100V Constant On-Time Synchronous Buck Regulator

General Description

The ZMCS3417 is a 100V, 600mA synchronous step-down regulator with integrated high side and low side MOSFETs. The constant-on-time (COT) control scheme employed in the ZMCS3417 requires no loop compensation, provides excellent transient response, and enables very low step-down ratios. The on-time varies inversely with the input voltage resulting in nearly constant frequency over the input voltage range. A high voltage startup regulator provides bias power for internal operation of the IC and for integrated gate drivers.

A peak current limit circuit protects against overload conditions. The undervoltage lockout (UVLO) circuit allows the input undervoltage threshold and hysteresis to be independently programmed. Other protection features include thermal shutdown and bias supply undervoltage lockout (VCC UVLO).

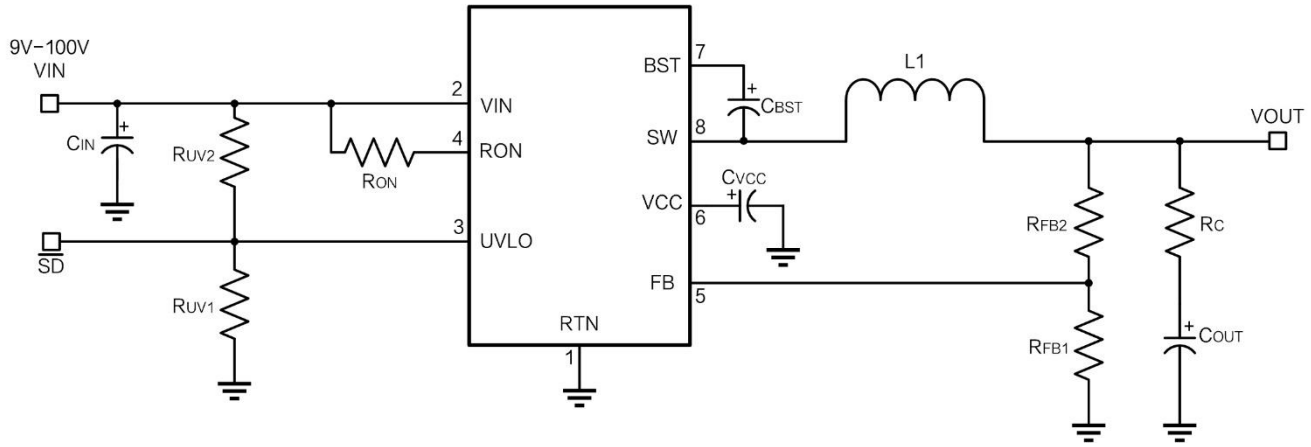
Applications

- Smart Power Meters
- Automotive Electronics

Features

- Wide 7.5V to 100V Input Range
- Integrated 100V, High and Low Side Switches
- No Schottky Required
- Constant On-time Control
- No Loop Compensation Required
- Ultra-Fast Transient Response
- Nearly Constant Operating Frequency
- Intelligent Peak Current Limit
- Adjustable Output Voltage
- High Precision Feedback Reference
- Frequency Adjustable to 1MHz
- Adjustable Undervoltage Lockout (UVLO)
- Remote Shutdown
- Thermal Shutdown
- ESOP8 & DFN4×4-8L Package

