# For Automotive 45 V 500 mA Fixed / Adjustable Output LDO Regulators

## BD6xxM5-C Series

### General Description

The BD6xxM5-C series is a low-current consumption regulator product designed with an absolute maximum voltage of up to 45 V, a very high output voltage accuracy of ±2.0 %, an output current of up to 500 mA, and a low current consumption of 25 µA. The output voltage line-up are fixed type 3.3 V, 5.0 V, and adjustable output voltage type. The Adjustable output voltage type can be adjusted between 1.5 V, and 26 V by an external resistive divider connected to the ADJ pin. These products are designed for power supplies in various automotive applications requiring a direct battery connection.
There is an output shutdown function, where the output of the device is “ON” when a logical “HIGH” is applied to the EN pin, and the output of the device is “OFF” when a logical “LOW” is applied to the EN pin. Furthermore, ceramic capacitors can be sufficiently used for the phase compensation.
The device features an integrated Over Current Protection to protect the device from a damage caused by short circuits or overload, and an integrated Thermal Shutdown Protection to avoid damage by overheating.

### Key Specifications

- Wide Temperature Range (Tj): -40 °C to +150 °C
- Wide Operating Input Range: 3 V to 42 V
- Output Voltage: 3.3 V / 5.0 V / Adjustable
- Low Current Consumption*(Note 1)*: 25 µA (Typ)
- Output Current Capability: 500 mA
- Output Voltage Accuracy*(Note 2)*: ±2.0 %

*(Note 1)* It does not contain the current of external feedback resistance.
*(Note 2)* The effect of external feedback resistor is not included.

### Features

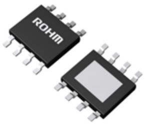
- AEC-Q100 Qualified*(Note 3)*
- Functional Safety Supportive Automotive Products
- Output Shutdown Function (Applicable only product)
- Over Current Protection (OCP)
- Thermal Shutdown Protection (TSD)

*(Note 3)* Grade 1

### Packages

**W (Typ) x D (Typ) x H (Max)**

- HTSOP-J8 — 4.9 mm × 6.0 mm × 1.0 mm




### Applications

- Automotive (Power Train, Body ECU)
- Car Infotainment System, etc.
- Also General Consumer, Industrial Equipment, etc.

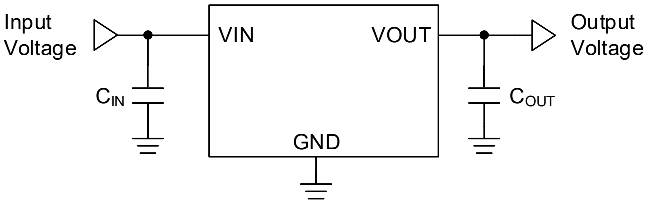
○Product structure : Silicon integrated circuit ○This product has no designed protection against radioactive rays.

## Typical Application Circuits1 (Output voltage fixed type)

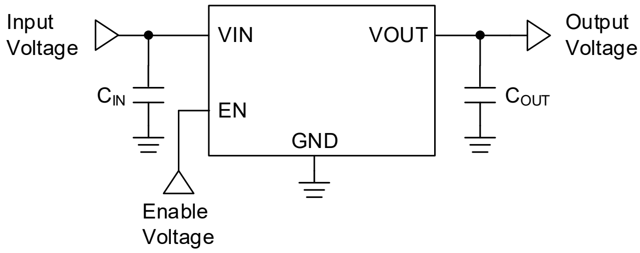
Components Externally Connected

Capacitor: 0.1 µF ≤ $C_{IN}$ (Min), 0.6 µF ≤ $C_{OUT}$ (Min)*(Note 1)*

*(Note 1)* Electrolytic capacitors, tantalum capacitors and ceramic capacitors can be used.




Applicable for products without Output Shutdown Function




Applicable for products with Output Shutdown Function

## Typical Application Circuits2 (Output voltage adjustable type)

Components Externally Connected

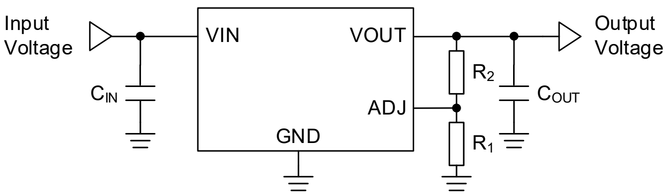
Capacitor: 0.1 µF ≤ $C_{IN}$ (Min), 0.6 µF ≤ $C_{OUT}$ (Min)*(Note 2)*

Resistor: 5 kΩ ≤ $R_1$ ≤ 200 kΩ*(Note 3)*

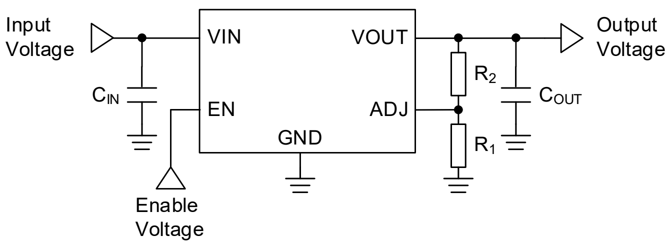
$V_{ADJ}$ (Typ): 1.230 V

$$V_{OUT} = V_{ADJ} \times \left(1 + \frac{R_2}{R_1}\right) + (I_{ADJ} \times R_2)$$

*(Note 2)* Electrolytic capacitors, tantalum capacitors and ceramic capacitors can be used.
*(Note 3)* The value of a feedback resistor $R_1$ must be within this range.
$R_2$ value is defined by following the formula using the limitation of $R_1$.
Error occurs due to the resistance value used and the ADJ pin input current.



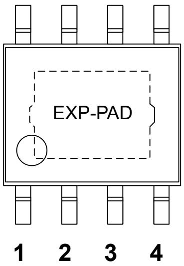

Applicable for products without Output Shutdown Function




Applicable for products with Output Shutdown Function

# Contents

## Pin Configurations




■BD633 / 650M5EFJ-C (HTSOP-J8)

| Pin No. | Pin Name | Function |
|---|---|---|
| 1 | VOUT | Output Voltage Pin |
| 2 | N.C. | Non-Connected Pin*(Note 1)* |
| 3 | N.C. | Non-Connected Pin*(Note 1)* |
| 4 | N.C. | Non-Connected Pin*(Note 1)* |
| 5 | GND | Ground Pin |
| 6 | N.C. | Non-Connected Pin*(Note 1)* |
| 7 | N.C. | Non-Connected Pin*(Note 1)* |
| 8 | VIN | Input Supply Voltage Pin |
| - | EXP-PAD | Heat Dissipation*(Note 2)* |

■BD633 / 650M5WEFJ-C (HTSOP-J8)

| Pin No. | Pin Name | Function |
|---|---|---|
| 1 | VOUT | Output Voltage Pin |
| 2 | N.C. | Non-Connected Pin*(Note 1)* |
| 3 | N.C. | Non-Connected Pin*(Note 1)* |
| 4 | N.C. | Non-Connected Pin*(Note 1)* |
| 5 | GND | Ground Pin |
| 6 | N.C. | Non-Connected Pin*(Note 1)* |
| 7 | EN | Control Output ON / OFF Pin |
| 8 | VIN | Input Supply Voltage Pin |
| - | EXP-PAD | Heat Dissipation*(Note 2)* |

■BD600M5EFJ-C (HTSOP-J8)

| Pin No. | Pin Name | Function |
|---|---|---|
| 1 | VOUT | Output Voltage Pin |
| 2 | ADJ | Adjustment Pin For Output Voltage |
| 3 | N.C. | Non-Connected Pin*(Note 1)* |
| 4 | N.C. | Non-Connected Pin*(Note 1)* |
| 5 | GND | Ground Pin |
| 6 | N.C. | Non-Connected Pin*(Note 1)* |
| 7 | N.C. | Non-Connected Pin*(Note 1)* |
| 8 | VIN | Input Supply Voltage Pin |
| - | EXP-PAD | Heat Dissipation*(Note 2)* |

■BD600M5WEFJ-C (HTSOP-J8)

| Pin No. | Pin Name | Function |
|---|---|---|
| 1 | VOUT | Output Voltage Pin |
| 2 | ADJ | Adjustment Pin For Output Voltage |
| 3 | N.C. | Non-Connected Pin*(Note 1)* |
| 4 | N.C. | Non-Connected Pin*(Note 1)* |
| 5 | GND | Ground Pin |
| 6 | N.C. | Non-Connected Pin*(Note 1)* |
| 7 | EN | Control Output ON / OFF Pin |
| 8 | VIN | Input Supply Voltage Pin |
| - | EXP-PAD | Heat Dissipation*(Note 2)* |

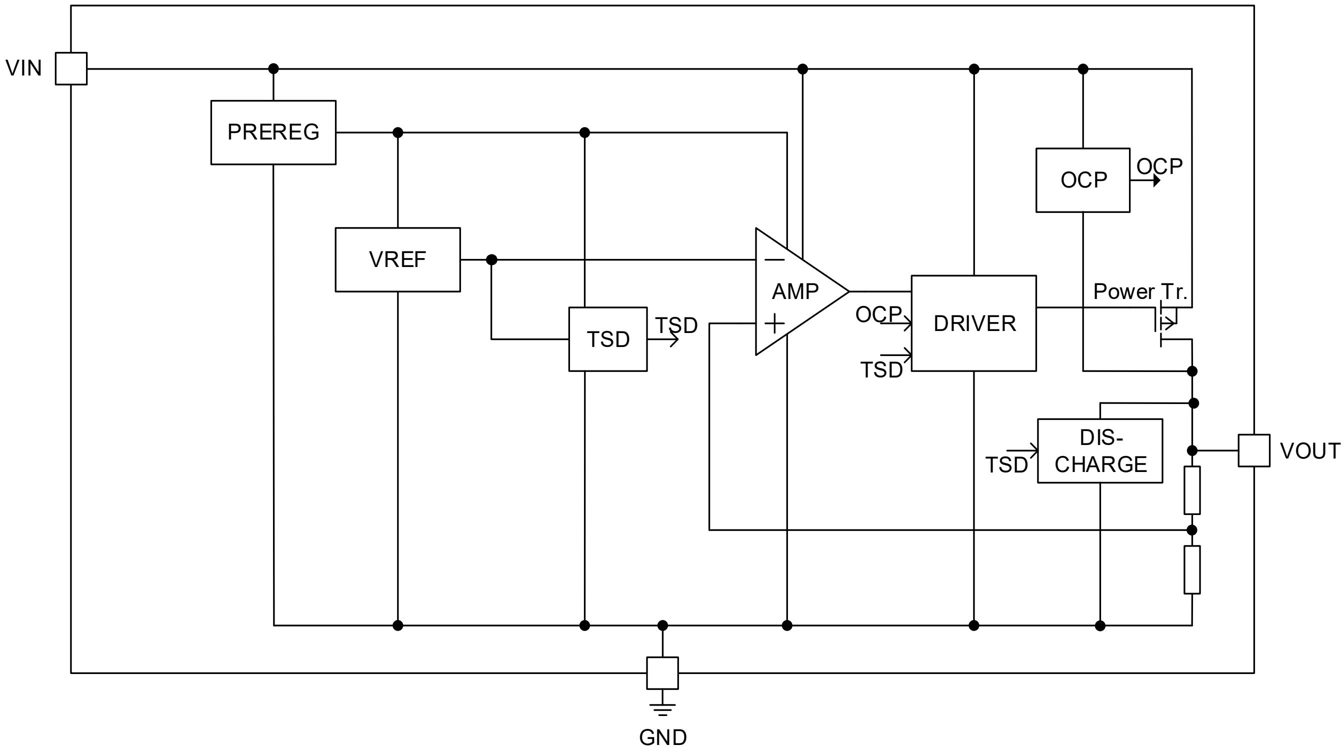
*(Note 1)* N.C. pin has no connection inside the IC and can be either left open/floating or connected to GND.
*(Note 2)* EXP-PAD is electrically connected to the IC Board Substrate and can therefore be connected to an external GND potential.

