500K, 36V, 2A Synchronous Step-Down Converter

Features

- 4.5V to 36V Operating Input Voltage Range
- 500KHz Switching Frequency
- 2.0A Continuous Output Current
- ECOT Mode Control with Fast Transient Response
- 100mΩ/50mΩ Low RDS(ON) Internal Power Response
- Output Adjustable V_{FB}=0.6V/0.8V/0.765V
- PSM Mode for 93% Efficiency in Light Load
- No Schottky Diode Required
- Internal Soft-Start
- Built-in Over Voltage Protection
- Built-in Over Current Limit
- Short Protection with Hiccup-Mode
- Thermal Shutdown
- Integrated internal compensation
- Available in a Green SOT23-6L package

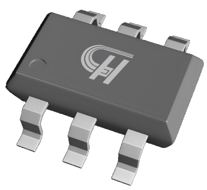
General Description

The HCR3238 is a high frequency, synchronous, rectified, step-down, switch-mode converter with internal power MOSFETs. The HCR3238 provides different frequency and FB versions, which can be selected according to different applications. It offers a very compact solution to provide a 2A continuous output current over a wide input supply range, with excellent load and line regulation. ECOT PSM control operation provides very fast transient response and easy loop design as well as very tight output regulation.

The HCR3238 requires a minimal number of readily available, external components and is available in a Green SOT23-6L package.

Applications

- Automotive Systems
- Network Terminal Equipment
- Security Monitoring Camera
- Industrial Power Systems
- Distributed Power Systems
- Printer Systems



SOT23-6L

Figure 1. Package Type of HCR3238

Pin Configuration

SOT23-6L Top View

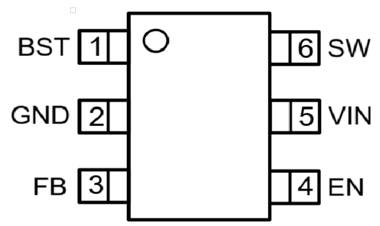
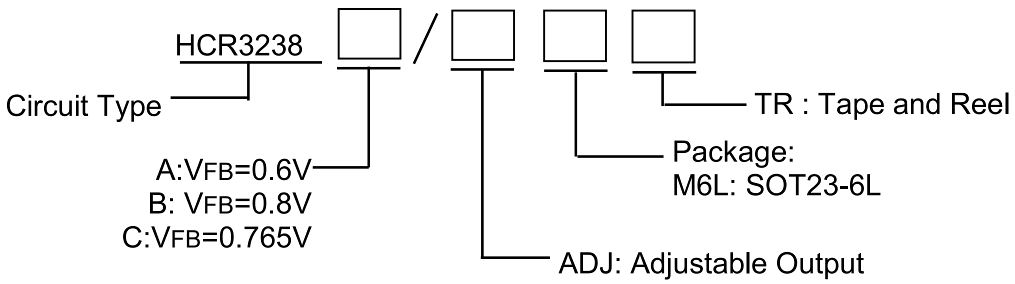


Figure 2. Pin Configuration of HCR3238 (Top View)

Pin Function Table

Pin Number	Pin Name	Function
1	BST	Bootstrap. A capacitor connected between SW and BST pins is required to form a floating supply across the high-side switch driver.
2	GND	Power Ground. Must be soldered directly to ground plane.
3	FB	Adjustable Version Feedback input. Connect FB to the center point of the external resistor divider.
4	EN	Drive this pin to a logic-high to enable the IC. Drive to a logic-low to disable the IC and enter micro-power shutdown mode.
5	VIN	Supply Input. Connect VIN to a power source with 4.5V to 36V input voltage range. Decouple VIN to GND as close as possible with a high frequency, low ESR ceramic capacitor (X5R or higher grade is recommended).
6	SW	Switching Node. Connection point of the internal converter lower and upper power MOSFETs. Connect this pin to the output inductor and the bootstrap capacitor

Ordering Information



Ordering Code

Part Number	Marking ID note2	Temperature Junction Range	Package	Quantity per Reel
HCR3238A/ADJM6LTR	hAYY	-40'C to +125'C	SOT23-6L	3000, Tape&Reel
HCR3238B/ADJM6LTR	hBYY	-40'C to +125'C	SOT23-6L	3000, Tape&Reel
HCR3238C/ADJM6LTR	hCYY	-40'C to +125'C	SOT23-6L	3000, Tape&Reel

Note 2: the "YY" is Inside code.

