ELM624BA 0.9V boot high efficiency synchronous step-up converter

■General description

ELM624BA provides power-supply solutions for products powered by either one, two or three-cell Alkaline, NiMH, or one-cell Li-Ion or Li-polymer battery. Its available output current depends on the input-to-output voltage ratio. ELM624BA works based on current–mode pulse-width-modulation (PWM) control using synchronous rectification to obtain maximum efficiency with the minimum quiescent current. The output voltage is programmed using an external resistor divider. ELM624BA circuit is switched off to minimize battery consumption during the shutdown mode and connects the VIN pin to the VOUT pin allowing the input battery to be used for backup systems like a real-time clock supply and SRAM data hold when the converter is off. ELM624BA is offered in a small 6-pin SOT-26 package.

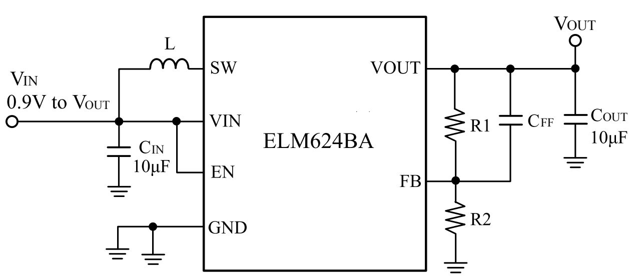
■Features

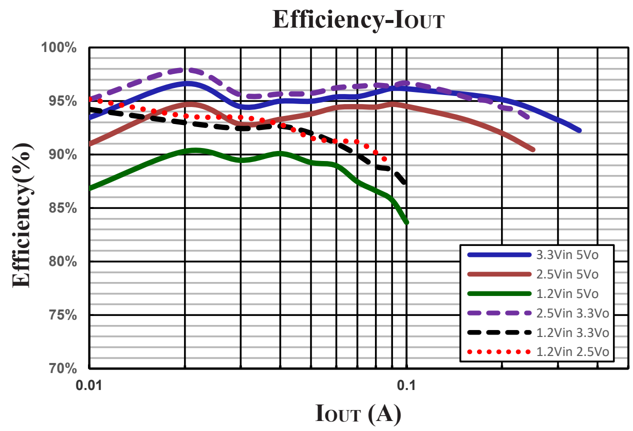
- VOUT pulled to VIN in shutdown mode
- Input under-voltage lockout
- Switching frequency : 800kHz (4.7µH)
- Adjustable output voltage : 2.5V to 5.5V
- High efficiency : 92%
- Quiescent current : 12µA
- Startup input voltage/load : 0.9V/10mA, 0.7V/1mA
- Operating input voltage : 0.9V to 5V
- Switch current : 450mA max.
- Package : SOT-26

■Application

- Battery powered applications :
  - 1 to 3 Cell Alkaline, NiCd or NiMH
  - 1 cell Li-Ion
- Solar or fuel cell powered applications
- Consumer and portable medical products
- Personal electronics goods.

■Standard circuit





■Selection Guide

ELM624BA-S

Symbol		
a	Part No.	ELM624
b	Package	B: SOT-26
c	Product version	A
d	Taping direction	S: Please refer to page 11

* Taping direction is one way.

ELM624 B A - S
↑ ↑ ↑ ↑
a b c d

■Maximum absolute ratings [1]

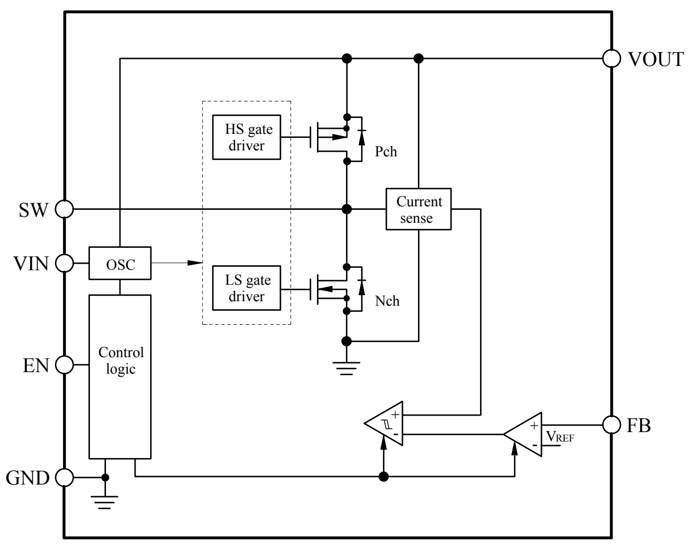
Parameter	Symbol	Limit	Unit
Supply voltage	V_{IN}	-0.3 to +6.0	V
Output voltage	V_{OUT}	-0.3 to +6.0	V
The other pins	V_{OTHER}	-0.3 to +6.0	V
Dynamic V_{SW} in 10ns duration	V_{SW}	-2.0 to V_{OUT} +2.0	V
Junction temperature	T_J	+150	°C
Lead temperature (Soldering 10s)		260	°C
Thermal resistance [3], [4]	θ_{JA}	125	°C/W
	θ_{JC}	66	°C/W
Power dissipation [3], [4]	P_D	0.8	W
Storage temperature range	T_{STG}	-55 to +150	°C

■Recommend operating conditions [2]

Parameter	Symbol	Limit	Unit
Input voltage	V_{IN}	+0.9 to +5.0	V
Output voltage	V_{OUT}	+1.8 to +5.5	V
Maximum junction temperature	T_{JMAX}	+125	°C
Ambient temperature range	T_A	-40 to +85	°C

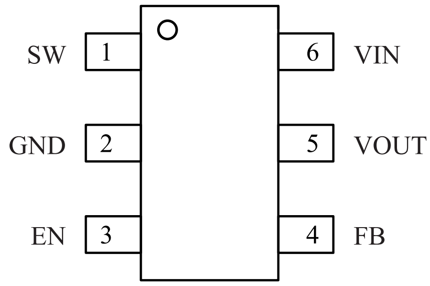
Note:
(1) Stress exceeding those listed "Maximum absolute ratings" may damage the device.
(2) The device is not guaranteed to function outside of the recommended operating conditions.
(3) Measured on JESD51-7, 4-Layer PCB.
(4) The maximum allowable power dissipation is a function of the maximum junction 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



■Pin configuration

SOT-26(TOP VIEW)



Pin name	Pin No.	Pin description
SW	1	An inductor Connecting pin. Nch MOSFET switch drain and synchronous Rectifier Pch MOSFET switch drain are connected.
GND	2	Control circuit and power Nch switch ground.
EN	3	Enable input pin (1: enabled, 0: disabled). Must be actively tied to high or low. When EN is low, the ELM624BA both Nch and Pch switches are turned off.
FB	4	Adjustable VOUT Feedback Input pin. Seting the output voltage by a resistor-divider network.
VOUT	5	Step-up converter output pin. Bootstrapped supply for the device. Output sense point for fixed VOUT.
VIN	6	Step-up converter power input pin.

■Electrical characteristics

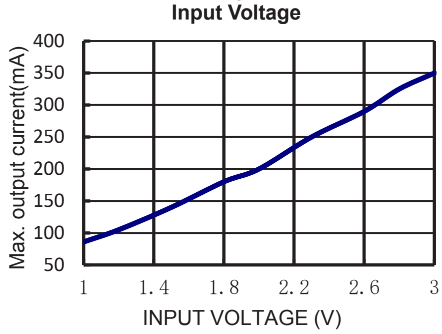
T_{OP}=+25°C, V_{IN}=V_{EN}=1.2V, 0.9V≤V_{IN}≤5V, unless otherwise noted.

Parameter		Symbol	Conditions	Min.	Typ.	Max.	Unit
Input voltage range		V_{IN}	V_{OUT}*0.9 or more	0.9	-	5.0	V
Minimum input voltage at startup		V_{ST}	I_{OUT}=1mA	-	0.7	-	V
Input under-voltage lockout threshold for Turn-off		V_{UVLO}	V_{IN} decreasing	-	0.5	-	V
Adjustable output voltage		V_{OUT}	V_{IN}<V_{OUT}	2.5	-	5.5	V
Adjustable Vout feedback voltage		V_{FB}		485	500	515	mV
Feedback input current		I_{FB}	V_{FB}=0.5V	-	3	-	nA
Switch current limit		I_{SW}	V_{OUT}=3.3V	-	450	-	mA
Rectifier Pch switch on resistance		R_{ON_P}	V_{OUT}=3.3V	-	300	-	mΩ
Main Nch switch on resistance		R_{ON_N}	V_{OUT}=3.3V	-	270	-	
Switching frequency		F_{SW}	V_{OUT}=3.3V and L=4.7μH	-	800	-	kHz
Quiescent current	V_{IN}	I_Q	V_{EN}=V_{IN}=1.2V, V_{OUT}=3.3V	-	2	-	μA
	V_{OUT}			-	10	-	
Shutdown current	V_{IN}	I_{SD}	V_{EN}=0V, V_{IN}=1.2V	-	0.01	1.00	μA
EN logic low threshold		V_{LL}	1.2V<V_{IN}<5.0V	-	-	0.3	V
			0.9V<V_{IN}<1.2V	-	-	0.2	
EN logic high threshold		V_{LH}	1.2V<V_{IN}<5.0V	0.5*V_{IN}	-	-	V
			0.9V<V_{IN}<1.2V	0.6	-	-	
EN input current		I_{EN}	V_{EN}=0V or 5V	-1	-	1	μA

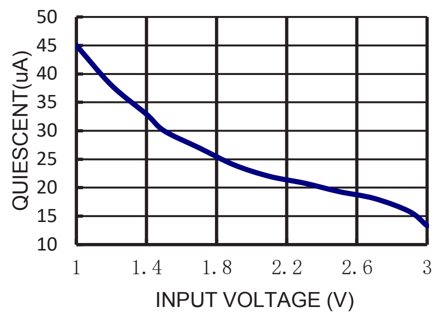
■Typical characteristics

- Standard circuit, VIN=1.2V, VOUT=3.3V, L=4.7μF, CIN=10μF, COUT=10μF, TA=+25°C, unless otherwise noted.

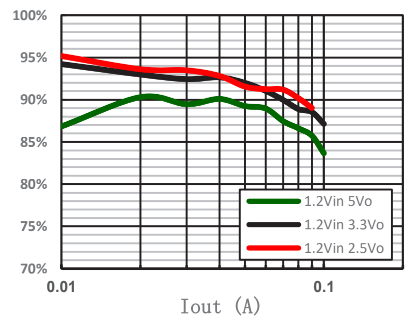
Maximum Output Current vs Input Voltage



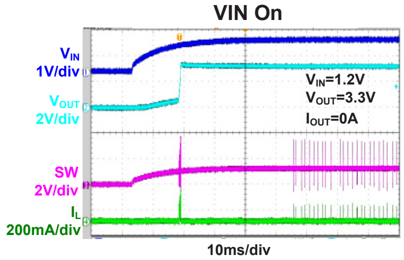
No Load Input Current vs Input Voltage, Device Enabled



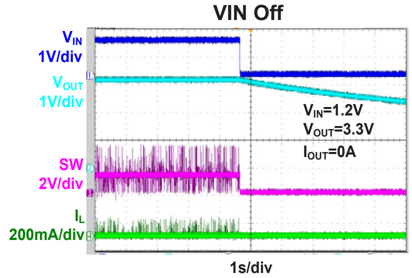
Efficiency vs Input Voltage and Output Current