## Pin Descriptions

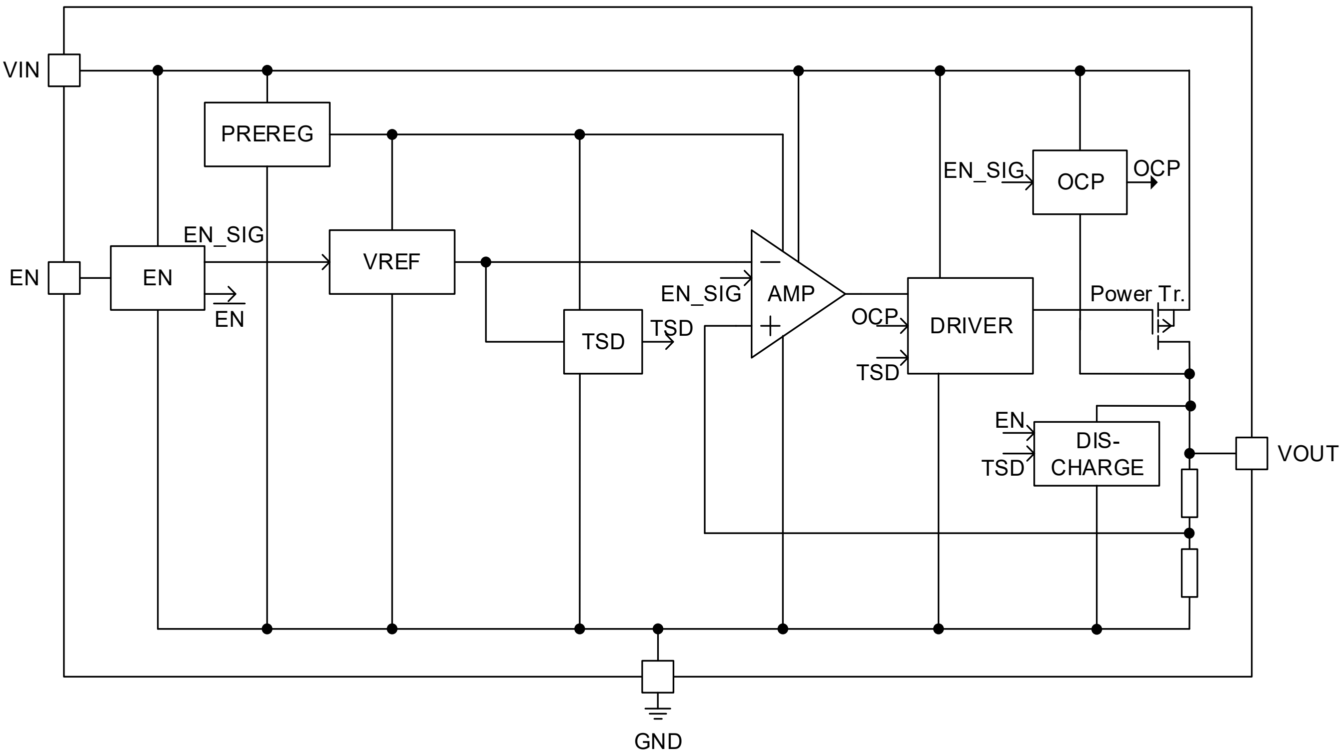
| Pin Name | Function | Descriptions |
|---|---|---|
| VIN | Input Supply Voltage Pin | Set a capacitor with a capacitance of 0.1 µF (Min) or higher between the VIN pin and the GND pin. The selecting method is described in **Selection of External Components.** If the impedance or inductance of power supply line is high, adjust input capacitor value. |
| EN | Control Output ON / OFF Pin | A logical "HIGH" ($V_{EN}$ ≥ 2.0 V) at the EN pin enables the device and "LOW" ($V_{EN}$ ≤ 0.8 V) at the EN pin disables the device.<br>Although the output is turned off when the EN pin is open, it is recommended to connect it to GND with low impedance to prevent incorrect operation. |
| ADJ | Adjustment Pin For Output Voltage | Connect an external resistor between the VOUT pin and the ADJ pin and between the ADJ pin and the GND pin to adjust output voltage. |
| VOUT | Output Voltage Pin | Set a capacitor with a capacitance of 0.6 µF (Min) or higher between the VOUT pin and the GND pin. The selecting method is described in **Selection of External Components**. |
| GND | Ground Pin | Ground. |
| N.C. | Non-Connected Pin | This pin is not connected (N.C.) to the chip.<br>This can be either left open/floating or connected to GND. |
| EXP-PAD | Heat Dissipation | It is recommended to connect EXP-PAD on the back side to external ground pattern in order to make heat dissipation better. |

## Block Diagrams

■ Applicable for product output voltage fixed type without Output Shutdown Function
BD6xxM5EFJ-C (xx = 33, 50)

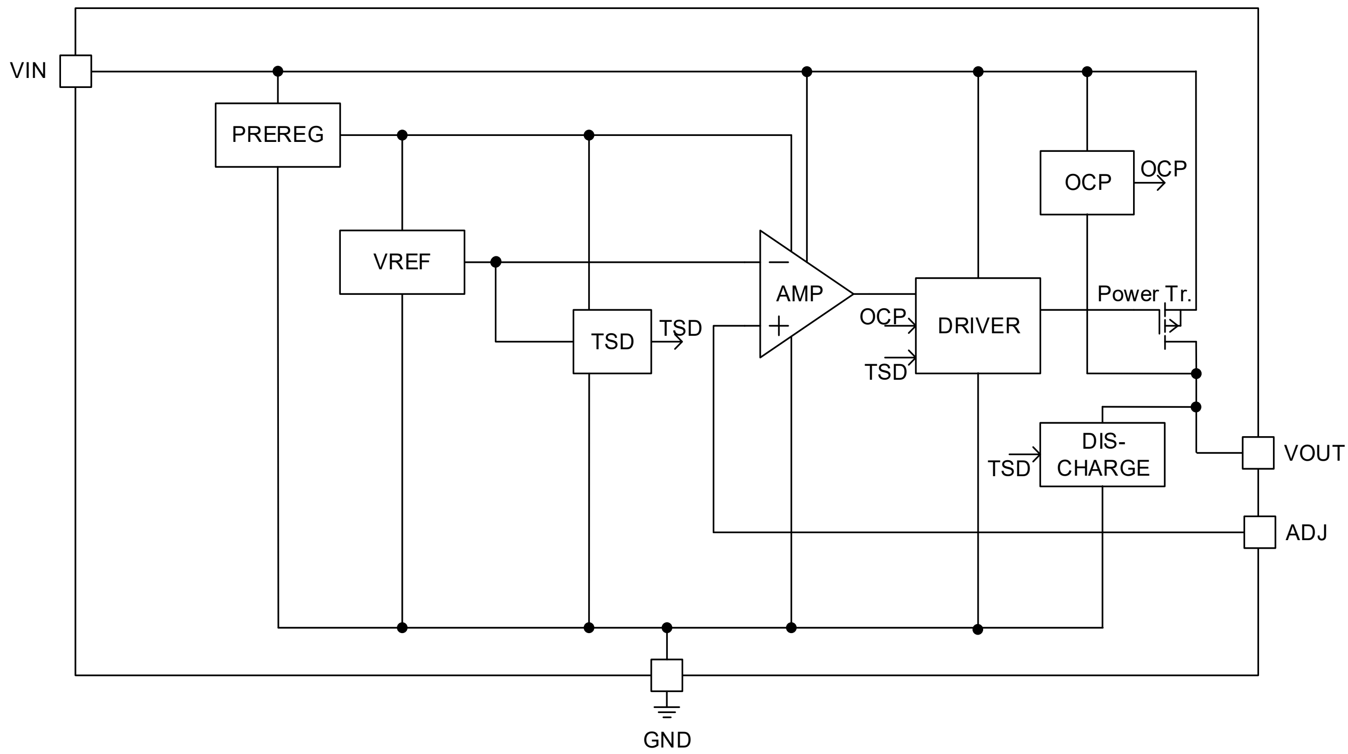



■ Applicable for product output voltage fixed type with Output Shutdown Function
BD6xxM5WEFJ-C (xx = 33, 50)

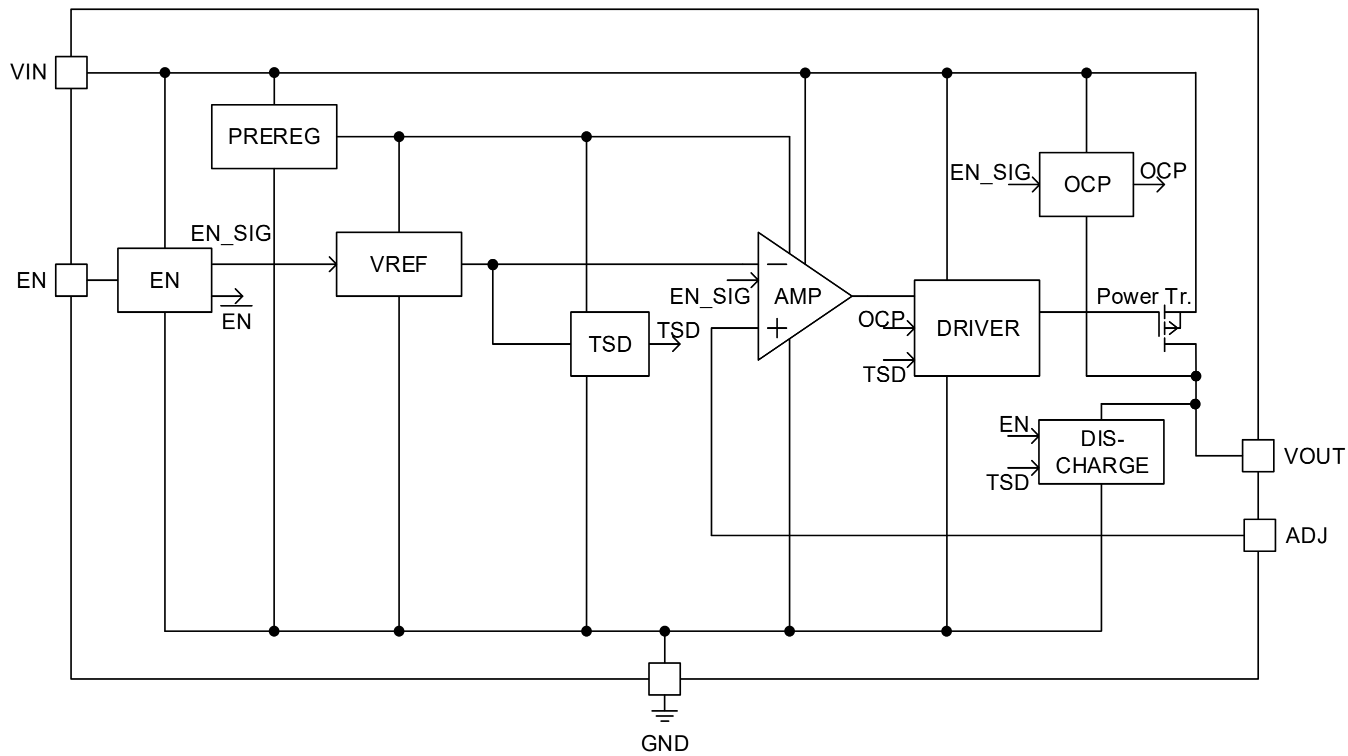


**Block Diagrams - continued**

■ Applicable for product output voltage adjustable type without Output Shutdown Function
BD600M5EFJ-C




■ Applicable for product output voltage adjustable type with Output Shutdown Function
BD600M5WEFJ-C



## Description of Blocks

| Block Name | Function | Description of Blocks |
|---|---|---|
| EN | Enable Input | A logical “HIGH” ($V_{EN}$ ≥ 2.0 V) at the EN pin enables the device and “LOW” ($V_{EN}$ ≤ 0.8 V) at the EN pin disables the device. |
| PREREG | Internal Power Supply | Power supply for internal circuit. |
| TSD | Thermal Shutdown Protection | In case maximum power dissipation exceeds or when the junction temperature rises and the chip temperature (Tj) exceeds the heating protection set temperature. The TSD protection circuit detects this and forces the gate of output MOSFET to turn off in order to protect the device from overheating. (Typ: 175 °C) When the junction temperature decreases to low, the thermal Shutdown protection is released, and the output turns on automatically. |
| VREF | Internal Reference Voltage | Generate the reference voltage. |
| DRIVER | Output MOSFET Driver | Drive the output MOSFET. |
| OCP | Over Current Protection | If the output current increases higher than the maximum output current, it is limited by Over Current Protection in order to protect the device from a damage caused by an over current. (Typ: 950 mA)<br>While this block is operating, the output voltage may decrease because the output current is limited.<br>If an abnormal state is removed and the output current value returns to normal, the output voltage also returns to normal state. |
| DISCHARGE | Output Discharge Function | Output pin is discharged when EN = “LOW” input or TSD is detected. |

