1.5A, 60V, 480KHz High Efficiency Step-down DCDC Converter

FEATURES

- Wide Input Range: 4.5V-60V
- Continuous Output Current: 1.5A
- Peak Output Current: 2A
- 0.8V Feedback Reference Voltage
- Integrated 500mΩ High-Side
- Low Quiescent Current: 80uA
- Pulse Skipping Mode (PSM) in light load
- 80ns Minimum On-time
- 6ms Internal Soft-start Time
- Internal compensation
- Switching Frequency 480kHz
- Precision Enable Threshold for Programmable Input Voltage Under-Voltage Lock Out Protection (UVLO) Threshold and Hysteresis
- Low Dropout Mode Operation
- Over-voltage and Over-Temperature Protection
- Available in an SOP-8(EP) Package

APPLICATIONS

- 12-V, 24-V, 48-V Industry and Telecom Power System
- Industrial Automation and Motor Control
- Vehicle Accessories
- Portable Handheld Instruments
- Portable Media Players

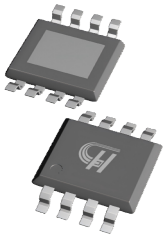
DESCRIPTION

The HCR3417 is 1.5A buck converter with wide input voltage, ranging from 4.5V to 60V, which integrates an 500mΩ high-side MOSFET. The HCR3417, adopting the peak current mode control, supports the Pulse Skipping Modulation (PSM) with 80uA low quiescent current which assists the converter on achieving high efficiency at light load or standby condition.

The HCR3417 features fixed 480kHz switching frequency, which minimizes the external off chip passive components size and reduces the output ripple. The HCR3417 allows power conversion from high input voltage to low output voltage with a minimum 80ns on-time of high-side MOSFET and supports low dropout operation with a low voltage difference from input to output.

The device offers fixed 6ms soft start to prevent inrush current during the startup of output voltage ramping, and compensation circuits are implemented internally which allows the device to be used with minimized external components.

The HCR3417 provides cycle-by-cycle current limit, thermal shutdown protection, output over-voltage protection and input voltage under-voltage protection. The device is available in an SOP-8(EP) package.



SOP-8(EP)

Figure 1. Package Type of HCR3417

1.5A, 60V, 480KHz High Efficiency Step-down DCDC Converter

PIN CONFIGURATION

HCR3417 Top View

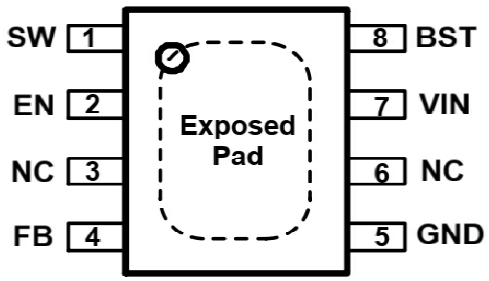
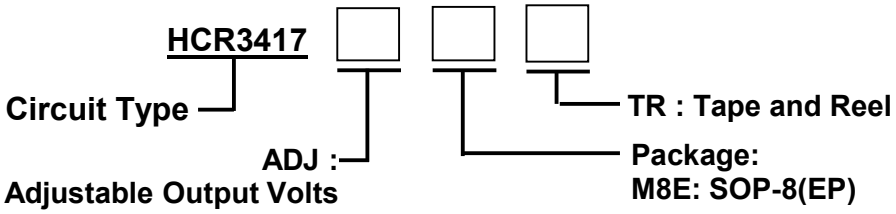


Figure 2. Pin Configuration of HCR3417 (Top View)

PIN FUNCTIONS

HCR 3417	Pin Name	Function Description
1	BST	Regulator switching output. Connect SW to an external power inductor
2	EN	Enable pin to the regulator with internal pull-up current source. Pull below 1.13V to disable the converter. Float or connect to VIN to enable the converter. The tap of resistor divider from VIN to GND connecting EN pin can adjust the input voltage lockout threshold.
3	NC	Not connected.
4	FB	Buck converter output feedback sensing voltage. Connect a resistor divider from VOUT to FB to set up output voltage. The device regulates FB to the internal reference of 0.8V typically
5	GND	Ground.
6	NC	Not connected.
7	VIN	Input supply voltage. Connect a local bypass capacitor from VIN pin to GND pin
8	BST	Power supply bias for high-side power MOSFET gate driver. Connect a 0.1uF capacitor from BOOT pin to SW pin. Bootstrap capacitor is charged when SW voltage is low.
-	EP	Exposed Pad

ORDER INFORMATION



ORDERING CODE

Part Number	Marking ID [a]	Package	Quantity per Reel
HCR3417ADJM8ETR	HCR3417 XXXX	SOP-8(EP)	4000pcs/TR

Note a. the HCR3417 is product model and the "XXXX" is Manufacturing Code.

Absolute Maximum Ratings Note 1

Parameter	Symbol	Value	Unit
Input Supply Voltage Range	V_{IN}	-0.3 to +65	V
SW Voltage Range	V_{SW}	-1.0 to +65	V
EN Voltage Range	V_{EN}	-0.3 to +65	V
BST Voltage Range	V_{BST}	-0.3 to +71	V
BST to SW Voltage Range	V_{BST-SW}	-0.3 to +6	V
FB Voltage Range	V_{FB}	-0.3 to +6	V
All Other Pin Voltage Range	-	-0.3 to +6.0	V
Junction to Ambient Thermal Resistance	$R_{\theta JA}$	47.6	'C/W
Junction to Case Thermal Resistance	$R_{\theta JCtop}$	86.2	'C/W
Junction Temperature	T_J	+150	'C
Storage Temperature Range	T_{STG}	-65 to 150	'C
Lead Temperature	T_{LEAD}	260	'C
Human Body Model for all pins [3]	V_{ESD_HBM}	±1K	V
Charge Device Model for all pins [4]	V_{ESD_CDM}	±1K	V

Note 3. JEDEC document JEP155 states that 500V HBM allows safe manufacturing with a standard ESD control process.