Functional Block Diagram

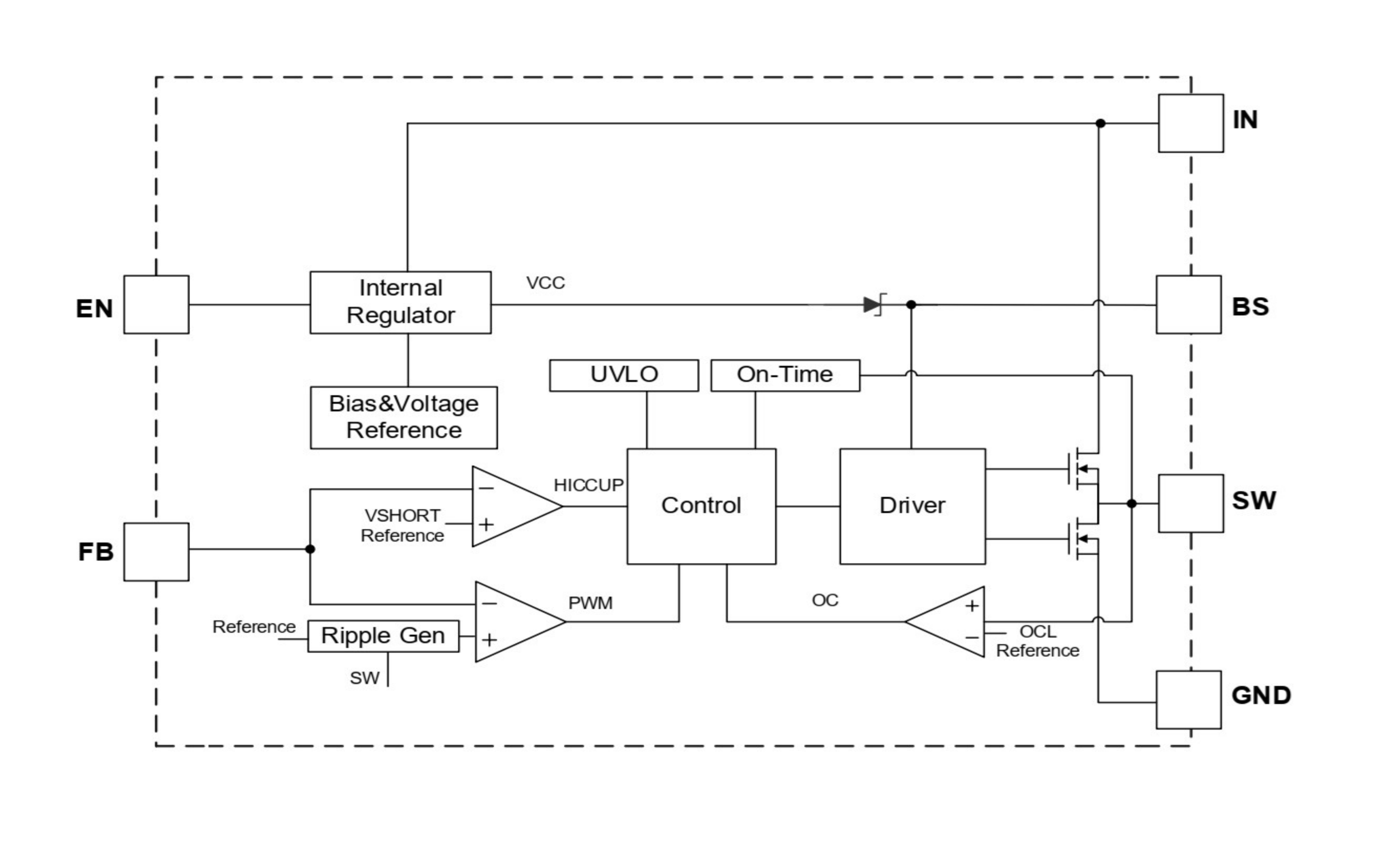


Figure 3. Functional Block Diagram of HCR3238

Typical Application Circuit

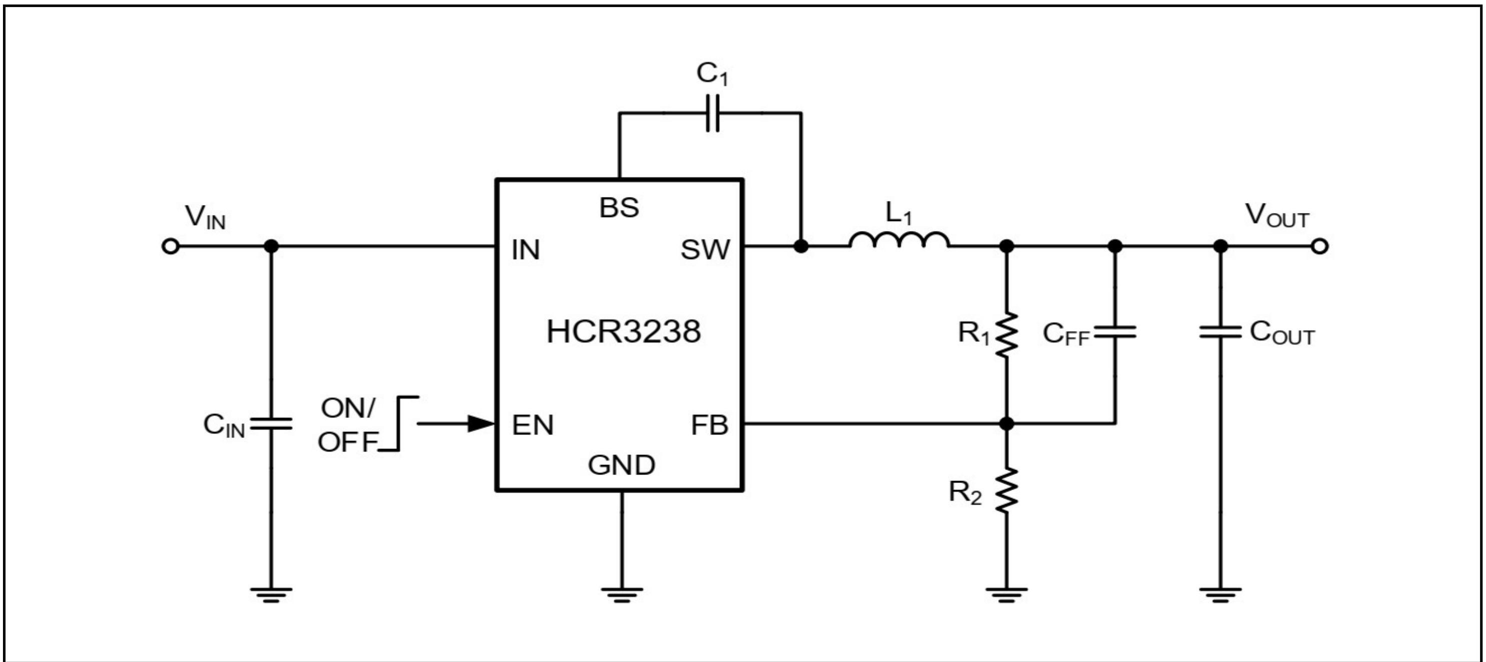


Figure 4. Typical Application Circuit of HCR3238

Absolute Maximum Ratings [1]

Parameter	Symbol	Value	Unit
Input Supply Voltage Range	V_{IN}	-0.3 to +45.0	V
EN Voltage Range	V_{EN}	-0.3 to +45.0	V
SW Voltage Range	V_{SW}	-0.3 to V_{IN}+1V	V
SW Voltage Range(10ns transient)	V_{SW}	-5 to V_{IN}+2V	V
BST Voltage Range	V_{BST}	-0.3 to V_{SW}+5V	V
FB Voltage Range	V_{FB}	-0.3 to +6	V
Power Dissipation[2]	P_O	Internally Limited	-
Thermal Resistance Junction to Ambient	$R_{\theta JA}$	105	'C/W
Thermal Resistance Junction to Case	$R_{\theta JC}$	55	'C/W
Storage Temperature Range	T_{STG}	-55 to +150	'C
Junction Temperature	T_J	-40 to +150	'C
Lead Temperature (Soldering, 10s)	T_{LEAD}	260	'C
Human Body Model for all pins	VESD_HBM	±2000	V
Charge Device Model for all pins	VESD_CDM	±200	V

Note [1]: Stresses beyond those listed under"Absolute maximum Ratings" may damage the device.

[2]: The maximum allowable power dissipation is a function of the maximum junction temperature, TJ(MAX), the junction-to-ambient thermal resistance, RθJA, and the ambient temperature, TA. The maximum allowable power dissipation at any ambient temperature is calculated using: PD (MAX) = (TJ(MAX) − TA)/RθJA. Exceeding the maximum allowable power dissipation causes excessive die temperature, and the regulator goes into thermal shutdown. Internal thermal shutdown circuitry protects the device from permanent damage. Thermal shutdown engages at TJ=160°C (typical) and disengages at TJ= 130°C (typical).

Recommended Operating Conditions

Parameter	Symbol	Test Condition	Min	Type	Max	Unit
Input Voltage Range	V_{IN}	-	4.5	-	36	V
Output Current	I_O	-	0	-	2	A
Operating Junction Temperature Range [3]	T_J	-	-40	-	+125	'C
Operating Temperature Range	T_a	-	-40	-	+85	'C

Note [3]: All limits specified at room temperature (TA = 25°C) unless otherwise specified. All room temperature limits are 100% production tested. All limits at temperature extremes are ensured through correlation using standard Statistical Quality Control (SQC) methods. All limits are used to calculate Average Outgoing Quality Level (AOQL).

500K, 36V, 2A Synchronous Step-Down Converter

Electrical Characteristics [3][4]

(VIN=12V, all typical values are measured at TA=+25'C, unless otherwise noted.)