## Absolute Maximum Ratings

| Parameter | Symbol | Ratings | Unit |
|---|---|---|---|
| Input Voltage(Note 1) | $V_{IN}$ | -0.3 to +45 | V |
| EN Pin Voltage(Note 2) | $V_{EN}$ | -0.3 to +45 | V |
| VOUT Pin Voltage | $V_{OUT}$ | -0.3 to +28 (≤ $V_{IN}$ + 0.3) | V |
| ADJ Pin Voltage(Note 3) | $V_{ADJ}$ | -0.3 to +7 | V |
| Junction Temperature Range | Tj | -40 to +150 | °C |
| Storage Temperature Range | Tstg | -55 to +150 | °C |
| Maximum Junction Temperature | Tjmax | 150 | °C |
| ESD Withstand Voltage (HBM)(Note 4) | $V_{ESD\_HBM}$ | ±2000 | V |
| ESD Withstand Voltage (CDM)(Note 5) | $V_{ESD\_CDM}$ | ±750 | V |

***Caution 1:*** *Operating the IC over the absolute maximum ratings may damage the IC. The damage can either be a short circuit between pins or an open circuit between pins and the internal circuitry. Therefore, it is important to consider circuit protection measures, such as adding a fuse, in case the IC is operated over the absolute maximum ratings.*

***Caution 2:*** *Should by any chance the maximum junction temperature rating be exceeded the rise in temperature of the chip may result in deterioration of the properties of the chip. In case of exceeding this absolute maximum rating, design a PCB with thermal resistance and power dissipation taken into consideration by increasing board size and copper area so as not to exceed the maximum junction temperature rating.*

*(Note 1)* Do not exceed Tjmax.
*(Note 2)* Applicable for product with output shutdown function.
The start-up orders of Input Voltage ($V_{IN}$) and $V_{EN}$ do not influence if the voltage is within the operation power supply voltage range.
*(Note 3)* Applicable for product output adjustable type.
*(Note 4)* ESD susceptibility Human Body Model “HBM”; based on AEC-Q100-002 (1.5 kΩ, 100 pF).
*(Note 5)* ESD susceptibility Charged Device Model “CDM”; base on AEC-Q100-011.

### Thermal Resistance(Note 1)

| Parameter | Symbol | Thermal Resistance (Typ) | | Unit |
|---|---|---|---|---|
| | | 1s(Note 3) | 2s2p(Note 4) | |
| HTSOP-J8 | | | | |
| Junction to Ambient | $\theta_{JA}$ | 134.2 | 31.9 | °C/W |
| Junction to Top Characterization Parameter(Note 2) | $\Psi_{JT}$ | 14 | 5 | °C/W |

*(Note 1)* Based on JESD51-2A (Still-Air), using a BD600M5WEFJ-C Chip.
*(Note 2)* The thermal characterization parameter to report the difference between junction temperature and the temperature at the top center of the outside surface of the component package.
*(Note 3)* Using a PCB board based on JESD51-3.
*(Note 4)* Using a PCB board based on JESD51-5, 7.

| Layer Number of Measurement Board | Material | Board Size |
|---|---|---|
| Single | FR-4 | 114.3 mm x 76.2 mm x 1.57 mmt |

| Top | |
|---|---|
| Copper Pattern | Thickness |
| Footprints and Traces | 70 µm |

| Layer Number of Measurement Board | Material | Board Size | Thermal Via(Note 5) | |
|---|---|---|---|---|
| | | | Pitch | Diameter |
| 4 Layers | FR-4 | 114.3 mm x 76.2 mm x 1.6 mmt | 1.20 mm | Φ0.30 mm |

| Top | | 2 Internal Layers | | Bottom | |
|---|---|---|---|---|---|
| Copper Pattern | Thickness | Copper Pattern | Thickness | Copper Pattern | Thickness |
| Footprints and Traces | 70 µm | 74.2 mm x 74.2 mm | 35 µm | 74.2 mm x 74.2 mm | 70 µm |

*(Note 5)* This thermal via connect with the copper pattern of layers 1,2, and 4. The placement and dimensions obey a land pattern.

## Operating Conditions (-40 °C ≤ Tj ≤ +150 °C)

| Parameter | Symbol | Min | Max | Unit |
|---|---|---|---|---|
| Input Voltage*(Note 1)(Note 2)* | $V_{IN}$ | 3 | 42 | V |
| | | $V_{OUT}$ (Max) + $\Delta V_D$ (Max) | 42 | V |
| Output Voltage*(Note 3)* | $V_{OUT}$ | 1.5 | 26 | V |
| Feedback Resistor ADJ vs GND*(Note 3)* | $R_1$ | 5 | 200 | kΩ |
| EN Input Voltage*(Note 4)* | $V_{EN}$ | 0 | 42 | V |
| Output Current | $I_{OUT}$ | 0 | 500 | mA |
| Input Capacitor*(Note 5)(Note 6)* | $C_{IN}$ | 0.1 | - | μF |
| Output Capacitor*(Note 6)* | $C_{OUT}$ | 0.6 | 1000 | μF |
| Output Capacitor Equivalent Series Resistance*(Note 7)* | ESR ($C_{OUT}$) | 0 | 10 | Ω |
| Operating Temperature | Ta | -40 | +125 | °C |

*(Note 1)* Consider that the output voltage would be dropped (Dropout voltage $\Delta V_D$) by the output current.
*(Note 2)* Apply 3.0 V or $V_{OUT}$ (Max) + $\Delta V_D$ (Max), whichever is higher.
*(Note 3)* Applicable for product output adjustable type.
*(Note 4)* Applicable for product with output shutdown function.
*(Note 5)* If the inductance of power supply line is high, adjust input capacitor value in order to lower the input impedance.
A lower input impedance can bring out the ideal characteristic of IC as much as possible.
It also has the effect of preventing the voltage-drop at the input line.
*(Note 6)* Set capacitor value which do not fall below the minimum value. This value needs to consider the temperature characteristics and DC bias characteristics.
*(Note 7)* It is recommended to use ceramic capacitors that have low ESR characteristics for the output phase compensation.

## Electrical Characteristics

Unless otherwise specified, -40 °C ≤ Tj ≤ +150 °C, $V_{IN}$ = 13.5 V, $V_{EN}$ = 5 V(Note 1), $I_{OUT}$ = 0 mA, $C_{OUT}$ = 1 µF
Output voltage adjustable type $V_{OUT}$ setting = 5 V, $R_1$ = 120 kΩ, $R_2$ = 369 kΩ
Typical values are defined at Tj = 25 °C, $V_{IN}$ = 13.5 V

| Parameter | Symbol | Limits | | | Unit | Conditions |
|---|---|---|---|---|---|---|
| | | Min | Typ | Max | | |
| Circuit Current(Note 2) | $I_{CC}$ | 10 | 25 | 50 | µA | $I_{OUT}$ = 0 mA, Tj ≤ 125 °C |
| | | 10 | 25 | 800 | µA | $I_{OUT}$ ≤ 500 mA, Tj ≤ 150 °C |
| Circuit Current(Note 3) (Note 4) | $I_{CC}$ | 10 | 30 | 55 | µA | $I_{OUT}$ = 0 mA, Tj ≤ 125 °C |
| | | 10 | 30 | 800 | µA | $I_{OUT}$ ≤ 500 mA, Tj ≤ 150 °C |
| Output Voltage(Note 3) | $V_{OUT}$ | 3.234 | 3.300 | 3.366 | V | 4.0 V ≤ $V_{IN}$ ≤ 42 V<br>0 µA ≤ $I_{OUT}$ ≤ 500 mA<br>Tj ≤ 125 °C<br>or<br>4.0 V ≤ $V_{IN}$ ≤ 42 V<br>100 µA ≤ $I_{OUT}$ ≤ 500 mA<br>Tj ≤ 150 °C |
| Output Voltage(Note 4) | $V_{OUT}$ | 4.900 | 5.000 | 5.100 | V | 5.7 V ≤ $V_{IN}$ ≤ 42 V<br>0 µA ≤ $I_{OUT}$ ≤ 500 mA<br>Tj ≤ 125 °C<br>or<br>5.7 V ≤ $V_{IN}$ ≤ 42 V<br>100 µA ≤ $I_{OUT}$ ≤ 500 mA<br>Tj ≤ 150 °C |
| Reference Voltage(Note 5) | $V_{ADJ}$ | 1.205 | 1.230 | 1.255 | V | 3.0 V ≤ $V_{IN}$ ≤ 42 V<br>0 µA ≤ $I_{OUT}$ ≤ 500 mA<br>Tj ≤ 125 °C<br>or<br>3.0 V ≤ $V_{IN}$ ≤ 42 V<br>100 µA ≤ $I_{OUT}$ ≤ 500 mA<br>Tj ≤ 150 °C |
| Dropout Voltage | $\Delta V_D$ | 150 | 350 | 650 | mV | $V_{IN}$ = 3.135 V, $I_{OUT}$ = 500 mA |
| | | 150 | 300 | 600 | mV | $V_{IN}$ = 4.75 V, $I_{OUT}$ = 500 mA |
| Ripple Rejection(Note 6) | R.R. | - | 70 | - | dB | f = 1 kHz, $V_{Ripple}$ = 1 Vrms<br>$I_{OUT}$ = 100 mA |
| Line Regulation | Reg.I | - | 0.2 | 0.4 | % | 6 V ≤ $V_{IN}$ ≤ 42 V, $I_{OUT}$ = 100 µA |
| Load Regulation | Reg.L | - | 0.2 | 0.4 | % | 100 µA ≤ $I_{OUT}$ ≤ 500 mA |
| Over Current Protection | $I_{OCP}$ | 501 | 950 | 1300 | mA | $V_{OUT}$ = 0.9 x $V_{OUT}$ (Typ) |
| Thermal Shutdown Temperature | $T_{TSD}$ | 151 | 175 | - | °C | - |
| Thermal Shutdown Hysteresis | $T_{TSDHYS}$ | - | 10 | - | °C | - |
| ADJ Input Current(Note 5) | $I_{ADJ}$ | 5 | 40 | 250 | nA | $V_{ADJ}$ = 1.3 V |

*(Note 1)* Applicable for product with output shutdown function.
*(Note 2)* Applicable for product with output voltage adjustable type. The current flowing through feedback resistor $R_1$ and $R_2$ is not included in the specifications.
*(Note 3)* Applicable for product with output voltage 3.3 V
*(Note 4)* Applicable for product with output voltage 5.0 V
*(Note 5)* Applicable for product with output voltage adjustable type
*(Note 6)* Not all devices are measured for shipment.

**Electrical Characteristics (Applicable for product with Output shutdown Function)**

Unless otherwise specified, -40 °C ≤ Tj ≤ +150 °C, $V_{IN}$ = 13.5 V, $I_{OUT}$ = 0 mA, $C_{OUT}$ = 1 µF
Output voltage adjustable type $V_{OUT}$ setting = 5 V, $R_1$ = 120 kΩ, $R_2$ = 369 kΩ
Typical values are defined at Tj = 25 °C, $V_{IN}$ = 13.5 V

| Parameter | Symbol | Limits | | | Unit | Conditions |
|---|---|---|---|---|---|---|
| | | Min | Typ | Max | | |
| Shutdown Current | $I_{SHUT}$ | 0.5 | 2.0 | 5.0 | µA | $V_{EN}$ = 0 V, Tj ≤ 125 °C |
| EN ON Mode Voltage | $V_{ENH}$ | 2.0 | - | 42.0 | V | - |
| EN OFF Mode Voltage | $V_{ENL}$ | 0.0 | - | 0.8 | V | - |
| EN Bias Current | $I_{EN}$ | 0.2 | 0.5 | 3.0 | µA | $V_{EN}$ = 5 V |
| Output Discharge Resistance | $R_{DSC}$ | 2.5 | 5.0 | 10.0 | kΩ | $V_{EN}$ = 0 V |

### Typical Performance Curves 5 V Output

Unless otherwise specified, Tj = -40 °C to +150 °C, $V_{IN}$ = 13.5 V, $V_{EN}$ = 5 V*(Note 1)*, $I_{OUT}$ = 0 mA, $C_{OUT}$ = 1 µF

*(Note 1)* Only for products with output shutdown function.

