ELM614MB 18V 720kHz 2A Fast-PWM synchronous step-down converter

■General description

ELM614MB is a fully integrated high efficiency synchronous step-down converter which requires minimum number of external components. It offers very compact solution with up to 2A continuous output current over a wide input range.

ELM614MB employs prorietary Constant On-Time (COT) control scheme providing superior transient response and maintaining conatant switching frequency under the continuous conduction mode operation. The external ramp compensation network allows stable operation with ultra-low equivalent series resistance (ESR) output ceramic capacitors. An internal compensated error amplifier in the control loop provides excellent line and load regulation.

ELM614MB integrates extensive protection functions include: NVLO, OCP, UVP and therrnal shutdown. The converter is available in a small 6 pin SOT-563.

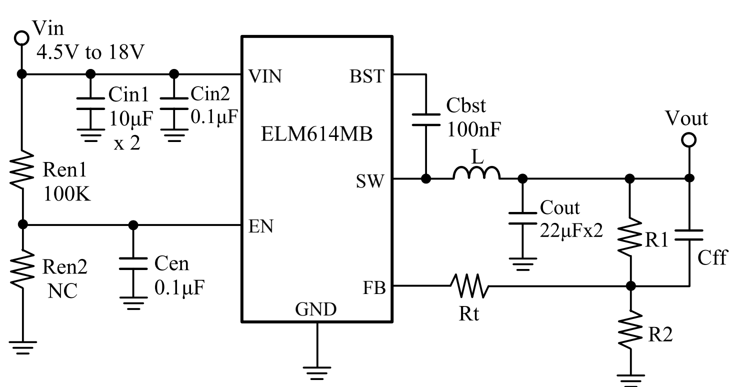
■Features

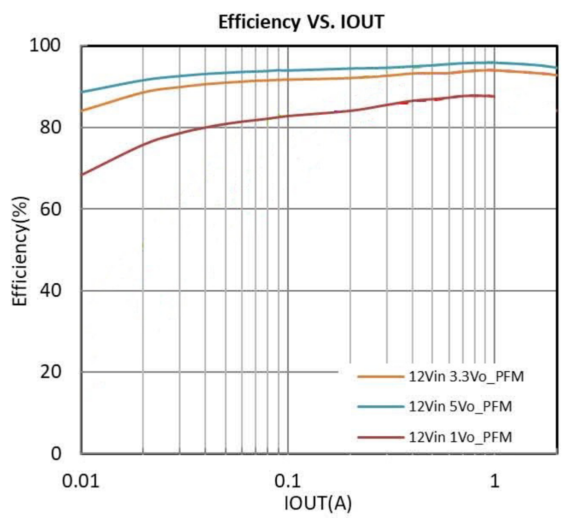
- Stable operation with low ESR ceramic output capacitors
- Fast PWM COT control with superior transient performance and stable switching frequency
- Accurate EN UVLO threshold
- High Efficiency Operation at light load
- Thermal Shutdown with Auto recovery
- Hiccup mode short circuit protection
- Input voltage range : 4.5V to 18V
- Output voltage range : 0.804V to 18V
- Continuous output current : 2A
- Duty cycle low dropout operation : 100%
- Switching frequency : 720kHz
- Internal soft start : 1.6ms
- Integrated HS/LS power switches : 60mΩ/37mΩ
- Package : SOT-563

■Application

- Laptop computer
- Tablet PC
- Networking systems
- Personal video recorders
- Flat panel television and monitors
- Distributed power systems

■Standard circuit





■Selection guide

ELM614MB-S

Symbol		
a	Part No.	ELM614
b	Package	M: SOT-563
c	Product version	B
d	Taping direction	S: Please refer to page 15

* Taping direction is one way.

ELM614 M B - S
↑ ↑ ↑ ↑
a b c d

■Maximum absolute ratings (Reference to GND) (1)

Parameter	Symbol	Limit	Unit
Supply voltage	V_{IN}	+19	V
EN voltage	V_{EN}	+19	V
SW voltage	V_{SW}	-0.3 to V_{IN} +0.3	V
Dynamic V_{SW} in 10ns duration	V_{DSW}	-3 to V_{IN} +3	V
BS-SW voltage	V_{BS-SW}	+6	V
FB voltage	V_{FB}	+6	V
Junction temperature range	T_J	-40 to +150	°C
Storage temperature range	T_{STG}	-65 to +150	°C
Lead temperature (Soldering 10s)		+260	°C

■Recommend operating conditions (2)

Parameter	Symbol	Limit	Unit
Input voltage	V_{IN}	+4.5 to +18.0	V
Operating temperature range	T_{OP}	-40 to +85	°C
Junction temperature range	T_J	-40 to +125	°C

■Thermal information (Maximum power dissipation (T_A=+25°C) (3)(4)

Parameter	Symbol	Limit	Unit
Power dissipation (SOT-563)	P_D	1.5	W
Thermal resistance	θ_{JA}	83	°C/W
	θ_{JC}	31	

Note:
(1) Stress exceeding those listed “Maximum absolute ratings” may damage the device.
(2) The device is not guaranteed to function outside of the recommended operating conditions.
(3) Measured on JESD51-7, 4-Layer PCB.
(4) The maximum allowable power dissipation is a function of the maximum junction temperature T_{J_MAX}, the junction to ambient thermal resistance θ_{JA}, and the ambient temperature T_A. The maximum allowable continuous power dissipation at any ambient temperature is calculated by $P_{D\_MAX}= (T_{J\_MAX}-T_A)/\theta_{JA}$. Exceeding the maximum allowable power dissipation will cause excessive die temperature, and the regulator will go into thermal shutdown. Internal thermal shutdown circuitry protects the device from permanent damage.

