600mA Step-Down Converter

Features

- Vin Range: 2.7V to 5.5V
- Maximum Output Current 600mA
- High Efficiency Up to 98%
- Low Quiescent Current
- High Switching Frequency: 1.6MHz
- Low Dropout in 100% Duty Cycle
- Shutdown Current < 1µA
- No Schottky Diode Required
- Output Auto Discharge when Disabled (Option)
- Integrated Soft-Start : 170µs
- Adjustable Output Voltage Down to 0.6V
- Short Circuit Protection
- Over-Temperature Protection
- Pb-Free Packages:
  - KTB851 : UDFN-6, 1.6x1.6x0.55mm
  - KTB851A/B : TSOT23-5
- RoHS and Green Compliant
- -40°C to +85°C Temperature Range

Applications

- Mobile Phones
- Portable Instruments
- Digital Still Cameras
- Microprocessor Power
- MP3 Players

Brief Description

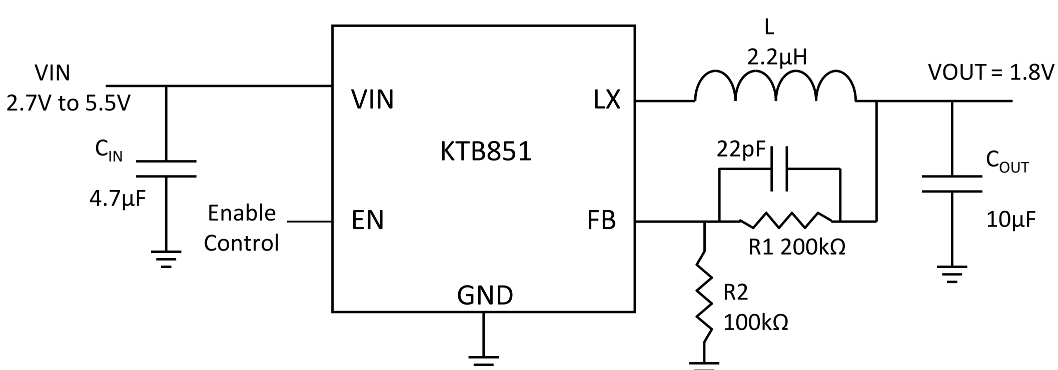
The KTB851 is a high efficiency step down converter, using constant frequency PWM current mode control. It uses 1.6MHz high switching frequency which allows the use of small external components. The 2.7V to 5.5V input operating range is ideal for Li-Ion/Polymer powered devices and systems running from regulated 3.3V or 5V voltage rails. 100% duty cycle operation provides the greatest design flexibility for achieving the lowest dropout.

Low output voltage down to 0.6V can be achieved due to the KTB851's low internal voltage reference.

The KTB851 is designed to maintain high efficiency throughout the operating range, which is critical for portable applications. In addition, the KTB851 has an option for output auto discharge feature. This enables the device to quickly discharge the output when the device is disabled.

The KTB851 is available in RoHS and Green compliant, small 5-pin TSOT23, and 6-pin UDFN 1.6 x 1.6 x 0.55mm packages.

Typical Application

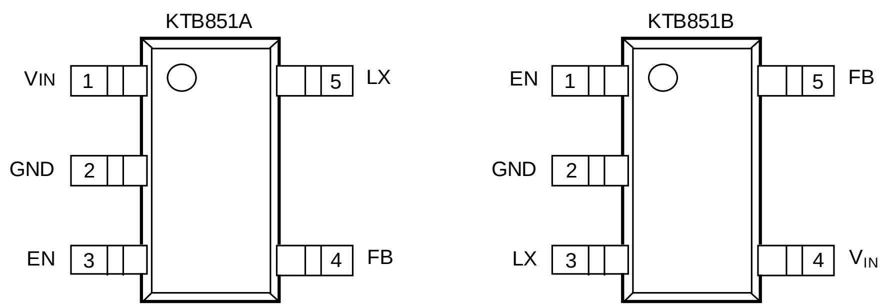


Pin Descriptions

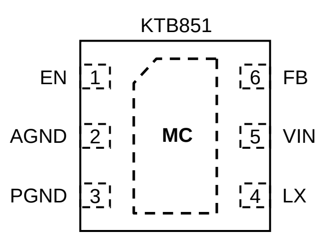
UDFN 1.6 x 1.6mm and TSOT23-5

Pin #			Name	Function
KTB851A (TSOT23)	KTB851B (TSOT23)	UDFN-6		
3	1	1	EN	IC enable pin. Should not be left floating.
4	5	6	FB	Feedback pin. Provides feedback information to the control loop via external resistor divider connected to the output.
1	4	5	V_{IN}	Input supply pin. Should be decoupled with a 2.2µF or greater capacitor to GND.
5	3	4	LX	Inductor connection pin
2	2	2	AGND	Analog ground pin.
		3	PGND	Power ground pin.

TSOT23-5
(Top View)



UDFN-6, 1.6mm x 1.6mm
(Top View)



Absolute Maximum Rating[1]

(T_A = 25°C unless otherwise noted)

Symbol	Description	Value	Units
V_{IN}, FB, VOUT	Input voltage	-0.3 to 6.0	V
EN, LX	Output and Control pins	-0.3 to VIN + 0.3	V
I_{LX}	Peak LX current	1.2	A
T_J	Operating Junction Temperature Range	-40 to 125	°C
T_S	Storage Temperature Range	-65 to 125	°C
T_{LEAD}	Maximum Soldering Temperature (at leads, 10 sec)	300	°C

Thermal Capabilities

Symbol	Description	Value	Units
TSOT23-5			
θ_{JA}	Thermal Resistance – Junction to Ambient[2]	250	°C/W
P_D	Maximum Power Dissipation at $T_A \leq 25$°C	400	mW
ΔP_D/°C	Derating Factor Above T_A = 25°C	-4.6	mW/°C
UDFN-6 1.6x1.6mm			
θ_{JA}	Thermal Resistance – Junction to Ambient[2]	150	°C/W
P_D	Maximum Power Dissipation at $T_A \leq 25$°C	667	W
ΔP_D/°C	Derating Factor Above T_A = 25°C	-6.7	mW/°C