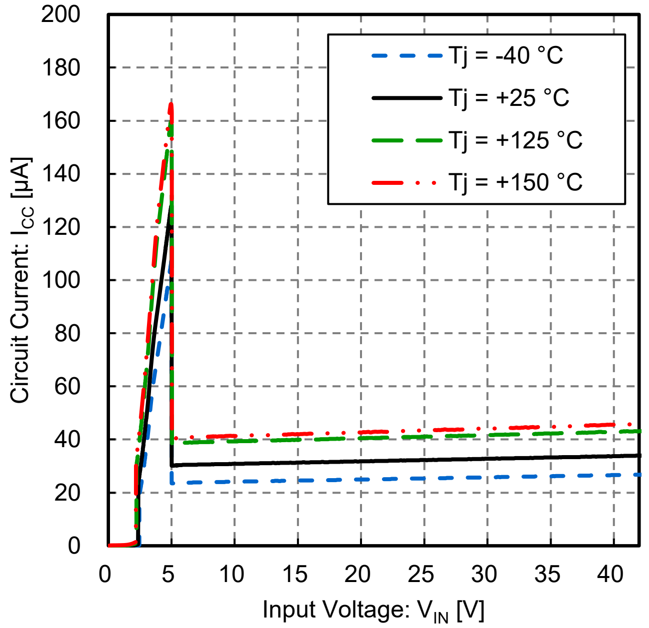



Figure 1. Circuit Current vs Input Voltage
(5 V Output)

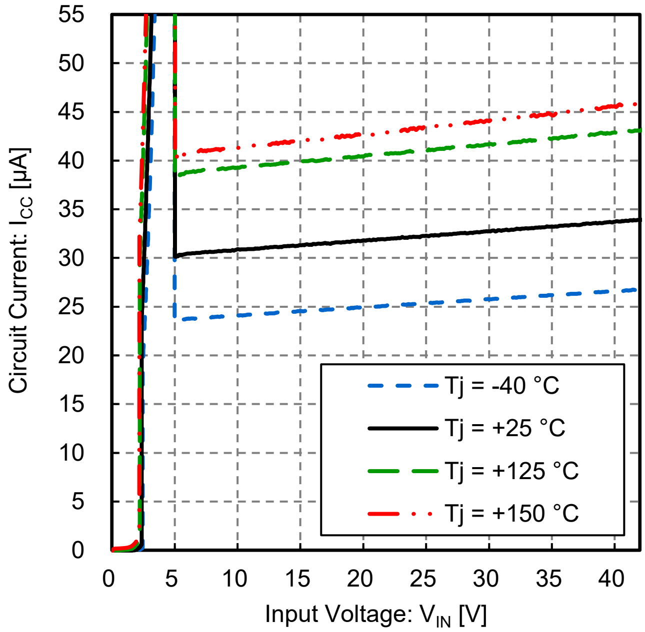



Figure 2. Circuit Current vs Input Voltage;
Enlarged view of Figure 1 at narrow Circuit Current range
(5 V Output)

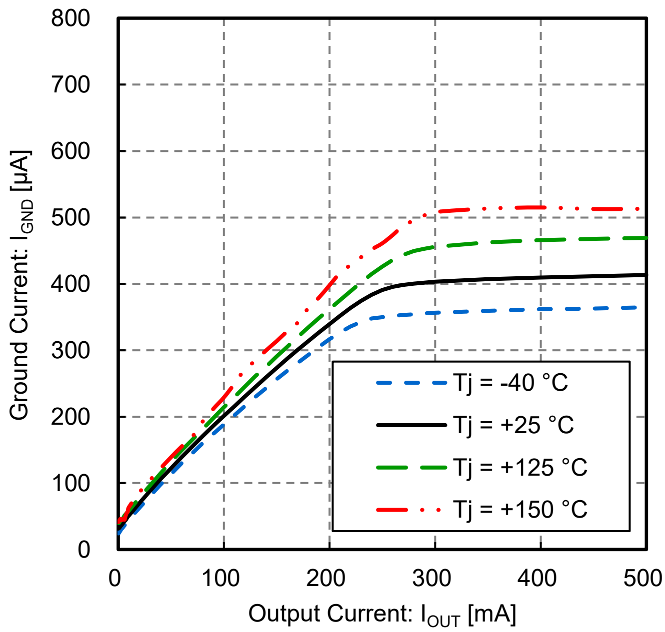



Figure 3. Ground Current vs Output Current
(5 V Output)

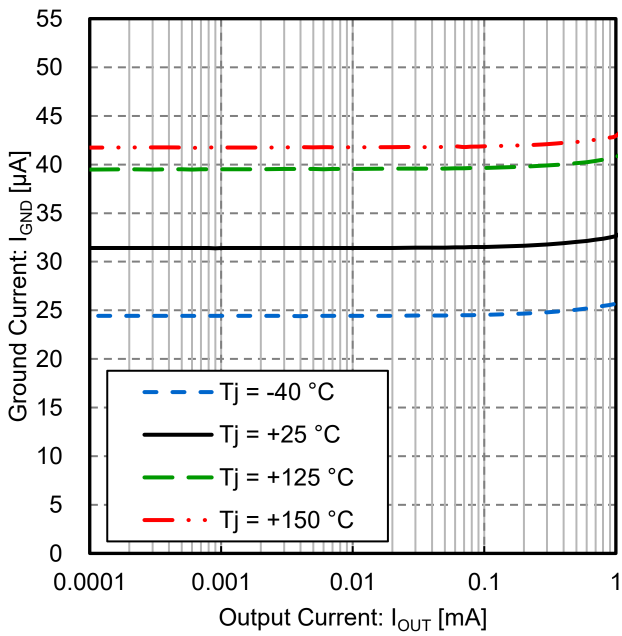



Figure 4. Ground Current vs Output Current;
Enlarged view of Figure 3 at low Output Current
(5 V Output)

**Typical Performance Curves 5 V Output - continued**

Unless otherwise specified, Tj = -40 °C to +150 °C, $V_{IN}$ = 13.5 V, $V_{EN}$ = 5 V*(Note 1)*, $I_{OUT}$ = 0 mA, $C_{OUT}$ = 1 μF

*(Note 1)* Only for products with output shutdown function.

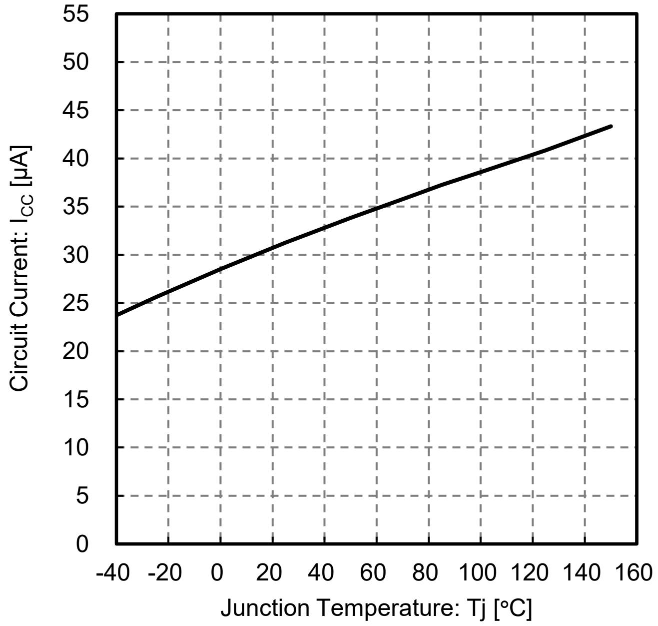



Figure 5. Circuit Current vs Junction Temperature (5 V Output)

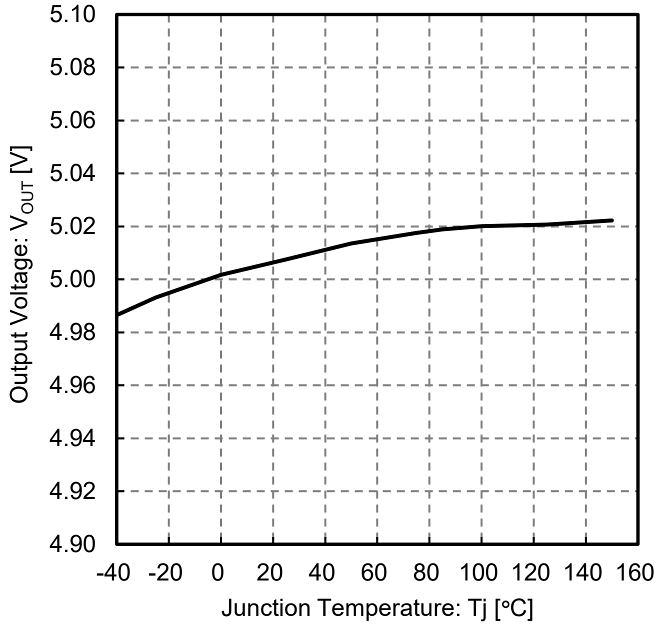



Figure 6. Output Voltage vs Junction Temperature (5 V Output)

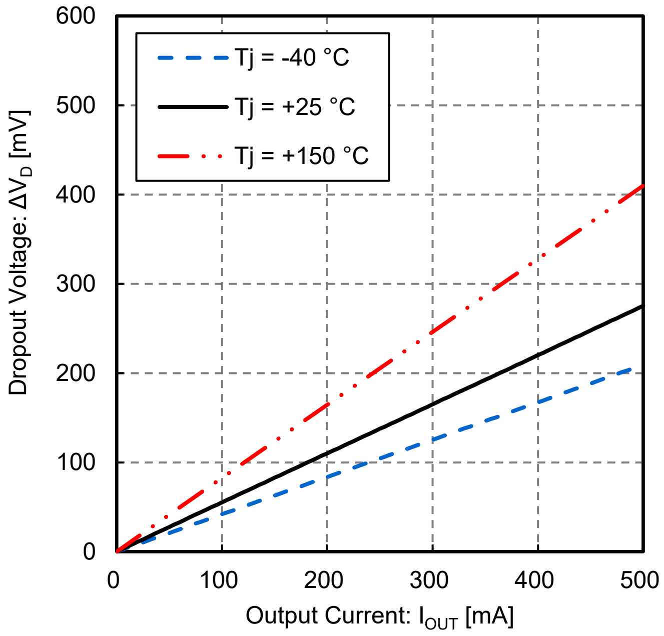



Figure 7. Dropout Voltage vs Output Current (5 V Output, $V_{IN}$ = 4.75 V)

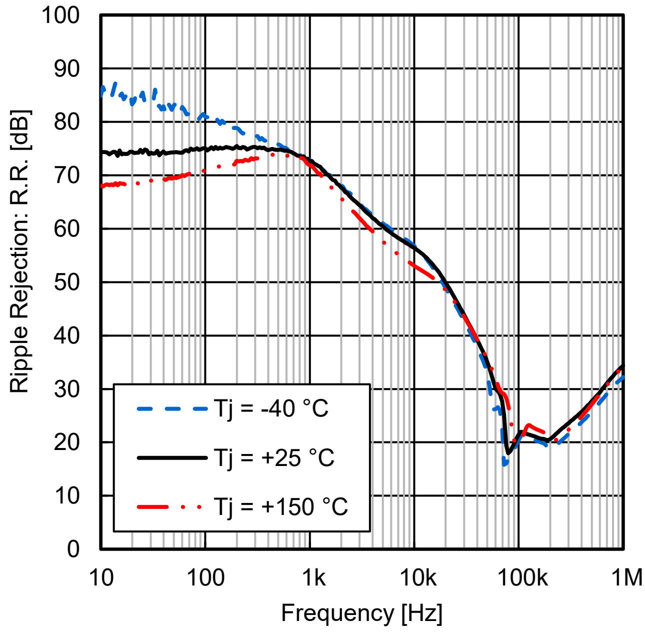



Figure 8. Ripple Rejection vs Frequency (5 V Output, $V_{Ripple}$ = 1 Vrms, $I_{OUT}$ = 100 mA)

**Typical Performance Curves 5 V Output - continued**

Unless otherwise specified, Tj = -40 °C to +150 °C, $V_{IN}$ = 13.5 V, $V_{EN}$ = 5 V*(Note 1)*, $I_{OUT}$ = 0 mA, $C_{OUT}$ = 1 µF

*(Note 1)* Only for products with output shutdown function.

