High-PSRR, Low-Noise, 300mA CMOS Linear Regulator with 3 Types of Output Select

General Description

The EMP8731 features ultra-high power supply rejection ratio, low output voltage noise, low dropout voltage, low quiescent current and fast transient response. It guarantees delivery of 300mA output current and supports 3 types of output voltages via ADJ pin.

Based on its low quiescent current consumption and its less than 1μA shutdown mode of logical operation, the EMP8731 is ideal for battery-powered applications. The high power supply rejection ratio of the EMP8731 holds well for low input voltages typically encountered in battery-operated systems. The regulator is stable with small ceramic capacitive loads (2.2μF typical). The EMP8731 is available in miniature SOT-23-5 packages.

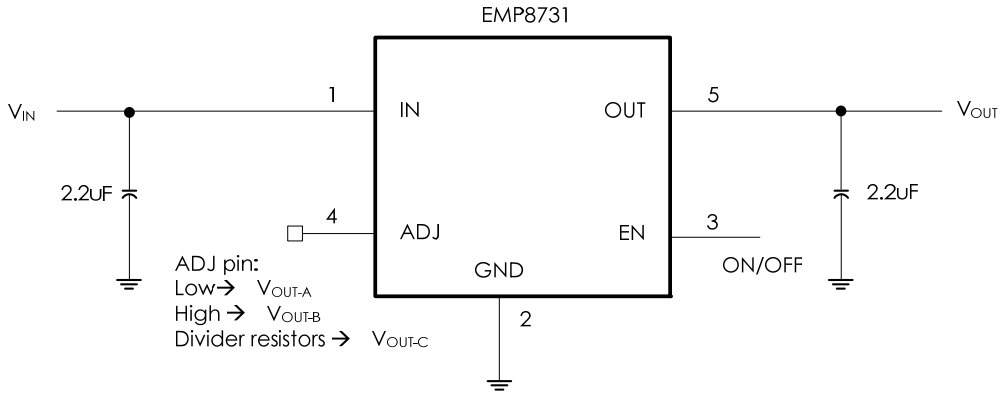
Applications

- Wireless handsets
- PCMCIA cards
- DSP core power
- Hand-held instruments
- Battery-powered systems
- Portable information appliances

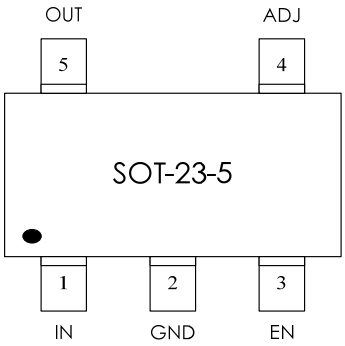
Features

- 300mA guaranteed output current
- 60dB typical PSRR at 1kHz
- 130μV (V_{OUT}=3.0V) RMS output voltage noise (10Hz to 100kHz)
- 264mV (V_{OUT}=2.8V) typical dropout at 300mA
- 60μA typical quiescent current
- Less than 1μA typical shutdown mode
- Fast line and load transient response
- 2.2V to 5.5V input range
- Auto-discharge during chip disable
- 60μs typical turn-on time
- Stable with small ceramic output capacitors
- Over temperature and over current protection
- ±2% output voltage tolerance

Typical Application



Connection Diagrams

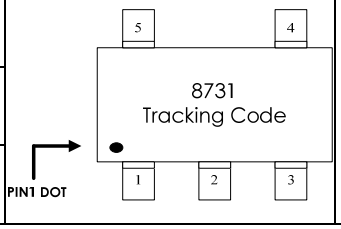


Order information

EMP8731-XXVF05NRR

XX	Output voltage control no.
VF05	SOT-23-5 Package
NRR	RoHS & Halogen free package Rating: -40 to 85°C Package in Tape & Reel

Order, Marking & Packing Information

Package	Vout-A	Vout-B	Product ID.	Marking	Packing
SOT-23-5	2.5V	3.0V	EMP8731-02VF05NRR		Tape & Reel 3Kpcs
	1.2V	3.3V	EMP8731-06VF05NRR		
	1.8V	2.8V	EMP8731-09VF05NRR		

Pin Functions

Name	SOT-23-5	Function
IN	1	**Supply Voltage Input**. Require a minimum input capacitor of close to 2.2μF to ensure stability and sufficient decoupling from the ground pin.
GND	2	**Ground Pin**.
EN	3	**Enable Input.** Enable the regulator by pulling the EN pin High. To keep the regulator on during normal operation, connect the EN pin to V_{IN}. The EN pin must not exceed V_{IN} under all operating conditions.
ADJ	4	**Adjustable Control.** Connecting to GND to get output Voltage-A, Connecting to V_{IN} to get output Voltage-B, Use external divider resistors to achieve desired output Voltage-C.
OUT	5	**Output Voltage Feedback**.

Functional Block Diagram

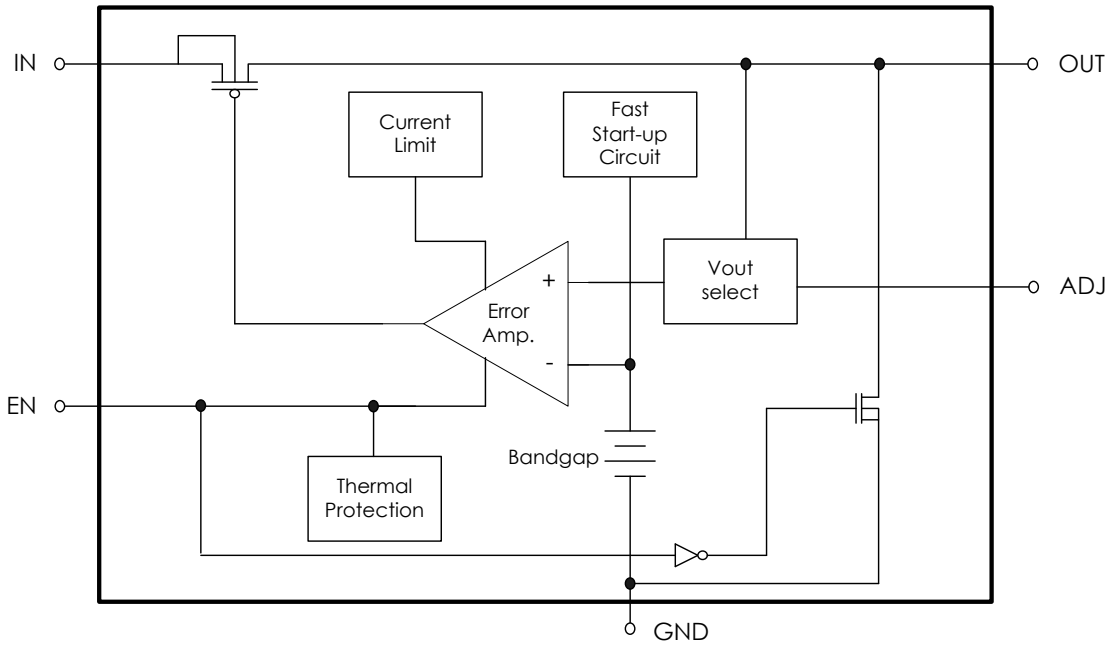


FIG.1. Functional Block Diagram of EMP8731

Absolute Maximum Ratings (Notes 1, 2)

IN, EN, ADJ	-0.3V to 6V	Junction Temperature (T_J)	150°C
OUT	1.0V to 4.5V	Lead Temperature (Soldering, 10 sec.)	260°C
Power Dissipation	(Note 8)	ESD Rating	
Storage Temperature Range	-65°C to 150°C	Human Body Model	2KV

Operating Ratings (Note 1, 2)

Supply Voltage	2.2V to 5.5V	Thermal Resistance (θ_{JA} , Note 3))	152°C/W (SOT-23-5)
Operating Temperature Range	-40°C to 85°C	Thermal Resistance (θ_{JC} , Note 4))	81°C/W (SOT-23-5)

Electrical Characteristics

Unless otherwise specified, all limits guaranteed for $V_{IN} = V_{OUT} + 1V$ (Note 5), $V_{EN}=V_{IN}$, $C_{IN} = C_{OUT} = 2.2\mu F$, $T_A = 25°C$.
Boldface limits apply for the operating temperature extremes: -40°C and 85°C.