■Block diagram

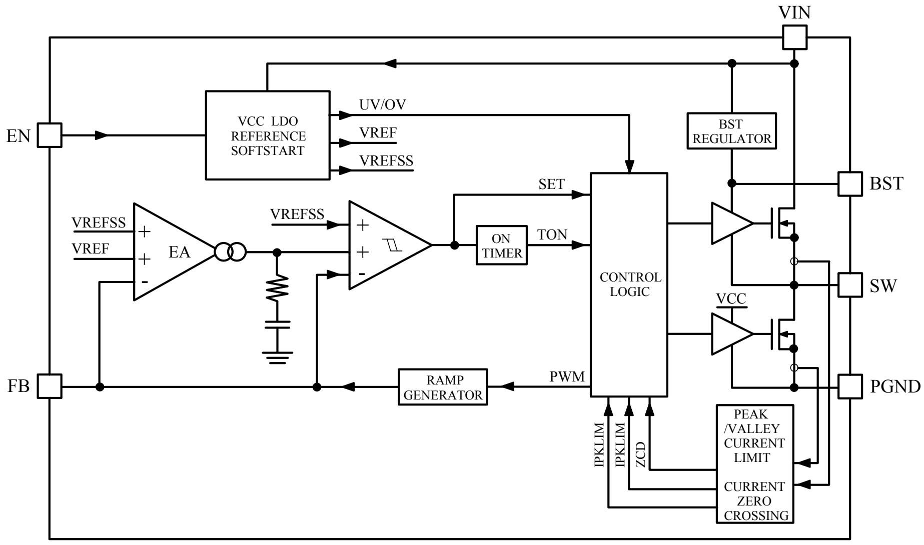
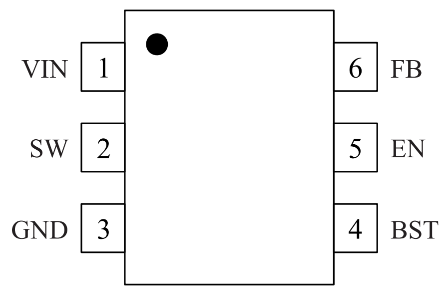


Figure 1-Functional Block Diagram

■Pin configuration

SOT-563(TOP VIEW)



Pin name	Pin No.	Pin description
VIN	1	Supply voltage. The VIN pin supplies power for internal MOSFET and regulator. ELM614MB operates from a 4.5V to 18V input rail. An input capacitor is needed to decouple the input rail.
SW	2	Switch output. Connect this pin to the inductor and bootstrap capacitor. SW node should be kept small on the PCB for good performance and low EMI.
GND	3	Power ground.
BST	4	Bootstrap. A 100nF ceramic capacitor connected between SW and BST pins is required to form a floating supply for the high-side switch driver.
EN	5	Enable pin. ELM614MB is shut down when this pin is low and active when this pin is high. The hysteretic enable threshold voltage is 1.21V going up and 1.11V going down. Connect EN with VIN through a pull-up resistor or a resistive voltage divider for automatic startup. An external resistor divider from VIN can be used to program a VIN threshold below to stop WLM614MB operation. There is an internal 1000kΩ (typical) pull down resistor from EN to AGND.
BF	6	Feedback. An external resistor divider from the output to GND, tapped to the FB pin, sets the output voltage.

■Electrical characteristics

T_A=+25°C, V_{IN}=12V, V_{EN}=5V, unless otherwise noted. Typical values are at V_{IN}=12V, V_{EN}=5V, V_{OUT}=5V.