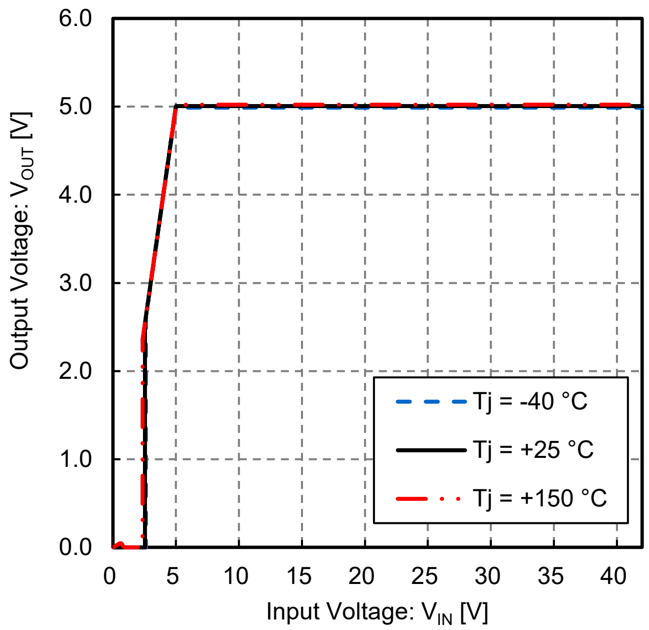



Figure 9. Output Voltage vs Input Voltage
(5 V Output)

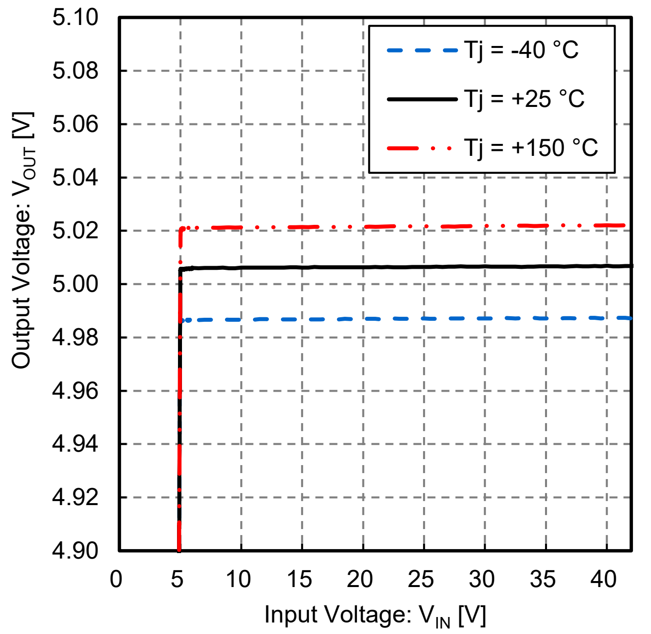



Figure 10. Output Voltage vs Input Voltage;
Enlarged view of Figure 9 at narrow Output Voltage range
(5 V Output, Line Regulation)

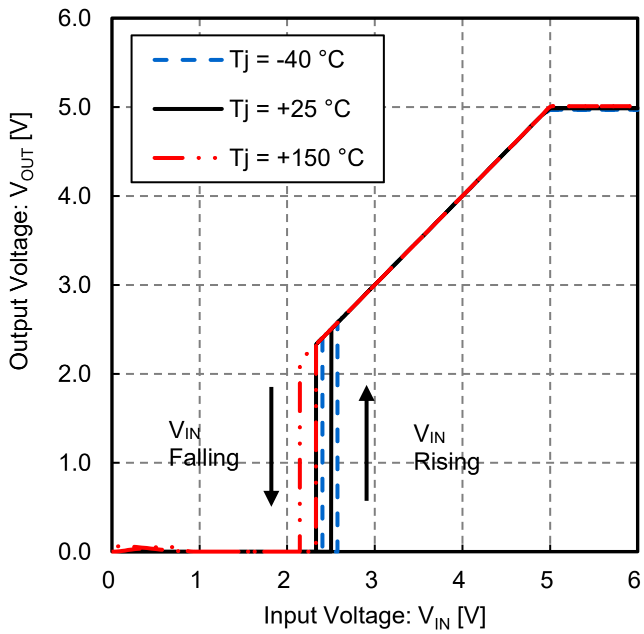



Figure 11. Output Voltage vs Input Voltage;
Enlarged view of Figure 9 at low Input Voltage
(5 V Output)

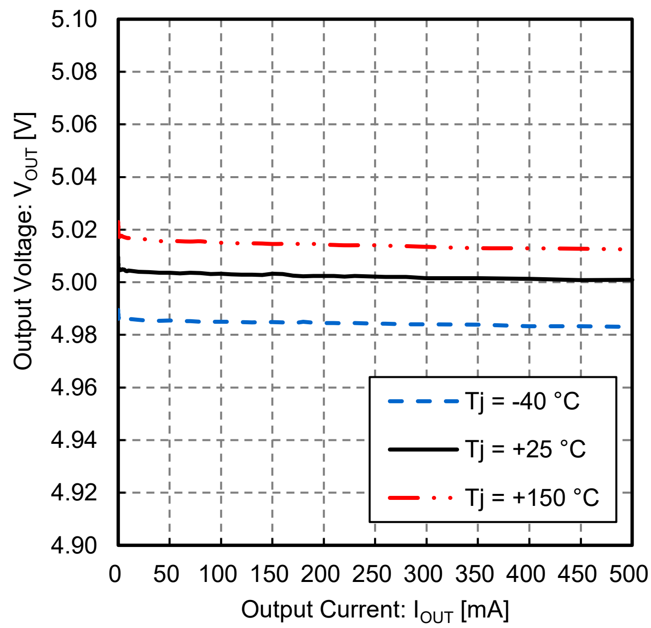



Figure 12. Output Voltage vs Output Current
(5 V Output, Load Regulation)

### Typical Performance Curves 5 V Output - continued

Unless otherwise specified, Tj = -40 °C to +150 °C, $V_{IN}$ = 13.5 V, $V_{EN}$ = 5 V*(Note 1)*, $I_{OUT}$ = 0 mA, $C_{OUT}$ = 1 µF

*(Note 1)* Only for products with output shutdown function.

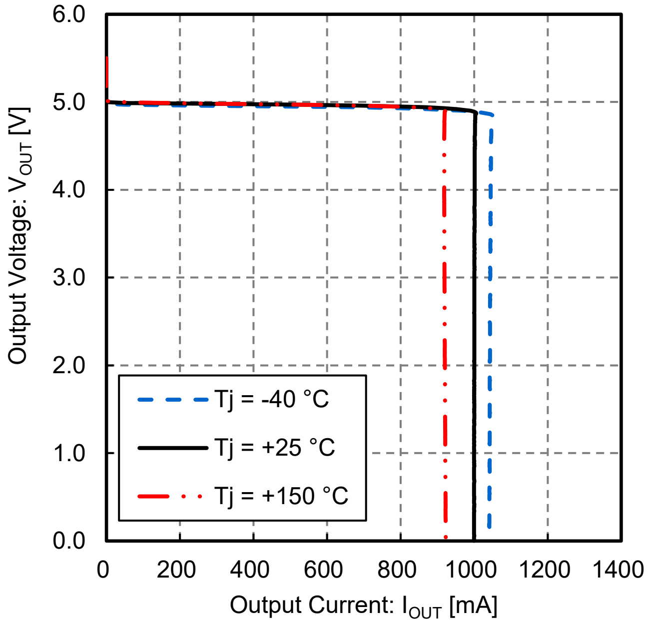



Figure 13. Output Voltage vs Output Current
(5 V Output, Over Current Protection)

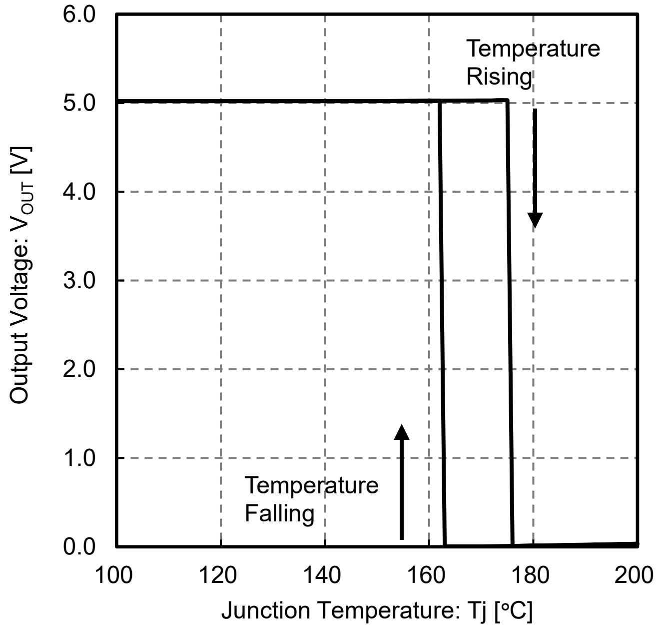



Figure 14. Output Voltage vs Junction Temperature
(5 V Output, Thermal Shutdown)

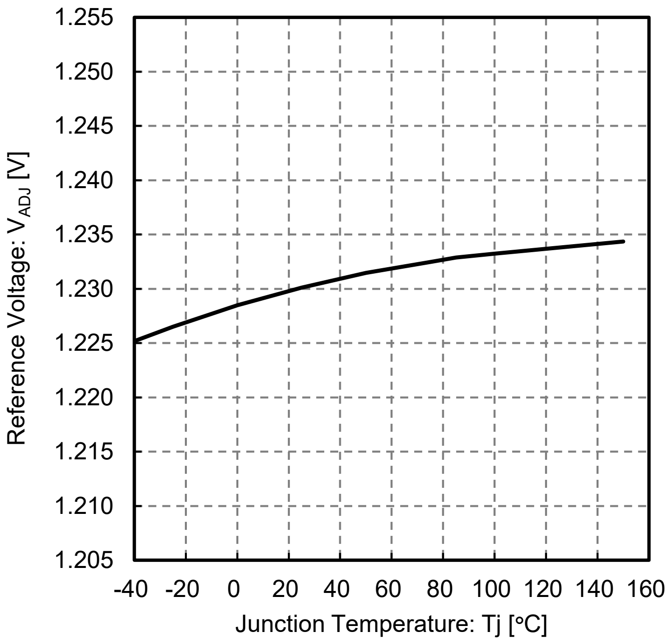



Figure 15. Reference Voltage vs Junction Temperature
(Output voltage adjustable type; $V_{OUT}$ = 5 V setting)

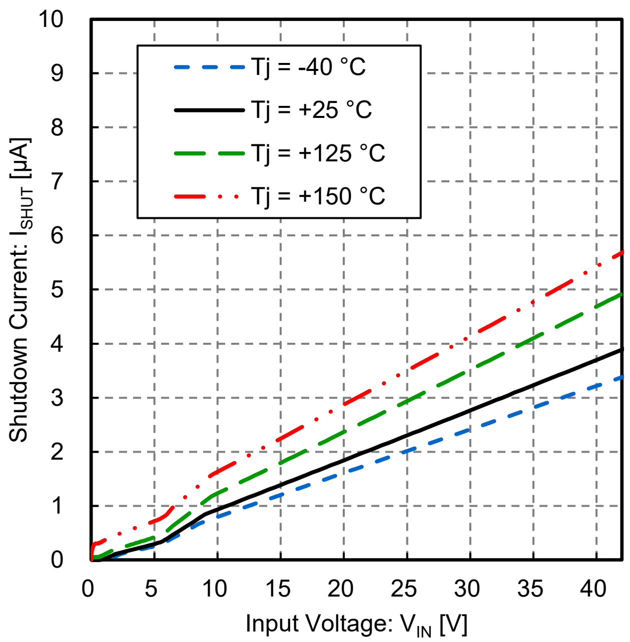



Figure 16. Shutdown Current vs Input Voltage
($V_{EN}$ = 0 V)

### Typical Performance Curves 5 V Output - continued

Unless otherwise specified, Tj = -40 °C to +150 °C, $V_{IN}$ = 13.5 V, $V_{EN}$ = 5 V*(Note 1)*, $I_{OUT}$ = 0 mA, $C_{OUT}$ = 1 µF

*(Note 1)* Only for products with output shutdown function.