Parameter	Symbol	Test Condition	Min	Type	Max	Unit
Input Voltage Range	V_{IN}		4.5	-	36	V
Non-Switching Quiescent Current	I_Q	V_{EN}=3V	-	0.6	0.8	mA
Shutdown Supply Current	I_{SD}	V_{EN}=0 or EN=GND	-	-	4	uA
EN Terminal Input Threshold	V_{EN-H}	V_{EN} Rising	1.1	-	-	V
	V_{EN-L}	V_{EN} falling	-	-	0.9	
EN Terminal Leakage Current	I_{EN-H}	V_{EN} =1.1V	-	1.45	-	uA
	I_{EN-L}	V_{EN} =0.9V	-	0.4	-	
Feedback						
Feedback Reference Voltage	V_{FB}	HCR3238A (A:V_{FB}=0.6V)	0.585	0.60	0.615	V
		HCR3238B (B:V_{FB}=0.8V)	0.78	0.80	0.82	V
		HCR3238C (C:V_{FB}=0.765V)	0.746	0.765	0.784	V
Power Stage						
High-Side Switch On Resistance	$R_{DS(ON)\_H}$	I_{SW}=100mA	-	100	-	mΩ
Low-Side Switch On Resistance	$R_{DS(ON)\_L}$	I_{SW}= -100mA	-	50	-	mΩ
Current Limit						
Valley Switch Current Limit	I_{LIM}	-	3.0	-	-	A
Input Under-Voltage Lockout						
Over Voltage Protection Threshold	V_{OVP}		-	38.5	-	V
UVLO Threshold Voltage	V_{UVLO}	Wake up V_{IN} Voltage	-	3.8	4.1	V
		Shutdown V_{IN} Voltage	3.2	3.5	-	
UVLO Hysteresis	V_{UVLO_HYS}	Hysteresis V_{IN} Voltage	-	300	-	mV
Frequency						
Switching Frequency	f_{SW}	-	-	500	-	KHz
Timing Requirements						
Soft-Start Time	T_{ss}		-	1.2	-	ms
Maximum Duty Cycle	-	V_{FB}=90%	-	92	-	%
Minimum Off-Time	toff		-	120	-	nS
Over-Temperature Protection						
Thermal Shutdown	T_{SHDN}	Rising temperature	-	160	-	'C
Thermal Shutdown Hysteresis	T_{HYS}	-	-	30	-	'C

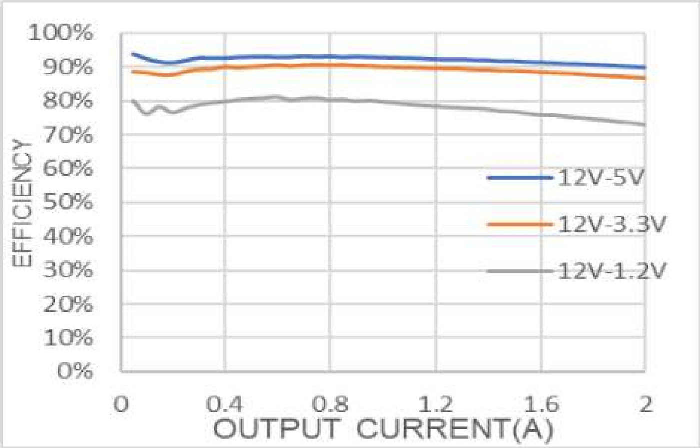
Note [3]. MOSFET on-resistance specifications are guaranteed by correlation to wafer level measurements.

[4]. Thermal shutdown specifications are guaranteed by correlation to the design and characteristics analysis.

Typical Performance Characteristics

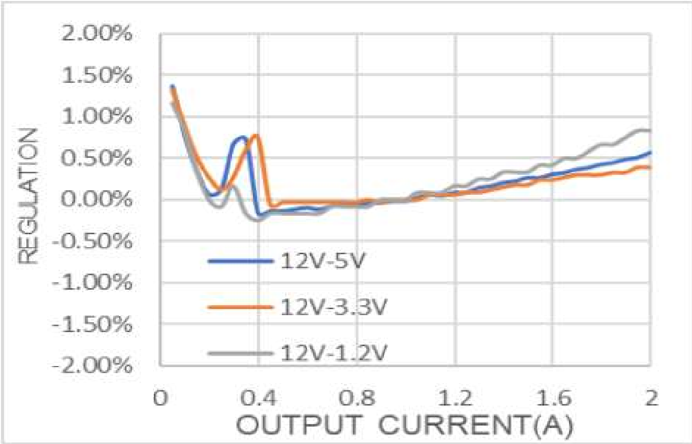
(VIN =12V, VOUT=3.3V, TA = +25ºC, 1MHz frequency version, unless otherwise noted.)

V_{OUT}=5V, 3.3V, 1.2V



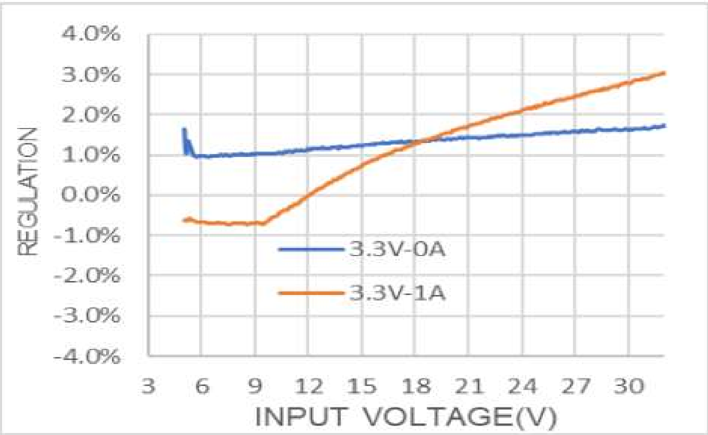
Efficiency vs Load Current

V_{OUT}=5V, 3.3V, 1.2V



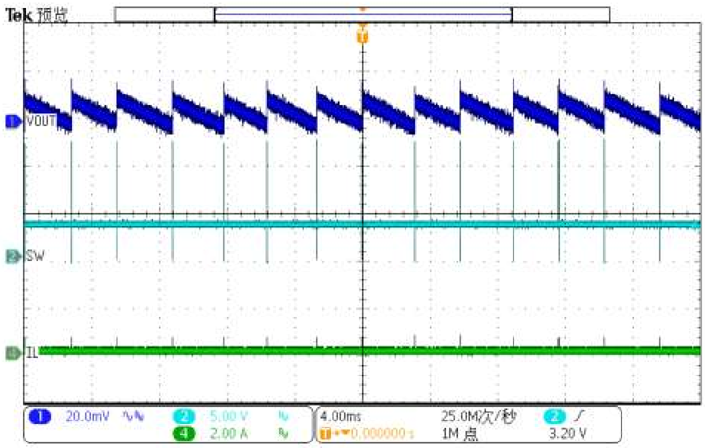
Load Regulation

V_{OUT}=3.3V



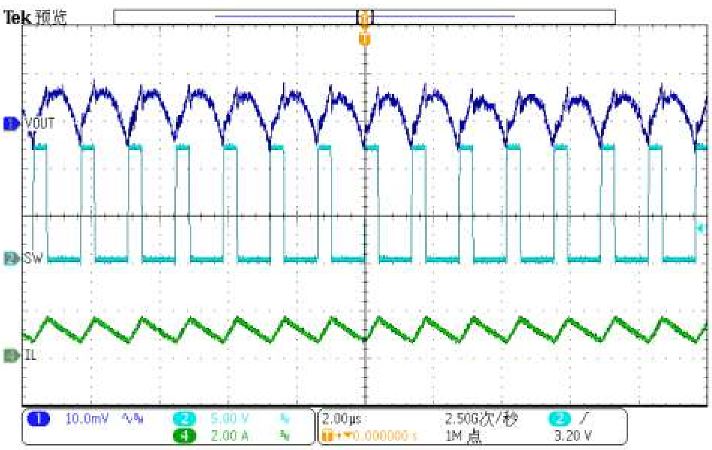
Line Regulation

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



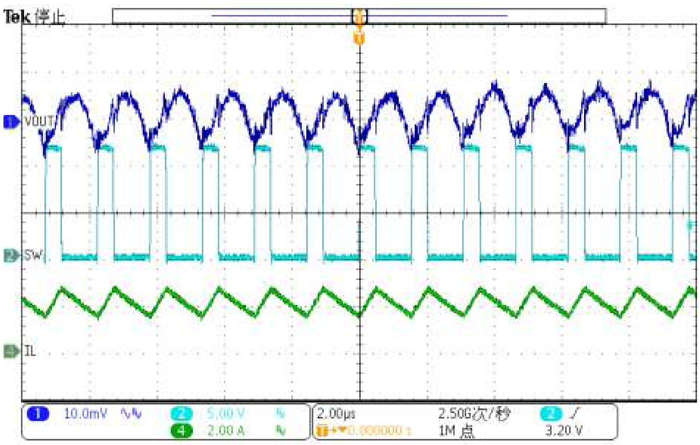
Output Ripple Voltage

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



Output Ripple Voltage

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

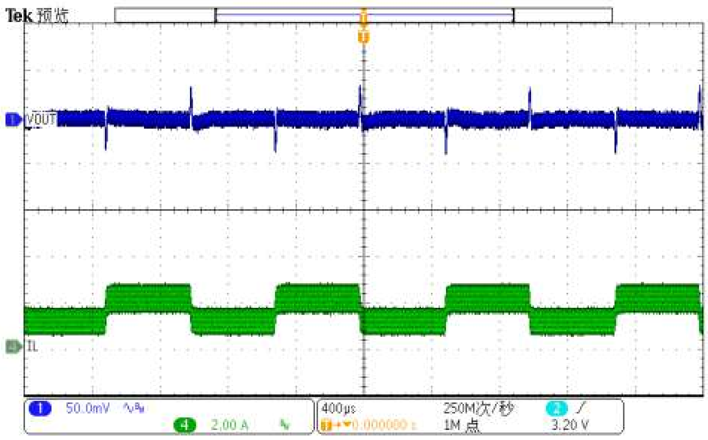


Output Ripple Voltage

Typical Performance Characteristics(Con.)

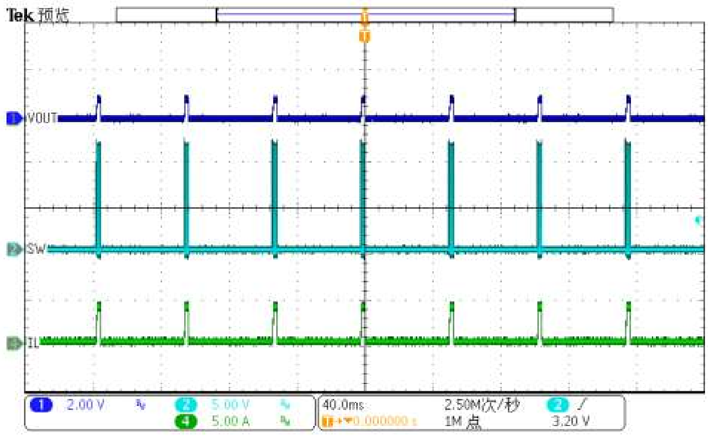
(VIN =12V, VOUT=3.3V, TA = +25ºC, 1MHz frequency version, unless otherwise noted.)

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



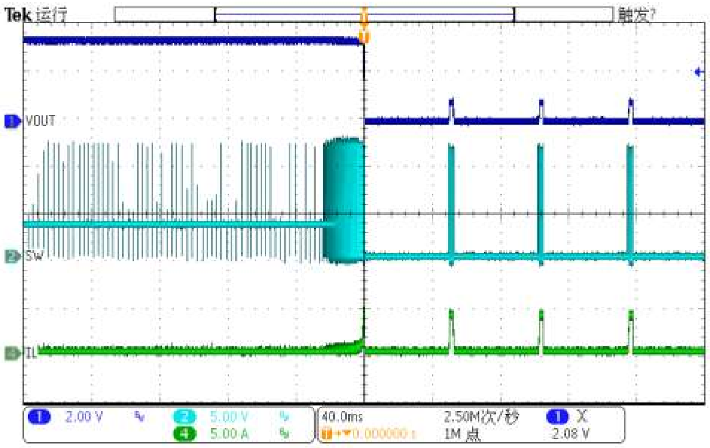
Loop Response

V_{IN}=12V, V_{OUT}=3.3V



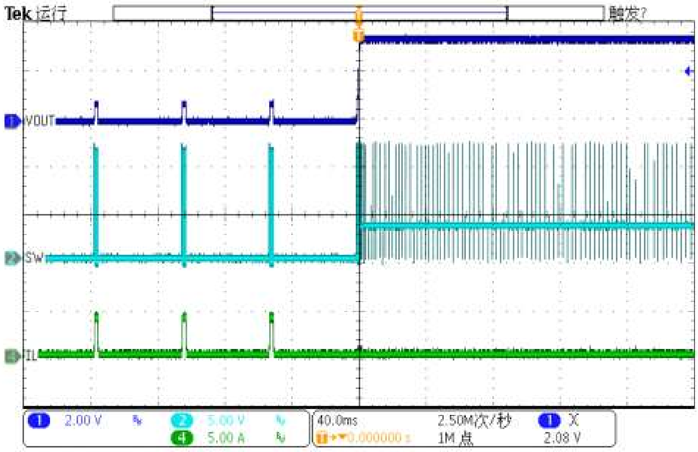
Output Short

V_{IN}=12V, V_{OUT}=3.3V



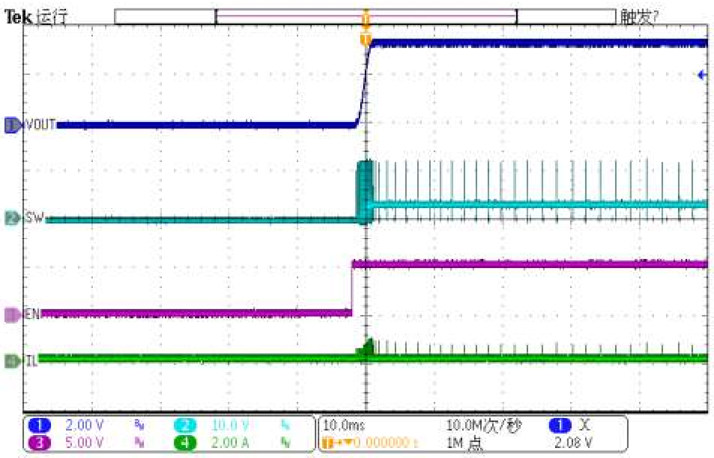
Short Circuit Entry

V_{IN}=12V, V_{OUT}=3.3V



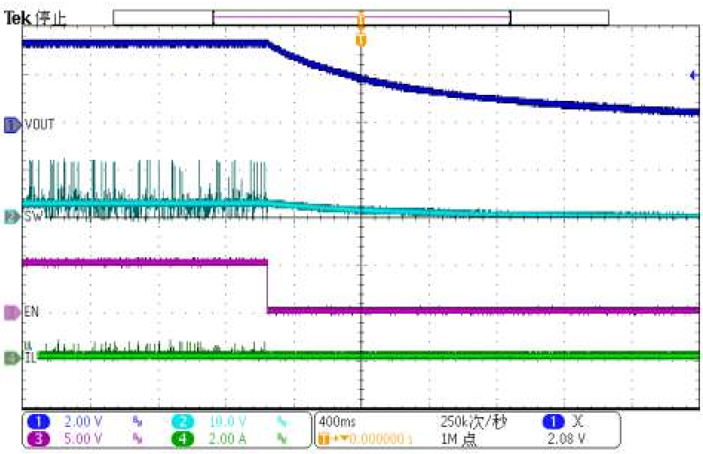
Short Circuit Recovery

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



Enable Startup at No Load

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

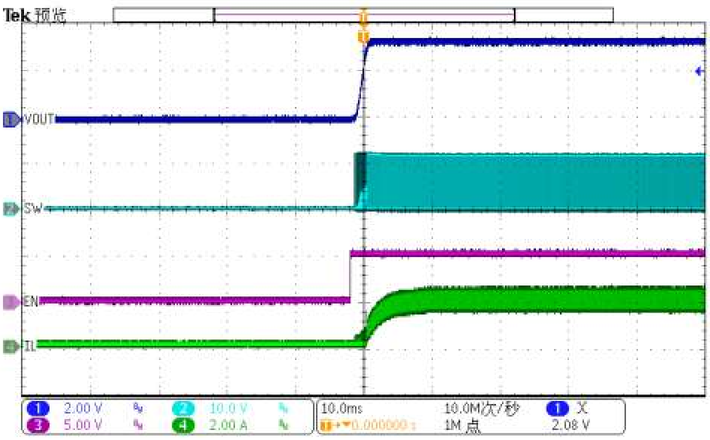


Enable Shutdown at No Load

Typical Performance Characteristics(Con.)

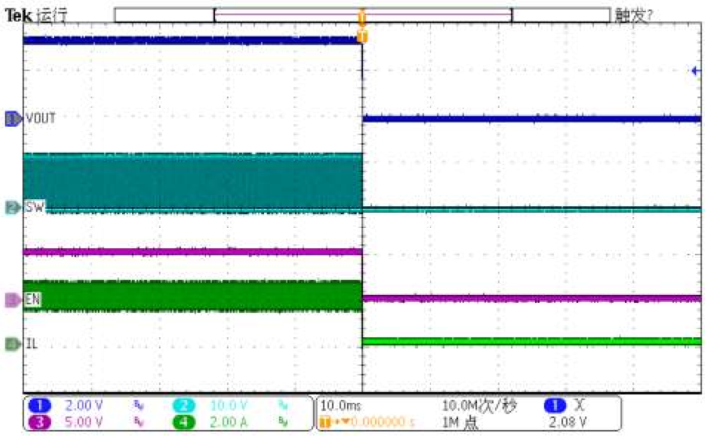
(VIN =12V, VOUT=3.3V, TA = +25ºC, 1MHz frequency version, unless otherwise noted.)

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



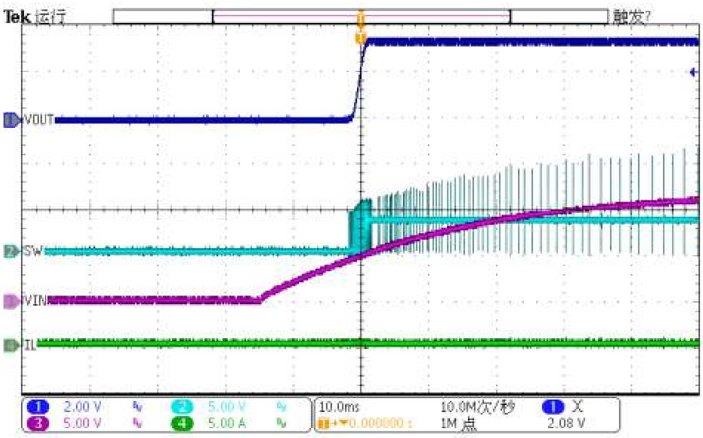
Enable Startup at Full Load

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



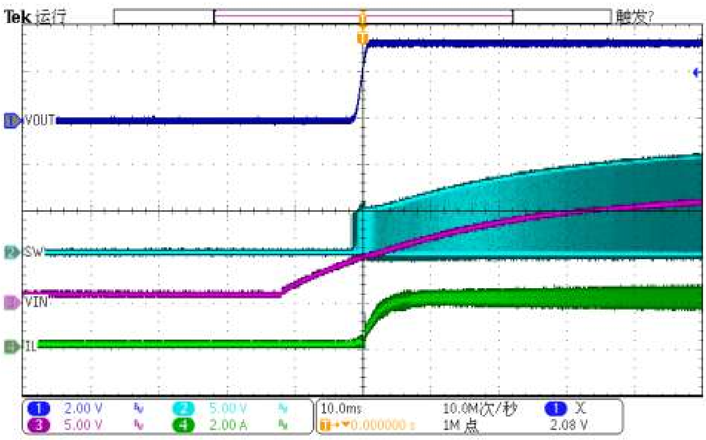
Enable Shutdown at Full Load

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



Power Up at No Load

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



Power Up at Full Load

Functions Description

Internal Regulator

The HCR3238 is an ECOT step down DC/DC converter that provides excellent transient response with no extra external compensation components. This device contains an internal, low resistance, high voltage power MOSFET, and operates at a high operating frequency to ensure a compact, high efficiency design with excellent performance.

Under-Voltage Lockout (UVLO)

Under-voltage lockout (UVLO) protects the chip from operating at an insufficient supply voltage. UVLO protection monitors the internal regulator voltage. When the voltage is lower than UVLO threshold voltage, the device is shut off. When the voltage is higher than UVLO threshold voltage, the device is enabled again.

Thermal Shutdown

Thermal shutdown prevents the chip from operating at exceedingly high temperatures. When the silicon die temperature exceeds 160°C, it shuts down the whole chip. When the temperature falls below its lower threshold (Typ. 130°C) the chip is enabled again.

Internal Soft-Start

The soft-start is implemented to prevent the converter output voltage from overshooting during startup. When the chip starts, the internal circuitry generates a soft-start voltage (SS) ramping up from 0V to VFB. When it is lower than the internal reference (REF), SS overrides REF so the error amplifier uses SS as the reference. When SS is

Internal Soft-Start(Con.)

higher than REF, REF regains control. The SS time is internally max to 1.2ms.

Over Current Protection and Hiccup

The HCR3238 has cycle-by-cycle over current limit when the inductor current valley value exceeds the set current limit threshold. Meanwhile, output voltage starts to drop until FB is below the Under-Voltage (UV) threshold. Once a UV is triggered, the HCR3238 enters hiccup mode to periodically restart the part. This protection mode is especially useful when the output is dead-short to ground. The average short circuit current is greatly reduced to alleviate the thermal issue and to protect the regulator. The HCR3238 exits the hiccup mode once the over current condition is removed.

Startup and Shutdown

If both VIN and EN are higher than their appropriate thresholds, the chip starts. The reference block starts first, generating stable reference voltage and currents, and then the internal regulator is enabled. The regulator provides stable supply for the remaining circuitries. Three events can shut down the chip: EN low, VIN low and thermal shutdown. In the shutdown procedure, the signaling path is first blocked to avoid any fault triggering. The comp voltage and the internal supply rail are then pulled down. The floating driver is not subject to this shutdown command.

Applications Information

Setting the Output Voltage

HCR3238 require an input capacitor, an output capacitor, and an inductor. These components are critical to the performance of the device. The HCR3238 are internally compensated and do not require external components to achieve stable operation. The output voltage can be programmed by resistor divider.

$$V_{OUT} = V_{FB} \times \frac{R1 + R2}{R2}$$

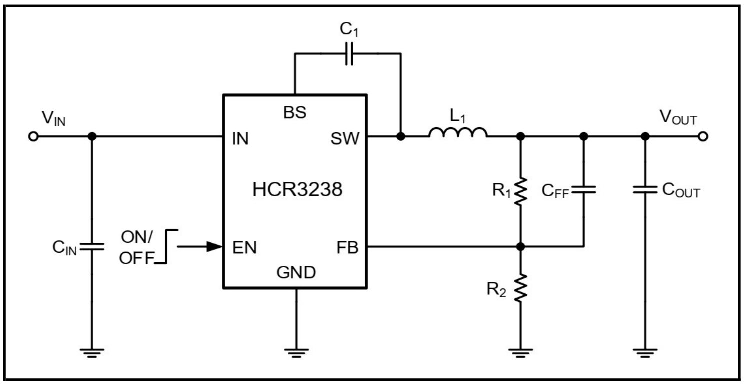


Figure 5. Typical Application Circuit of HCR3238

Applications Information (Con.)

Setting the Output Voltage (Con.)

Example for VFB=0.8V

VOUT(V)	R1(KΩ)	R2(KΩ)	L1(uH)	C1(nF)	CIN(uF)	COUT(uF)	CFF(pF) Opt.
1.0	2.50	10	1.0	100	22	22 x 2	CFF Chapter
1.2	5.00	10	1.5	100	22	22 x 2	CFF Chapter
1.5	8.75	10	2.2	100	22	22 x 2	CFF Chapter
1.8	12.50	10	2.2	100	22	22 x 2	CFF Chapter
2.5	21.25	10	2.2	100	22	22 x 2	CFF Chapter
3.3	31.25	10	3.3	100	22	22 x 2	CFF Chapter
5.0	52.50	10	4.7	100	22	22 x 2	CFF Chapter

All the external components are the suggested values, the final values are based on the application testing results.

Selecting the Inductor

The recommended inductor values are shown in the Application Diagram. It is important to guarantee the inductor core does not saturate during any foreseeable operational situation. The inductor should be rated to handle the maximum inductor peak current: Care should be taken when reviewing the different saturation current ratings that are specified by different manufacturers. Saturation current ratings are typically specified at 25°C, so ratings at maximum ambient temperature of the application should be requested from the manufacturer.

The inductor value can be calculated with:

$$L = \frac{V_{OUT} \times (V_{IN} - V_{OUT})}{V_{IN} \times \Delta I_L \times F_{OSC}}$$

Where ΔIL is the inductor ripple current. Choose inductor ripple current to be approximately 30% to 40% of the maximum load current. The maximum inductor peak current can be estimated as:

$$I_{L(MAX)} = I_{LOAD} + \frac{\Delta I_L}{2}$$

Under light load conditions below 100mA, larger inductance is recommended for improved efficiency. Larger inductances lead to smaller ripple currents and voltages, but they also have larger physical dimensions, lower saturation currents and higher linear impedance. Therefore, the choice of inductance should be compromised according to the specific application.

Selecting the Input Capacitor

The input current to the step-down converter is discontinuous and therefore requires a capacitor to supply AC current to the step-down converter while maintaining the DC input voltage. For a better performance, use ceramic capacitors placed as close to VIN as possible and a 0.1μF input capacitor to filter out high frequency interference is recommended. Capacitors with X5R and X7R ceramic dielectrics are recommended because they are stable with temperature fluctuations.

The capacitors must also have a ripple current rating greater than the maximum input ripple current of the converter. The input ripple current can be estimated with Equation:

$$I_{CIN} = I_{OUT} \times \sqrt{\frac{V_{OUT}}{V_{IN}} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)}$$

From the above equation, it can be concluded that the input ripple current reaches its maximum at VIN=2VOUT where $I_{CIN} = \frac{I_{OUT}}{2}$.

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

The input capacitance value determines the input voltage ripple of the converter. If there is an input voltage ripple requirement in the system, choose the input capacitor that meets the specification. The input voltage ripple can be

Applications Information (Con.)

Selecting the Input Capacitor

estimate with Equation:

$$\Delta V_{IN} = \frac{I_{OUT}}{F_{OSC} \times C_{IN}} \times \frac{V_{OUT}}{V_{IN}} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

Similarly, when VIN=2VOUT, input voltage ripple reaches its maximum of

$$\Delta V_{IN} = \frac{1}{4} \times \frac{I_{OUT}}{F_{OSC} \times C_{IN}}.$$

Selecting the Output Capacitor

An output capacitor is required to maintain the DC output voltage. The output voltage ripple can be estimated with Equation:

$$\Delta V_{OUT} = \frac{V_{OUT}}{F_{OSC} \times L} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \times \left(R_{ESR} + \frac{1}{8 \times F_{OSC} \times C_{OUT}}\right)$$

There are some differences between different types of capacitors. In the case of ceramic capacitors, the impedance at the switching frequency is dominated by the capacitance. The output voltage ripple is mainly caused by the capacitance. For simplification, the output voltage ripple can be estimated with Equation:

$$\Delta V_{OUT} = \frac{V_{OUT}}{8 \times {F_{OSC}}^2 \times L \times C_{OUT}} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

A larger output capacitor can achieve a better load transient response, but the maximum output capacitor limitation should also be considered in the design application. If the output capacitor value is too high, the output voltage will not be able to reach the design value during the soft-start time and will fail to regulate. The maximum output capacitor value (COUT_MAX) can be limited approximately with Equation:

$$C_{OUT\_MAX} = \left(I_{LIM\_AVG} - I_{OUT}\right) \times T_{SS}/V_{OUT}$$

Where LLIM_AVG is the average start-up current during the soft-start period, and TSS is the soft- start time.

On the other hand, special attention should be paid when selecting these components. The DC bias of these capacitors can result in a capacitance value that falls below the minimum value given in the recommended capacitor specifications table.

The ceramic capacitor's actual capacitance can vary with temperature. The capacitor type X7R, which operates over a temperature range of −55°C to +125°C, will only vary the capacitance to within ±15%. The capacitor type X5R has a similar tolerance over a reduced temperature range of −55°C to +85°C. Many large value ceramic capacitors, larger than 1uF are manufactured with Z5U or Y5V temperature characteristics. Their capacitance can drop by more than 50% as the temperature varies from 25°C to 85°C. Therefore, X5R or X7R is recommended over Z5U and Y5V in applications where the ambient temperature will change significantly above or below 25°C.

Feed-Forward Capacitor (CFF)

HCR3238 has internal loop compensation, so adding CFF is optional. Specifically, for specific applications, if necessary, consider whether to add feed-forward capacitors according to the situation.

The use of a feed-forward capacitor (CFF) in the feedback network is to improve the transient response or higher phase margin. For optimizing the feed-forward capacitor, knowing the cross frequency is the first thing. The cross frequency (or the converter bandwidth) can be determined by using a network analyzer. When getting the cross frequency with no feed-forward capacitor identified, the value of feed-forward capacitor (CFF) can be calculated with the following equation:

$$C_{FF} = \frac{1}{2\pi \times F_{CROSS}} \times \sqrt{\frac{1}{R1} \times \left(\frac{1}{R1} + \frac{1}{R2}\right)}$$

Where FCROSS is the cross frequency.

To reduce transient ripple, the feed-forward capacitor value can be increased to push the cross frequency to higher region. Although this can improve transient response, it also decreases phase margin and cause more ringing. In the other hand, if more phase margin is desired, the feed-forward capacitor value can be decreased to push the cross frequency to lower region.

Applications Information (Con.)

PC Board Layout Consideration

PCB layout is very important to achieve stable operation. It is highly recommended to duplicate EVB layout for optimum performance. If change is necessary, please follow these guidelines for reference.

1). Keep the path of switching current short and minimize the loop area formed by Input capacitor, high-side MOSFET and low-side MOSFET.

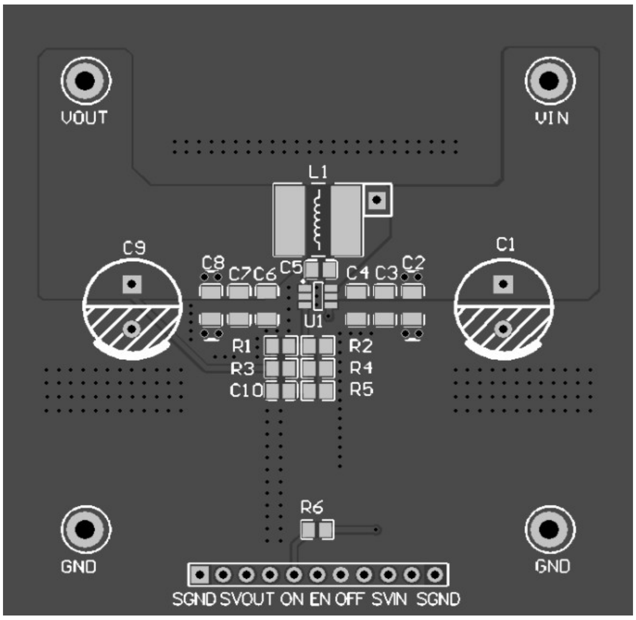
2). Bypass ceramic capacitors are suggested to be put close to the VIN Pin.

3). Ensure all feedback connections are short and direct. Place the feedback resistors and compensation components as close to the chip as possible.

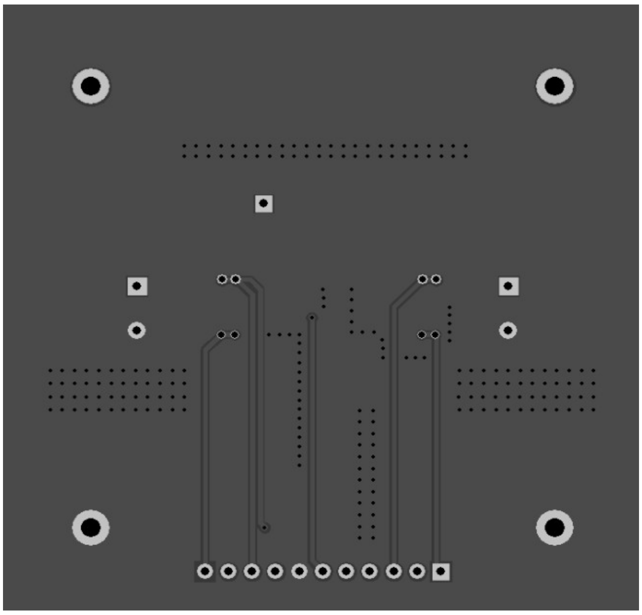
4). VOUT, SW away from sensitive analog areas such as FB.

5). Connect IN, SW, and especially GND respectively to a large copper area to cool the chip to improve thermal performance and long-term reliability.

Top Layer



Bottom Layer



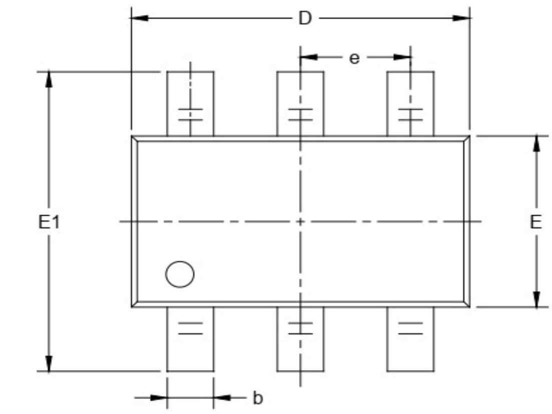
Sample Board Layout

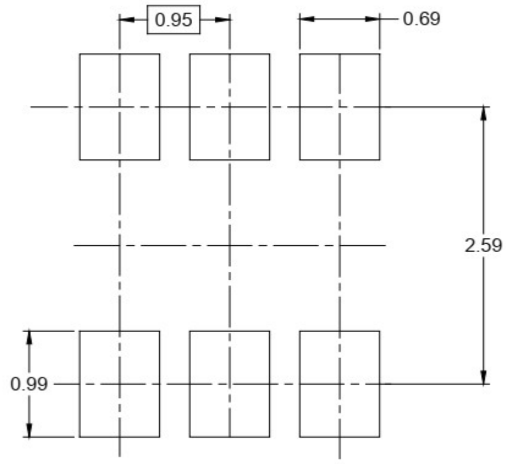
500K, 36V, 2A Synchronous Step-Down Converter

Mechanical Dimensions

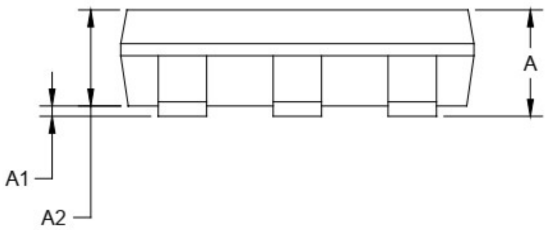
M6L PKG: TSOP-6 (SOT23-6L)

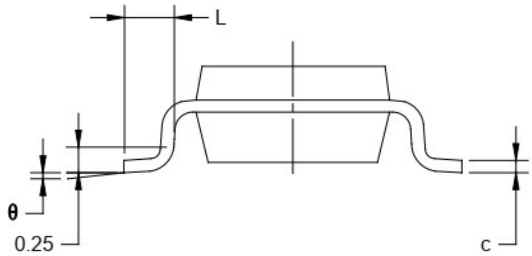
Unit: mm





RECOMMENDED LAND PATTERN





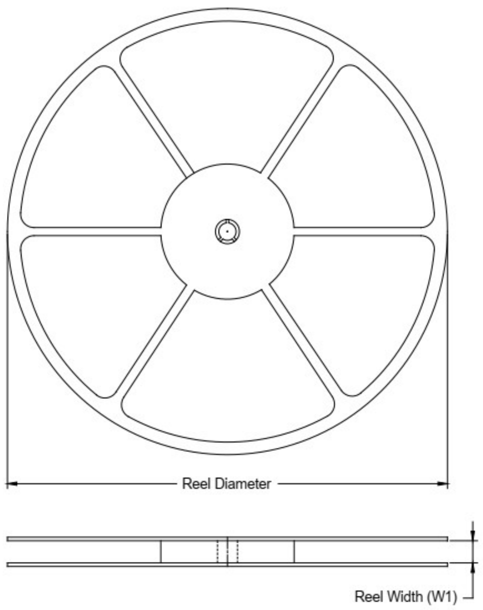
Symbol	Dimensions In Millimeters		
	MIN	MOD	MAX
A	-	-	1.100
A1	0.000	-	0.100
A2	0.700	-	1.000
b	0.300	-	0.500
c	0.080	-	0.200
D	2.820	-	3.050
E	1.550	-	1.700
E1	2.650	-	2.950
e	0.950 BSC		
L	0.300	-	0.600
θ	0°	-	8°

NOTES:

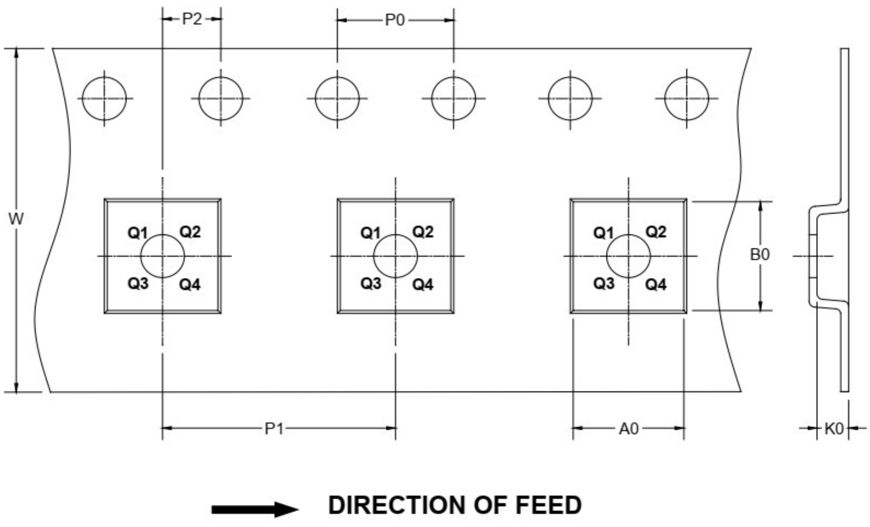
1. Body dimensions do not include mode flash or protrusion.
2. This drawing is subject to change without notice.

Tape and Reel Information

REEL DIMENSIONS



TAPE DIMENSIONS



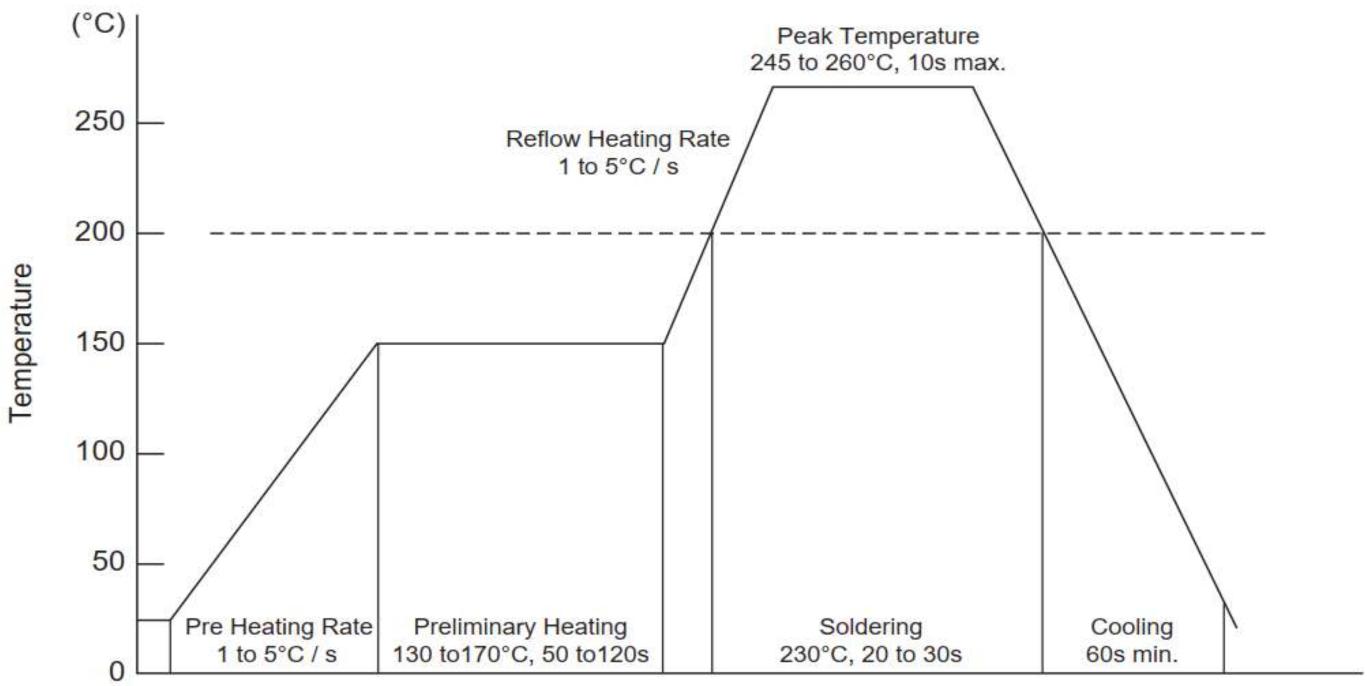
NOTE: The picture is only for reference. Please make the object as the standard.

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

Conditins of Soldering and Storage

* Recommended condition of reflow soldering



Recommended peak temperature is over 245'C, if peak temperature is below 245'C, you may adjust the following parameters:

* Time length of peak temperature (longer)
* Time length of soldering (longer)
* Thickness of solder paste (thicker)

* Conditions of hand soldering
  * Temperature : 300'C
  * Time : 3s max
  * Times : one time

* Storage conditions
  * Temperature
    5 to 40'C
  * Humidity
    30 to 80% RH
  * Recommended period
    One year after manufacturing