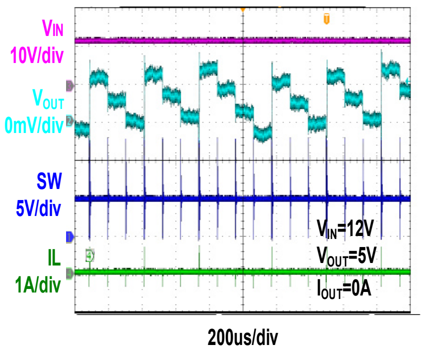
Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Input voltage range	V_{IN}		4.5	-	18.0	V
Shutdown current	I_S	V_{EN}=0V, V_{IN}=12V	-	5	-	μA
Input under voltage lockout threshold	V_{UVLO}	V_{IN} decreasing	3.8	4.0	4.2	V
Input under voltage lockout hysteresis	V_{UVLO_HYS}		-	300	-	mV
Supply current (Quiescent)	I_{IN}	V_{FB}=0.9V	-	250	300	μA
Feedback regulation voltage	V_{FBREF}		790	804	818	mV
Feedback current	I_{FB}	V_{FB}=0.804V	-	10	50	nA
Internal soft-start time Note(5)	T_{SS}		-	1.6	-	msec
Switching frequency	F_{SW}	I_{OUT}=1A	-	720	-	kHz
Minimum off time Note(5)	T_{OFF_MIN}		-	140	-	ns
Maximum duty cycle Note(6)	D_{MAX}		-	100	-	%
HS main switch-on resistance	RON_{HS}		-	60	-	mΩ
HS switch leakage current	HS_SW_{LKG}	V_{IN}=18V, V_{EN}=V_{SW}=0V	-	0.1	10.0	μA
PK Current limit	I_{LIMIT}		3.8	4.5	5.2	A
LS switch zero-cross current	I_{ZX}		-	0	-	mA
LS switch-on resistance	RON_{LS}		-	37	-	mΩ
LS switch leakage current	LS_SW_{LKG}	V_{IN}=V_{SW}=18V, V_{EN}=0V	-	0.1	10.0	μA
EN on threshold	VIH	V_{EN} ramp up	-	1.21	-	V
EN off threshold	VIL	V_{EN} ramp down	-	1.11	-	V
EN internal pull-down resistor			-	1000	-	KΩ
Thermal shutdown Note(5)	T_{SD}		-	160	-	°C
Thermal shutdown hysteresis Note(5)			-	30	-	°C

Note:
(5) Guaranteed by design, no production test.
(6) When the input voltage approaches the output voltage, ELM614MB will extend the on-time and force the main high side switch remaining on for multiple cycles (>10 μsec). High side switch is only turned off momentarily, and low side switch is forced on shortly (typical 140ns) to refresh the BST capacitor. High side switch will resume on after the BST refresh.

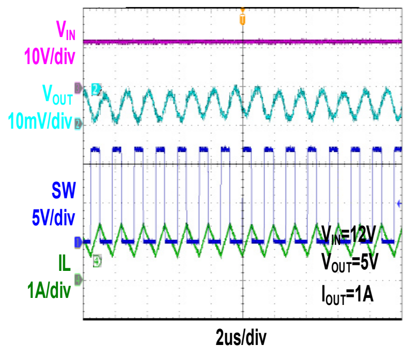
■Typical characteristics

• V_{IN}=1.2V, V_{OUT}=1V(L=1.5μH), 3.3V(L=3.3μH), 5V(L=4.7μH), T_J=+25°C, unless otherwise noted.