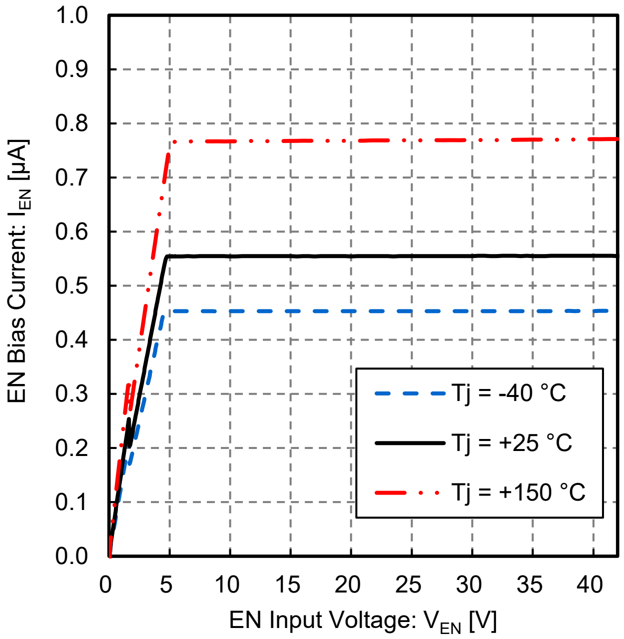



Figure 17. EN Bias Current vs EN Input Voltage

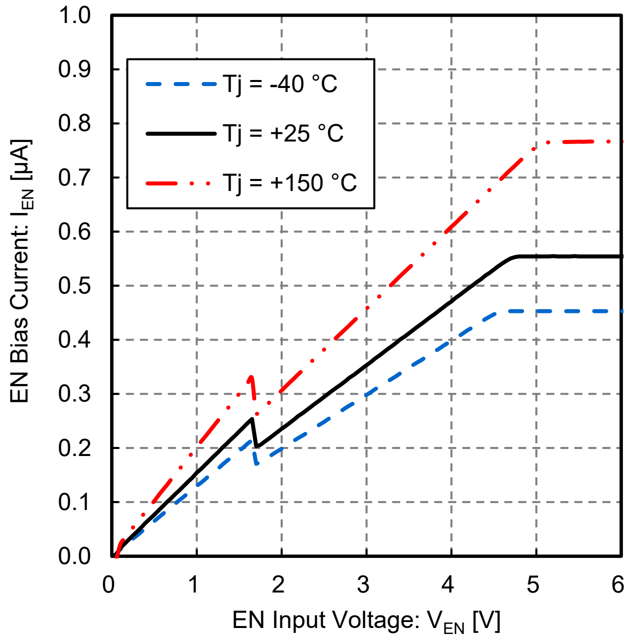



Figure 18. EN Bias Current vs EN Input Voltage
Enlarged view of Figure 17 at narrow EN Input Voltage range

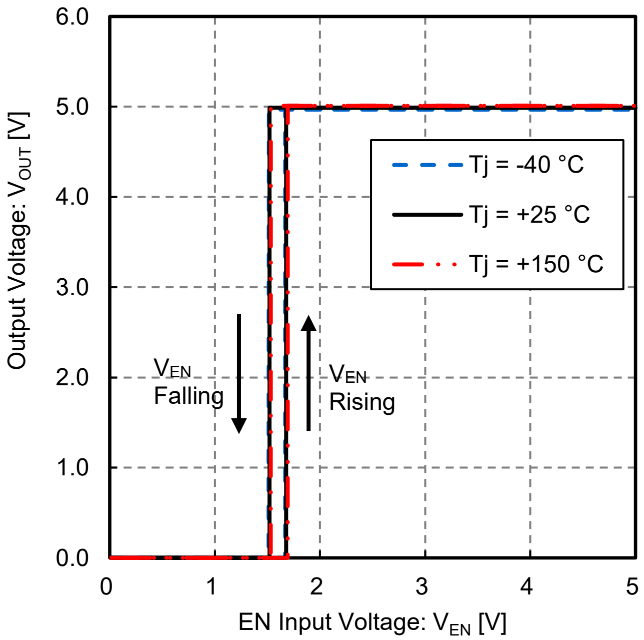



Figure 19. Output Voltage vs EN Input Voltage
(5 V Output)

## Typical Performance Curves 5 V Output - continued

Unless otherwise specified, Ta = 25 °C, $V_{IN}$ = 13.5 V, $V_{EN}$ = 5 V*(Note 1)*, $I_{OUT}$ = 0 mA, $C_{OUT}$ = 1 µF

*(Note 1)* Only for products with output shutdown function.

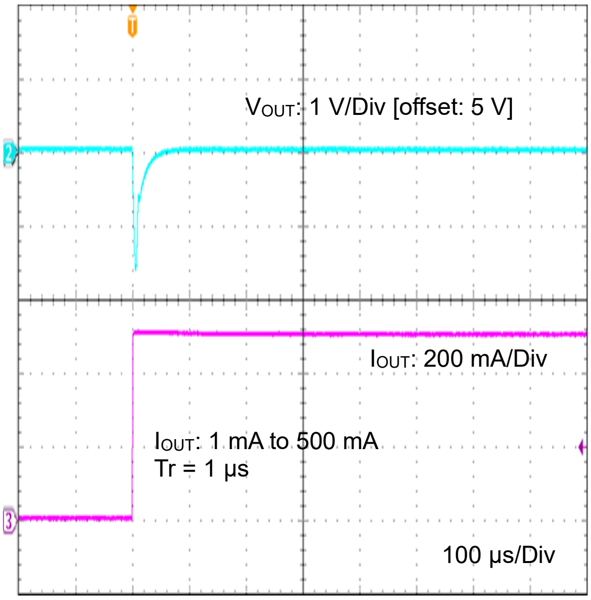



Figure 20. Load Transient 1 mA to 500 mA
(5 V Output, Tr = 1 µs, $C_{OUT}$ = 1 µF)

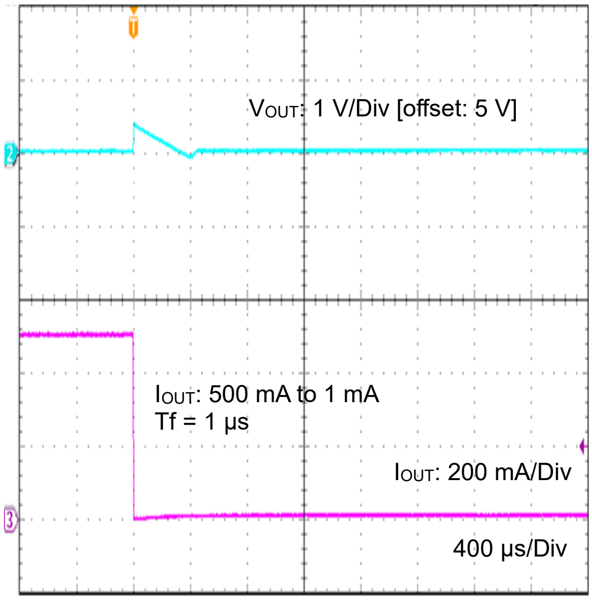



Figure 21. Load Transient 500 mA to 1 mA
(5 V Output, Tf = 1 µs, $C_{OUT}$ = 1 µF)

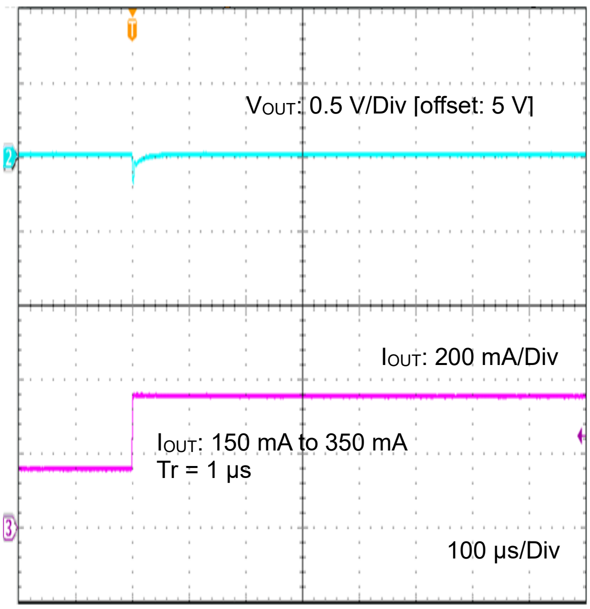



Figure 22. Load Transient 150 mA to 350 mA
(5 V Output, Tr = 1 µs, $C_{OUT}$ = 1 µF)

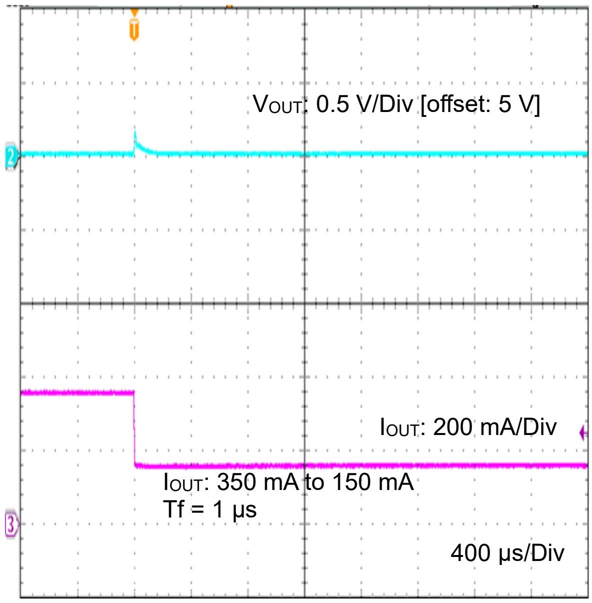



Figure 23. Load Transient 350 mA to 150 mA
(5 V Output, Tf = 1 µs, $C_{OUT}$ = 1 µF)

### Typical Performance Curves 5 V Output - continued

Unless otherwise specified, Ta = 25 °C, $V_{IN}$ = 13.5 V, $V_{EN}$ = 5 V*(Note 1)*, $I_{OUT}$ = 0 mA, $C_{OUT}$ = 2.2 µF

*(Note 1)* Only for products with output shutdown function.

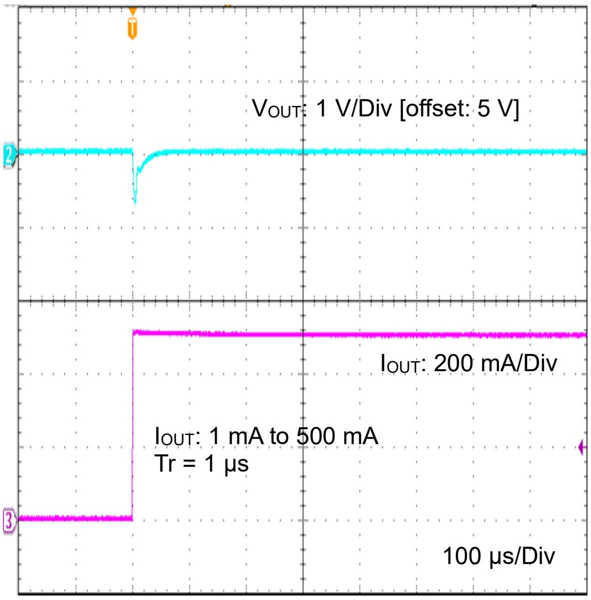



Figure 24. Load Transient 1 mA to 500 mA
(5 V Output, Tr = 1 µs, $C_{OUT}$ = 2.2 µF)

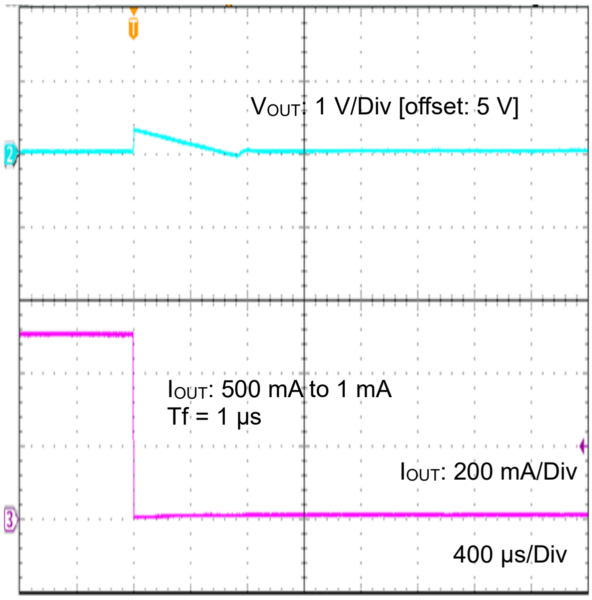



Figure 25. Load Transient 500 mA to 1 mA
(5 V Output, Tf = 1 µs, $C_{OUT}$ = 2.2 µF)

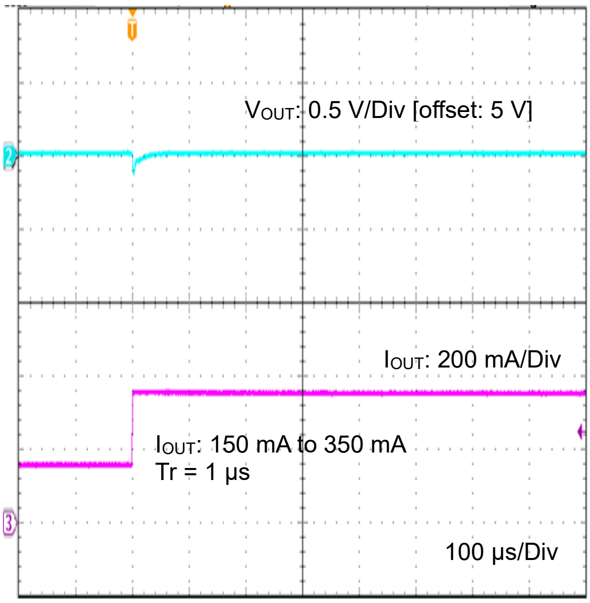



Figure 26. Load Transient 150 mA to 350 mA
(5 V Output, Tr = 1 µs, $C_{OUT}$ = 2.2 µF)

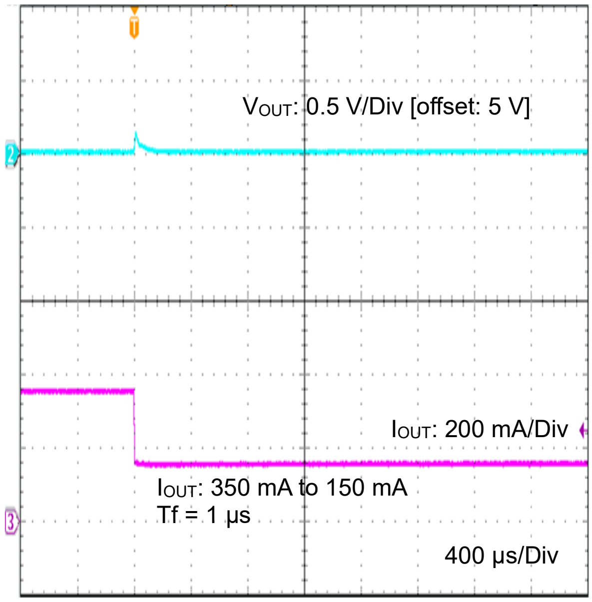



Figure 27. Load Transient 350 mA to 150 mA
(5 V Output, Tf = 1 µs, $C_{OUT}$ = 2.2 µF)

## Typical Performance Curves 5 V Output - continued

Unless otherwise specified, Ta = 25 °C, $V_{IN}$ = 13.5 V, $V_{EN}$ = 5 V*(Note 1)*, $I_{OUT}$ = 0 mA, $C_{OUT}$ = 4.7 µF

*(Note 1)* Only for products with output shutdown function.

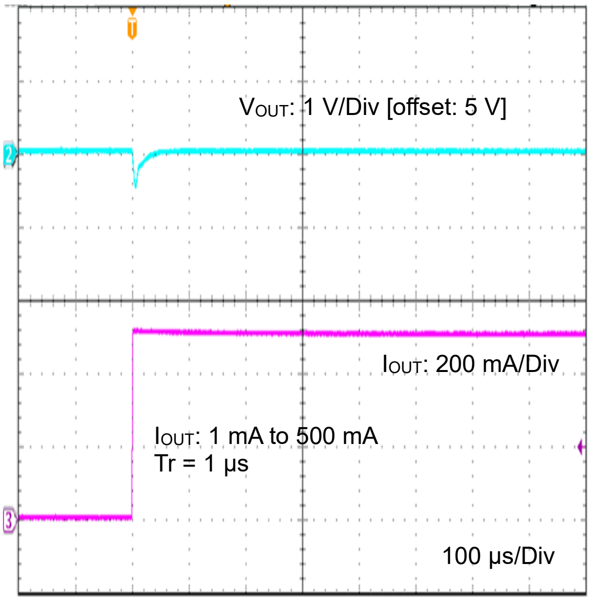



Figure 28. Load Transient 1 mA to 500 mA
(5 V Output, Tr = 1 µs, $C_{OUT}$ = 4.7 µF)

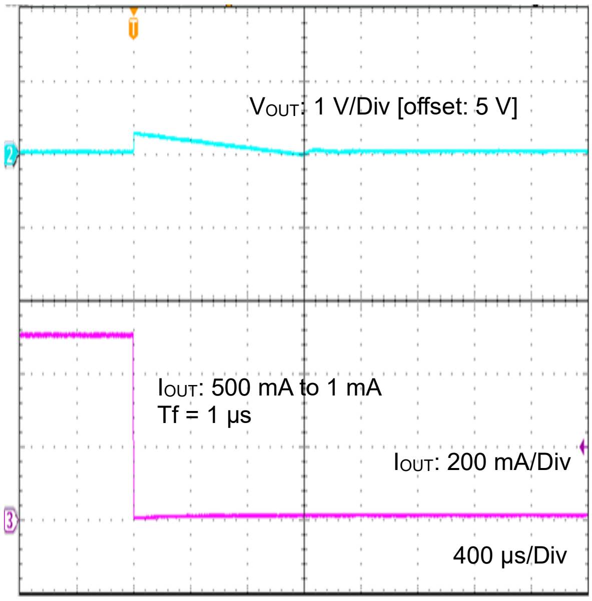



Figure 29. Load Transient 500 mA to 1 mA
(5 V Output, Tf = 1 µs, $C_{OUT}$ = 4.7 µF)

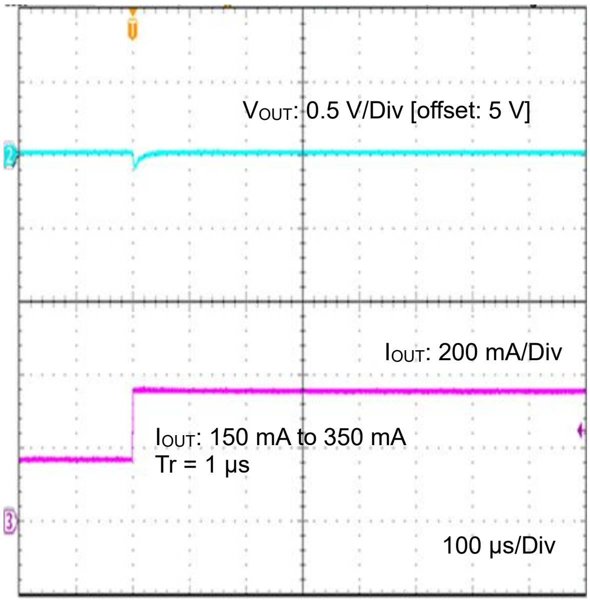



Figure 30. Load Transient 150 mA to 350 mA
(5 V Output, Tr = 1 µs, $C_{OUT}$ = 4.7 µF)

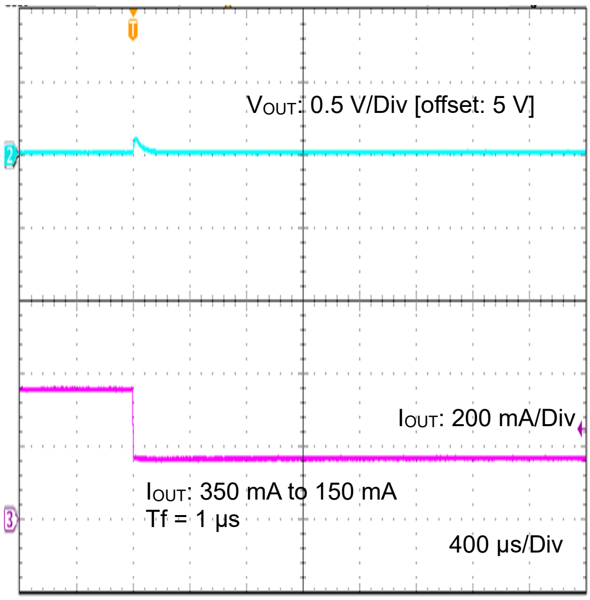



Figure 31. Load Transient 350 mA to 150 mA
(5 V Output, Tf = 1 µs, $C_{OUT}$ = 4.7 µF)

## Typical Performance Curves 5 V Output - continued

Unless otherwise specified, Ta = 25 °C, $V_{IN}$ = 13.5 V, $V_{EN}$ = 5 V*(Note 1)*, $I_{OUT}$ = 0 mA, $C_{OUT}$ = 1 µF

*(Note 1)* Only for products with output shutdown function.

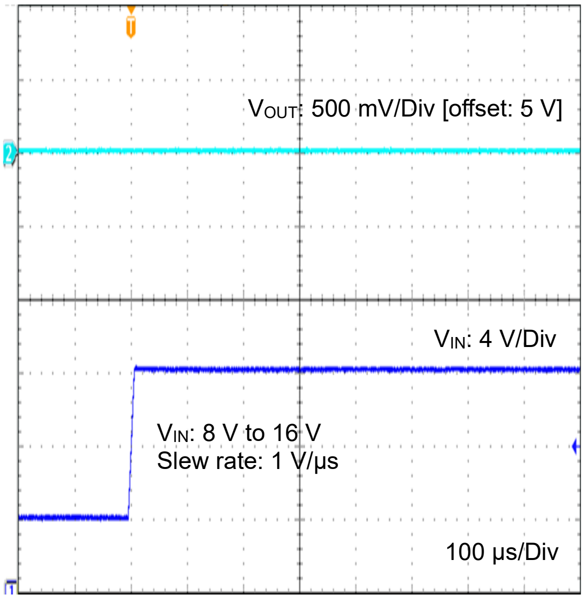



Figure 32. Line Transient 8 V to 16 V
(5 V Output, Slew rate = 1 V/µs, $I_{OUT}$ = 0 mA)

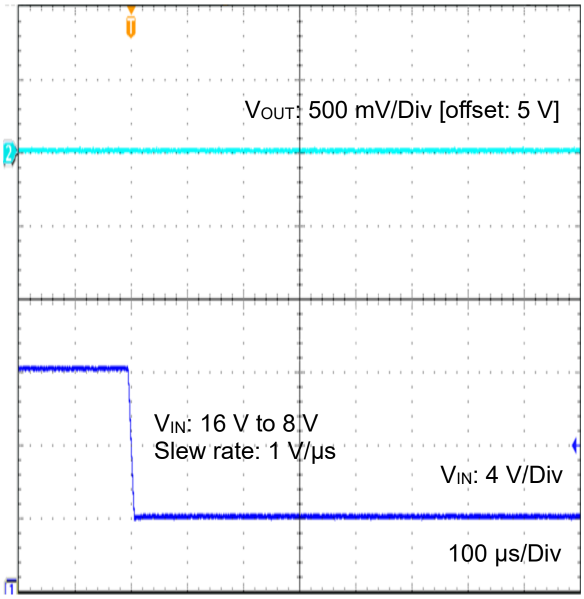



Figure 33. Line Transient 16 V to 8 V
(5 V Output, Slew rate = 1 V/µs, $I_{OUT}$ = 0 mA)

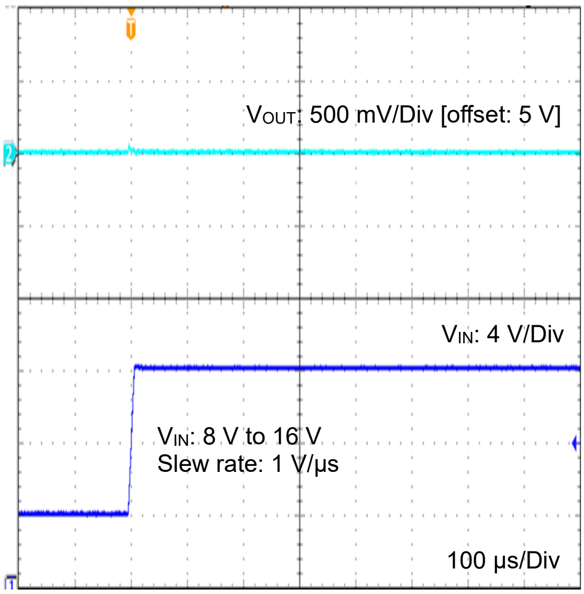



Figure 34. Line Transient 8 V to 16 V
(5 V Output, Slew rate = 1 V/µs, $I_{OUT}$ = 500 mA)

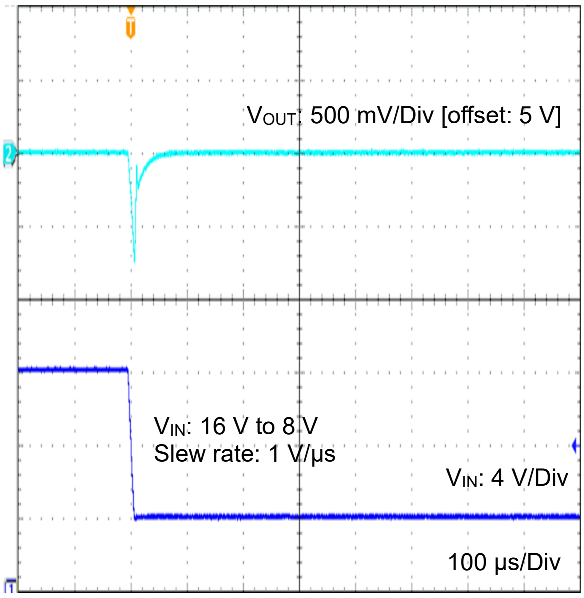



Figure 35. Line Transient 16 V to 8 V
(5 V Output, Slew rate = 1 V/µs, $I_{OUT}$ = 500 mA)

## Typical Performance Curves 5 V Output - continued

Unless otherwise specified, Ta = 25 °C, $V_{IN}$ = 13.5 V, $V_{EN}$ = 5 V*(Note 1)*, $I_{OUT}$ = 0 mA, $C_{OUT}$ = 1 µF

*(Note 1)* Only for products with output shutdown function.

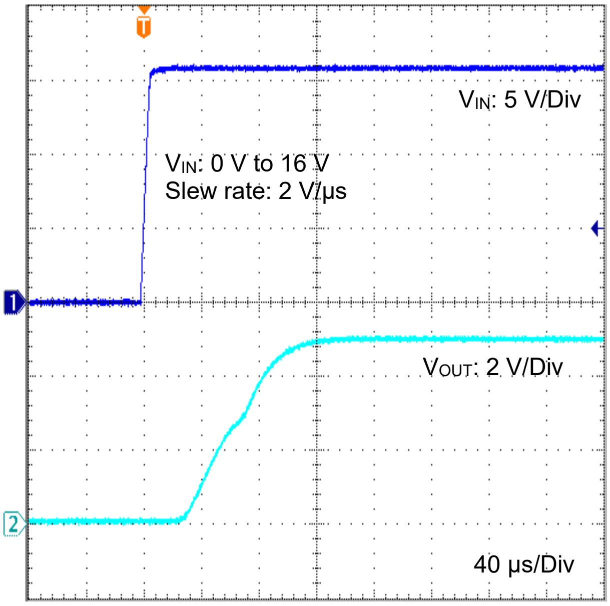



Figure 36. VIN Startup Waveform
$V_{IN}$: 0 V to 16 V
(5 V Output, Slew rate = 2 V/µs, $I_{OUT}$ = 0 mA)

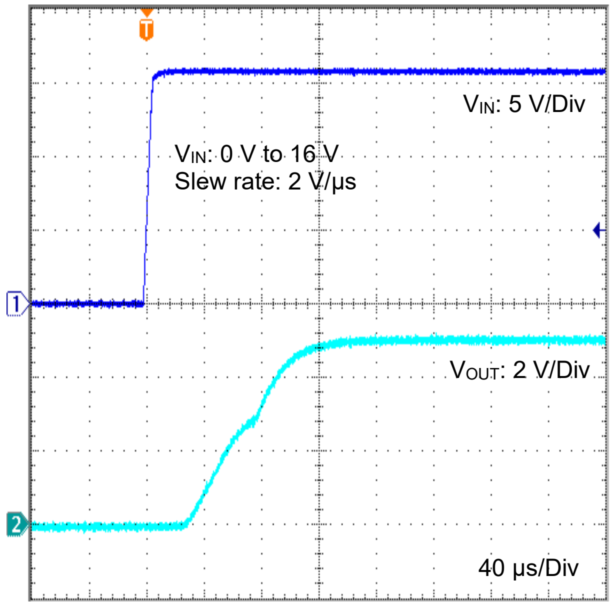



Figure 37. VIN Startup Waveform
$V_{IN}$: 0 V to 16 V
(5 V Output, Slew rate = 2 V/µs, $I_{OUT}$ = 500 mA)

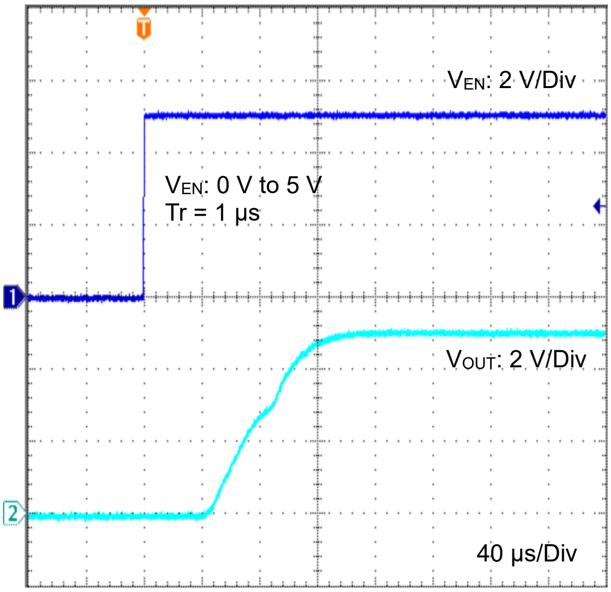



Figure 38. EN Startup Waveform
(5 V Output, Tr = 1 µs, $I_{OUT}$ = 1 mA)

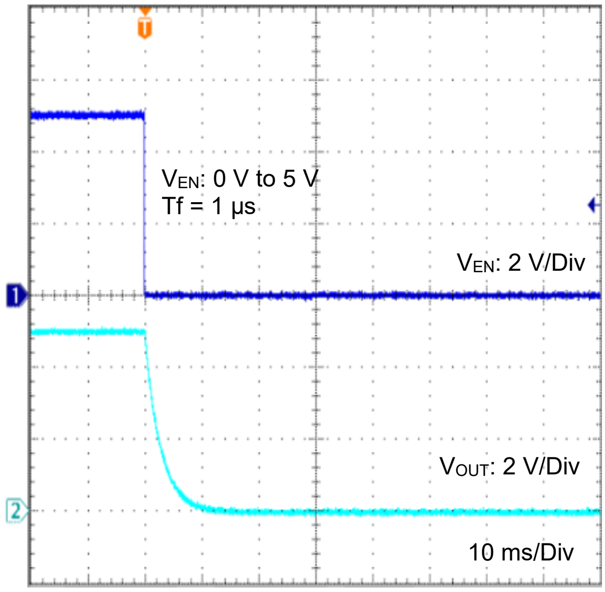



Figure 39. EN Shutdown Waveform
(5 V Output, Tf = 1 µs, $I_{OUT}$ = 1 mA)

### Typical Performance Curves 3.3 V Output

Unless otherwise specified, Tj = -40 °C to +150 °C, $V_{IN}$ = 13.5 V, $V_{EN}$ = 5 V *(Note 1)*, $I_{OUT}$ = 0 mA, $C_{OUT}$ = 1 µF

*(Note 1)* Only for products with output shutdown function.

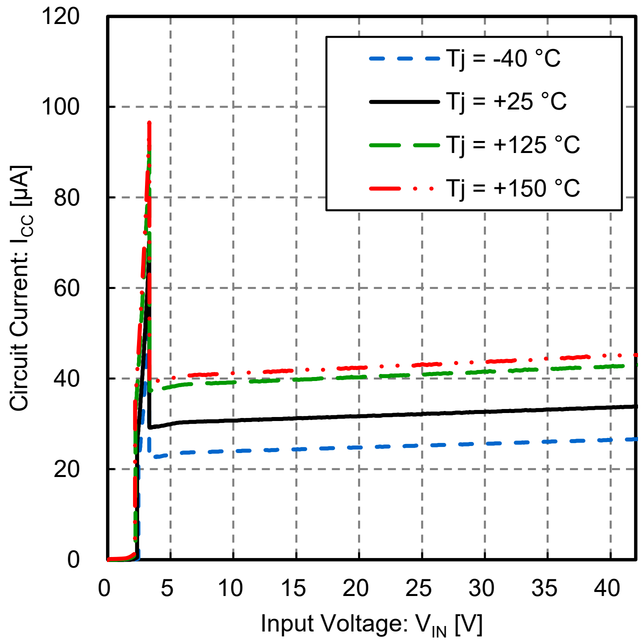



Figure 40. Circuit Current vs Input Voltage (3.3 V Output)

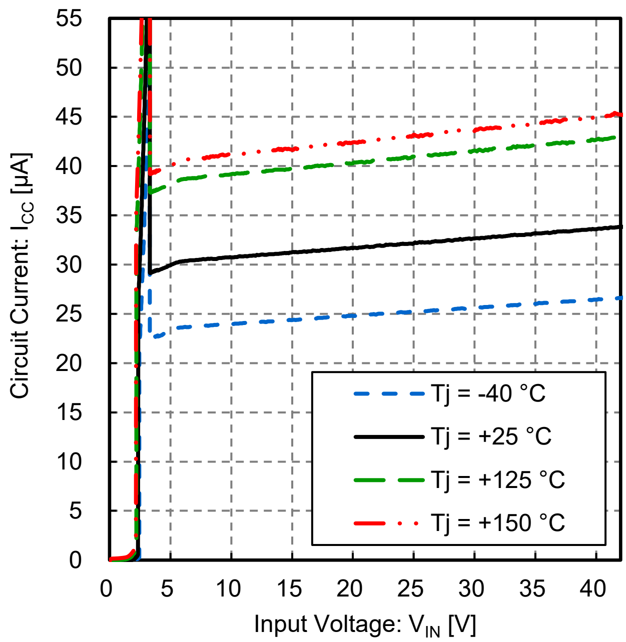



Figure 41. Circuit Current vs Input Voltage; Enlarged view of Figure 40 at narrow Circuit Current range (3.3 V Output)

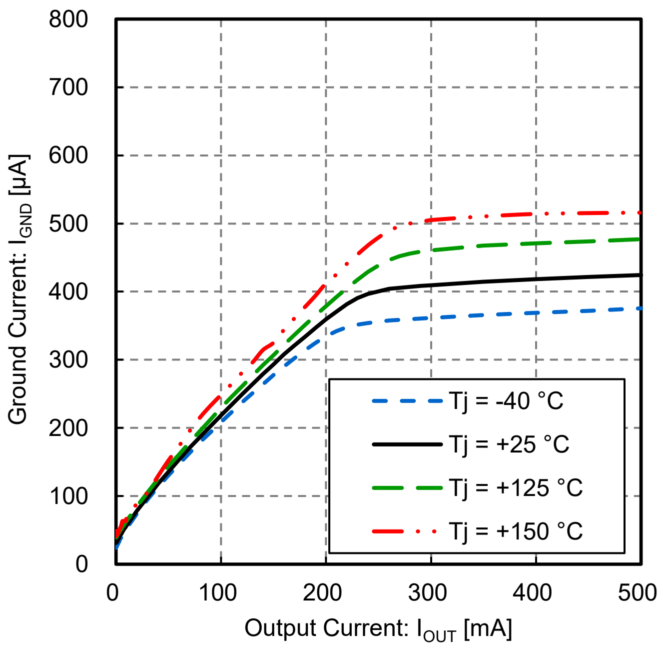



Figure 42. Ground Current vs Output Current (3.3 V Output)

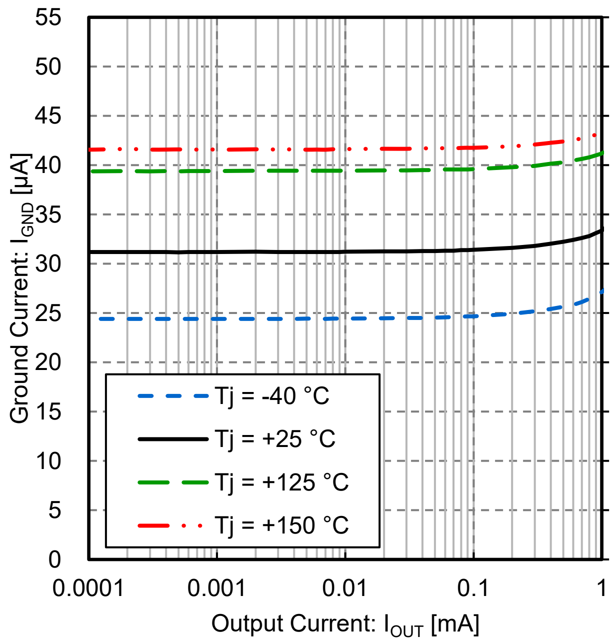



Figure 43. Ground Current vs Output Current; Enlarged view of Figure 42 at low Output Current (3.3 V Output)

**Typical Performance Curves 3.3 V Output - continued**

Unless otherwise specified, Tj = -40 °C to +150 °C, $V_{IN}$ = 13.5 V, $V_{EN}$ = 5 V*(Note 1)*, $I_{OUT}$ = 0 mA, $C_{OUT}$ = 1 µF

*(Note 1)* