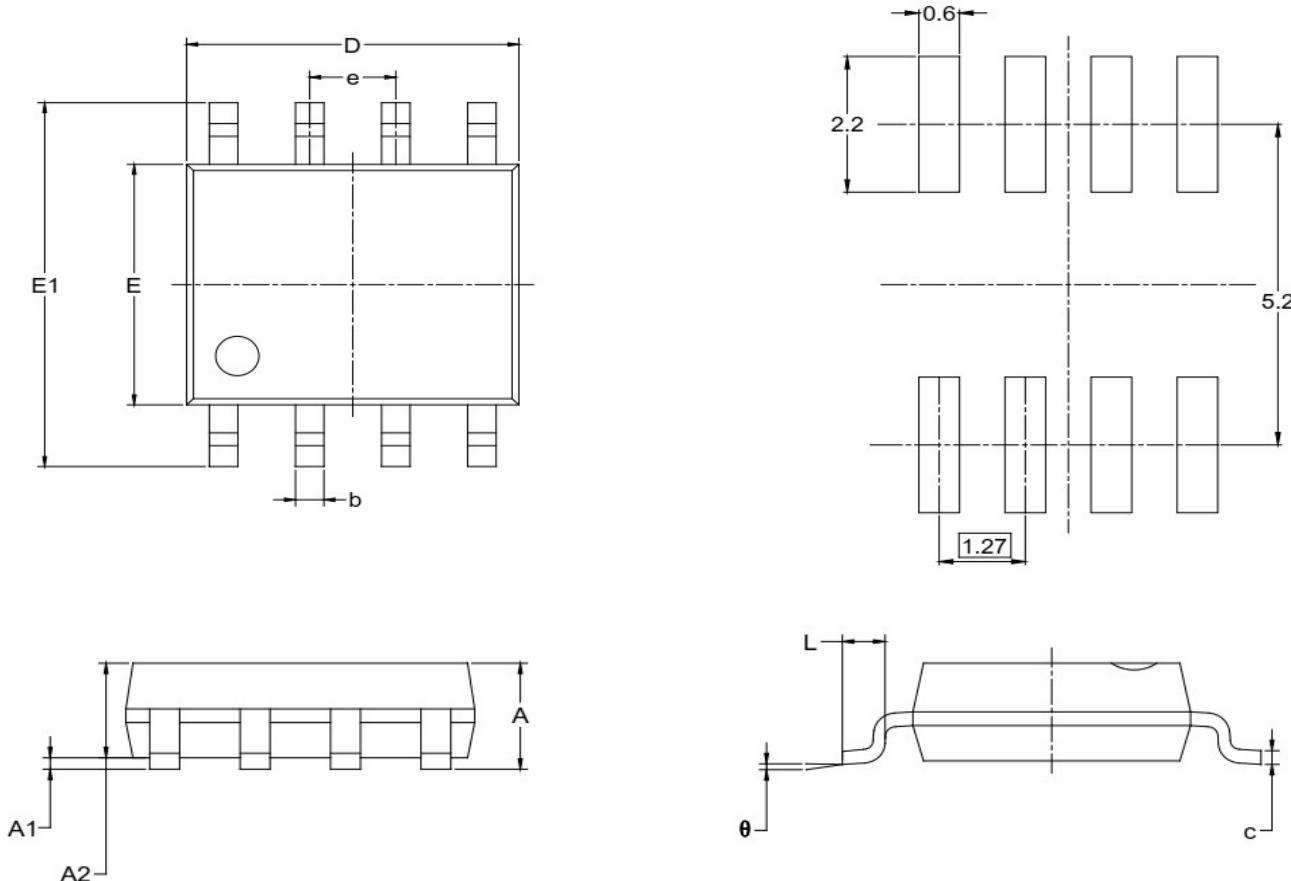
Vin(V)	Vout(V)	L1(uH)	C2 (uF)	R1(KΩ)	R2(KΩ)	R3(KΩ)	C3(nF)	C4(pF)
5	1.0	3.3	22*2	1.0	10	2.2	3.3	open
5	1.2	4.7	22*2	3.2	10	2.2	3.3	open
5	3.3	10.0	22*2	26.1	10	2.2	3.3	open
12	1.0	3.3	22*2	1.0	10	2.2	10.0	open
12	1.2	4.7	22*2	3.2	10	2.2	10.0	open
12	3.3	10.0	22*2	26.1	10	2.2	3.3	open
12	5.0	10.0	22*2	45.0	10	2.2	3.3	open
24	3.3	10.0	22*2	26.1	10	2.2	3.3	open
24	5.0	10.0	22*2	45.0	10	2.2	3.3	open

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Mechanical Dimensions

M8 : SOIC-8

Unit: mm(inch)



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.350	1.750	0.053	0.069
A1	0.100	0.250	0.004	0.010
A2	1.350	1.550	0.053	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.006	0.010
D	4.700	5.100	0.185	0.200
E	3.800	4.000	0.150	0.157
E1	5.800	6.200	0.228	0.244
e	1.27 BSC		0.050 BSC	
L	0.400	1.270	0.016	0.050
θ	0°	8°	0°	8°

