

# High Input Voltage, Low Quiescent Current, Low-Dropout Linear Regulator

## General Description

The EMP8040 is a high voltage, low quiescent current, low dropout regulator with 150mA output driving capacity. The EMP8040, which operates over an input range up to 40V, is stable with any capacitors, whose capacitance is larger than 1μF, and suitable for powering battery-management ICs because of the virtue of its low quiescent current consumption and low dropout voltage. EMP8040 also includes bandgap voltage reference, constant current limiting and thermal overload protection.

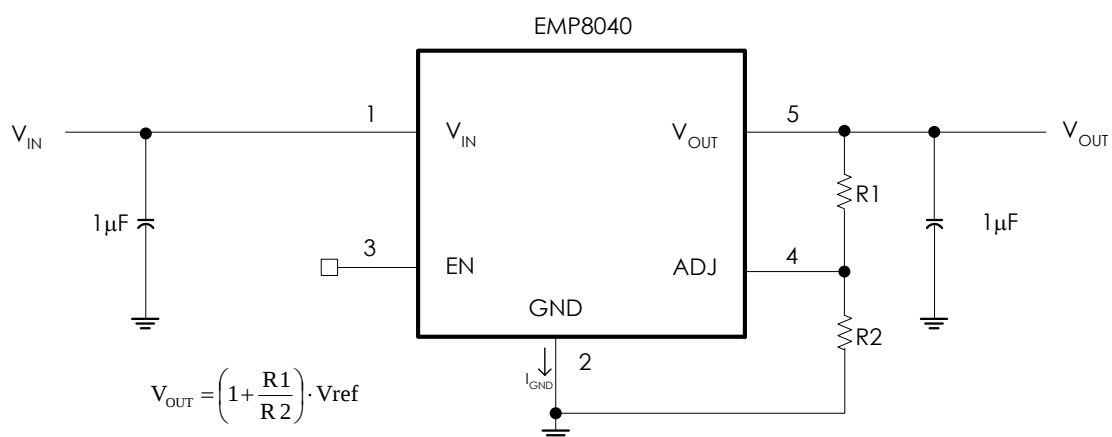
## Applications

- Logic Supply for High Voltage Batteries
- Keep-Alive Supply
- 3-4 Cell Li-ion Batteries Powered systems

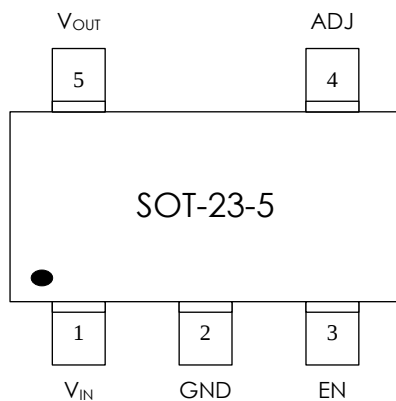
## Features

- 150mA output current driving capacity
- 780mV typical dropout at  $I_o=150\text{mA}$
- 10μA typical quiescent current
- 1μA typical shutdown mode
- Up to 40V input range
- Stable with small ceramic output capacitors (1μF)
- Over temperature and over current protection

## Typical Application



## Connection Diagrams



## Order information

### EMP8040B-XXVF05NRR

XX Output voltage

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 | Product ID.        | Marking | Packing              |
|----------|------|--------------------|---------|----------------------|
| SOT-23-5 | ADJ  | EMP8040B-00VF05NRR |         | Tape & Reel<br>3Kpcs |

## Pin Functions

| Name             | SOT-23-5 | Function                                                                                                                                                                                                                                              |
|------------------|----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| V <sub>IN</sub>  | 1        | <b>Supply Voltage Input</b><br>Require a minimum input capacitor of close to 1μF to ensure stability and sufficient decoupling from the ground pin.                                                                                                   |
| GND              | 2        | <b>Ground Pin</b>                                                                                                                                                                                                                                     |
| EN               | 3        | <b>Shutdown Input</b><br>Set the regulator into the disable mode by pulling the EN pin low. To keep the regulator on during normal operation, force this pin > 1V. Once the forcing voltage > 6V, there will be several micro-ampere leaking current. |
| ADJ              | 4        | <b>Adjust:</b><br>Feedback input. Connect to resistive voltage-divider network.                                                                                                                                                                       |
| V <sub>OUT</sub> | 5        | <b>Output Voltage</b>                                                                                                                                                                                                                                 |