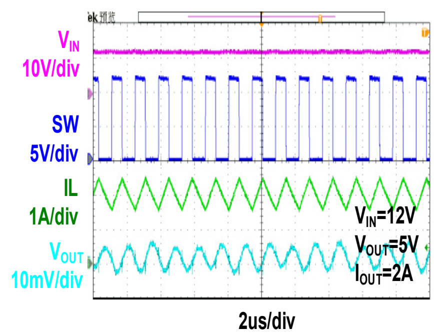
Steady State Test



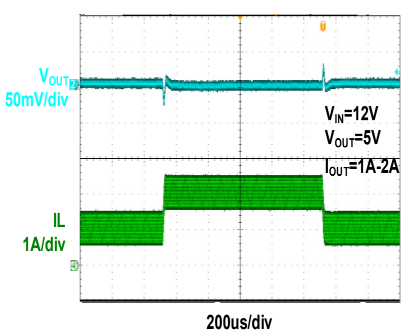
Steady State Test



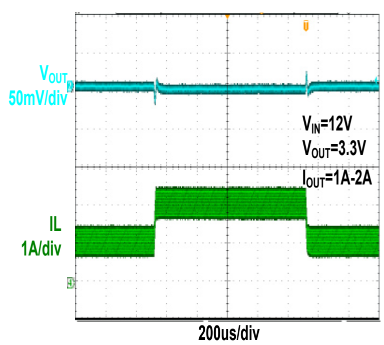
Steady State Test



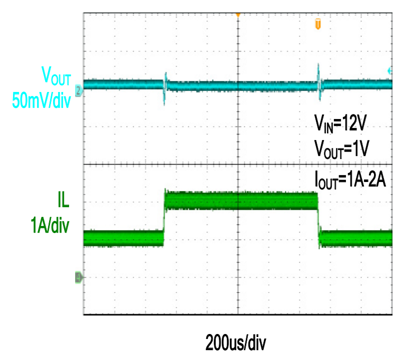
Load Transient Response



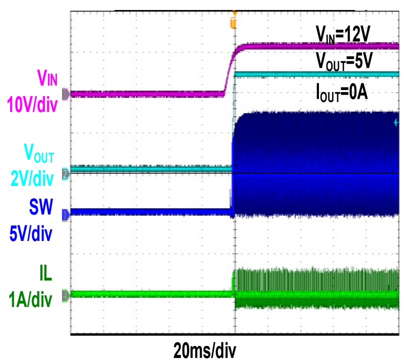
Load Transient Response



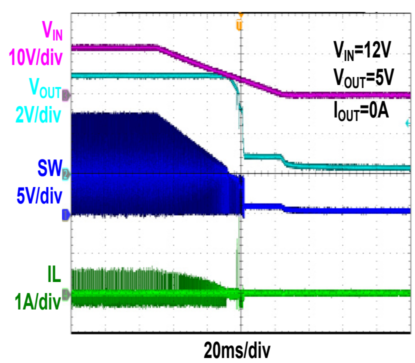
Load Transient Response



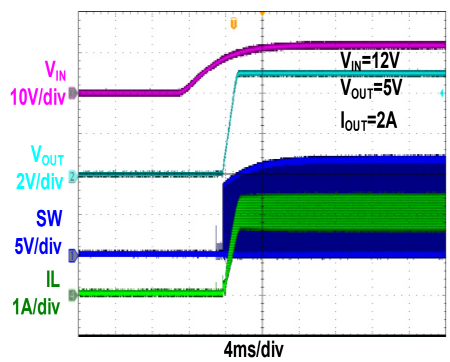
VIN power on



VIN power off



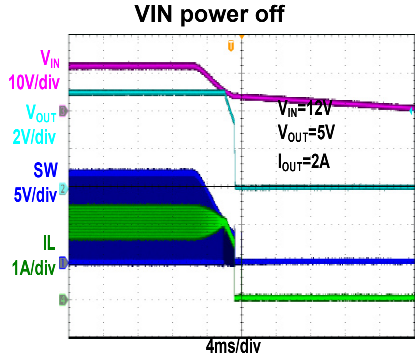
VIN power on



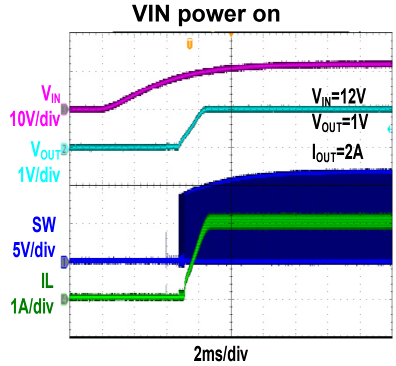
* Performance waveforms are tested on the evaluation board of the design example section.

- V_{IN}=1.2V, V_{OUT}=1V(L=1.5μH), 3.3V(L=3.3μH), 5V(L=4.7μH), T_J=+25°C, unless otherwise noted.

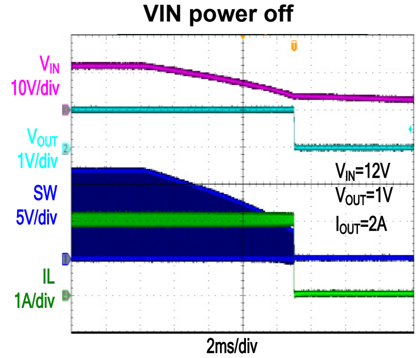
VIN power off



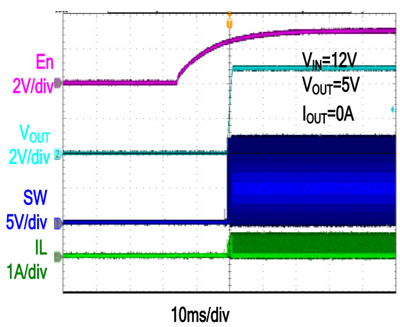
VIN power on



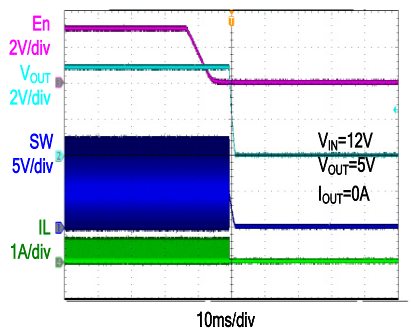
VIN power off



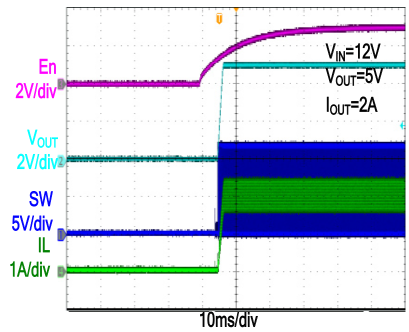
EN power on



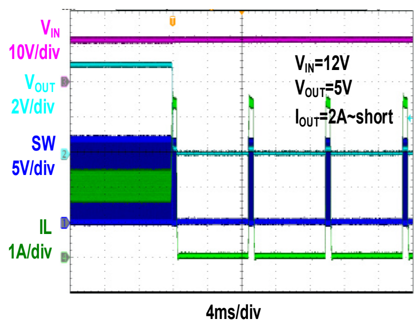
EN power off



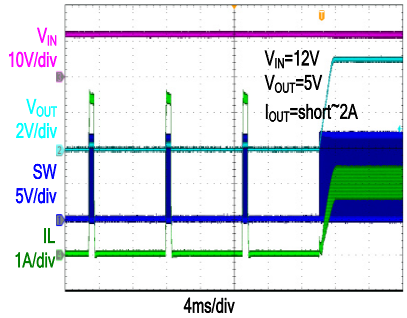
EN power on



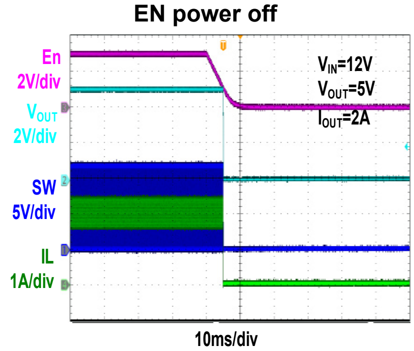
Short Circuit Protection



Short Circuit Protection Recovery



EN power off



* Performance waveforms are tested on the evaluation board of the design example section.