Symbol	Parameter	Conditions	Min	Typ (Note. 9)	Max	Units
V_{IN}	Input Voltage		**2.2**		**5.5**	V
V_{OUT}	Output Voltage		**1.0**		**4.5**	V
ΔV_{OTL}	Output Voltage Tolerance (Note 5)	$V_{OUT} \geqq 1.8V$, I_{OUT} = 10mA	-2		+2	% of $V_{OUT (NOM)}$
			-3		**+3**	
		$V_{OUT} < 1.8V$, I_{OUT} = 10mA	-35		35	mV
			-50		**50**	
I_{OUT}	Maximum Output Current	Average DC Current Rating	**300**			mA
I_{LIMIT}	Output Current Limit		300	450		mA
I_Q	Supply Current	I_{OUT} = 0mA		60		μA
		I_{OUT} = 300mA		130		
	Shutdown Supply Current	V_{OUT} = 0V, EN = GND			1	
V_{DO}	Dropout Voltage(Note 6)	V_{OUT} = 3.0V, I_{OUT} = 100mA		100		
		V_{OUT} = 3.0V, I_{OUT} = 300mA		275		
ΔV_{OUT}	Line Regulation	I_{OUT} = 1mA, $(V_{OUT} + 1V) \leq V_{IN} \leq$ 5.5V (Note 5)	-0.1	0.01	0.1	%/V
	Load Regulation	$1mA \leq I_{OUT} \leq 300mA$		0.003		%/mA
e_n	Output Voltage Noise	V_{OUT} = 3.0V, I_{OUT} = 10mA, $10Hz \leq f \leq 100kHz$		130		μV_{RMS}
T_{SD}	Thermal Shutdown Temperature			165		℃
	Thermal Shutdown Hysteresis			30		
V_{EN}	EN Input Threshold	V_{IH}, $(V_{OUT} + 1V) \leq V_{IN} \leq 5.5V$ (Note 5)	**1.2**			V
		V_{IL}, $(V_{OUT} + 1V) \leq V_{IN} \leq 5.5V$ (Note 5)			**0.4**	
I_{EN}	EN Input Bias Current	EN = GND or V_{IN}		0.1	100	nA
T_{ON}	Turn-On Time	V_{OUT} at 95% of Final Value		60		μs
T_{OFF}	Turn-Off Time	I_{OUT} = 0mA (Note 7)		2.2		ms

Note 1: Absolute Maximum ratings indicate limits beyond which damage may occur. Electrical specifications do not apply when operating the device outside of its rated operating conditions.

Note 2: All voltages are with respect to the potential at the ground pin.

Note 3: θ_{JA} is measured in the natural convection at T_A=25℃ on a high effective thermal conductivity test board (2 layers, 2S0P).

Note 4: θ_{JC} represents the resistance to the heat flows the chip to package top case.

Note 5: Condition does not apply to input voltages below 2.2V since this is the minimum input operating voltage.

Note 6: Dropout voltage is measured by reducing V_{IN} until V_{OUT} drops 100mV from its nominal value at V_{IN} –V_{OUT} = 1V. Dropout voltage does not apply to the regulator versions with V_{OUT} less than 2.2V.

Note 7: Turn-off time is time measured between the enable input just decreasing below V_{IL} and the output voltage just decreasing to 10% of its nominal value.

Note 8: Maximum Power dissipation for the device is calculated using the following equations:

$$P_D = \frac{T_{J(MAX)} - T_A}{\theta_{JA}}$$

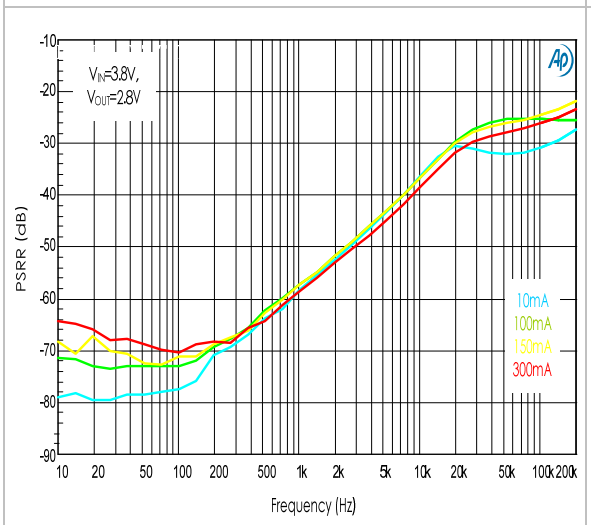
Where T_J(MAX) is the maximum junction temperature, T_A is the ambient temperature, and θ_{JA} is the junction-to-ambient thermal resistance. E.g. for the SOT-23-5 package θ_{JA} = 152°C/W, T_J (MAX) = 150°C and using T_A = 25°C, the maximum power dissipation is found to be 0.82W. The derating factor (-1/θ_{JA}) = -6.6mW/°C, thus below 25°C the power dissipation figure can be increased by 6.6mW per degree, and similarity decreased by this factor for temperatures above 25°C.

Note 9: Typical Values represent the most likely parametric norm

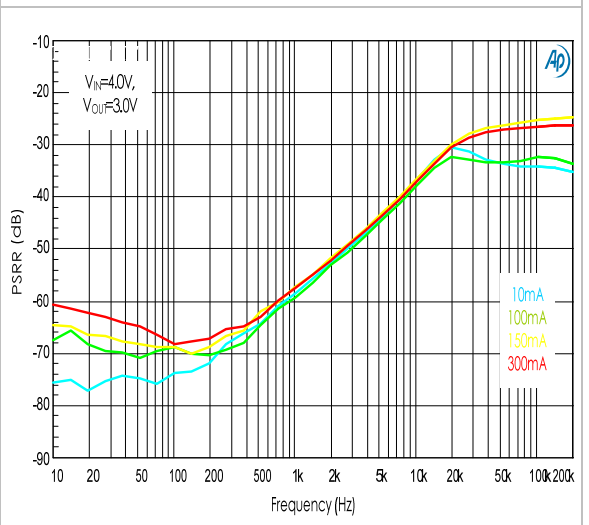
Typical Performance Characteristics

Unless otherwise specified, V_{IN} = $V_{OUT\ (NOM)}$ + 1V, V_{EN}=V_{IN}, C_{IN} = C_{OUT} = 2.2μF, T_A = 25°C

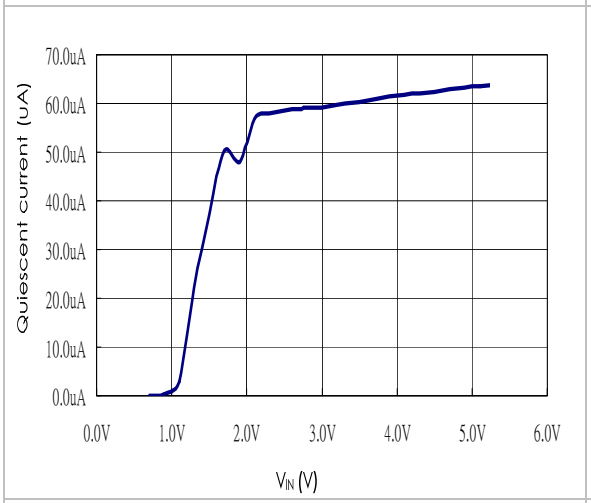
PSRR vs. Frequency (V_{OUT}=2.8V)



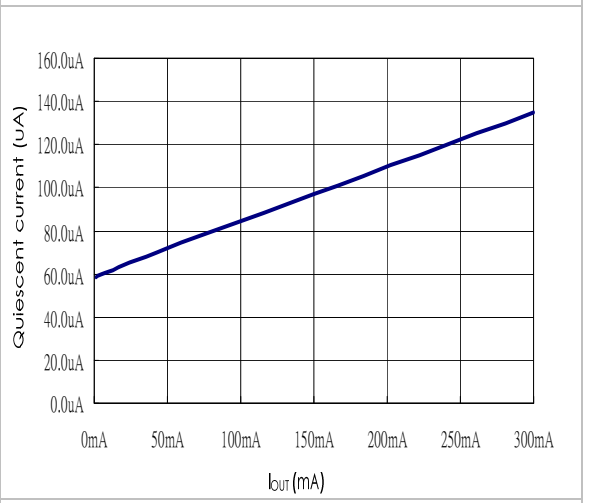
PSRR vs. Frequency (V_{OUT}=3.0V)



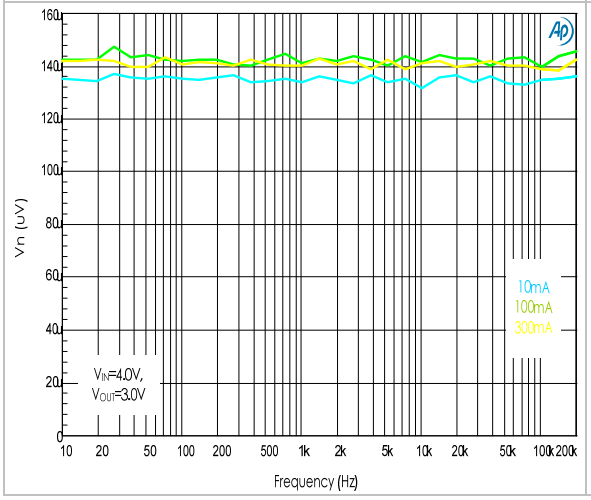
Creound Current vs. V_{IN} (V_{OUT}=1.8V)



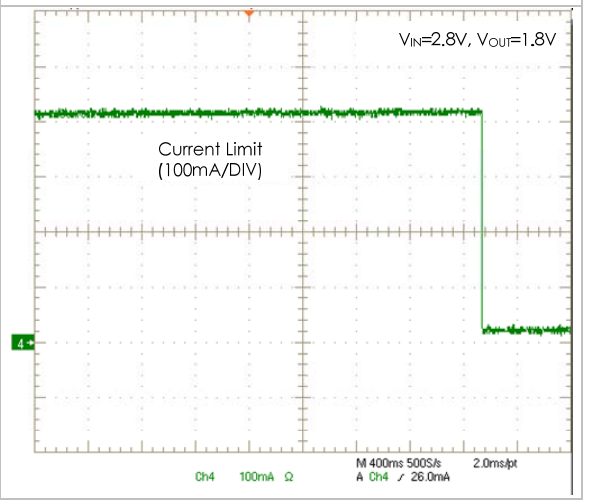
Ground Current vs. I_{OUT} (V_{OUT}=1.8V)



Output Voltage Noise



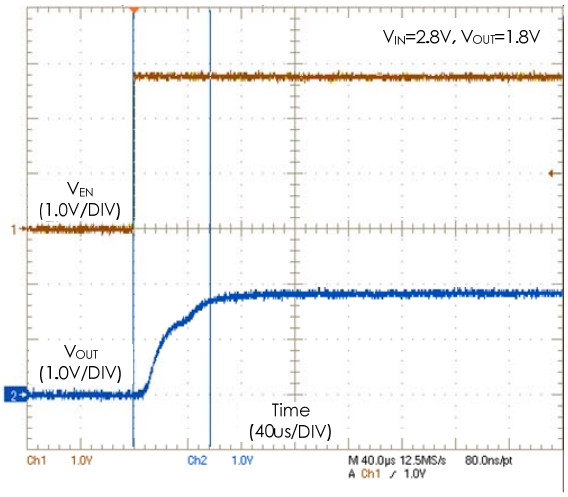
Output Current Limit



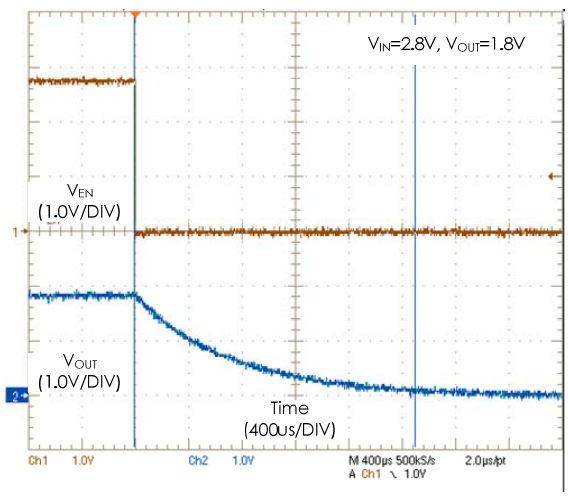
Typical Performance Characteristics (cont.)

Unless otherwise specified, V_{IN} = $V_{OUT\ (NOM)}$ + 1V, V_{EN}=V_{IN}, C_{IN} = C_{OUT} = 2.2µF, T_A = 25°C

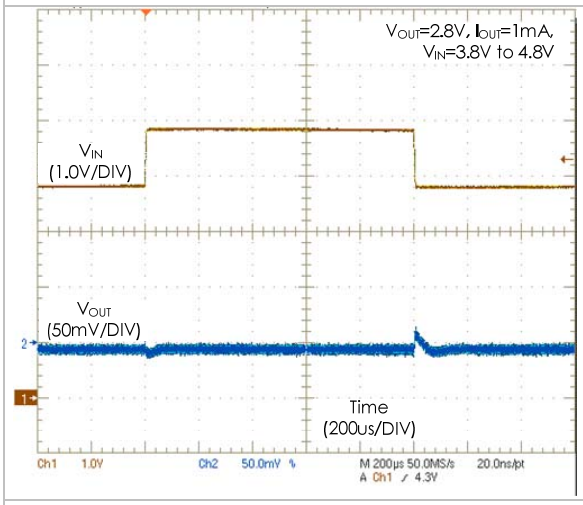
Enable Response



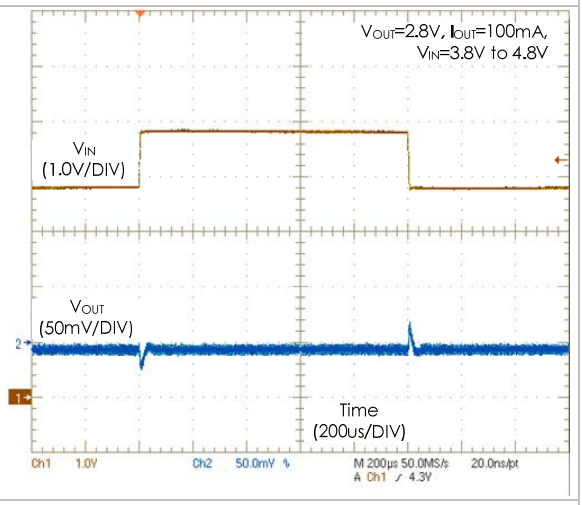
Disable Response



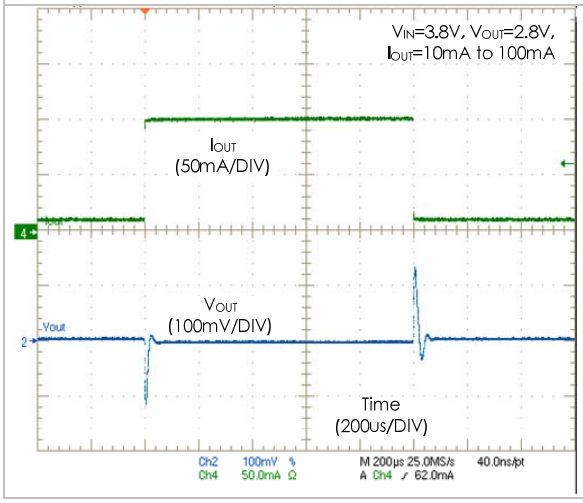
Line transient (Iout=1mA)



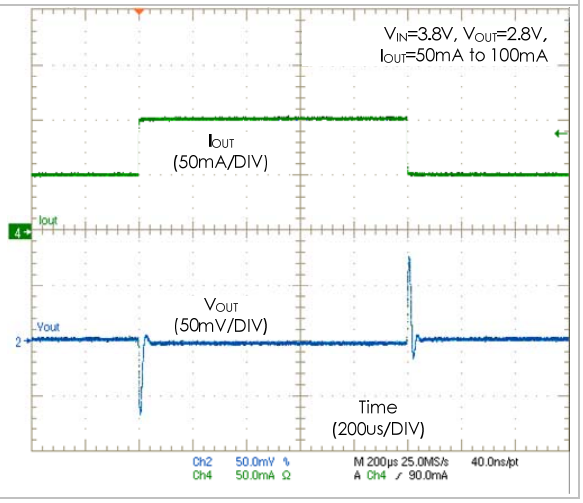
Line transient (Iout=100mA)



Load transient (V_{OUT}=2.8V, I_{OUT}=10mA to 100mA)



Load transient (V_{OUT}=2.8V, I_{OUT}=50mA to 100mA)



Application Information

General Description

Referring to Fig.1 as shown in the Functional Block Diagram section, the EMP8731 adopts the classical regulator topology in which negative feedback control is used to perform the desired voltage regulating function. The sub Vout-select form the feedback circuit which samples the output voltage for the error amplifier's non-inverting input. The inverting input is set to the bandgap reference voltage. Due to its high open-loop gain, the error amplifier ensures that the sampled output feedback voltage at its non-inverting input is virtually equal to the preset bandgap reference voltage. The error amplifier compares the voltage difference at its inputs and produces an appropriate driving voltage to the P-channel MOS pass transistor, which controls the amount of current reaching the output. If there are changes in the output voltage due to load changes, the feedback resistors register these changes to the non-inverting input of the error amplifier. The error amplifier then adjusts its driving voltage to maintain virtual short between its two input nodes under all loading conditions. The regulation of the output voltage is achieved as a direct result of the error amplifier keeping its input voltages equal. This negative feedback control topology is further augmented by the shutdown, the temperature and current protection circuitry.

Selecting the Output Voltage

V_{OUT} can be simply set to V_{OUT-A}/V_{OUT-B} by connecting ADJ pin to GND/V_{IN} via the internal resistors divider in the IC. EMP8731 provides adjusted output voltage function also via a resistor divider is connected to OUT, ADJ and GND. The V_{OUT} can be calculated by the following equation:

$R1 = R2\ [(V_{OUT} / V_{REF})-1]$ .....(1) (FIG.2)

Where V_{REF} = 0.746V and V_{OUT} is ranging from 1.0V to 4.5V, the recommended R2 is 240KΩ.

Output Capacitor

The EMP8731 is specially designed for use with ceramic output capacitors of as low as 2.2μF to take advantage of the savings in cost and space, as well as the superior filtering of high frequency noise. Capacitors of higher value or other types may be used, but it is important to make sure its equivalent series resistance (ESR) be restricted to less than 0.5Ω. The use of larger capacitors with smaller ESR values is desirable for applications involving large and fast input or output transients, as well as situations where the application systems are not physically located immediately adjacent to the battery power source. Typical ceramic capacitors suitable for use with the EMP8731 are X5R and X7R. The X5R and the X7R capacitors are able to maintain their capacitance values to within ±20% and ±10%, respectively, as the temperature increases.

No-Load Stability

The EMP8731 is capable of stable operation during no-load conditions, a mandatory feature for some applications such as CMOS RAM keep-alive operations.

Input Capacitor

A minimum input capacitance of 2.2μF is required for EMP8731. The capacitor value may be increased without limit. Improper workbench set-ups may have adverse effects on the normal operation of the regulator. A case in point is the instability that may result from long supply lead inductance coupling to the output through the gate capacitance of the pass transistor. This will establish a pseudo LCR network, and is likely to happen under high current conditions or near dropout. A 10μF tantalum input capacitor will dampen the parasitic LCR action thanks to its high ESR. However, cautions should be exercised to avoid regulator short-circuit damage when tantalum capacitors are used, for they are prone to fail in short-circuit operating conditions.

Power Dissipation and Thermal Shutdown

Thermal overload results from excessive power dissipation that causes the IC junction temperature to increase beyond a safe operating level. The EMP8731 relies on dedicated thermal shutdown circuitry to limit its total power dissipation. An IC junction temperature T_J exceeding 165°C will trigger the thermal shutdown logic, turning off the P-channel MOS pass transistor. The pass transistor turns on again after the junction cools off by about 30°C. When continuous thermal overload conditions persist, this thermal shutdown action then results in a pulsed waveform at the output of the regulator. The concept of thermal resistance θ_{JA} (°C/W) is often used to describe an IC junction's relative readiness in allowing its thermal energy to dissipate to its ambient air. An IC junction with a low thermal resistance is preferred because it is relatively effective in dissipating its thermal energy to its ambient, thus resulting in a relatively low and desirable junction temperature. The relationship between θ_{JA} and T_J is as follows:

$$T_J = \theta_{JA} \times (P_D) + T_A$$

T_A is the ambient temperature, and P_D is the power generated by the IC and can be written as:

$$P_D = I_{OUT} (V_{IN} - V_{OUT})$$

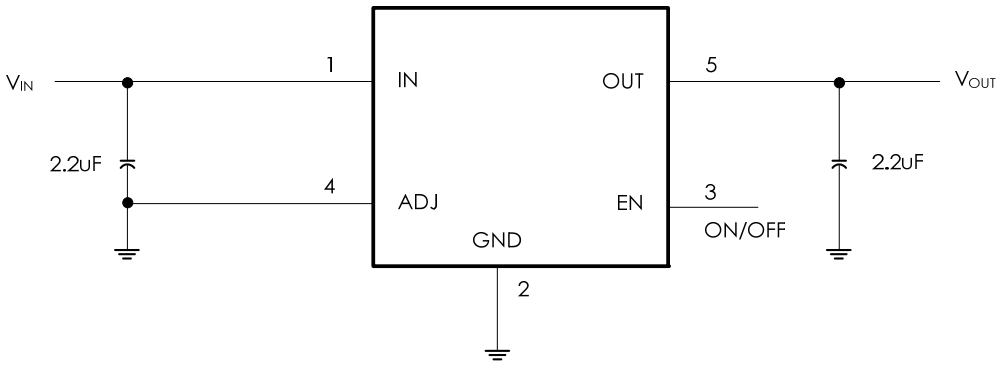
As the above equations show, it is desirable to work with Ics whose θ_{JA} values are small such that T_J does not increase strongly with P_D. To avoid thermally overloading the EMP8731, refrain from exceeding the absolute maximum junction temperature rating of 150°C under continuous operating conditions. Overstressing the regulator with high loading currents and elevated input-to-output differential voltages can increase the IC die temperature significantly.

Shutdown

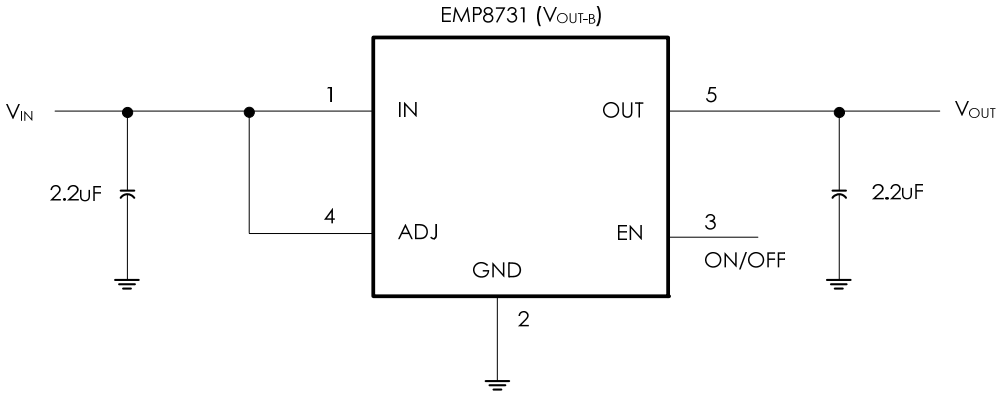
The EMP8731 enters sleep mode when the EN pin is low. When this occurs, the pass transistor, the error amplifier, and the biasing circuits, including the bandgap reference, are turned off, thus reducing the supply current to typically < 1uA. The low supply current makes the EMP8731 best suited for battery-powered applications. The maximum guaranteed voltage at the EN pin to enter sleep mode is 0.4V. A minimum guaranteed voltage of 1.2V at the EN pin will activate the EMP8731. To constantly keep the regulator on, direct connection of the EN pin to the VIN pin is allowed.

Application Examples

0. V_{OUT-A} output, ADJ pin connected to GND



(B) V_{OUT-B} output, ADJ pin connected to V_{IN}



© V_{OUT-C} output, ADJ pin connected to a divider resisters

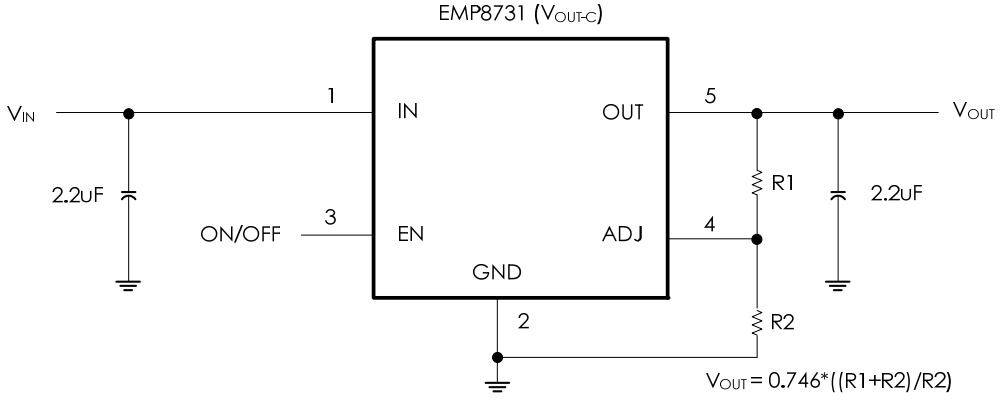
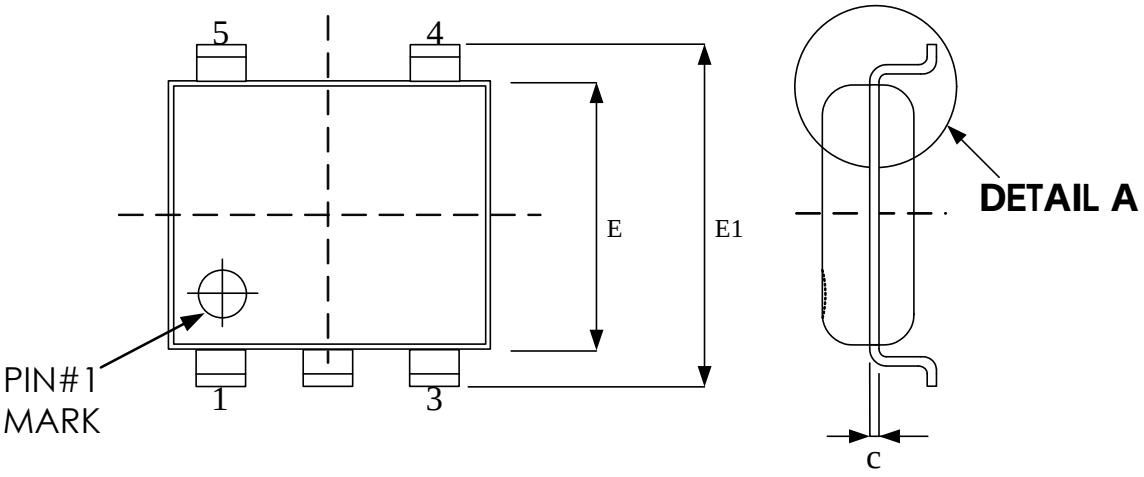
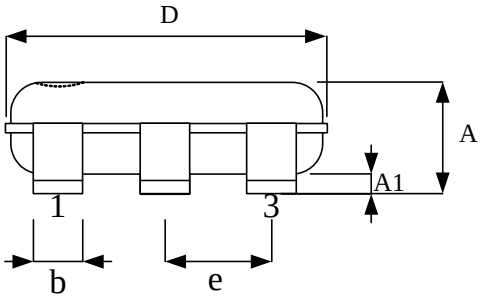


Fig.2 The application circuit of EMP8731

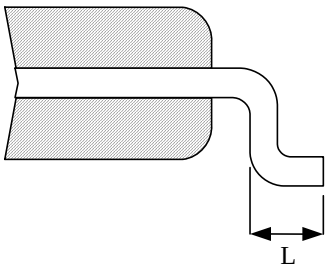
Package Outline Drawing
SOT-23-5



TOP VIEW



SIDE VIEW



DETAIL A

Symbol	Dimension in mm	
	Min.	Max.
A	0.90	1.45
A1	0.00	0.15
b	0.30	0.50
c	0.08	0.25
D	2.70	3.10
E	1.40	1.80
E1	2.60	3.00
e	0.95 BSC	
L	0.30	0.60

Revision History

Revision	Date	Description
0.1	2011.12.12	Original
0.2	2012.04.02	1. Revise output voltage tolerance spec for Vout<1.8V option (page 4) 2. Revise VDO typing error (page 4) 3. Revise package outline drawing (page 11)
0.3	2013.10.16	Modify package outline drawing

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