Ordering Information

Part Number	Auto Discharge	Marking[3]	Operating Temperature	Package
KTB851EVD-ADJ-TR	NO	EKYYZ	-40°C to +85°C	UDFN-6 1.6x1.6x0.55mm
KTB851EVD-ADJ-1-TR	YES	SDYYZ	-40°C to +85°C	UDFN-6 1.6x1.6x0.55mm
KTB851AEHC-ADJ-TR	YES	EKYYZ	-40°C to +85°C	TSOT23-5
KTB851BEHC-ADJ-TR	YES	CAYYZ	-40°C to +85°C	TSOT23-5

1. Stresses above those listed in Absolute Maximum Ratings may cause permanent damage to the device. Functional operation at conditions other than the operating conditions specified is not implied. Only one Absolute Maximum rating should be applied at any one time.
2. Junction to Ambient thermal resistance is highly dependent on PCB layout. Values are based on thermal properties of the device when soldered to an EV board.
3. “YYZ” is the date code and assembly code.

Electrical Characteristics[4]

The *Min* and *Max* specs are applied over the full operation temperature range of –40°C to +85°C, VIN = EN = 3.6V, while Typ values are specified at room temperature (25°C) unless otherwise noted.

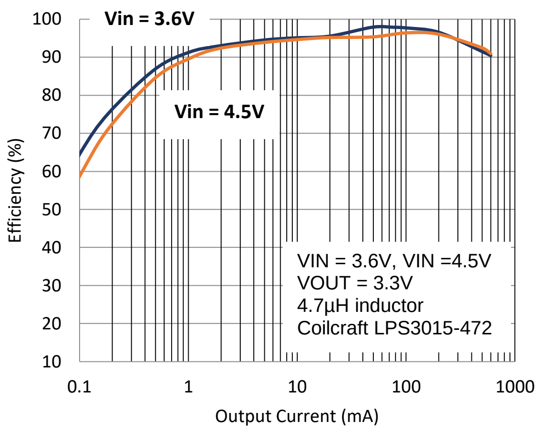
Symbol	Description		Conditions	Min	Typ	Max	Units
V_{IN}	Input Voltage Range			2.7		5.5	V
V_{UVLO}	UVLO Threshold		V_{IN} Rising			2.7	V
			Hysteresis		200		mV
			V_{IN} Falling		2.3		V
I_Q	IC supply current		V_{IN} = V_{EN} = V_{FB} = 3.6V		44	70	µA
I_{SHDN}	Vin pin shutdown current		EN = GND		0.1	1.0	µA
V_{FB}	Feedback Voltage	KTB851-ADJ	T_A = 25°C	0.588	0.600	0.612	V
ΔV_{OUT}	Output Voltage Accuracy		V_{IN} = V_{OUT} + 0.2V to 5.5V, V_{IN} ≧ 3.5V, T_A = 25°C, 0A < I_{OUT} < 600mA	-3		3	%
I_{OUT}	Output Current			600			mA
ΔV_{FB}	VFB Line Regulation		V_{IN} = 2.7V to 5.5V		0.1		%/V
ΔV_{OUT_LINE}	Output Voltage Line Regulation		V_{IN} = 2.7V to 5.5V, I_{OUT} = 300mA		0.5		%/V
ΔV_{OUT_LOAD}	Output Voltage Load Regulation		I_{OUT} = 1mA to 600mA		0.4		%
f_{OSC}	Oscillator Frequency				1.6		MHz
D_{MAX}	Maximum Duty Cycle			100			%
I_{LIM}	Output Current Limit				1.0		A
$R_{DS(ON)P}$	High-side P-Channel on-resistance		I_{LX} = 100mA		0.35		Ω
$R_{DS(ON)N}$	Low-side N-Channel on-resistance		I_{LX} = -100mA		0.3		Ω
I_{LX_LKG}	LX Leakage Current		EN = GND, V_{LX} = GND, V_{IN} = 5.5V		±0.01		µA
$T_{PULLDOWN}$	Output pull-down discharge time		EN = GND, C_{OUT} = 10µF, V_{OUT} = 3.3V		2.5		ms
T_S	Soft-start time				170		µs
V_{Th-L}	EN pin logic low voltage					0.4	V
V_{Th-H}	EN pin logic high voltage			1.4V		VIN	V
I_{EN}	Enable Leakage Current				±0.1	±1	µA
T_{J_TH}	Junction thermal shutdown temperature				140		°C
	Junction thermal shutdown hysteresis				15		°C

4. The KTB851 is guaranteed to meet performance specifications over the –40°C to +85°C operating temperature range by design, characterization and correlation with statistical process controls.

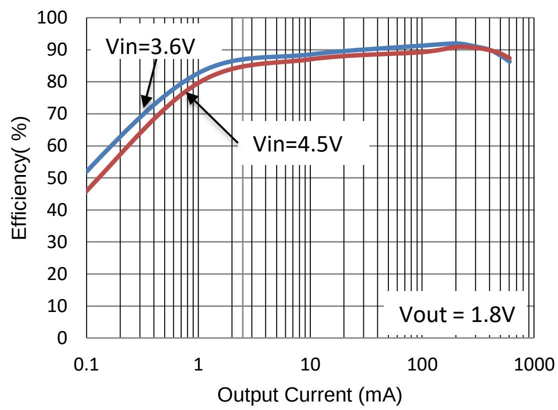
Typical Characteristics

V_{IN} = 3.6V, L = 2.2µH (Murata LQH3NPN2R2NJ0), C_{IN} = 4.7µF, C_{OUT} = 10µF with VOUT = 1.8V, T_{AMB} = 25°C unless otherwise specified.

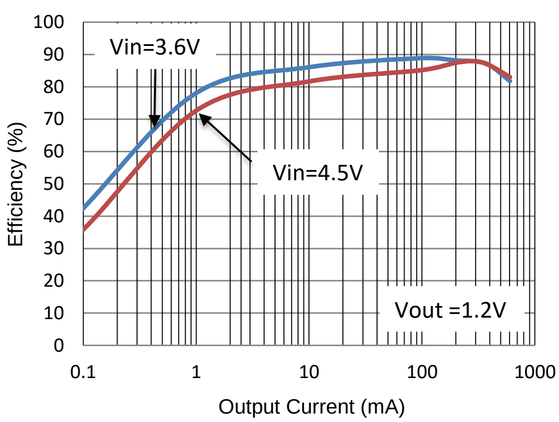
Efficiency vs. Output Current (VOUT = 3.3V)



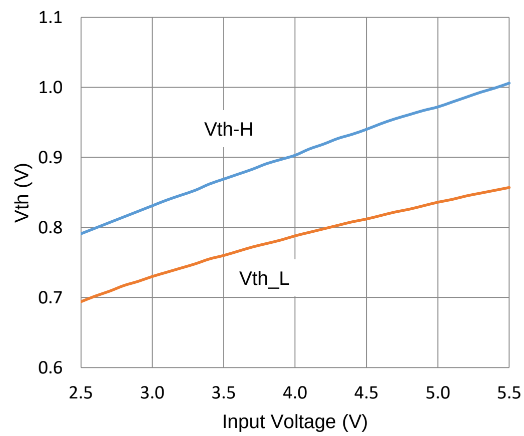
Efficiency vs. Output Current (VOUT = 1.8V)



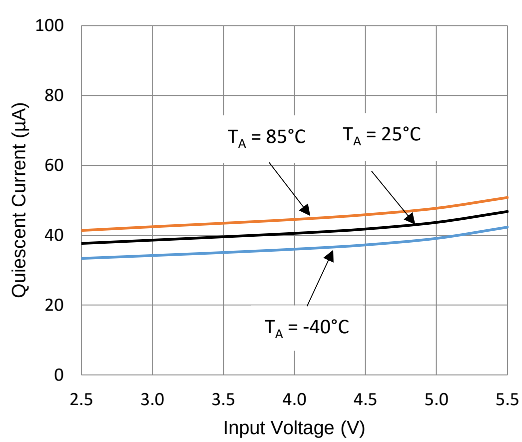
Efficiency vs. Output Current (VOUT = 1.2V)



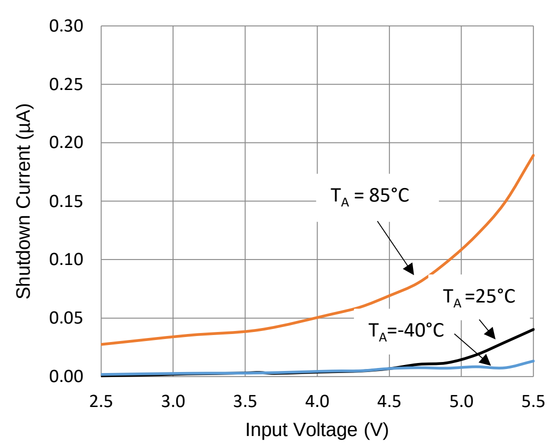
EN Logic Threshold Voltage



Quiescent Current (non-switching)

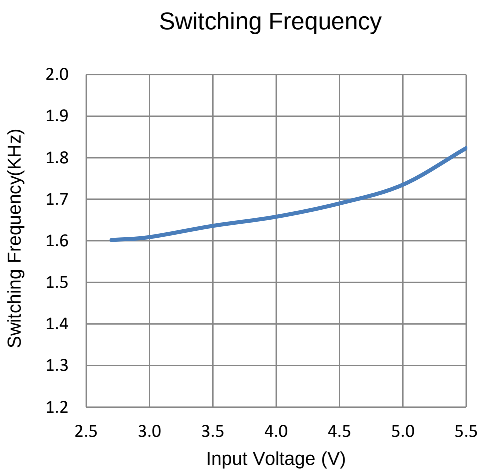


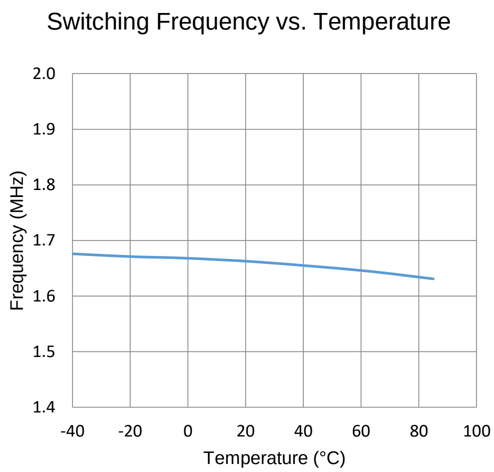
Shutdown Current (EN Low)

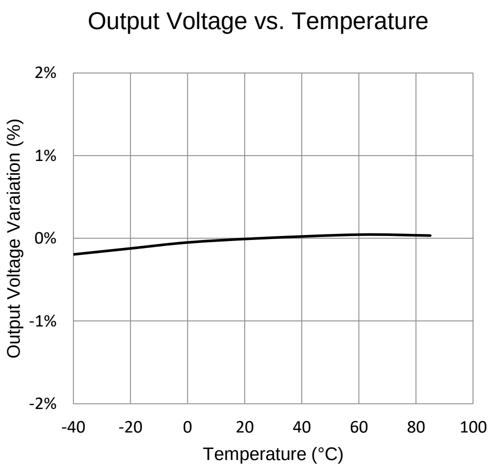


Typical Characteristics

V_{IN} = 3.6V, L = 2.2µH (Murata LQH3NPN2R2NJ0), C_{IN} = 4.7µF, C_{OUT} = 10µF with VOUT = 1.8V, T_{AMB} = 25°C unless otherwise specified.



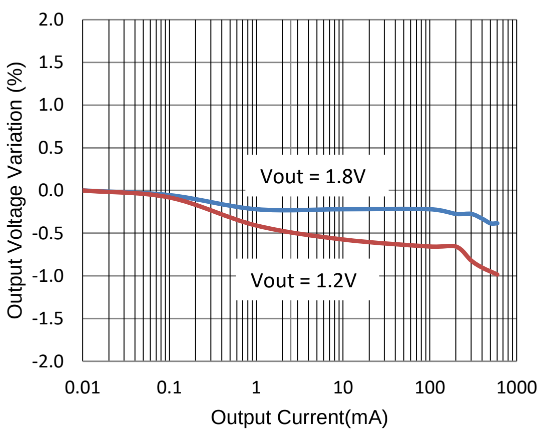




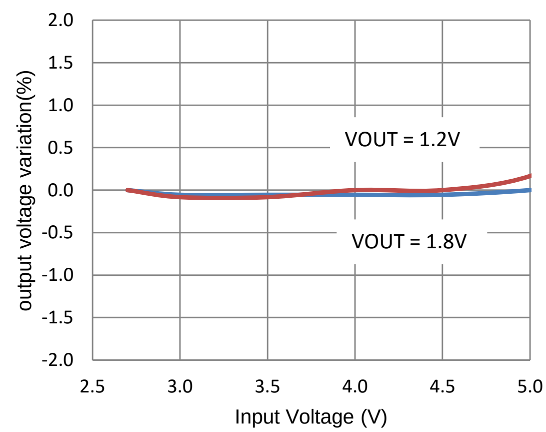
Typical Characteristics (Continued)

V_{IN} = 3.6V, L = 2.2µH (Murata LQH3NPN2R2NJ0), C_{IN} = 4.7µF, C_{OUT} = 10µF with VOUT = 1.8V, T_{AMB} = 25°C unless otherwise specified.

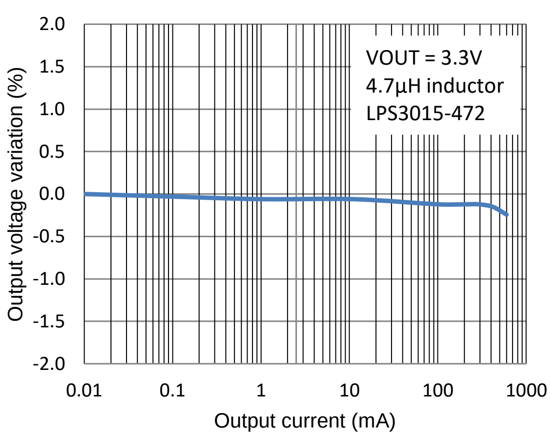
Load Regulation



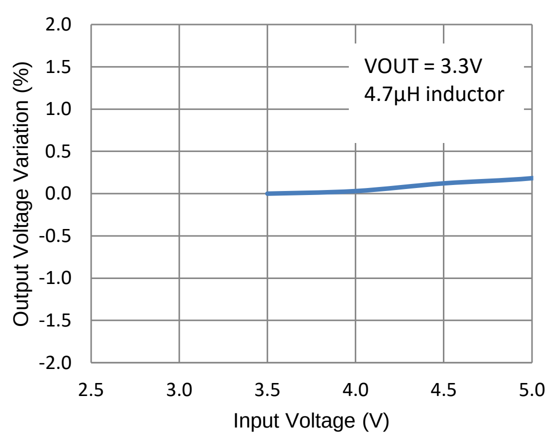
Line Regulation



Load Regulation (VOUT = 3.3V)



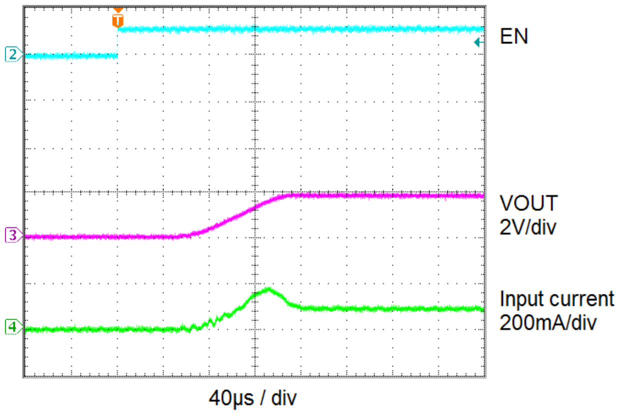
Line Regulation (VOUT = 3.3V)



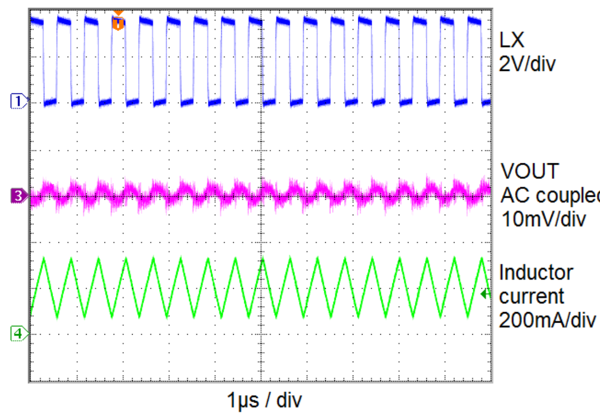
Typical Characteristics (Continued)

V_{IN} = 3.6V, L = 2.2μH (Coilcraft LPS3015-222), C_{IN} = 4.7μF, C_{OUT} = 10μF, C1 = 22pF with VOUT = 1.8V, T_{AMB} = 25°C unless otherwise specified.

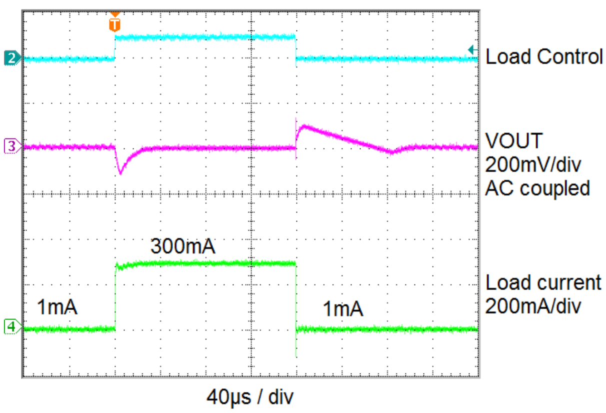
Soft-Start Turn On (10Ω load)



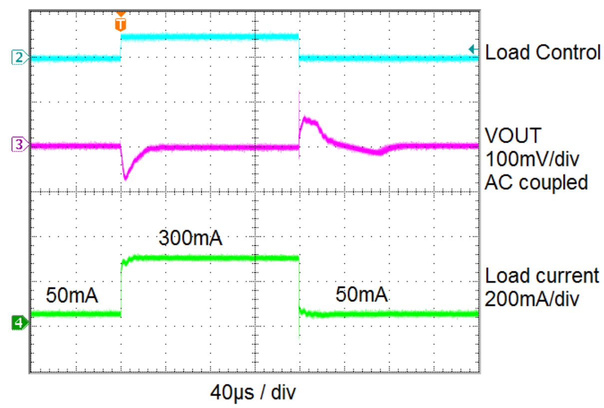
Steady State Switching (200mA load)



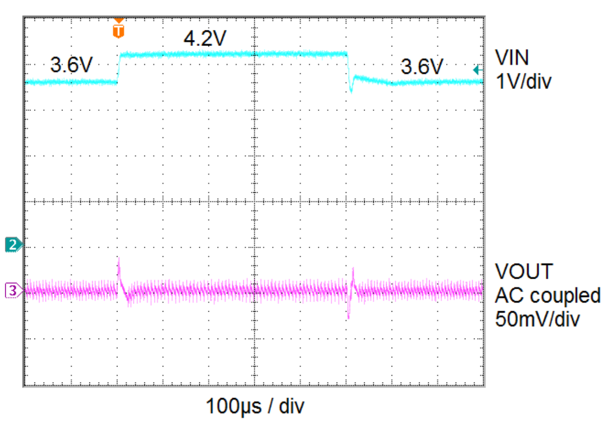
Load Transient 1mA to 300mA



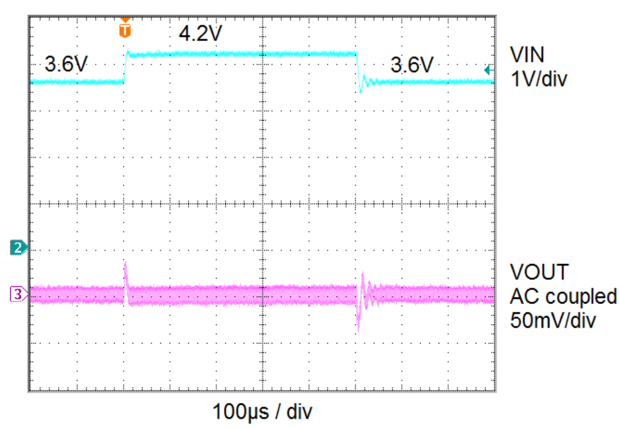
Load Transient 50mA to 300mA



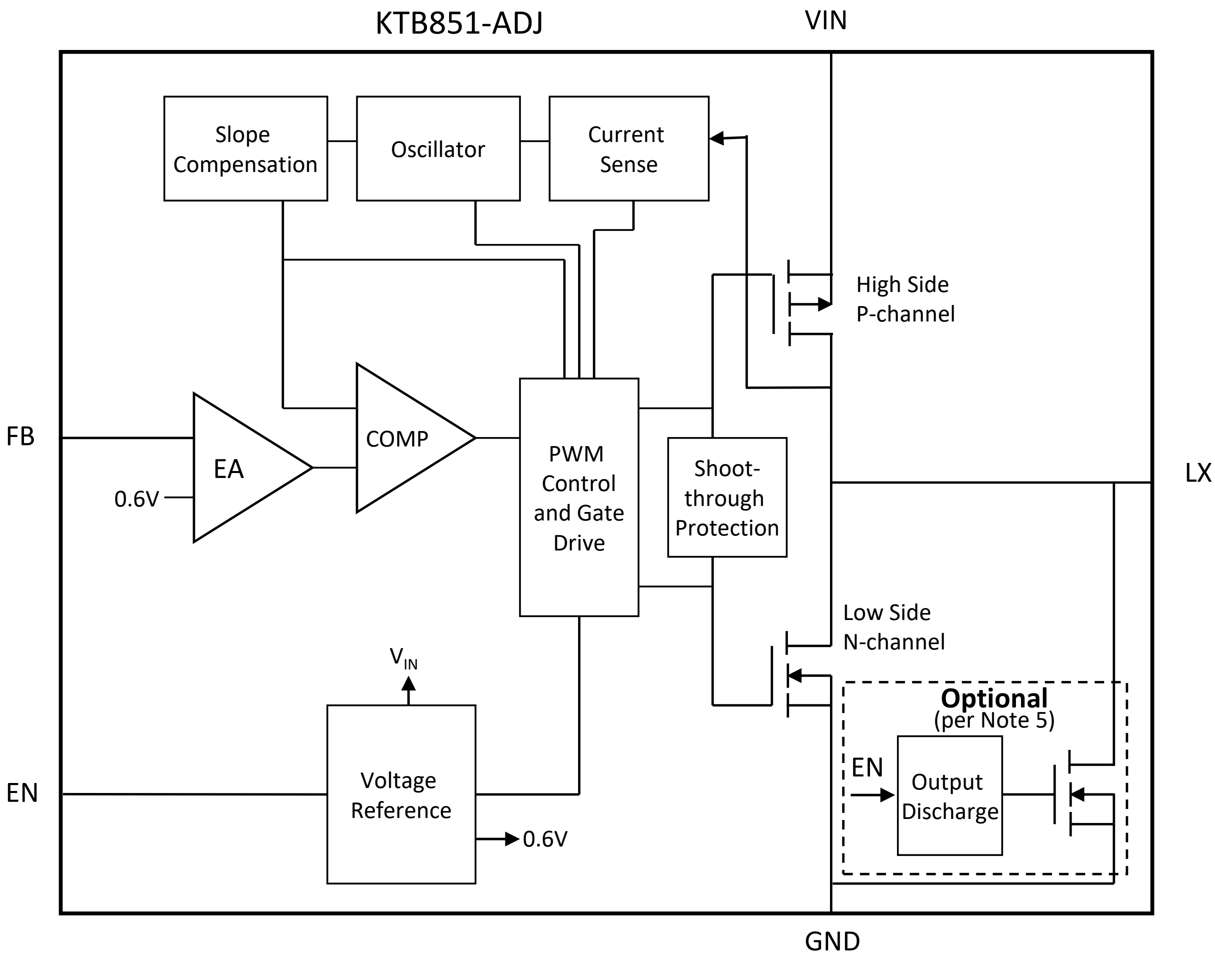
Line transient (10mA load)



Line transient 200mA load



Functional Block Diagram[5]



Functional Description

The KTB851 is a step-down converter, using constant frequency current-mode control. The 2.7V to 5.5V input operating range is ideal for both Li-Ion/Polymer powered devices and systems running from regulated 3.3V or 5V voltage rails. It can deliver up to 600mA with its integrated power MOSFETs. It uses high frequency 1.6MHz switching to allow the use of small external components, which makes it ideally suited for small form factor portable systems. Integrating very low $R_{DS(ON)}$ power MOSFETs enables power conversion efficiency up to 97%. Fixed and adjustable output options are available, providing the flexibility to deliver output voltages from 0.6V to V_{IN}. The KTB851 will operate with input voltages as low as 2.7V, however due to increased resistance of the power devices as the input voltage decreases, the maximum load current decreases. A feature provided in the KTB851 is 100% duty cycle operation, which allows the input voltage to decrease until the high side P-channel MOSFET no longer turns off at each oscillator cycle. Further decrease in the input voltage forces the high side MOSFET to remain turned on 100% of the time. At this point, the output voltage is determined by the input voltage minus the voltage drops across the high side MOSFET and the output inductor. The KTB851 is protected against short circuit conditions as well as IC over-temperature conditions. When the IC is disabled, the shutdown current decreases to less than 1µA.

5. The KTB851EVD-ADJ-TR ordering option does not have output auto discharge feature.

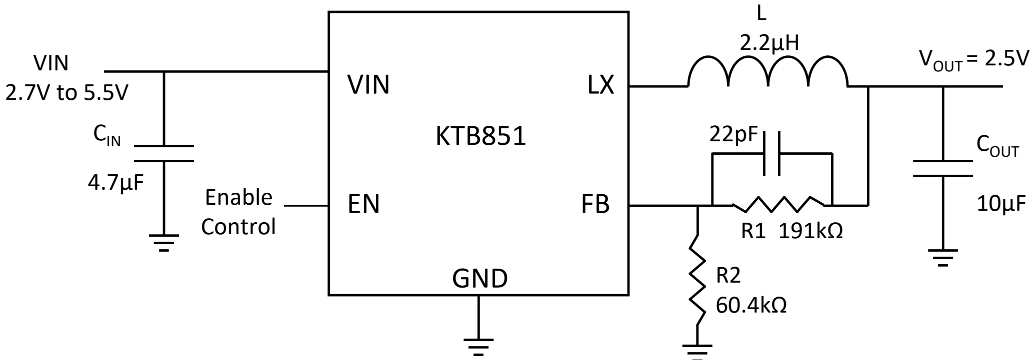


Figure 1. Typical Application Circuit – Adjustable Output Voltage

Control Loop Operation

The output voltage of KTB851 is regulated by modulating the pulse width of the high-side switch at a fixed frequency determined by the internal oscillator. The high-side switch is controlled by a flip-flop driven by the internal oscillator and a comparator that takes inputs from the error signal from an error amplifier with the sum of the sensed current signal and compensation ramp. The driver turns ON and OFF the high-side PMOS while the low-side NMOS transistor is turned OFF then ON; the switches are never turned ON at the same time in order to prevent a direct path from input to ground. Each new cycle starts with the high-side PMOS switch turning ON with the rising edge of the internal oscillator clock. The inductor current ramps up until the sum of the current sense signal and compensation ramp becomes higher than the error amplifier's voltage. Once this has occurred, the PWM comparator resets the flip-flop, the high-side switch is turned OFF while the low-side switch is turned ON. Due to the internal low-side switch, there is no need for an external Schottky diode. To avoid shoot-through current passing directly from input to ground in case the PMOS is not fully turned off before the NMOS is turned ON, a short amount of break-before-make time is factored into the gate drive circuitry.

Dropout Operation with 100% Duty Cycle

In order to operate with an input voltage close to the output voltage, the KTB851 allows the high-side PMOS switch to remain on for more than one cycle which will increase the converter duty cycle as the input voltage approaches the output voltage. When the duty cycle reaches 100%, the PMOS switch is turned on continuously to deliver current to the output. At this point, the output voltage is determined by the input voltage minus the cumulative voltage drop across the high-side PMOS switch and inductor.

Current Limit Protection

To protect the IC and the system, KTB851 limits the peak current through the main P-channel MOSFET switch. To minimize power dissipation and stresses under current limit and short-circuit conditions, the inductor switching current cannot exceed a fixed current limit. Once the current in the P-channel MOSFET reaches its current limit and the feedback FB pin voltage is below about 0.3V, the P-channel MOSFET is turned off and the N-channel MOSFET is turned on to discharge the current in the inductor. After some delay, the switching operation restarts automatically and P-channel current monitoring continues.

Application Information

Output Voltage Programming

The external resistor divider connected between the converter's output and FB pin of KTB851 sets the output voltage as shown in Figure 1. In order to limit the bias current required in the resistor divider while maintaining good noise immunity, the minimum suggested value for R2 is 40kΩ. A larger value resistor has the benefit of lower quiescent current; however, it increases the impedance of the IC's FB node, increasing the sensitivity to external noise. Selecting R2 of approximately 60kΩ will provide better transient response. R1 can be calculated by the following equation:

$$R1 = R2 \times \left(\frac{V_{OUT}}{0.6V} - 1 \right)$$

R1	R2	Output Voltage
60.4kΩ (1%)	60.4kΩ (1%)	1.2V
121kΩ (1%)	60.4kΩ (1%)	1.8V
191kΩ (1%)	60.4kΩ (1%)	2.5V
243kΩ (1%)	60.4kΩ (1%)	3.0V
274kΩ (1%)	60.4kΩ (1%)	3.3V

Capacitor Selection

Small size X5R or X7R ceramic capacitors are required. A 4.7μF or higher input capacitor is recommended to improve transient behavior of the regulator and EMI behavior of the total power supply circuit. The input capacitor should be placed as close as possible to the input VIN pin and the PGND pin of the KTB851.

The output capacitance depends on the maximum output current required. A 4.7μF or 10μF ceramic capacitor works well in most situations.

Inductor Selection

The KTB851 is designed to use a 2.2μH to 10μH inductor. To prevent core saturation, ensure that the inductor-saturation current rating exceeds the peak inductor current for the application. The worst-case peak inductor current can be calculated with the following formula:

$$I_{Peak(L)} = \frac{V_{OUT} \times I_{OUT(MAX)}}{\eta \times V_{IN(MIN)}} + \left[\frac{V_{OUT}}{2 \times L \times f_{SW}} \times \left(1 - \frac{V_{OUT}}{V_{IN}} \right) \right]$$

where η is the estimated efficiency.

The recommended inductor value depends on the output voltage VOUT setting. For most applications, a 2.2μH inductor is preferred. For higher output voltage setting above 2.8V, it is recommended to use a larger inductor value of 4.7μH.

VOUT Setting (V)	Inductor L (μH)
< 2.8V	2.2
2.8V or higher	4.7

If the inductor value is smaller, the inductor peak current will increase. To maintain stable operations for the buck converter, the inductor peak current must be less than both the KTB851 current limit threshold and the inductor saturation current rating. Manufacturer's specifications of inductors list both the inductor DC current rating, which is a thermal limitation, and peak inductor current rating, which is determined by the saturation characteristics. Measurements at full load and high ambient temperature should be performed to ensure that the inductor does not saturate or overheat due to its parasitic resistance. Bench measurements are recommended to confirm actual inductor peak current I_{PEAK} and to ensure that the inductor does not saturate at maximum output current.

Recommended Inductor Part Numbers

Inductor Part Number	Value (μH)	DCR (Ω)	Saturation Current (A)	Dimensions (mm)	Manufacturer
LPS3015-222ML	2.2	0.11 max	2.0	3 × 3 × 1.5	Coilcraft
LPS3015-472ML	4.7	0.20 max	1.3	3 × 3 × 1.5	Coilcraft
MIPS2520D2R2	2.0	0.11 typ	1.1	2.5 x 2 x 1	FDK

Layout Guidelines

Proper layout techniques are critical when implementing a high frequency DC-DC converter to minimize noise coupling between the converter and the system. Use short and wide traces in the main current path. Keep the same ground reference for input and output capacitors. A pulsating high-frequency current path includes the input capacitor Cin and the buck high-side and low-side internal FETs. Therefore the input capacitor should be located close to the VIN pin and PGND pin. Take care to isolate the feedback pin (FB) from the switching pin (LX) and the current path to guard against external noise coupling into the sensitive node. The resistor divider R2 ground terminal should be connected directly to the AGND pin. Add a feed-forward capacitor between the converter's output and KTB851's FB pin to improve stability and transient response. A four layer PCB with a ground plane and a power plane will help the converter's noise immunity and overall performance.

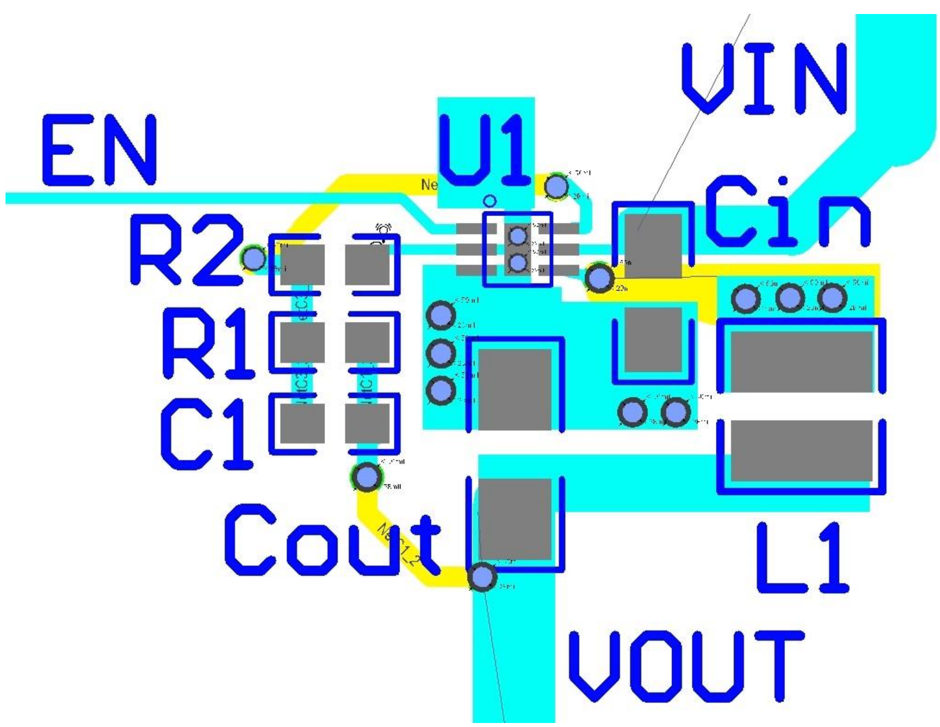
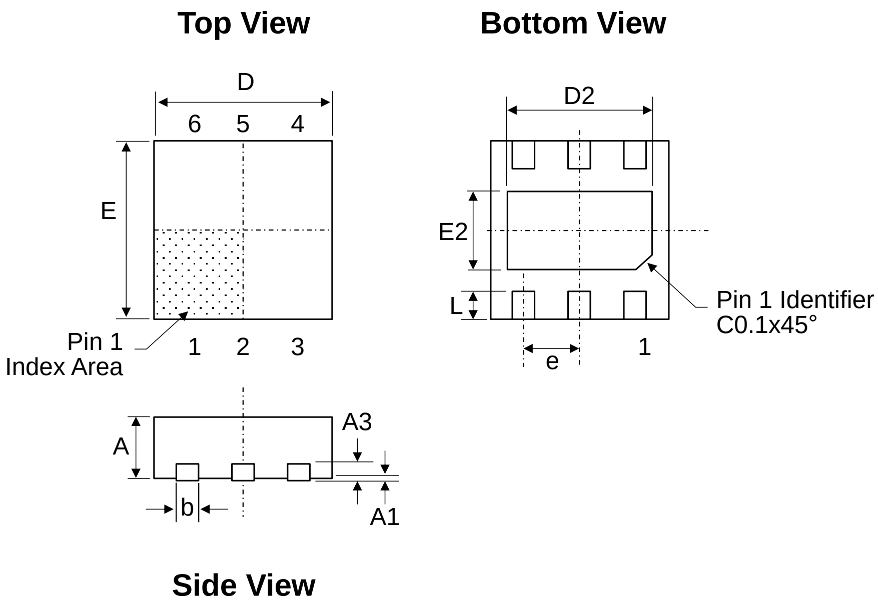


Figure 2. Recommended Layout for UDFN-6 Package

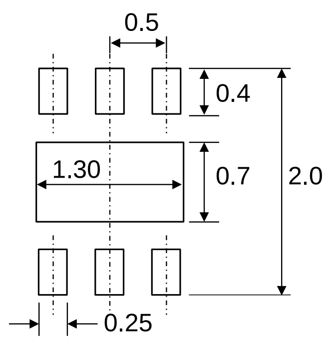
Packaging Information

UDFN1.6x1.6-6 (1.60mm x 1.60mm x 0.55mm)



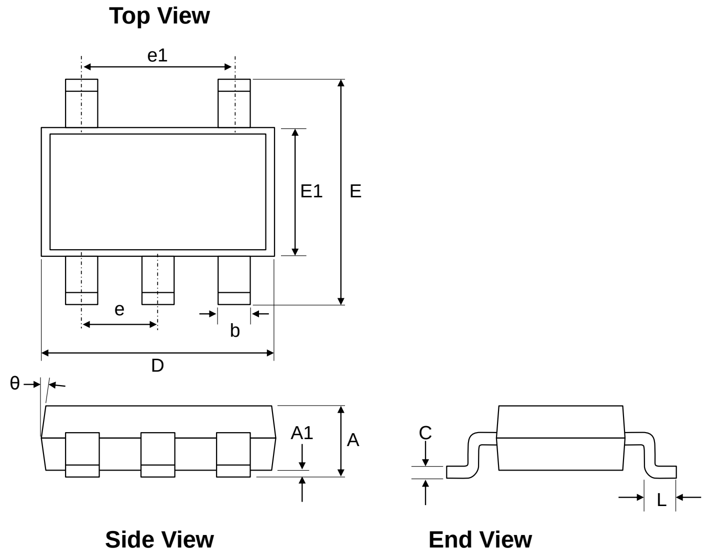
Dimension	mm		
	Min.	Typ.	Max.
A	0.50	0.55	0.60
A1	0.00	0.02	0.05
A3	0.152 REF.		
b	0.15	0.20	0.25
D	1.50	1.60	1.70
D2	1.25	1.30	1.35
E	1.50	1.60	1.70
E2	0.65	0.70	0.75
e	0.50 BSC		
L	0.20	0.25	0.30

Recommended Footprint



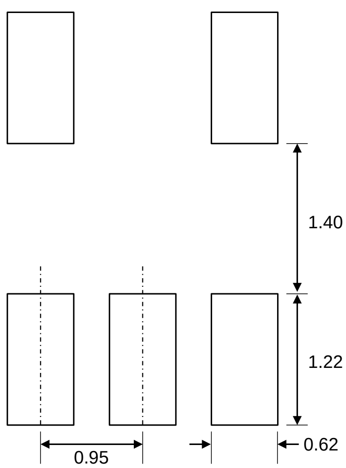
* Dimensions are in millimeters.

TSOT23-5



Dimension	mm		
	Min.	Typ.	Max.
A	0.70	0.80	0.90
A1	0.00	0.05	0.10
b	0.30	0.40	0.50
c	0.10	0.15	0.20
D	2.80	2.90	3.00
E	2.65	2.80	2.95
E1	1.50	1.60	1.70
e	0.95 BSC		
e1	1.9 BSC		
L	0.30		0.60
Θ	4°		8°

TSOT23-5 Recommended Footprint



* Dimensions are in millimeters.