■Operation

ELM614MB is a fully integrated synchronous step-down converter employing constant on-time (COT) control scheme to achieve superior transient performance. With adjustable external ramp compensation, it can achieve stable operation with lower ESR ceramic output capacitors and excellent transient response.

Constant On-Time Control

The constant on-time control (COT) operates by comparing the feedback voltage V_{FB} with the reference voltage (V_{FBREG}). When FB drops below the reference, the control circuit turns on HS switch immediately for a pre-determined period of time (on-time) to ramp up the inductor current. When this on-time times out, the LS switch is then turned on to ramp down the inductor current. The LS switch is turned off when inductor current reaches zero I_{ZX} (or triggers negative current limit I_{NEG} ELM614MB) or HS switch is turned on again for the next cycle. This operation repeats itself if FB drops below reference again.

ELM614MB uses a proprietary algorithm to calculate the on-time based on input voltage, output voltage and load current to achieve nearly constant switching frequency over entire continuous conduction load current range. The on-time can be estimated as:

$$T_{ON} = \frac{V_{OUT}}{V_{IN}} \times \frac{1}{F_{SW}}$$

Due to its immediate response on FB voltage droop and simplified loop compensation, ELM614MB offers superior transient response compare to traditional fixed frequency PWM control converters.

Light Load Operation

In medium and heavy load condition, ELM614MB operates in PWM mode with typical switching frequency of 720kHz. When load current reduces, ELM614MB naturally transitions from PWM mode to PFM mode where the pulse width remains the calculated on-time but the switching frequency reduces to accommodate the low output current. The lower the output current, the lower the switching frequency. Once the switching frequency drops to low enough, the devices enter sleep mode to cut down its quiescent current to maintain high efficiency in light load.

The critical load current at the boundary of PWM mode and PFM mode is related to the inductor ripple current, which depends on the inductor value, input voltage and output voltage. Typically this critical load current level is estimated as:

$$I_{CRIT} = \frac{1}{2} \times \frac{(V_{IN} - V_{OUT}) \times V_{OUT}}{L \times F_{SW} \times V_{OUT}}$$

100% Duty Cycle Low Dropout Operation

When input voltage approaches the output voltage, ELM614MB will extend the on-time toward the maximum on-time to satisfy the duty cycle requirement to regulate the output voltage. If the input further drops to equal or lower than the output level, ELM614MB forces the main high side (HS) switch to remain on for more than one cycle, eventually reaching 100% duty cycle. The 100% duty cycle operation allows the converter to effectively pass through the input voltage directly to output with minimum voltage drops on the HS switch and the inductor. In the low dropout operation mode, ELM614MB turns on HS switch for multiple switching cycles until it turns off HS switch momentarily and turns on low side (LS) switch (typical 140ns) to refresh the BST supply voltage. The LS switch is turned off after the BST refresh pulse, then the HS switch resumes on for multiple switching cycles which gives the effective 100% duty cycle. The refresh BST pulse is needed to charge the BST capacitor and ensure the HS switch driver circuits proper operation.

Enable

ELM614MB offers an accurate enable threshold of EN pin, which is typically 1.21V rise and 1.11V fall. ELM614MB is enabled by pulling up the EN pin above 1.21V and ELM614MB is disabled by pulling down the EN pin above below 1.11V.

When using the EN pin threshold voltage to program the input startup voltage level, the following equation shall be used:

$$V_{IN\_START} = 1.21V \times \frac{R_{UP} + R_{DOWN} \,//\, 1M\Omega}{R_{DOWN} \,//\, 1M\Omega}$$

Where the 1MΩ is the internal pull-down resistor on EN pin.

When EN is pulled high, ELM614MB will start up if V_{IN} is higher than UVLO threshold. When EN is pulled low, ELM614MB will go into shutdown. Tie EN pin to V_{IN} if the shutdown feature is not used.

Soft Start

ELM614MB has built-in internal soft start of 1.6 msec. During the soft start period, output voltage is ramped up linearly to the regulation level, independent of the load current and output capacitor value.

Current Limit and Hiccup Mode

ELM614MB has built-in cycle-by-cycle current limit protection to prevent inductor current from running away in any fault conditions. ELM614MB continuously monitors the inductor valley current during its operation. Once the valley current exceeds the limit level, ELM614MB will turn on LS and wait for the inductor current to drop down to a pre-determined level before the HS can be turned on again. If this current limit condition is repeated for a sustained long period of time, ELM614MB will enter hiccup mode, where it stop switching for a pre-determined period of time before automatically re-try to start up again. It always starts up with soft-start to limit inrush current and avoid output overshoot.

When ELM614MB enters valley current limit mode, the peak current is also limit due to the fixed on-time of the HS, and this peak current can be estimated as:

$$I_{PEAK} = I_{VALLEY} + T_{ON} \times \frac{V_{IN} - V_{OUT}}{L}$$

■Application information

Setting the Output Voltage

The external feedback resistors divider sets the output voltage (see Typical Application Circuit on page 1). 1% resistors are recommended to maintain output voltage accuracy. The feedback resistor R1 has some impact on the loop stability with the internal compensation capacitor. Choose a value for R1, R2 is then given by:

$$R_1 = R_2 \times \left(\frac{V_{OUT}}{V_{FB}} - 1 \right)$$

Inductor

The inductor is necessary to supply constant current to the output load while being driven by the switched input voltage. A larger-value inductor will result in less ripple current that will result in lower output ripple voltage. However, a larger-value inductor will have a larger physical footprint, higher series resistance, and/or lower saturation current. A good rule for determining the inductance value is to design the peak-to-peak ripple current in the inductor to be in the range of 30% to 40% of the maximum output current, and that the peak inductor current is below the maximum switch current limit. The inductance value can be calculated by:

$$L = \frac{V_{OUT}}{F_{SW} \times \Delta I_L} \times \left(1 - \frac{V_{OUT}}{V_{IN}} \right)$$

Where ΔI_L is the peak-to-peak inductor ripple current.

To avoid overheating and poor efficiency, an inductor must be chosen with an RMS current rating that is greater than the maximum expected output load of the application. In addition, the saturation current (typically labeled ISAT) rating of the inductor must be higher than the maximum load current plus 1/2 of in inductor ripple current.

The peak inductor current can be calculated by:

$$I_{L\_PEAK} = I_{OUT} + \frac{V_{OUT}}{2F_{SW} \times L} \times \left(1 - \frac{V_{OUT}}{V_{IN}} \right)$$

Input Capacitor

The input current to the step-down converter is discontinuous and therefore requires a capacitor to supply the AC current to the step-down converter while maintaining the DC input voltage. Ceramic capacitors are recommended for best performance and should be placed as close to the VIN pin as possible. Capacitors with X5R and X7R ceramic dielectrics are recommended because they are fairly 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 as follows:

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

The worst-case condition occurs at $V_{IN} = 2V_{OUT}$, where:

$$I_{CIN} = \frac{I_{OUT}}{2}$$

For simplification, choose the 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 estimated as follows:

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

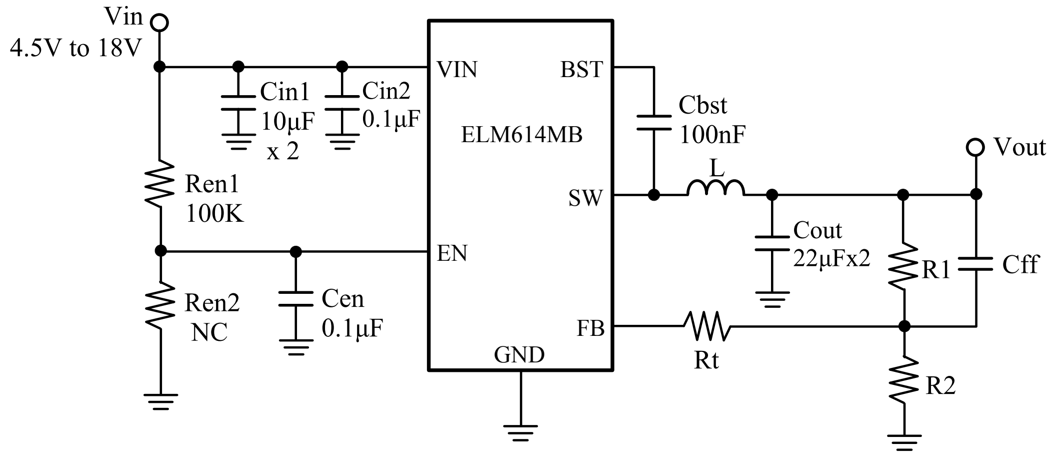
Under worst-case conditions where $V_{IN} = 2*V_{OUT}$:

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

Output Capacitor

The output capacitor has two essential functions. Along with the inductor, it filters the square wave generated by ELM614MB to produce the DC output. In this role it determines the output ripple, thus low impedance at the switching frequency is important. The second function is to store energy in order to satisfy transient loads and stabilize ELM614MB's control loop. X5R or X7R type ceramic capacitors have very low equivalent series resistance (ESR) and provide low output ripple and good transient response. Transient performance can be improved with a higher value output capacitor and the addition of a feed-forward capacitor placed between V_{OUT} and FB. Increasing the output capacitance will also decrease the output voltage ripple. A lower value of output capacitor can be used to save space and cost, but transient performance will suffer and may cause loop instability. When choosing a capacitor, special attention should be given to the data sheet to calculate the effective capacitance under the relevant operating conditions of voltage bias and temperature. A physically larger capacitor or one with a higher voltage rating may be required.

■Application schematic



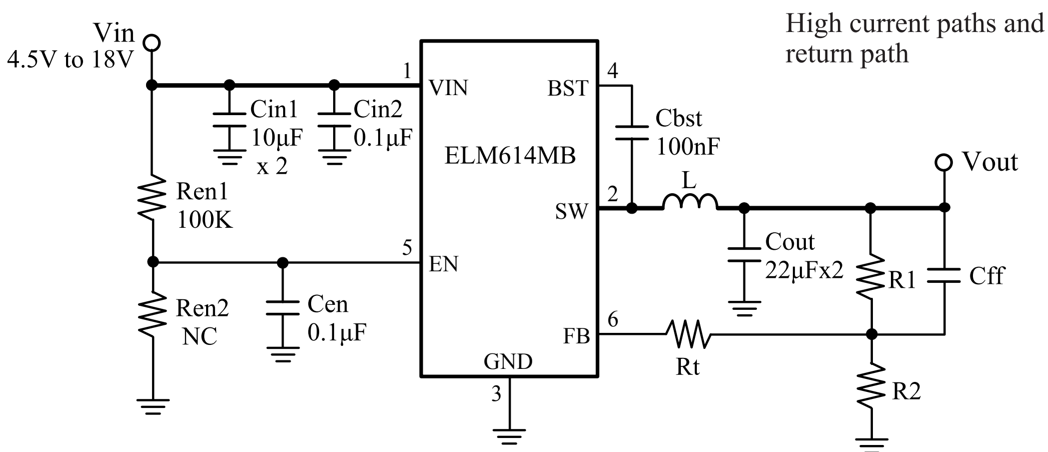
EVB BOM list

Qty	Ref	Value		Description
2	CIN1	10µF		Ceramic capacitor, 35V, X5R
2	CIN2, CEN	0.1µF		Ceramic capacitor, 50V, X5R
2	COUT	22µF		Ceramic capacitor, 16V, X5R
1	CBST	100nF		Ceramic capacitor, 10V, X5R
1	L	VOUT=5.0V	4.7µH	Inductor, Isat > 6A
		VOUT=3.3V	3.3µH	
		VOUT=1.0V	1.5µH	
1	R1	VOUT=5.0V	100kΩ	Resistor, ±1%
		VOUT=3.3V	100kΩ	
		VOUT=1.0V	100kΩ	
1	R2	VOUT=5.0V	19.1kΩ	Resistor, ±1%
		VOUT=3.3V	32.4kΩ	
		VOUT=1.0V	390kΩ	
1	Rt	500Ω		Resistor, ±1%
1	CFF	100pF		Ceramic capacitor, 10V, X5R
1	REN1	100KΩ		Resistor, ±1%
1	Power IC	ELM614MB		Step-down DC/DC converter

■PCB layout guide

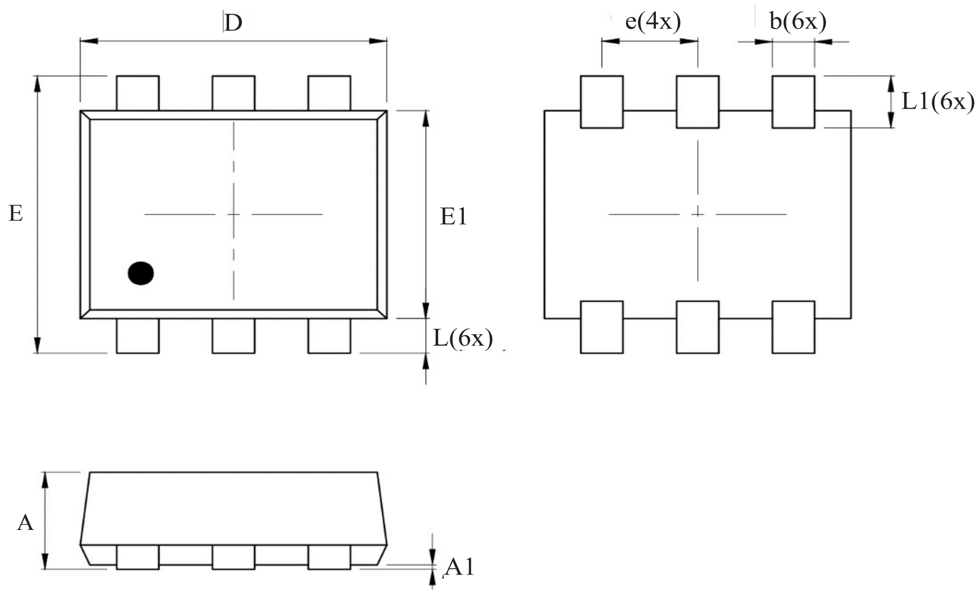
PCB layout is very important to achieve stable operation. Please follow the guidelines below.

1) The high current paths (GND, VIN, and SW) should be placed very close to the device with short, direct and wide traces.
2) Put the input capacitors as close to the IN and GND pins as possible.
3) Keep the switching node SW short and away from the feedback network.
4) The external feedback resistors should be placed next to the FB pin. Make sure that there is no via on the FB trace.
5) Keep the BST voltage path (BST, CBST and SW) as short as possible.
6) Keep the VIN and GND pads connected with large copper and use at least two layers for IN and GND trace to achieve better thermal performance. Also, add several Vias with 10mil_drill/18mil_copper_width close to the VIN and GND pads to help on thermal dissipation.Keep the VIN and GND pads connected with large copper and use at least two layers for VIN and GND trace to achieve better thermal performance. Also, add several Vias with 10mil_drill/18mil_copper_width close to the VIN and GND pads to help on thermal dissipation.



$R_{EN}1$ and $R_{EN}2$ are optional depending on the enable usage conditions.

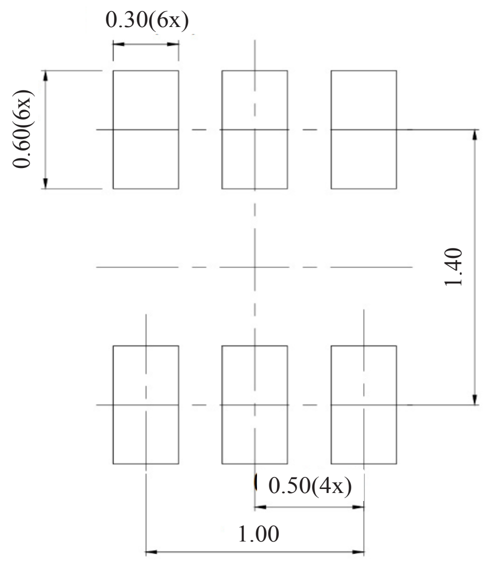
■SOT-563 Outline dimensions



Symbol	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A	0.52	0.60	0.020	0.024
A1	0.00	0.05	0.000	0.002
b	0.17	0.27	0.007	0.011
D	1.50	1.70	0.059	0.067
E	1.50	1.70	0.059	0.067
E1	1.10	1.30	0.043	0.051
e	0.50 BSC		0.020 BSC	
L	0.10	0.30	0.004	0.012
L1	0.20	0.40	0.008	0.016

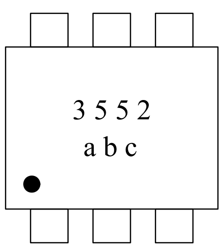
■Land pattern information

SOT-563



Note:
- Dimensions in mm.
- For reference only.

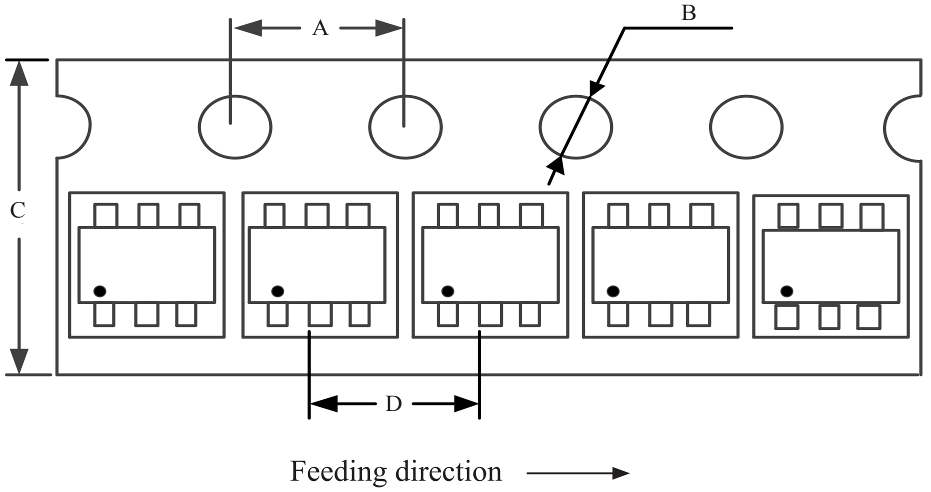
■Marking



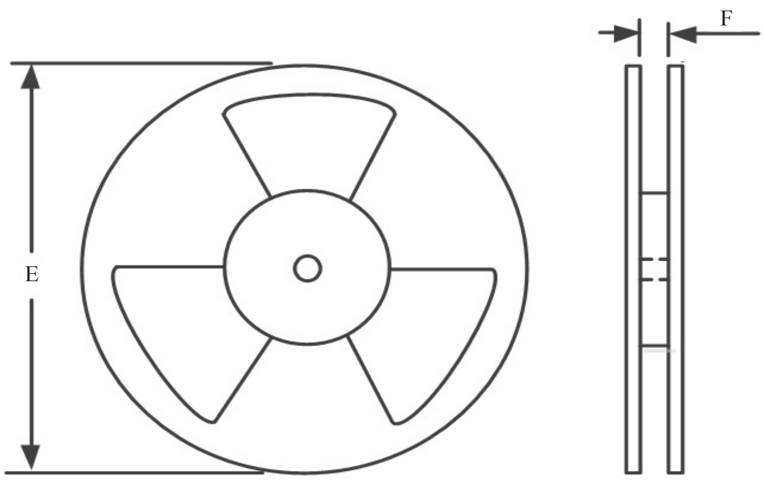
Mark	Content
3552	Product ID
a	Year
b	Week
c	Control code

■Reel & carrier tape dimension

• Orientation / Carrier tape information



• Reel information



• Dimension details

PKG type	A	B	C	D	E	F	Q'ty/Reel
SOT-563	4.0 mm	1.5 mm	8.0 mm	4.0 mm	7 inches	9.5 mm	5,000