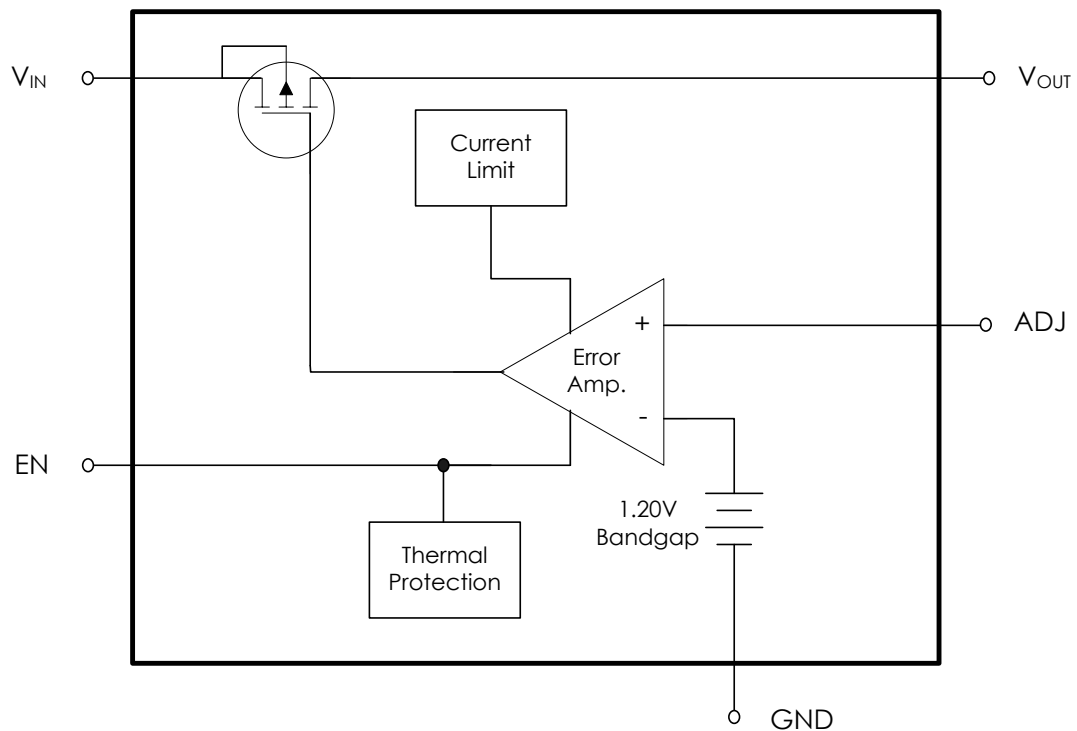
**Functional Block Diagram**

FIG.1. Functional Block Diagram of EMP8040

## Absolute Maximum Ratings (Notes 1, 2)

|                           |                |                                       |       |
|---------------------------|----------------|---------------------------------------|-------|
| $V_{IN}, EN$              | -0.3V to 42V   | Junction Temperature ( $T_J$ )        | 150°C |
| $V_{OUT}$                 | -0.3V to 13.2V | Lead Temperature (Soldering, 10 sec.) | 260°C |
| Power Dissipation         | (Note 3)       | ESD Rating                            |       |
| Storage Temperature Range | -65°C to 150°C | Human Body Model                      | 2KV   |

## Operating Ratings (Note 1, 2)

|                             |               |                                               |         |
|-----------------------------|---------------|-----------------------------------------------|---------|
| Supply Voltage              | 2.7V to 40V   | Thermal Resistance ( $\theta_{JA}$ )          |         |
| Operating Temperature Range | -40°C to 85°C | SOT-23-5                                      | 152°C/W |
|                             |               | Thermal Resistance ( $\theta_{JC}$ , Note 3)) |         |
|                             |               | SOT-23-5                                      | 81°C/W  |