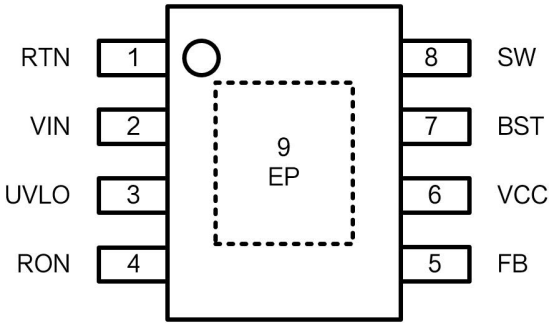
Typical Application



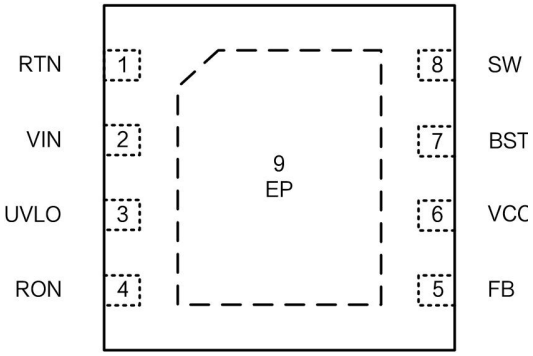
Ordering Information

Product Model	Order Code	Package Type	Packing Method
ZMCS3417S	ZMCS3417S	ESOP8	tape & reel/material pipe
ZMCS3417N	ZMCS3417N	DFN4×4-8L	tape & reel

Pin Definition



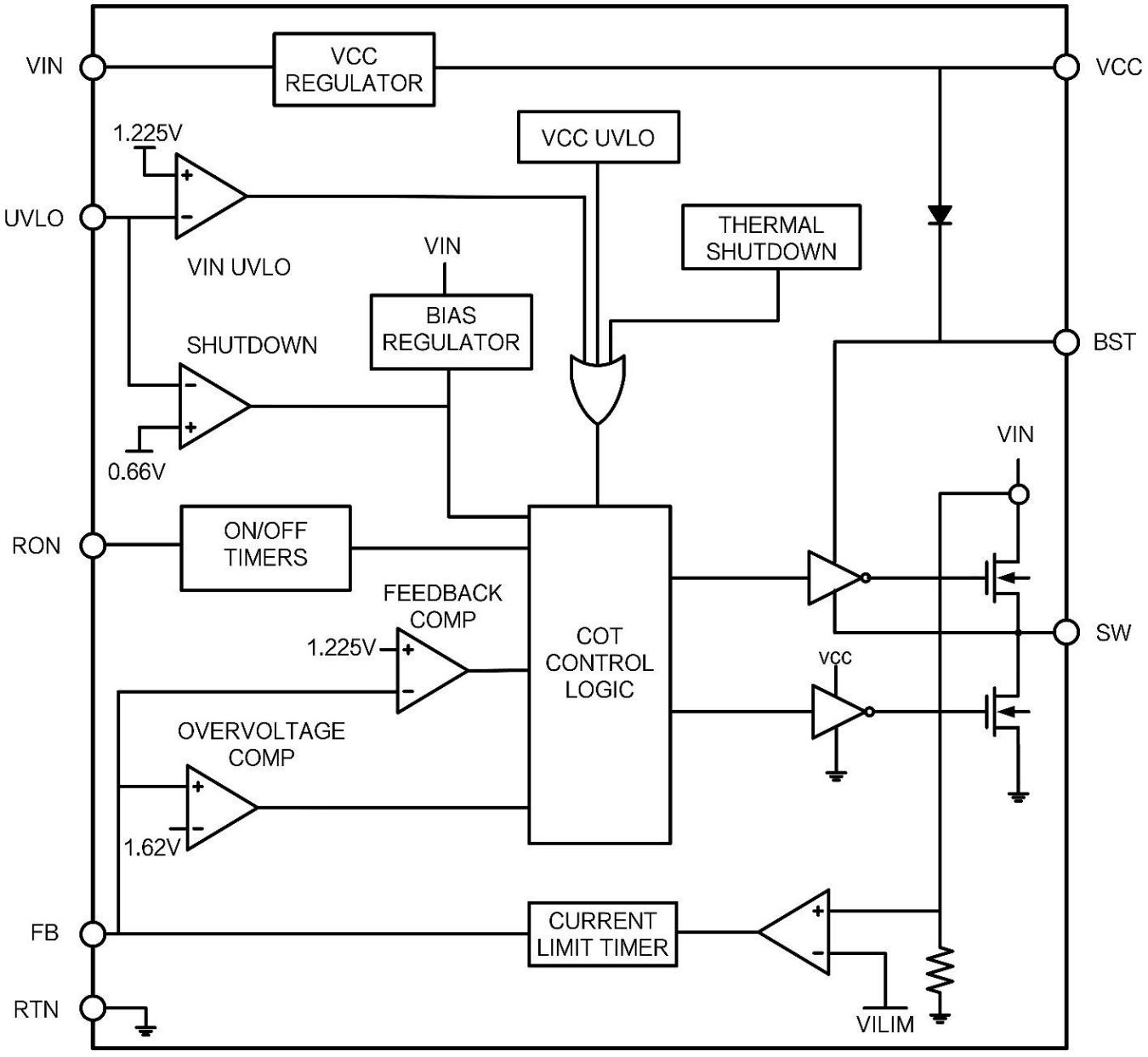
Pin	Symbol	Function Description
1	RTN	Ground
2	VIN	Input Voltage
3	UVLO	Input Pin of Undervoltage Comparator
4	RON	On-Time Control
5	FB	Feedback
6	VCC	7.6V Power Supply
7	BST	Bootstrap Capacitor
8	SW	Switching Node
9	EP	Exposed Pad



Pin	Symbol	Function Description
1	RTN	Ground
2	VIN	Input Voltage
3	UVLO	Input Pin of Undervoltage Comparator

4	RON	On-Time Control
5	FB	Feedback
6	VCC	7.6V Power Supply
7	BST	Bootstrap Capacitor
8	SW	Switching Node
9	EP	Exposed Pad

Functional Block Diagram



Absolute Maximum Ratings (1)

VIN、UVLO to GND.....-0.3~100V
SW to GND.....-1.5~VIN+0.3V
BST to VCC.....100V
BST to SW.....13V
RON to GND.....-0.3~100V
VCC to GND.....-0.3~13V
FB to GND.....-0.3~5V
Junction Temperature.....150℃
Storage Temperature.....-55~150℃
Human Body Model.....±2KV

(1) Absolute Maximum Ratings are limits beyond which damage to the device may occur. Operating Ratings are conditions under which operation of the device is intended to be functional. For guaranteed specifications and test conditions, see the Electrical Characteristics.

Operating Ratings (1)

	MIN	TYP	MAX	UNIT
VIN Voltage	7.5		100	V
Junction Temperature	-40		125	℃

（1）Recommended working conditions refer to the conditions for the normal operation of the chip. Refer to electrical Characteristics for exact specifications and test conditions.

Electrical Characteristics

Unless otherwise noted, T=25℃，V_{IN}=48 V

SYMBOL	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Vcc Supply						
V_{CC}	V_{CC} Regulator Output	V_{IN} = 48V, I_{CC} = 20mA	6.25	7.6	8.55	V
ILIM_VCC	VCC Current Limit	VIN=48V	26			mA
VCC_ON	VCC Undervoltage Lockout Voltage		4.15	4.5	4.9	V
V_{CC_Hys}	V_{CC} Undervoltage Hysteresis			300		mV
V_{CC_Drop}	V_{IN}-V_{CC}	V_{IN} = 9V, I_{CC} = 20mA		2.0		V
I_{IN}	IIN Operating Current	FB=3V		1.75		mA
I_{IN_SD}	IIN Shutdown Current	UVLO = 0V		50	225	uA
Switch Characteristics性						
B_{UCK} $R_{DS（ON）}$	Buck Switch RDS(ON)	ITEST = 200mA, BST-SW = 7V		0.8	1.8	Ω
S_{YNC} $R_{DS（ON）}$	Synchronous RDS(ON)	ITEST = 200mA		0.45	1	Ω
BST_{UVLO}	Gate Drive UVLO	VBST-VSW	2.7	3.3	3.9	V
BST_{UVLO_Hys}	Gate Drive UVLO Hysteresis			300		mV
Current Limit						
I_{LIMIT}	Current Limit Threshold		0.7	1.02	1.3	A
I_{LIMIT_TIME}	Current Limit Response Time			150		ns
T_{OFF1}	OFF-Time Generator (Test 1)	FB = 0.1V, V_{IN} = 48V		12		us
T_{OFF2}	OFF-Time Generator (Test 2)	FB = 1.0V, V_{IN} = 48V		2.5		us
On-Time Generator						
T_{ON1}	TON Test 1	VIN = 32V, RON = 100k	270	350		ns
T_{ON2}	TON Test 2	VIN = 48V, RON = 100k	188	250		ns
T_{ON3}	TON Test 3	VIN = 75V, RON = 250k	250	370		ns
T_{ON4}	TON Test 4	VIN = 10V, RON = 250k	1880	3200		ns
Minium OFF-Time						
T_{OFF_MIN}	Minimum Off-Time	FB=0V		144		ns
Regulation Sensing Function						
V_{FB}	FB Regulation Level		1.2	1.225	1.25	V
V_{FB_OV}	FB Overvoltage Threshold			1.62		V
I_{FB_Bias}	FB Bias Current			60		nA
Undervoltage Sensing Function						
V_{UVLO_ON}	UV Threshold		1.19	1.225	1.26	V

I_{UVLO_Hys}	UV Hysteresis Input Current	UV=2.5V	-10	-20	-29	uA

Electrical Characteristics(continued)

Unless otherwise noted, T=25℃，V_{IN}=48 V

SYMBOL	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{SD_TH}	Remote Shutdown Threshold		0.32	0.66		V
V_{SD_HYS}	Remote Shutdown Hysteresis			110		mV
Thermal Shutdown						
T_{SD}	Thermal Shutdown Temperature			165		℃
T_{HYS}	Thermal Shutdown Hysteresis			20		℃

Function Description

The ZMCS3417 step-down switching regulator features all the functions needed to implement a low cost, efficient, buck converter capable of supplying up to 0.6A to the load. This high voltage regulator contains 100V, N-channel buck and synchronous switches, is easy to implement, and is provided in thermally enhanced ESOP8 package. The regulator operation is based on a constant on-time control scheme using an on-time inversely proportional to VIN. This control scheme does not require loop compensation. The current limit is implemented with a forced off-time inversely proportional to VOUT. This scheme ensures short circuit protection while providing minimum foldback.

The ZMCS3417 can be applied in numerous applications to efficiently regulate down higher voltages. This regulator is well suited for 48V telecom and 42V automotive power bus ranges. Protection features include: thermal shutdown, Undervoltage Lockout (UVLO), minimum forced off-time, and an intelligent current limit.

➢ Control Overview

The ZMCS3417 buck regulator employs a control principle based on a comparator and a one-shot on-timer, with the output voltage feedback (FB) compared to an internal reference (1.225V). If the FB voltage is below the reference the internal buck switch is turned on for the one-shot timer period, which is a function of the input voltage and the programming resistor (RON). Following the on-time the switch remains off until the FB voltage falls below the reference, but never before the minimum off-time forced by the minimum off-time one-shot timer. When the FB pin voltage falls below the reference and the minimum off-time one-shot period expires, the buck switch is turned on for another on-time one-shot period. This will continue until regulation is achieved and the FB voltage is approximately equal to 1.225V (typ).

In a synchronous buck converter, the low side (sync) FET is 'on' when the high side (buck) FET is 'off'. The inductor current ramps up when the high side switch is 'on' and ramps down when the high side switch is 'off'. There is no diode emulation feature in this IC, and therefore, the inductor current may ramp in the negative direction at light load. This causes the converter to operate in continuous conduction mode (CCM) regardless of the output loading. The operating frequency remains relatively constant with load and line variations. The operating frequency can be calculated as follows:

$$f_{SW} = \frac{V_{OUT}}{10^{-10} \times R_{ON}}$$

The output voltage (VOUT) is set by two external resistors (RFB1, RFB2). The regulated output voltage is calculated as follows:

$$V_{OUT} = 1.225V \times \frac{R_{FB2}+R_{FB1}}{R_{FB1}}$$

$$\frac{R_{FB2}}{R_{FB1}} = \frac{V_{OUT}-1.225V}{1.225V}$$

This regulator regulates the output voltage based on ripple voltage at the feedback input, requiring a minimum amount of ESR for the output capacitor (COUT). A minimum of 25mV of ripple voltage at the feedback pin (FB) is required for the ZMCS3417. In cases where the capacitor ESR is too small, additional series resistance may be required (RC in Figure 1 Low Ripple Output Configuration). For applications where lower output voltage ripple is required the output can be taken directly from a low ESR output capacitor, as shown in Figure 1 Low Ripple Output Configuration.

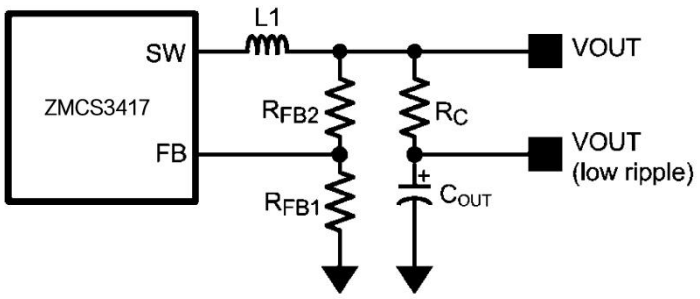


Figure 1 Low Ripple Output Configuration

➢ VCC Regulator

The ZMCS3417 contains an internal high voltage linear regulator with a nominal output of 7.6V. The input pin (VIN) can be connected directly to the line voltages up to 100V. The VCC regulator is internally current limited to 30mA. The regulator sources current into the external capacitor at VCC. This regulator supplies current to internal circuit blocks including the synchronous MOSFET driver and the logic circuits. When the voltage on the VCC pin reaches the undervoltage lockout (VCC UVLO) threshold of 4.5V, the IC is enabled.

The VCC regulator contains an internal diode connection to the BST pin to replenish the charge in the gate drive boot capacitor when SW pin is low.

At high input voltages, the power dissipated in the high voltage regulator is significant and can limit the overall achievable output power. As an example, with the input at 48V and switching at high frequency, the VCC regulator may supply up to 7mA of current resulting in 48V × 7mA = 336mW of power dissipation. If the VCC voltage is driven externally by an alternate voltage source, between 8V and 13V, the internal regulator is disabled. This reduces the power dissipation in the IC.

➢ Regulation Comparator

The feedback voltage at FB is compared to an internal 1.225V reference. In normal operation, when the output voltage is in regulation, an on-time period is initiated when the voltage at FB falls below 1.225V. The high side switch will stay on for the on-time, causing the FB voltage to rise above 1.225V. After the on-time period, the high side switch will stay off until the FB voltage again falls below 1.225V. During start-up, the FB voltage will be below 1.225V at the end of each on-time, causing the high side switch to turn on immediately after the minimum forced off-time of 144ns. The high side switch can be turned off before the on-time is over, if the peak current in the inductor reaches the current limit threshold.

➢ Overvoltage Comparator

The feedback voltage at FB is compared to an internal 1.62V reference. If the voltage at FB rises above 1.62V the on-time pulse is immediately terminated. This condition can occur if the input voltage and/or the output load changes suddenly. The high side switch will not turn on again until the voltage at FB falls below 1.225V.

➢ On-Time Generator

The on-time for the ZMCS3417 is determined by the RON resistor, and is inversely proportional to the input voltage (VIN), resulting in a nearly constant frequency as VIN is varied over its range. The on-time equation for the ZMCS3417 is:

$$T_{ON} = \frac{10^{-10} \times R_{ON}}{V_{IN}}$$

➢ Current Limit

The ZMCS3417 contains an intelligent current limit off-timer. If the current in the buck switch exceeds 1.02A the present cycle is immediately terminated, and a non-resetable off-timer is initiated. The length of off-time is controlled by the FB voltage and the input voltage VIN. As an example, when FB = 0V and VIN = 48V, the maximum off-time is set to 16 μ s. This condition occurs when the output is shorted, and during the initial part of start-up. This amount of time ensures safe short circuit operation up to the maximum input voltage of 100V.

In cases of overload where the FB voltage is above zero volts (not a short circuit) the current limit off-time is reduced. Reducing the off-time during less severe overloads reduces the amount of foldback, recovery time, and start-up time. The off-time is calculated from the following equation:

$$T_{OFF(ILIM)} = \frac{0.07 \times V_{IN}}{V_{FB} + 0.2V} \text{us}$$

The current limit protection feature is peak limited. The maximum average output will be less than the peak.

➢ N-Channel Buck Switch and Driver

The ZMCS3417 integrates an N-Channel Buck switch and associated floating high voltage gate driver. The gate driver circuit works in conjunction with an external bootstrap capacitor and an internal high voltage diode. A 0.01uF ceramic capacitor connected between the BST pin and the SW pin provides the voltage to the driver during the on-time. During ach off-time, the SW pin is at approximately 0V, and the bootstrap capacitor charges from VCC through the internal diode. The minimum off-timer, set to 144ns , ensures a minimum time each cycle to recharge the bootstrap capacitor.

➢ Synchronous Rectifier

The ZMCS3417 provides an internal synchronous N-Channel MOSFET rectifier. This MOSFET provides a path for the inductor current to flow when the high-side MOSFET is turned off. The synchronous rectifier has no diode emulation mode, and is designed to keep the regulator in continuous conduction mode even during light loads which would otherwise result in discontinuous operation.

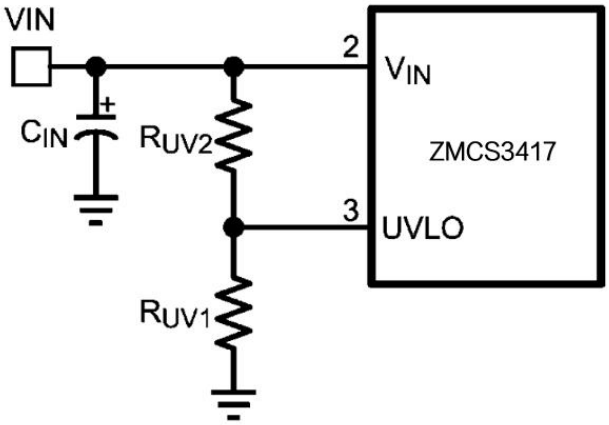
➢ Undervoltage Detector

The ZMCS3417 contains a dual level undervoltage lockout (UVLO) circuit. When the UVLO pin voltage is below 0.66V, the controller is in a low current shutdown mode. When the UVLO pin voltage is greater than 0.66V but less than 1.225V, the controller is in standby mode. In standby mode the VCC bias regulator is active while the regulator output is disabled. When the VCC pin exceeds the VCC undervoltage threshold and the UVLO pin voltage is greater than 1.225V, normal operation begins. An external set-point voltage divider from VIN to GND can be used to set the minimum operating voltage of the regulator.

UVLO hysteresis is accomplished with an internal 20μA current source that is switched on or off into the impedance of the set-point divider. When the UVLO threshold is exceeded, the current source is activated to quickly raise the voltage at the UVLO pin. The hysteresis is equal to the value of this current times the resistance RUV2.

UVLO	VCC	Mode	Description
<0.66V		Shutdown	VCC regulator disabled. Switcher disabled.
0.66V~1.225V		Standby	VCC regulator enabled. Switcher disabled.
>1.225V	VCC<4.5V	Standby	VCC regulator enabled. Switcher disabled.
	VCC>4.5V	Operating	VCC regulator disabled. Switcher enabled.

If the UVLO pin is wired directly to the VIN pin, the regulator will begin operation once the VCC undervoltage is satisfied.

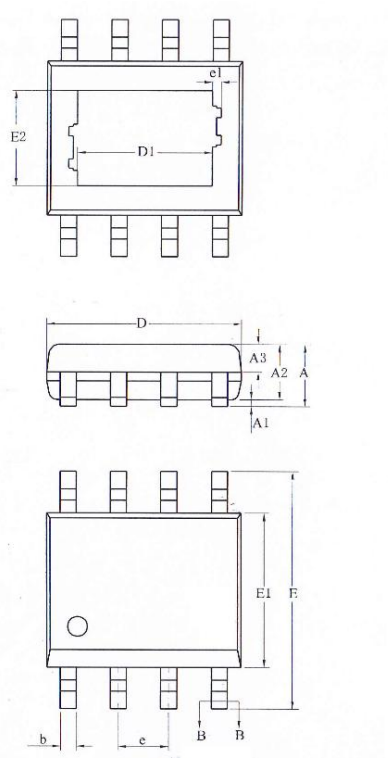


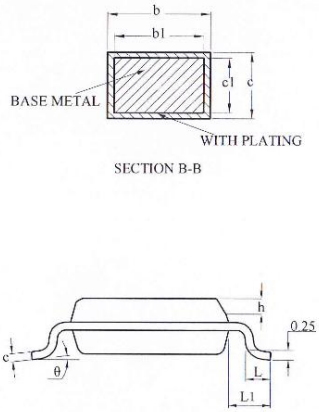
➢ Thermal Protection

The ZMCS3417 should be operated so the junction temperature does not exceed 150℃ during normal operation. An internal Thermal Shutdown circuit is provided to protect the ZMCS3417 in the event of a higher than normal junction temperature. When activated, typically at 165℃, the controller is forced into a low power reset state, disabling the buck switch and the VCC regulator. This feature prevents catastrophic failures from accidental device overheating. When the junction temperature reduces below 145℃ (typical hysteresis = 20℃), the VCC regulator is enabled, and normal operation is resumed.

Package Outline Drawing

ESOP8

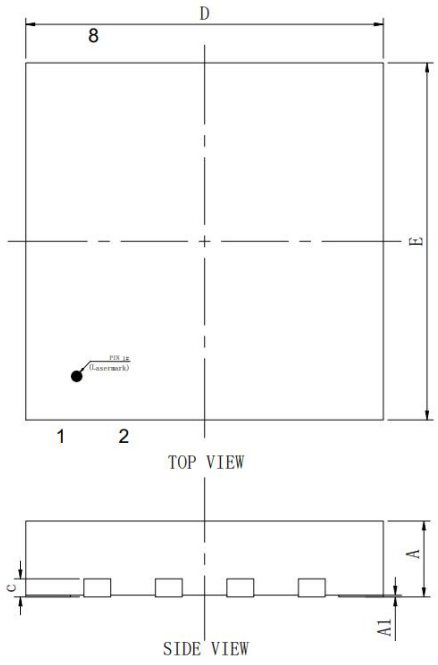


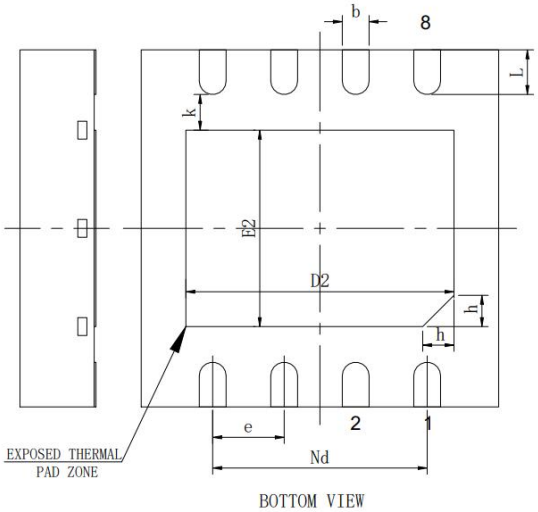


SYMBOL	MILLIMETER		
	MIN	NOM	MAX
A	—	—	1.65
A1	0.05	—	0.15
A2	1.30	1.40	1.50
A3	0.60	0.65	0.70
b	0.39	—	0.47
b1	0.38	0.41	0.44
c	0.20	—	0.24
c1	0.19	0.20	0.21
D	4.80	4.90	5.00
E	5.80	6.00	6.20
E1	3.80	3.90	4.00
e	1.27BSC		
h	0.25	—	0.50
L	0.50	0.60	0.80
L1	1.05REF		
θ	0	—	8°

Size (mil) / L/F Size (mil)	D1	E2	e1
90*90	2.09REF	2.09REF	0.16REF
95*130	3.10REF	2.21REF	0.10REF

DFN4×4-8L





SYMBOL	MILLIMETER		
	MIN	NOM	MAX
A	0.80	0.85	0.90
A1	0	0.02	0.05
b	0.25	0.30	0.35
c	0.203REF		
D	3.90	4.00	4.10
D2	2.90	3.00	3.10
Nd	2.40BSC		
E	3.90	4.00	4.10
E2	2.10	2.20	2.30
e	0.80BSC		
K	0.40REF		
L	0.45	0.50	0.55
h	0.30	0.35	0.40