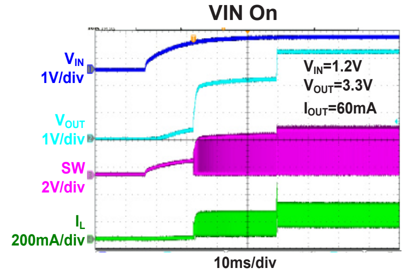
VIN On



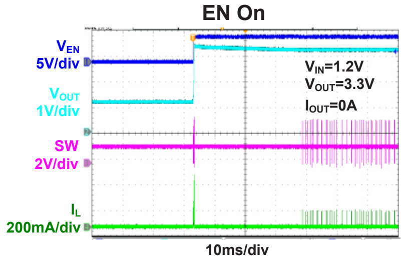
VIN Off



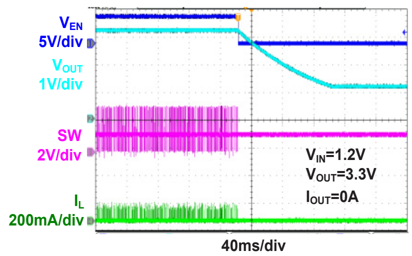
VIN On



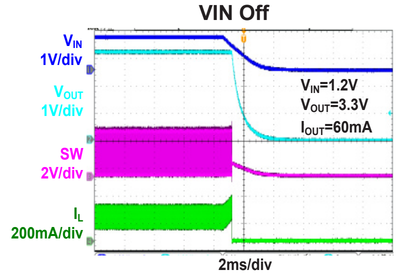
EN On



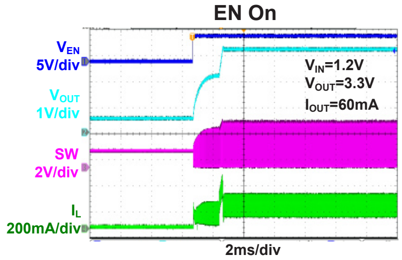
EN off



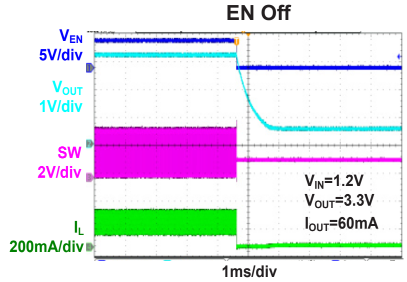
VIN Off



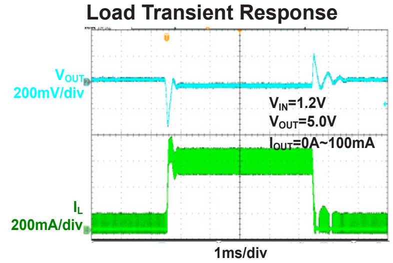
EN On



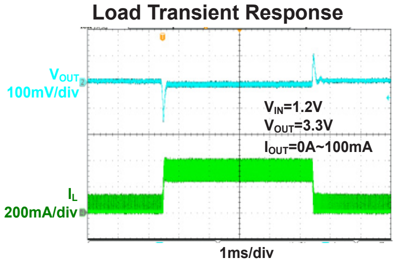
EN Off



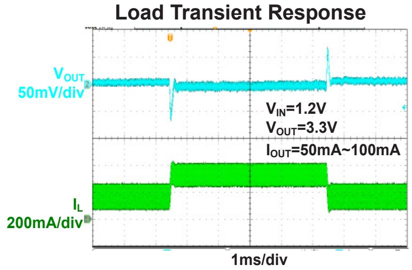
Load Transient Response



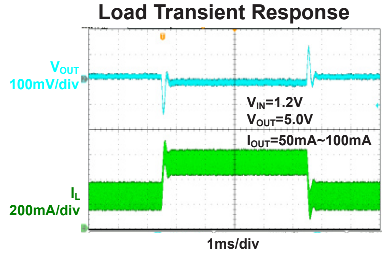
Load Transient Response



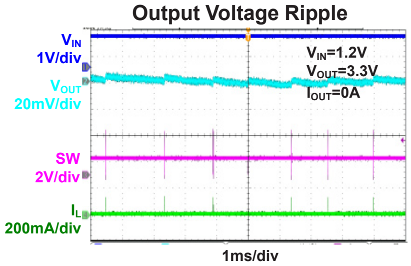
Load Transient Response



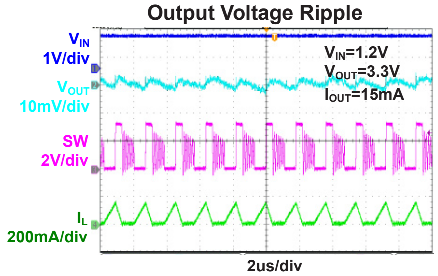
Load Transient Response



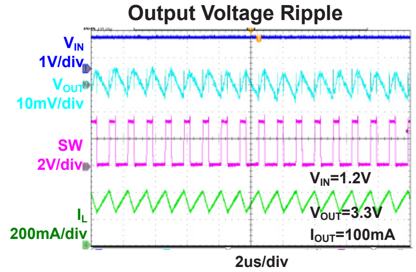
Output Voltage Ripple



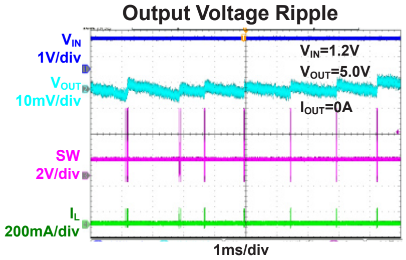
Output Voltage Ripple



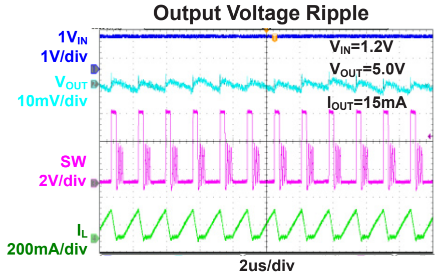
Output Voltage Ripple



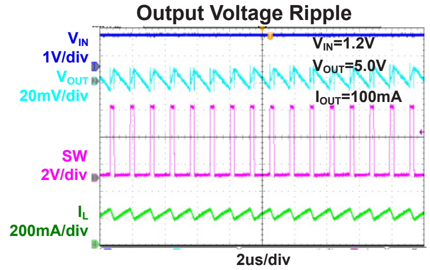
Output Voltage Ripple



Output Voltage Ripple



Output Voltage Ripple



■Detailed description

ELM624BA is compact, high-efficiency step-up converters feature 12µA quiescent supply current to ensure the highest possible efficiency over a wide load range. With a minimum +1.1V input voltage, ELM624BA is well suited for applications with 1 to 3 alkaline cells, nickel-metal-hydride (NiMH) cells, or one lithium ion (Li+) cell.

ELM624BA is based on current mode pulse width modulation topology without an external oscillator. It regulates the output voltage by keeping the inductor ripple current around 200 mA, and the error comparator senses that the output to adjust the offset of the inductor current depending on the output load current. If the required average input current is lower than the average inductor current defined by the constant 200mA ripple current, the inductor current becomes discontinuous to keep the efficiency high under the light load condition. The inductor current is limited by the internal 450mA Nch main switch current limit for over-load protection. An internal synchronous rectifier Pch switch eliminates the need for an external Schottky diode reducing cost and board space. While the inductor discharges, the Pch switch turns on and shunts the MOSFET body diode. As a result, the rectifier voltage drop is significantly reduced, improving efficiency without adding external components.

Shutdown

When EN is low, ELM624BA device is off and no current is drawn from the input. When EN is high, the device is on. EN is driven from a logic-level output, and connect EN to V_{IN} If it is not used. In shutdown, ELM624BA connects the input to the output through the inductor and the internal synchronous rectifier Pch switch. This allows the input battery (rather than a separate backup battery) to provide backup power for devices such as an idled microcontroller, SRAM, or real-time clock (RTC), without the usual diode forward drop. If the output has a residual voltage during shutdown, a small amount of energy will be transferred from the output back to the input immediately after shutdown. This energy transfer may cause a slight momentary "bump" in the input voltage. The magnitude and duration of the input bump are related to the ratio of C_{IN} and C_{OUT} and the ability of the input to sink current. With battery input sources, the bump will be negligible, but with power-supply inputs (typically cannot sink current), the bump may be 100s of mV.

Startup

When the EN pin is tied high, the device begins to operate. If the input voltage (ELM624BA V_{IN}<2.2V) is not high enough to supply the control circuit properly, a startup oscillator controls the main Nch switch to operate in Asynchronous mode (The synchronous rectifier Pch switch remains off). During this phase, the switching frequency is controlled by the startup oscillator, and the maximum switch current is limited. When the device has built up the output voltage to approximately 2.2V, high enough to supply the control circuit, the device switches to its normal current mode operation. The startup time depends on the minimum input voltage V_{IN_MIN} and load current. For proper startup with low input voltage, recommend to limit load current as shown below.

$$I_{OUT\_STARTUP} \leq 80\text{mA} \times \frac{V_{IN\_MIN}}{2.2\text{V}}$$

Input Under-Voltage Lockout

The input under-voltage lockout circuit prevents the device from malfunctioning at low input voltages and the battery from excessive discharge. It disables the output stage of the converter once the falling VIN trips the under-voltage lockout threshold V_{UVLO} which is typically 0.5V. The device starts operation once the rising VIN trips V_{UVLO} threshold plus its hysteresis of 50mV at typically 0.55V.

■Application information

Design Procedure

ELM624BA DC/DC converter is intended for systems powered by a single cell battery to up to three Alkaline, NiCd or NiMH cells with a typical terminal voltage between 0.9V and 4.5V. They can also be used in systems powered by one-cell Li-Ion or Li-Polymer batteries with a typical voltage between 2.5V and 4.2V. Additionally, any other voltage source with a typical output voltage between 1.8V and 5V can be used.

Setting the Output Voltage

The output voltage is set using FB pin and a resistor divider connected to VOUT pin as shown in the standard circuit on page1, The output voltage (V_{OUT}) can be calculated according to the voltage of the FB pin (V_{FB}) and ratio of the feedback network resistors by the following equation, where V_{FB} is 0.5V:

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

Thus the output voltage is:

$$V_{OUT} = 0.5 \times \frac{(R_1 + R_2)}{R_2}$$

Choose R_2=100kΩ~1000kΩ to ensure feedback loop noise immunity. It is optional to add a feed-forward capacitor C_{FF}=22~33pF in parallel with R1 to achieve better transient response performance.

Inductor Selection

ELM624BA converters can operate with an effective inductance in the range of 3.3μH to 10μH. Inductor values of 4.7μH show good performance over the whole input and output voltage range. The switching frequency f_{SW} is proportional to inductance value 1/L as shown below.

$$f_{SW} = \frac{1}{0.2A \times L} \times \frac{V_{IN} \times (V_{OUT} - V_{IN})}{V_{OUT}}$$

The inductor should have low DCR (copper-wire resistance) to reduce I^2R losses, and must be able to handle the maximum peak inductor current (internally limited to 450mA (Typ)) without saturating. The inductor DC current rating should be greater than the maximum input average current. The highest peak current through the inductor and the switch depends on the output load, converter efficiency η, the minimum input voltage (V_{IN_MIN}), and the output voltage (V_{OUT}). Estimation of the maximum average inductor current can be done using:

$$I_L = I_{OUT} \times \frac{V_{OUT}}{V_{IN\_MIN} \times \eta}$$

For example, for an output current of 100mA at 3.3V_{OUT} with 85% efficiency, at least 323mA of average current flows through the inductor at a minimum input voltage of 1.2V.

Having selected an inductance value, the maximum output current depends on the steady-state operation mode. The maximum output current I_{OUT_MAX} in continuous conduction mode can be estimated with the equation below.

$$I_{OUT\_MAX} \leq 350mA \times \frac{V_{IN\_MIN} \times \eta}{V_{OUT}}$$

where η is the converter efficiency, and 350mA is average inductor current with I_{LMAX}=450mA and ripple current ΔI_L=200mA. For example, the maximum output current is around 108mA at 3.3V_{OUT} with 85% efficiency at a minimum input voltage of 1.2V.

Input Capacitor

An input capacitor value of at least 10μF is recommended to improve transient behavior of the regulator and EMI behavior of the total power supply circuit. A ceramic capacitor placed as close as possible to the VIN and GND pins of the IC is recommended.

Output Capacitor

The output capacitor must completely supply the load during the charging phase of the inductor. A reasonable value of the output capacitance depends on the speed of the load transients and the load current during the load change. It is recommended to use X5R/X7R ceramic capacitors placed as close as possible to the VOUT and GND pins of the IC. A recommended output capacitance value is around 4.7~10μF. Note that high capacitance ceramic capacitors have a DC Bias effect, which will have a strong influence on the final effective capacitance. A 10V rated 0805 capacitor with 10μF can have an effective capacitance of less 5μF at an output voltage of 5V.

Thermal information

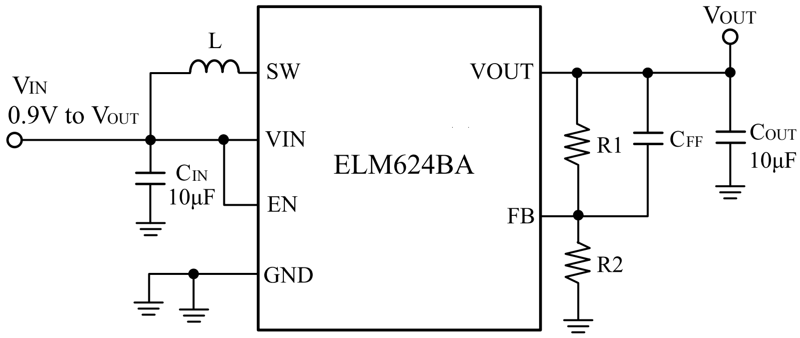
Implementation of integrated circuits in low-profile and fine-pitch surface-mount packages typically requires special attention to power dissipation. Many system-dependent issues such as thermal coupling, airflow, added heat sinks and convection surfaces, and the presence of other heat-generating components affect the power-dissipation limits of a given component. Three basic approaches for enhancing thermal performance are listed below:

- Improve the power dissipation capability of the PCB design.
- High speed switching path (SW, GND and VOUT with wide PCB traces) must be kept as short as possible.
- Choose a bigger size 4.7μH Inductor with the lowest DCR value for given PCB space.

The recommended maximum junction temperature (T_J) of the ELM624BA devices is 125°C. The thermal resistance of the SOT-26 package is $R_{\theta JA}$=125°C/W. Therefore, the maximum power dissipation for the SOT-26 package is about 0.8W.

$$P_{D(MAX)} = \frac{T_{J(MAX)} - T_A}{R_{\theta JA}} = \frac{125°C - 25°C}{125°C/W} = 0.8W$$

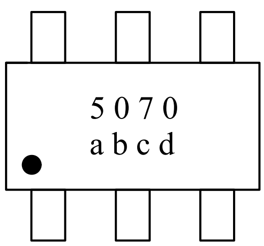
■Application schematic



EVB BOM list

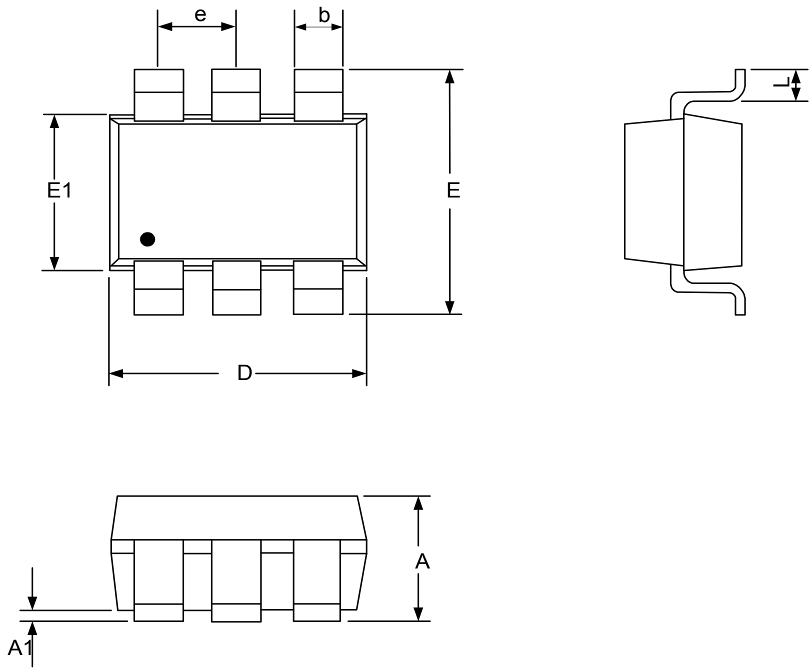
Qty	Ref	Value		Description	Package
1	C_{IN}	10µF		Ceramic capacitor, 10V, X5R/X7R	0805
1	C_{OUT}	10µF		Ceramic capacitor, 10V, X5R/X7R	0805
option	C_{FF}	22~33pF		Ceramic capacitor, 10V, X5R/X7R	0603
1	L	4.7µH		Inductor, 32mΩ, 5.5A	SMD
1	R1	V_{OUT}=5.0V	5.1MΩ	Resistor, ±1%	0603
		V_{OUT}=3.3V	2.2MΩ		
		V_{OUT}=2.5V	2.0MΩ		
1	R2	V_{OUT}=5.0V	560KΩ	Resistor, ±1%	0603
		V_{OUT}=3.3V	390KΩ		
		V_{OUT}=2.5V	490MΩ		
1	Power IC	ELM624BA		Step-up converter	SOT-26

■Marking



Mark	Content
5070	Product ID: ELM624BA
a	Year
b	Week
c, d	Control code

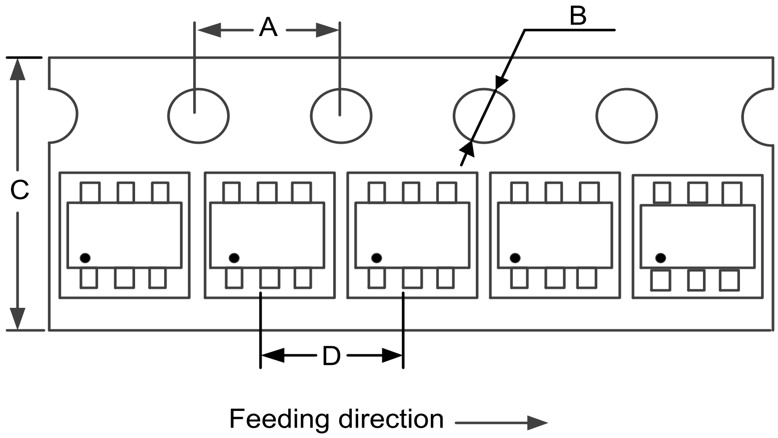
■SOT-26 Outline dimensions



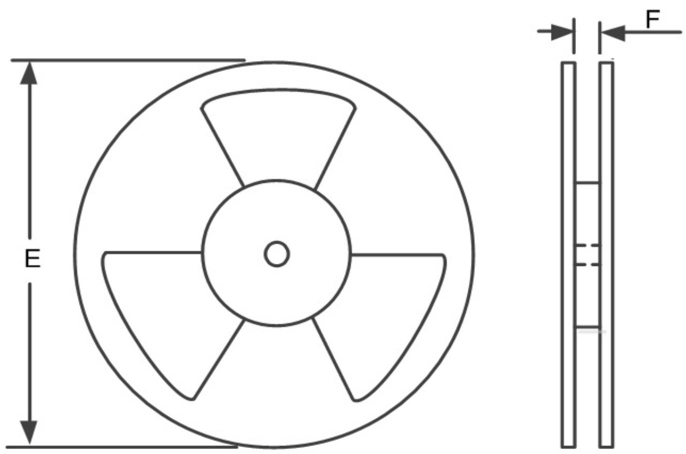
Symbol	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A	0.89	1.45	0.035	0.057
A1	0.00	0.15	0.000	0.006
b	0.30	0.50	0.012	0.020
D	2.70	3.10	0.106	0.122
E1	1.40	1.80	0.055	0.071
e	0.95 BSC		0.037 BSC	
E	2.60	3.00	0.102	0.118
L	0.30	0.60	0.012	0.024

■Reel & carrier tape dimension

• Orientation / Carrier tape information



• Reel information



• Dimension details

PKG type	A	B	C	D	E	F	Q'ty/Reel
SOT-26	4.0 mm	1.5 mm	8.0 mm	4.0 mm	7 inches	9.0 mm	3,000