## Electrical Characteristics

$T_A = 25^\circ\text{C}$ ,  $V_{OUT(NOM)} = 5V$ ; unless otherwise specified, all limits guaranteed for  $V_{IN} = V_{OUT} + 1V$ ,  $EN = 2V$ ,  $C_{IN} = C_{OUT} = 1\mu F$ .

| Symbol           | Parameter                                     | Conditions                                                       | Min   | Typ<br>(Note4) | Max   | Units               |
|------------------|-----------------------------------------------|------------------------------------------------------------------|-------|----------------|-------|---------------------|
| $\Delta V_{OTL}$ | Output Voltage Tolerance                      | $I_{OUT} = 10mA$<br>$V_{OUT(NOM)} + 1V \leq V_{IN} \leq 40V$     | -1    |                | +1    | % of $V_{OUT(NOM)}$ |
| $V_{ref}$        | Reference voltage                             |                                                                  | 1.188 | 1.200          | 1.212 | V                   |
| $I_{OUT}$        | Maximum Output Current                        | Average DC Current Rating                                        | 150   |                |       | mA                  |
| $I_{LIMIT}$      | Output Current Limit                          |                                                                  | 300   |                |       | mA                  |
| $I_Q$            | Supply Current                                | $I_{OUT} = 0.1mA$                                                |       | 10             | 30    | $\mu A$             |
|                  |                                               | $I_{OUT} = 100mA$                                                |       | 50             | 100   |                     |
|                  |                                               | $I_{OUT} = 150mA$                                                |       | 80             | 130   |                     |
|                  | Shutdown Supply Current                       | $V_{OUT} = 0V$ , $EN = GND$                                      |       | 1              | 5     |                     |
| $V_{DO}$         | Dropout Voltage<br>$V_{OUT} = 5.0V$ (Note. 5) | $I_{OUT} = 30mA$                                                 |       | 135            |       | mV                  |
|                  |                                               | $I_{OUT} = 100mA$                                                |       | 500            |       |                     |
|                  |                                               | $I_{OUT} = 150mA$                                                |       | 780            |       |                     |
| $\Delta V_{OUT}$ | Line Regulation                               | $I_{OUT} = 1mA$ , $(V_{OUT} + 1V) \leq V_{IN} \leq 40V$          |       | 0.1            |       | %                   |
|                  | Load Regulation                               | $0.1mA \leq I_{OUT} \leq 100mA$                                  |       | 0.5            |       | %                   |
| $e_n$            | Output Voltage Noise                          | $I_{OUT} = 10mA$ , $10Hz \leq f \leq 100kHz$<br>$V_{OUT} = 5.0V$ |       | 800            |       | $\mu V_{RMS}$       |
| $V_{EN}$         | EN Input Threshold                            | $V_{IH}$ , $(V_{OUT} + 1V) \leq V_{IN} \leq 40V$                 | 1.0   |                |       | V                   |
|                  |                                               | $V_{IL}$ , $(V_{OUT} + 1V) \leq V_{IN} \leq 40V$                 |       |                | 0.3   |                     |
| $I_{EN}$         | EN Input Bias Current                         | $EN = GND$ or $V_{IN} (V_{IN} < 6V)$                             |       | 0.1            |       | $\mu A$             |
|                  |                                               | $EN = V_{IN} (40V > V_{IN} > 6V)$                                |       |                | 35    |                     |
| $T_{SD}$         | Thermal Shutdown Temperature                  |                                                                  |       | 160            |       | $^\circ C$          |
|                  | Thermal Shutdown Hysteresis                   |                                                                  |       | 30             |       |                     |
| $t_{ON}$         | Start-Up Time                                 | $C_{OUT} = 1.0\mu F$ , $V_{OUT}$ at 90% of Final Value           |       | 500            |       | $\mu s$             |

**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:** 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  $\theta_{JA}$  is the junction-to-ambient thermal resistance. E.g. for the SOT-23-5 package  $\theta_{JA} = 152^{\circ}\text{C}/\text{W}$ ,  $T_{J(MAX)} = 150^{\circ}\text{C}$  and using  $T_A = 25^{\circ}\text{C}$ , the maximum power dissipation is found to be 822mW. The derating factor ( $-1/\theta_{JA}$ ) =  $-6.57\text{mW}/^{\circ}\text{C}$ , thus below  $25^{\circ}\text{C}$  the power dissipation figure can be increased by 6.57mW per degree, and similarly decreased by this factor for temperatures above  $25^{\circ}\text{C}$ .

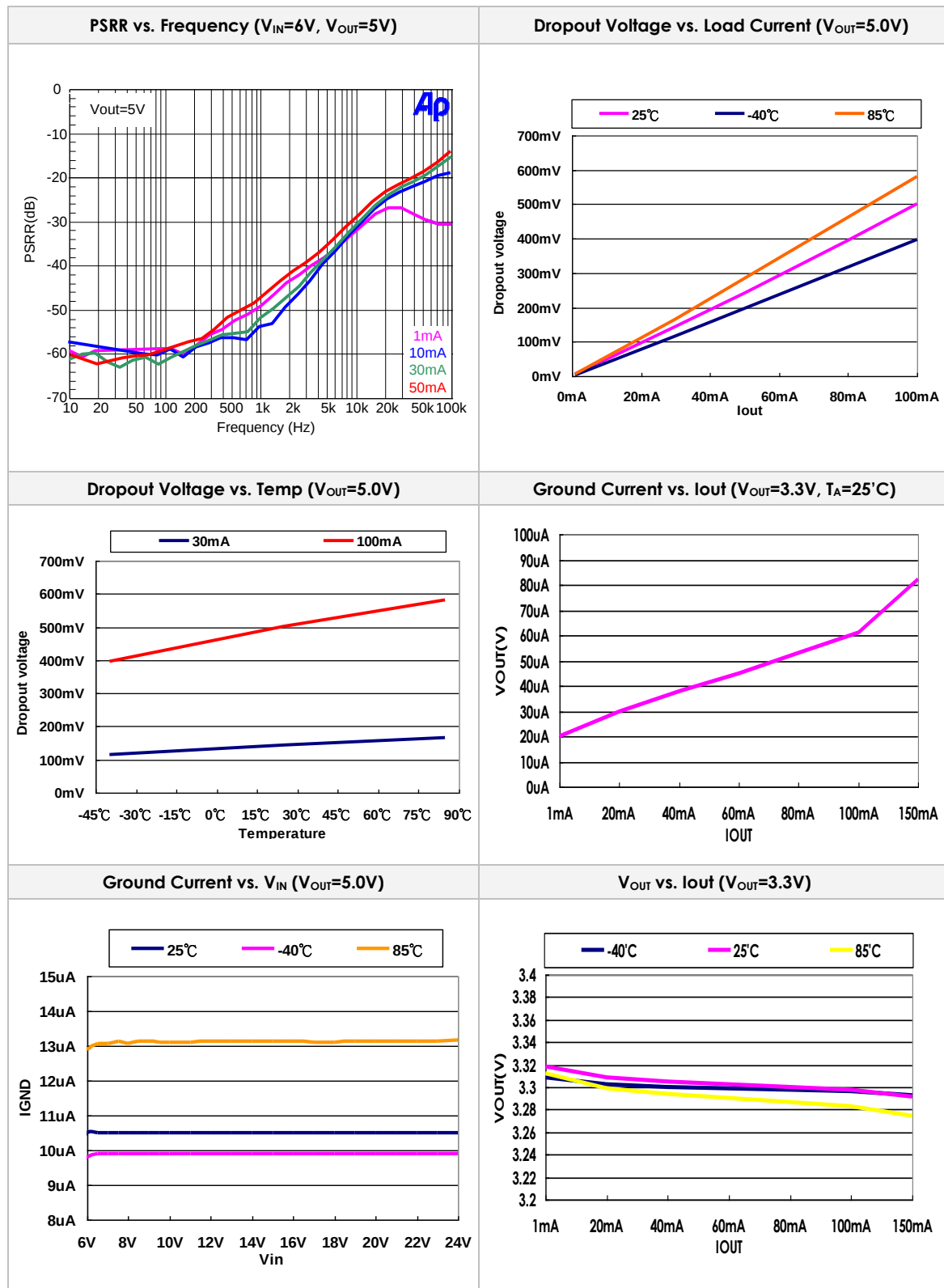
- $\theta_{JC}$  represents the resistance between the chip and the top of the package case.

**Note 4:** Typical Values represent the most likely parametric norm

**Note 5:** Dropout voltage is measured by reducing  $V_{IN}$  until  $V_{OUT}$  drops to 98% its nominal value.

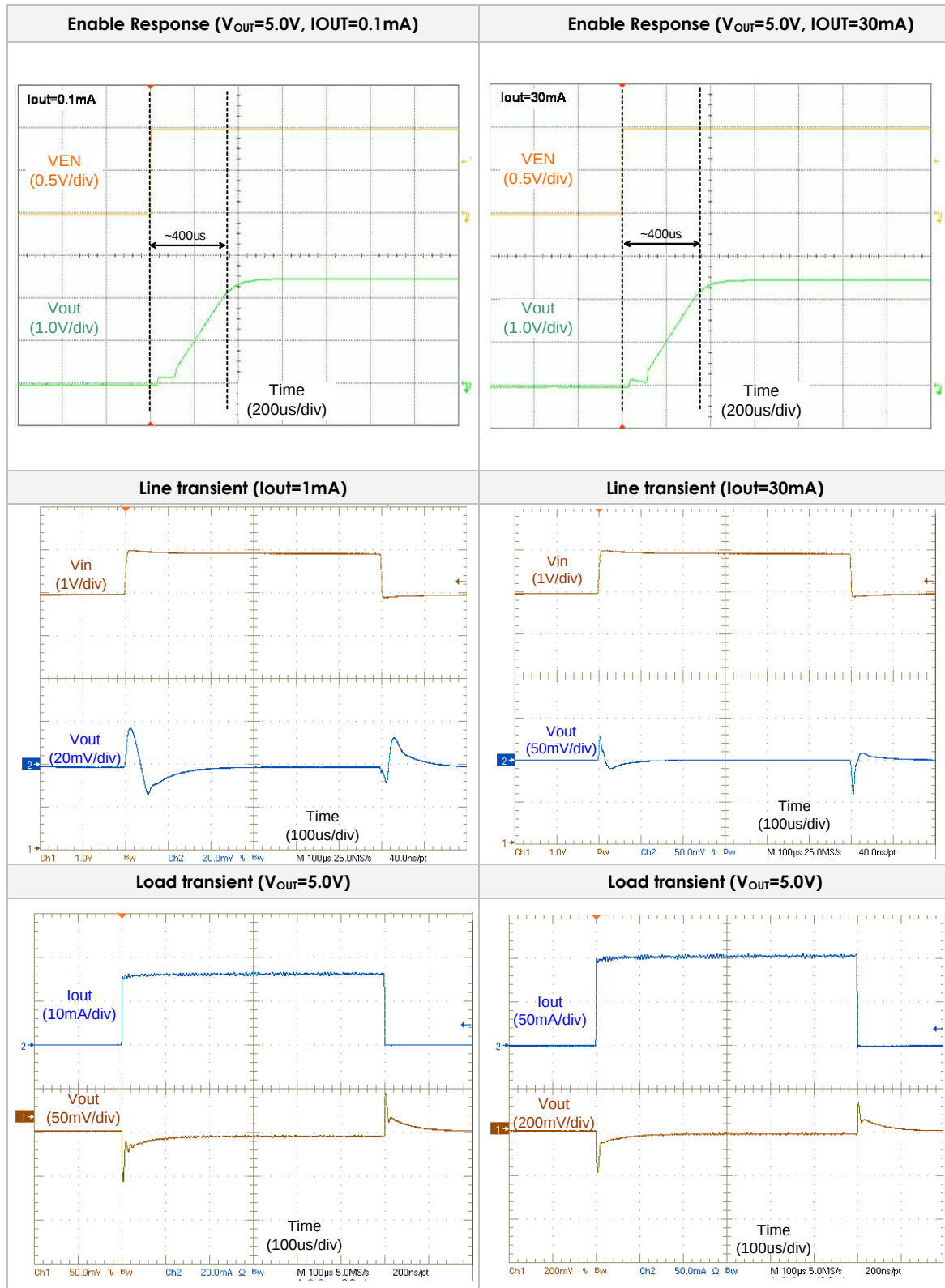
## Typical Performance Characteristics

Unless otherwise specified,  $V_{IN} = V_{OUT(NOM)} + 1V$ ,  $V_{OUT}=5V$ ,  $C_{IN} = C_{OUT} = 1.0\mu F$ ,  $T_A = 25^\circ C$ ,  $EN = 2V$



## Typical Performance Characteristics (cont.)

Unless otherwise specified,  $V_{IN} = V_{OUT(NOM)} + 1V$ ,  $V_{OUT}=5V$ ,  $C_{IN} = C_{OUT} = 1.0\mu F$ ,  $T_A = 25^\circ C$ ,  $EN = 2V$



## Application Information

### General Description

Referring to Fig.1 as shown in the Functional Block Diagram section, the EMP8040 adopts the classical regulator topology in which negative feedback control is used to perform the desired voltage regulating function. The negative feedback is formed by using feedback resistors (R1, R2) to sample the output voltage for the non-inverting input of the error amplifier, whose inverting input is set to the bandgap reference voltage. By the virtue of its high open-loop gain, the error amplifier operates to ensure 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 to control the amount of current reaching the output. If there are changes in the output voltage due to load changes, the feedback resistors register such 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. In a nutshell, 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 fault detection, and the temperature and current protection circuitry.

### Output Voltage Setting

The output voltage of EMP8040 can be adjusted by a resistive divider according to the following formula:

$$V_{OUT} = V_{REF} * \left(1 + \frac{R_1}{R_2}\right) = 1.2 * \left(1 + \frac{R_1}{R_2}\right)$$

The resistive divider senses the fraction of the output voltage as shown in page 1 typical application circuit. The recommended value for R2 is in the range of 200K~500KΩ.

### Output Capacitor

The EMP8040 is specially designed for use with ceramic output capacitors of as low as 1.0μF 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) is 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 for situations where the application systems are not physically located immediately adjacent to the battery power source. Typical ceramic capacitors suitable for use with the EMP8040 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 EMP8040 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 1 $\mu$ F is required for EMP8040. 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 10 $\mu$ F 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 EMP8040 relies on dedicated thermal shutdown circuitry to limit its total power dissipation. An IC junction temperature  $T_J$  exceeding 150°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  $\theta_{JA}$  (°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  $\theta_{JA}$  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:

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

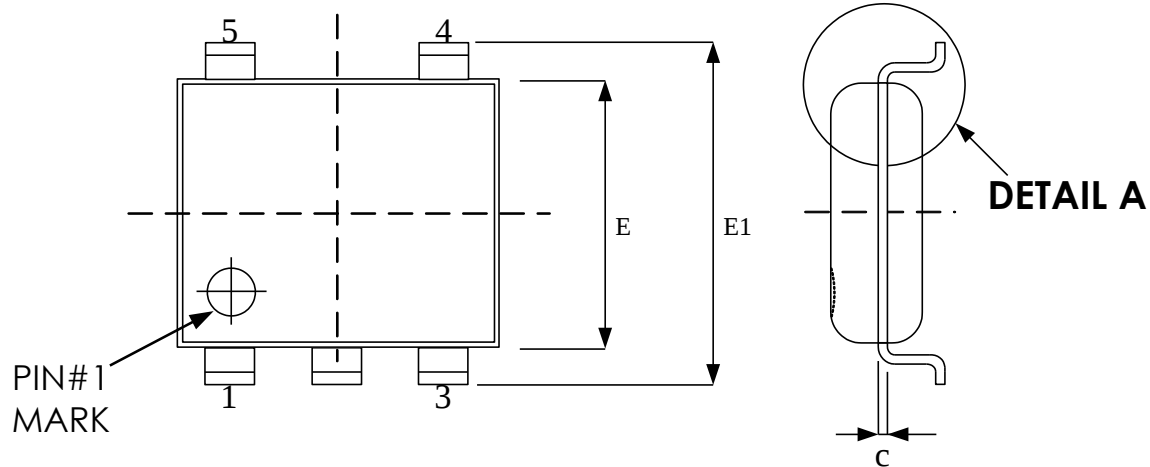
As the above equations show, it is desirable to work with ICs whose  $\theta_{JA}$  values are small such that  $T_J$  does not increase strongly with  $P_D$ . To avoid thermally overloading the EMP8040, refrain from exceeding the absolute maximum junction temperature rating of 150°C under continuous operating conditions. Overstressing the regulator with high loading currents and elevated input-to-output differential voltages can increase the IC die temperature significantly.

**Shutdown**

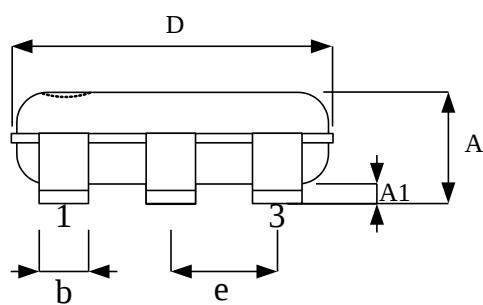
The EMP8040 enters the sleep mode when the EN pin is low. When this occurs, the pass transistor, the error amplifier, and the biasing circuits, including the bandgap reference, are turned off, thus reducing the supply current to typically 1 $\mu$ A. Such a low supply current makes the EMP8040 best suited for battery-powered applications. The maximum guaranteed voltage at the EN pin for the sleep mode to take effect is 0.3V. A minimum guaranteed voltage of 1.0V at the EN pin will activate the EMP8040. Direct connection of the EN pin to the  $V_{IN}$  to keep the regulator on is allowed for the EMP8040, but there will be several micro-ampere leaking current for  $V_{IN}$  to GND when  $V_{IN} > 6V$ .



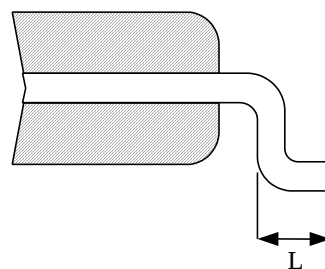
## Package Outline Drawing SOT-23-5



### 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      | 2011.01.06 | Original                                                                                                                                                                                                                                                                                 |
| 1.0      | 2011.02.23 | 1. Skip "Preliminary"<br>2. Revise page3 "FIG.1"<br>3. Revise page4 "Electrical Characteristics"                                                                                                                                                                                         |
| 1.1      | 2011.12.13 | 1) Modified 100mA output driving capacity to 150mA.<br>2) Modified the output voltage accuracy is based on I <sub>out</sub> =10mA this condition.<br>3) Added I <sub>out</sub> =150mA spec. into electrical characteristics table.<br>4) Updated the OT temperature from 150'C to 160'C. |
| 1.2      | 2012.03.29 | 1) Modified the operating voltage from 36V to 40V.<br>2) Modified the absolute maximum ratings V <sub>IN</sub> , EN from 40V to 42V.<br>3) Updated the package outline drawing.                                                                                                          |
| 1.3      | 2013.10.17 | Modify package outline drawing                                                                                                                                                                                                                                                           |
| 1.4      | 2017.06.26 | Added EMP8040B series product                                                                                                                                                                                                                                                            |
| 1.5      | 2018.05.18 | Added output voltage setting information.                                                                                                                                                                                                                                                |
| 1.6      | 2022.01.25 | Delete EMP8040 series product                                                                                                                                                                                                                                                            |

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