4. JEDEC document JEP157 states that 250V CDM allows safe manufacturing with a standard ESD control process.

Recommended Operating Conditions note2

Parameter	Symbol	Test Condition	Min	Type	Max	Unit
Input Voltage Range	V_{IN}		4.5	-	60	V
Output Voltage Range	V_{OUT}		0.8	-	57	V
Operating Junction Temperature Range	T_J		-40	-	+150	'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.

ELECTRICAL CHARACTERISTICS

(VIN=24V, TA=-40~+125'C, typical value is tested under 25'C, unless otherwise noted.)

Parameter	Symbol	Test Condition	Min	Type	Max	Unit
Power Supply						
Operating input voltage	V_{IN}	-	4.5	-	60	V
V_{IN} Under-voltage Lockout Threshold	V_{IN_MIN}	V_{IN} rising	-	4.23	4.45	V
V_{IN} Under-voltage Lockout Hysteresis	$V_{IN\_MIN\_HYST}$	V_{IN} falling	-	200	-	mV
Shutdown Supply Current	I_{SHDN}	V_{EN}=0V, no load	-	2	5	uA
Quiescent Current form Vin pin	IQ	EN floating, no load, no-switching	-	80	-	uA
Power MOSFETs						
High-side MOSFET on-resistance	R_{DSON_H}	V_{BOOT}-V_{SW}=5V	-	500	-	mΩ
Reference						
Reference voltage of FB	V_{REF}	-	0.77	0.8	0.83	V
Current Limit and Over Current Protection						
High-side power MOSFET peak current limit threshold	I_{LIM_HS}	-	2.8	3.5	4.1	A
Enable and Soft Startup						
Enable high threshold	V_{EN_H}	-	-	1.223	1.4	V
Enable low threshold	V_{EN_L}	-	0.9	1.13	-	V
Enable threshold hysteresis	V_{EN_HYS}	-	-	93	-	mV
Enable pin pull-up current	I_{EN_L}	EN=1V	-	1	-	uA
Enable pin pull-up current	I_{EN_H}	EN=1.5V	-	4	-	uA
Soft Start Time	T_{SS}	-	-	6	-	ms
Switching Frequency						
Switch Frequency Range	F_{SW}		390	480	566	KHz
Minimum on-time	t_{ON_MIN}	V_{IN}=12V	-	100	-	ns
Protection						
Feedback overvoltage with respect to reference voltage	V_{OVP}	V_{FB}/V_{REF} rising	-	110	-	%
		V_{FB}/V_{REF} falling	-	105	-	%
BOOT-SW UVLO threshold	V_{BOOTUV}	BOOT-SW falling	-	2.2	-	V
		Hysteresis	-	250	-	mV
Thermal Shutdown threshold	T_{SD}	TJ rising	-	173	-	'C
		Hysteresis	-	10	-	'C

Note: 3) Ferived from bench characterization

TYPICAL PERFORMANCE CHARACTERISTICS

VIN=48V, VOUT=12V, L=33uH, COUT=90uF, RRT=124KΩ, TA=+25'C, Unless Otherwise noted

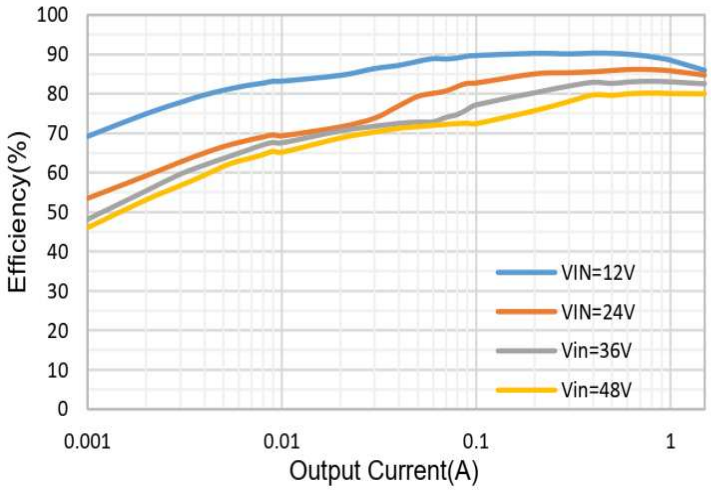


Figure 5. Efficiency vs Load Current, Vout=5V

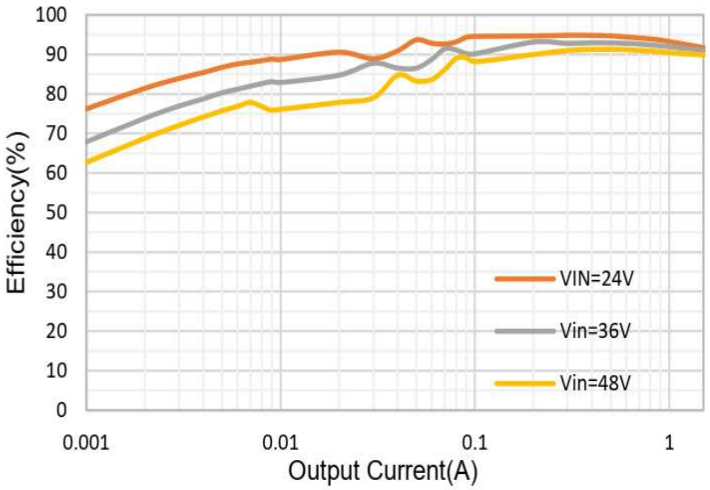


Figure 6. Efficiency vs Load Current, Vout=12V

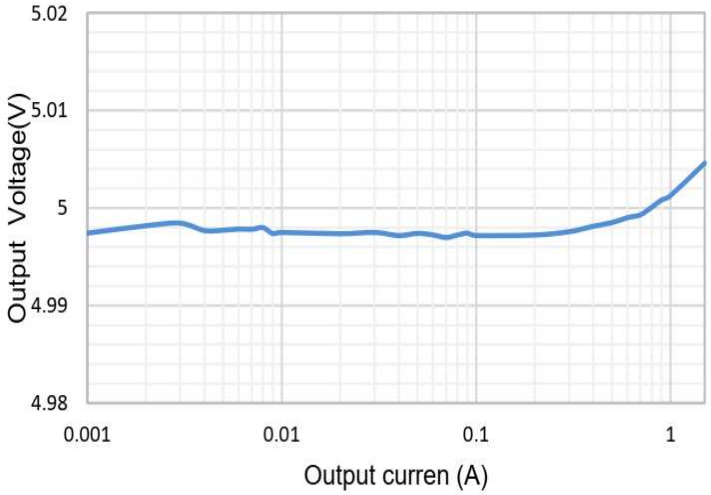


Figure 7. Load Regulation, Vin=24V, Vout=5V

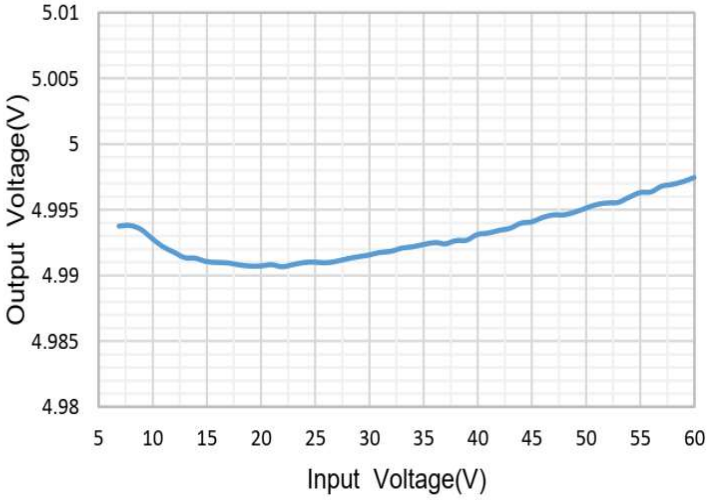


Figure 8. Line Regulation, Vout=5V, Iout=1.5A

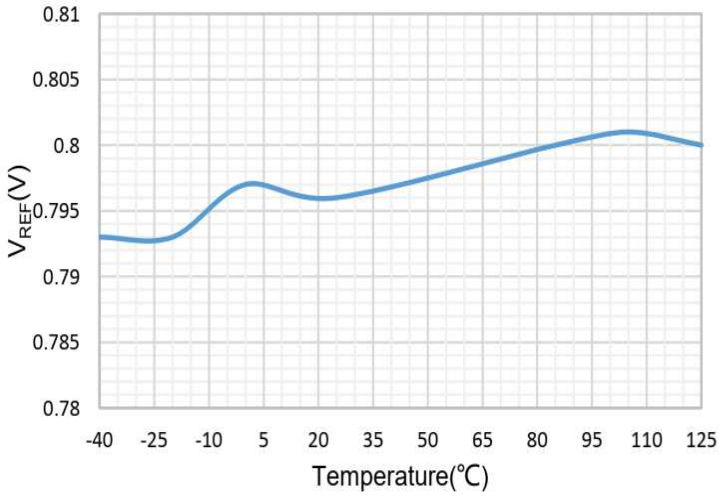


Figure 9. Reference Voltage VS Temperature

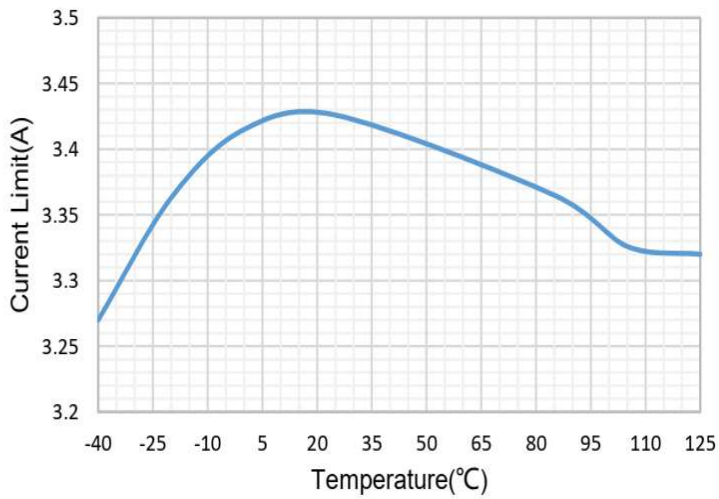


Figure10. HS Current Limit VS Temperature

BLOCK DIAGRAM

The block diagram of HCR3417

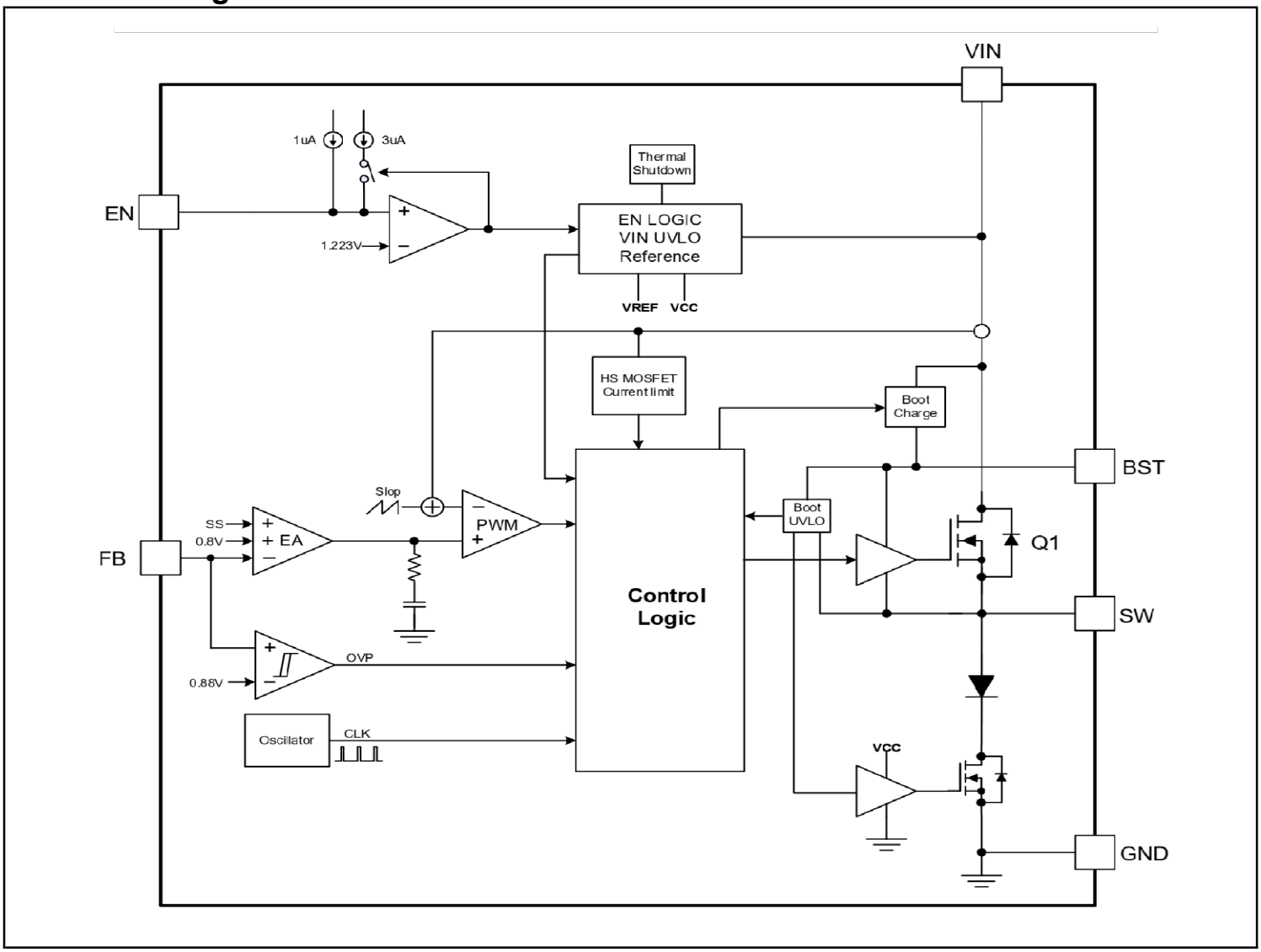


Figure 3. Block diagram of HCR3417

Typical Application of HCR3417

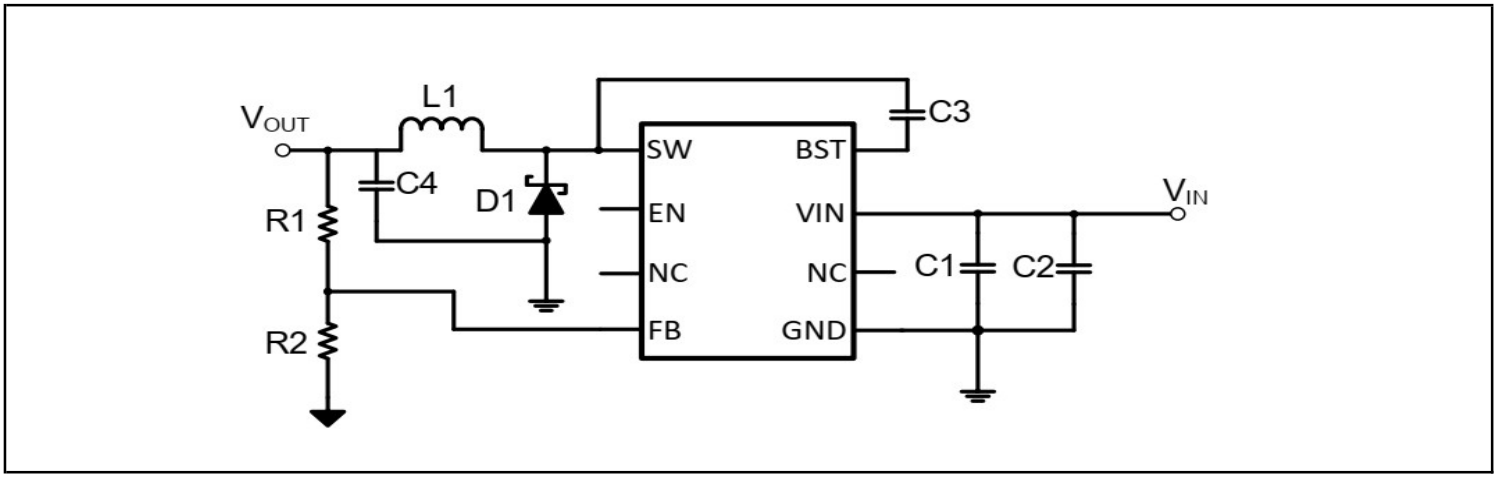


Figure 4. 4.5V-60V, Asynchronous Buck Converter

Functional Description

Overview

The HCR3417 is a 4.5V-60V input, 1.5A output, buck converter with integrated 500mΩ Rdson high-side power MOSFET. It implements constant frequency peak current mode control to regulate output voltage, providing excellent line and load transient response.

The HCR3417 features fixed 480kHz switching frequency, which minimizes the external off chip passive components size and reduces the output ripple. The HCR3417 features an internal 6ms soft-start time to avoid large inrush current and output voltage overshoot during startup. The device also supports monolithic startup with pre-biased output condition. The seamless mode-transition between PWM mode and PSM mode operations ensure high efficiency over wide load current range. The quiescent current is typically 80uA under no load or sleep mode condition to achieve high efficiency at light load.

The HCR3417 has a default input start-up voltage of 4.23V with 200mV hysteresis. The EN pin is a high-voltage pin with a precision threshold that can be used to adjust the input voltage lockout thresholds with two external resistors to meet accurate higher UVLO system requirements. Floating EN pin enables the device with the internal pull-up current to the pin. Connecting EN pin to VIN directly starts up the device automatically

The HCR3417 full protection features include the input under-voltage lockout, the output over-voltage protection, over current protection with cycle-by-cycle current limiting, output hard short protection and thermal shutdown protection.

Peak Current Mode Control

The HCR3417 employs fixed frequency peak current mode control. An internal clock initiates turning on the integrated high-side power MOSFET Q1 in each cycle, then inductor current rises linearly. When the current through high-side MOSFET reaches the threshold level set by the COMP voltage of the internal error amplifier, the integrated high-side MOSFET is turned off. The error amplifier serves the COMP node by comparing the voltage of the FB pin with an internal 0.8V reference voltage. When the load current increases, a reduction in the feedback voltage relative to the reference raises COMP voltage till the average inductor current matches the increased load current. This feedback loop well regulates the output voltage to the reference. The device also integrates an internal slope compensation circuitry to prevent sub-harmonic oscillation when duty cycle is greater than 50% for a fixed frequency peak current mode control.

The HCR3417 operates in Pulse Skipping Mode (PSM) with light load current to improve efficiency. When the load current decreases, an increment in the feedback voltage leads COMP voltage drop. When COMP falls to a low clamp threshold (450mV typically), device enters PSM. The output voltage decays due to output capacitor discharging during skipping period. Once FB voltage drops lower than the reference voltage, and the COMP voltage rises above low clamp threshold. Then high-side power MOSFET turns on in next clock pulse. After several switching cycles with typical 140mA peak inductor current, COMP voltage drops and is clamped again and pulse skipping mode repeats if the output continues light loaded.

This control scheme helps achieving higher efficiency by skipping cycles to reduce switching power loss and gate drive charging loss. The controller consumption quiescent current is 80uA during skipping period with no switching to improve efficiency further.

Functional Description(con.)

Enable and Under Voltage Lockout Threshold

The HCR3417 is enabled when the VIN pin voltage rises above 4.23V and the EN pin voltage exceeds the enable threshold of 1.223V. The device is disabled when the VIN pin voltage falls below 4.03V or when the EN pin voltage is below 1.13V. An internal 1uA pull up current source to EN pin allows the device enable when EN pin floats.

EN pin is a high voltage pin that can be connected to VIN directly to start up the device.

For a higher system UVLO threshold, connect an external resistor divider (R3 and R4) shown in Figure 11 from VIN to EN. The UVLO rising and falling threshold can be calculated by Equation 1 and Equation 2 respectively.

$$R3 = \frac{V_{rise} * 0.924 - V_{fall}}{3.076uA} \quad (1)$$

$$R4 = \frac{R_3 \times 1.13}{V_{fall} - 1.13 + R_3 * 4uA} \quad (2)$$

where

- Vrise is rising threshold of Vin UVLO
- Vfall is falling threshold of Vin UVLO

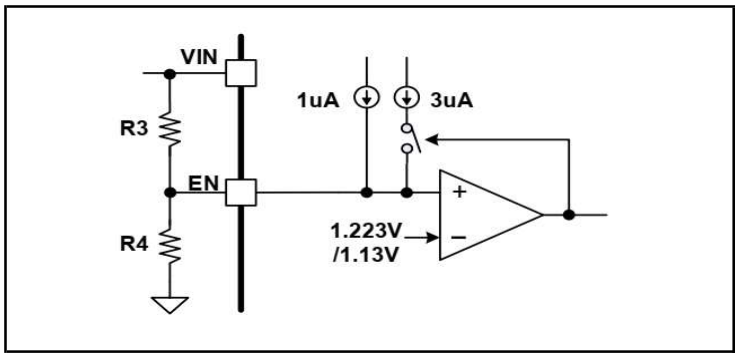


Figure 11. System UVLO by enable divide

Output Voltage

The HCR3417 regulates the internal reference voltage at 0.8V typical over the operating temperature and voltage range. The output voltage is set by a resistor divider from the output node to the FB pin. It is recommended to use 1% tolerance or better resistors. Use Equation 3 to calculate resistance of resistor dividers. To improve efficiency at light loads, larger value resistors are

Output Voltage(con.)

recommended. However, if the values are too high, the regulator will be more susceptible to noise affecting output voltage accuracy

$$R_{FB\_TOP} = \left(\frac{V_{OUT}}{V_{REF}} - 1\right) * R_{FB\_BOT}$$

Where:

- RFB_TOP is the resistor connecting the output to the FB pin.
- RFB_BOT is the resistor connecting the FB pin to the ground.

Internal Soft-Start

The HCR3417 integrates an internal soft-start circuit that ramps the reference voltage from zero volts to 0.8V reference voltage in 6ms. If the EN pin is pulled below 1.13V, switching stops and the internal soft-start resets. The soft start also resets during shutdown due to thermal overloading.

Bootstrap Voltage Regulator and Low Drop-out Operation

An external bootstrap capacitor between BOOT pin and SW pin powers the floating gate driver to high-side power MOSFET. The bootstrap capacitor voltage is charged from an integrated voltage regulator when high -side power MOSFET is off and the external low-side diode conducts. The recommended value of the BOOT capacitor is 0.1 μF.

The UVLO of high-side MOSFET gate driver has rising threshold of 2.45V and hysteresis of 250mV. When the device operates with high duty cycle or extremely light load, bootstrap capacitor may be not recharged in considerable long time. The voltage at bootstrap capacitor is insufficient to drive high-side MOSFET fully on. When the voltage across bootstrap capacitor drops below 2.2V, BOOT UVLO occurs. The converter forces turning on an integrated low-side MOSFET periodically to refresh the voltage of bootstrap capacitor to

Functional Description(con.)

Bootstrap Voltage Regulator and Low Drop-out Operation

guarantee the converter's operation over a wide duty range.

During the condition of ultra-low voltage difference from the input to the output, HCR3417 operates in Low Drop -Out LDO mode. High-side MOSFET remains turning on as long as the BOOT pin to SW pin voltage is higher than BOOT UVLO threshold 2.45V. When the voltage from BOOT to SW drops below 2.2V, the high-side MOSFET turns off and low-side MOSFET turns on to recharge bootstrap capacitor periodically in the following several switching cycles. Low-side MOSFET only turns on for 200ns in each refresh cycle to minimize the output voltage ripple. Low-side MOSFET may turn on for several times till the bootstrap voltage is charged to higher than 2.45V for high-side MOSFET working normally. The effective duty cycle of the converter during LDO operation can be approaching to 100%.

During slowing power up and power down application, the output voltage can closely track the input voltage ramping down thanks to LDO operation mode. As the input voltage is reduced to near the output voltage, i.e., during slowing power-up and power-down application, the off-time of the high side MOSFET starts to approach the minimum value. Without LDO operation mode, beyond this point the switching may become erratic and /or the output voltage will fall out of regulation. To avoid this problem, the HCR3417 LDO mode automatically reduces the switching frequency to increase the effective duty cycle and maintain regulation.

Over Current Limit

The HCR3417 implements over current protection with fold back current limit. The HCR3417 cycle-by-cycle limits high-side MOSFET peak current to avoid inductor current running away during unexpected overload or output hard When overload or hard short happens, the converter cannot provide output current to satisfy loading requir-

Over Current Limit(con.)

ement. The inductor current is clamped at over current limitation. Thus, the output voltage drops below regulated voltage with FB voltage less than internal reference voltage continuously.

The HCR3417 implements frequency fold back to protect the converter in unexpected overload or output hard short condition at higher switching frequencies and input voltages. The oscillator frequency is divided by 1, 2, 4, and 8 as the FB pin voltage falls from 0.8V to 0V. The HCR3417 uses a digital frequency fold back to enable synchronization to an external clock during normal start -up and fault conditions. During short-circuit events, the inductor current can exceed the peak current limit because of the high input voltage and the minimum on-time. When the output voltage is forced low by the shorted load, the inductor current decreases slowly during the switch off-time. The frequency fold back effectively increases the off time by increasing the period of the switching cycle providing more time for the inductor current to ramp down.

With a maximum frequency fold back ratio of 8, there is a maximum frequency at which the inductor current can be controlled by frequency fold back protection. Equation 4 calculates the maximum switching frequency at which the inductor current remains under control when VOUT is forced to VOUT_SHORT. The selected operating frequency must not exceed the calculated value.

$$f_{sw(\max skip)} = \frac{f_{DIV}}{t_{min\_ON}} \times \left(\frac{I_{LIMIT} \times R_{DC} + V_{OUT\_SHORT} + V_d}{V_{IN\_MAX} - I_{LIMIT} \times R_{DS(on)} + V_d}\right) \quad (4)$$

Where:

I_{LIMIT}: Limited average current.

R_{DC}: Inductor DC resistance.

V_{IN_MAX}: Maximum input voltage.

V_{OUT_SHORT}: Output voltage during short.

V_d: Diode voltage drop.

$R_{DS(on)}$: Integrated high side FET on resistance.

T_{min_ON}: Controllable minimum on time.

f_{DIV}: Frequency divide equals (1,2,4 or 8).

Functional Description(con.)

Over voltage Protection

The HCR3417 implements the Over-voltage Protection OVP circuitry to minimize output voltage overshoot during load transient, recovering from output fault condition or light load transient. The overvoltage comparator in OVP circuit compares the FB pin voltage to the internal reference voltage. When FB voltage exceeds 110% of internal 0.8V reference voltage, the high-side MOSFET turns off to avoid output voltage continue to increase. When the FB pin voltage falls below

Over voltage Protection(con.)

105% of the 0.8V reference voltage, the high-side MOSFET can turn on again.

Thermal Shutdown

The HCR3417 protects the device from the damage during excessive heat and power dissipation conditions. Once the junction temperature exceeds 173℃, the internal thermal sensor stops power MOSFETs switching. When the junction temperature falls below 163℃, the device restarts with internal soft start phase.

Typical Application

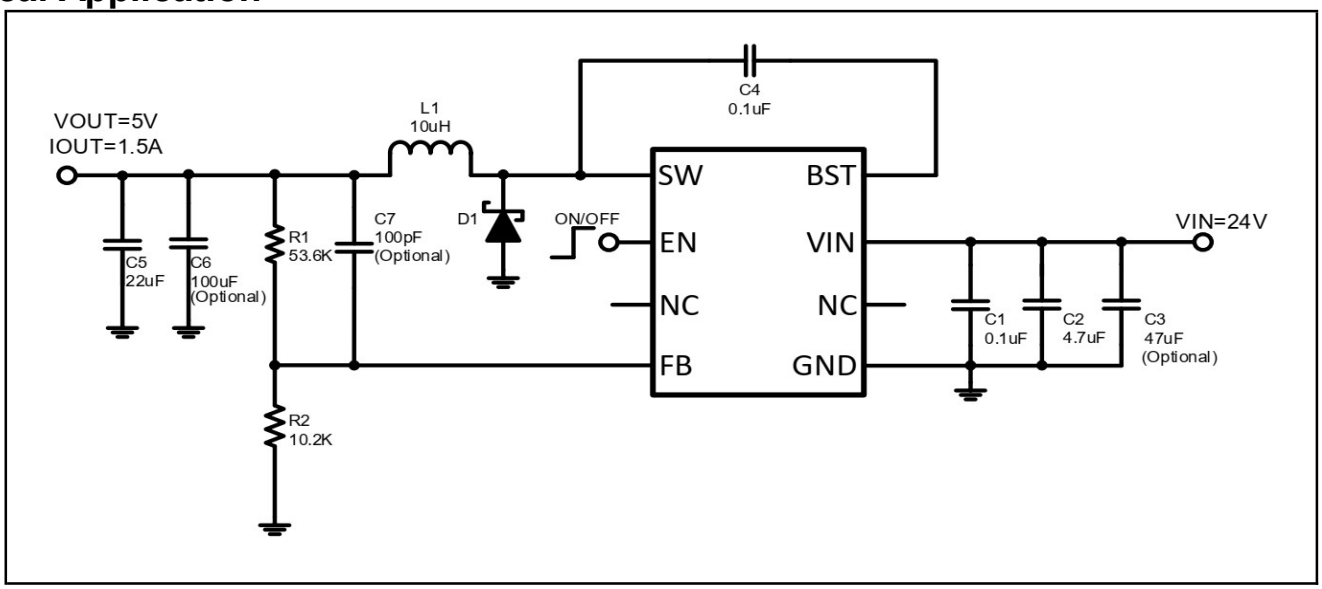
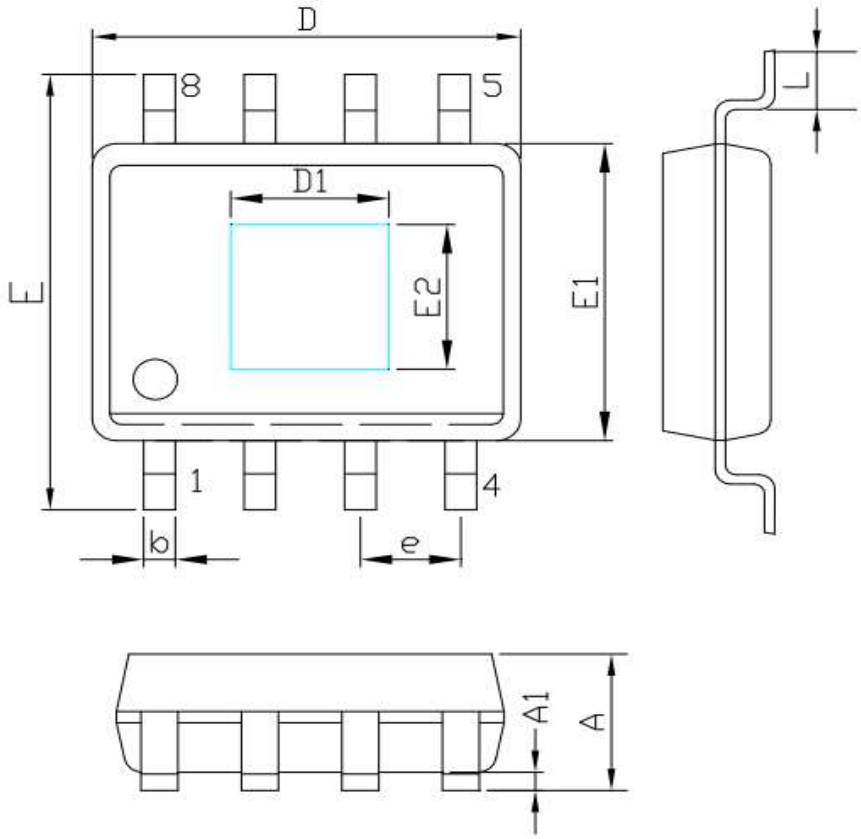


Figure 12. HCR3417 Designning the 5V Output with Programmable UVLO

Mechanical Dimensions

M8E PKG: SOP-8(EP)

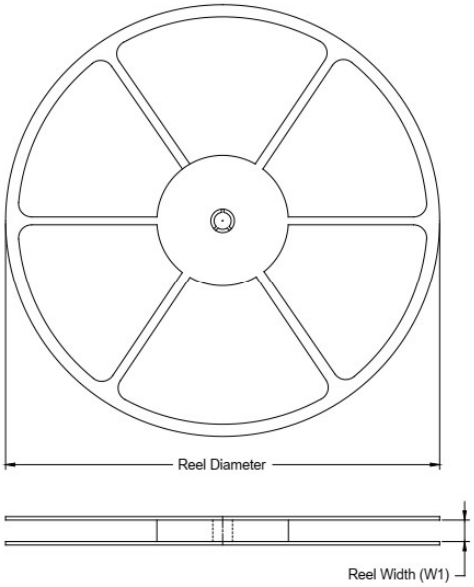
Unit: mm(inch)



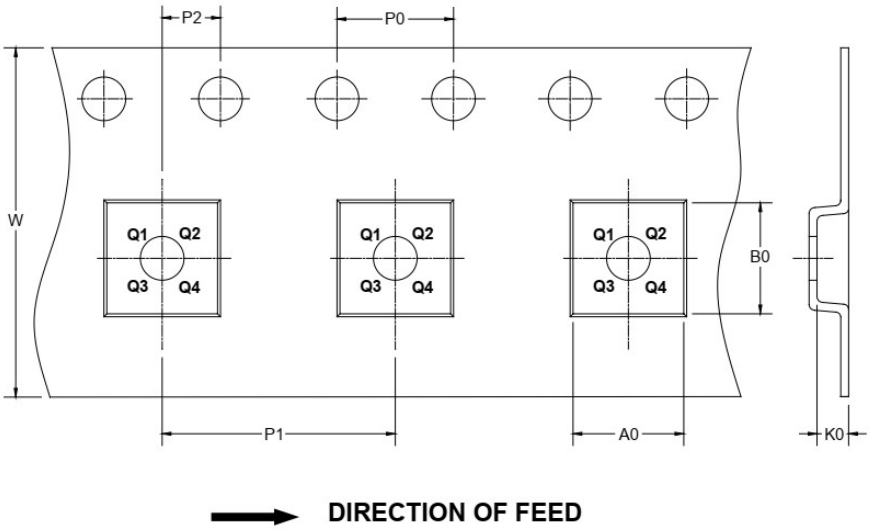
SYMBOLS	MILLIMETERS			INCHES		
	MIN.	Normal	MAX.	MIN.	Normal	MAX.
A	1.35	-	1.75	0.053	-	0.069
A1	0.00	-	0.25	0.000	-	0.010
D	4.80	4.90	5.00	0.189	0.193	0.197
E1	3.70	3.90	4.00	0.146	0.154	0.157
D1	2.67	2.97	3.50	0.105	0.117	0.138
E2	1.78	2.18	2.60	0.070	0.086	0.102
E	5.80	6.00	6.20	0.228	0.236	0.244
L	0.40	-	1.27	0.016	-	0.050
b	0.31	-	0.51	0.012	-	0.020
e	1.27 REF			0.050 REF		

TAPE AND REEL INFORMATION

REEL DIMENSIONS



TAPE DIMENSIONS

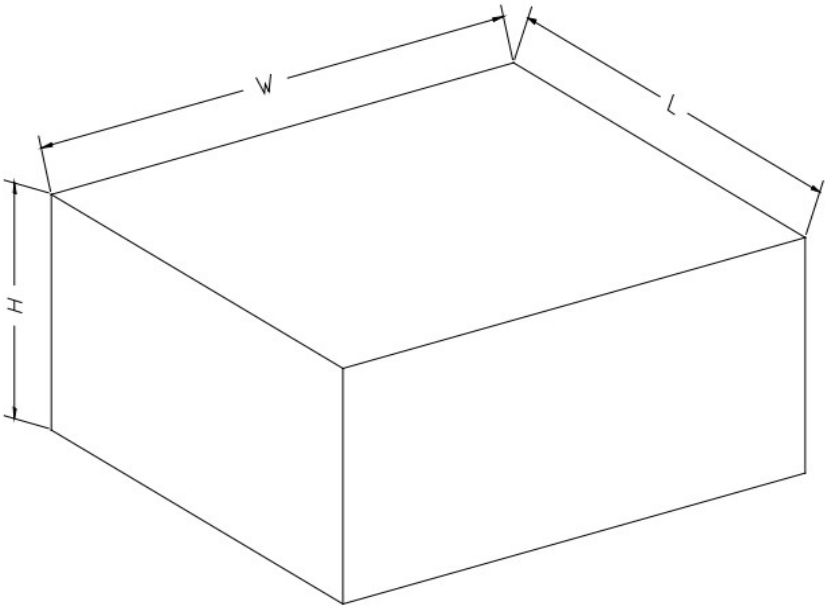


NOTE: The picture is only for reference. Please make the object as the standard.

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
SOP-8(EP)	13"	12.4	6.40	5.40	2.10	4.0	8.0	2.0	12.0	Q1

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