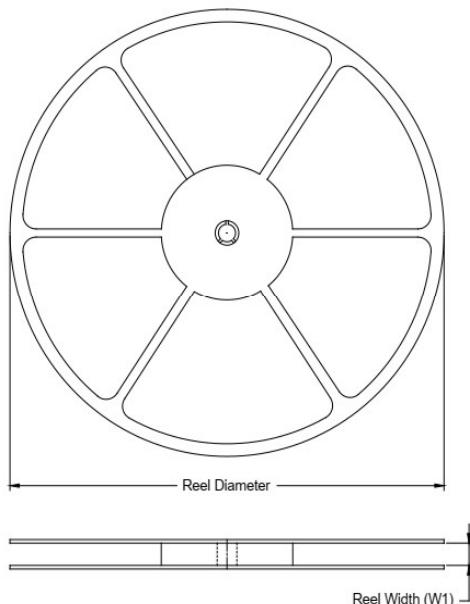
NOTES:

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

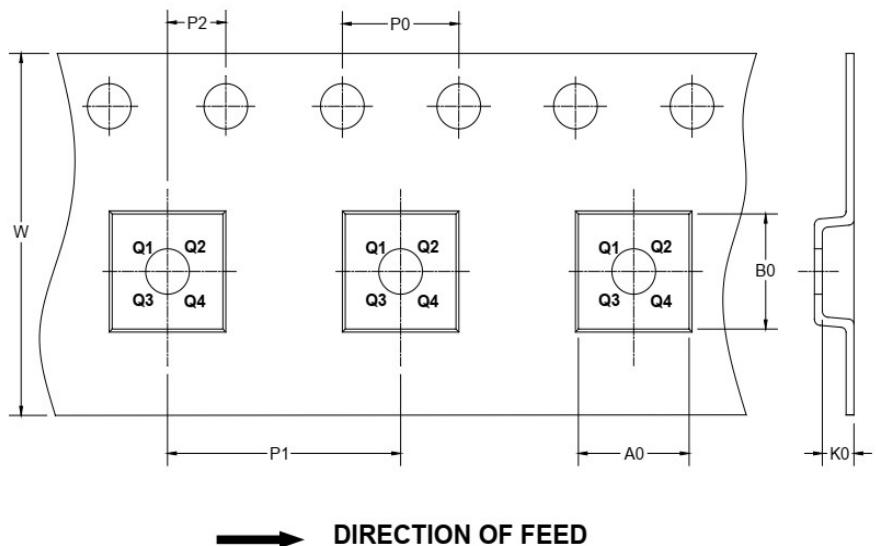
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TAPE AND REEL INFORMATION

REEL DIMENSIONS



TAPE DIMENSIONS



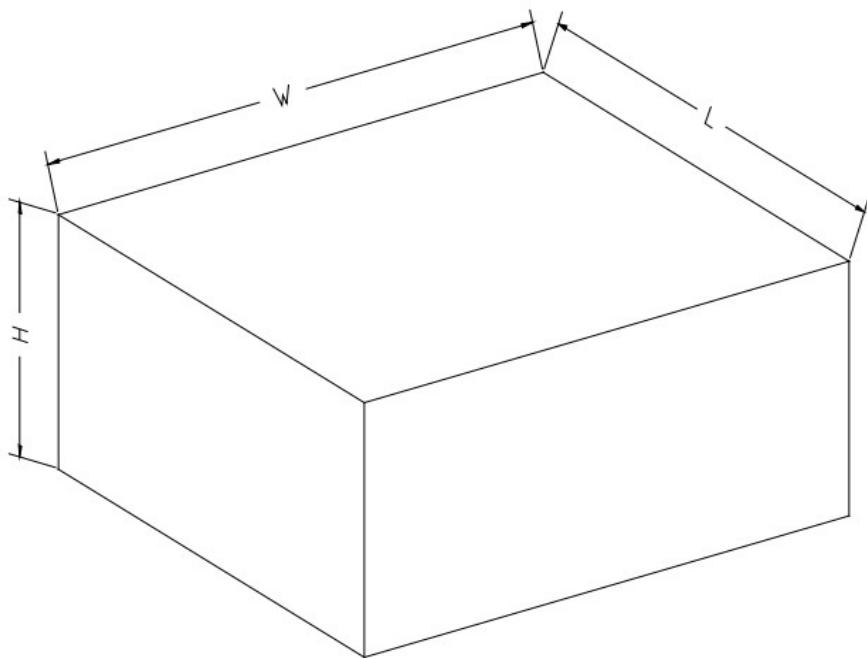
NOTE: The picture is only for reference. Please make the object as the standard.

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
SOIC-8	13"	12.4	6.40	5.40	2.10	4.0	8.0	2.0	12.0	Q1

340KHz, 30V, 2A Synchronous Step-Down Converter

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
13"	386	280	370	5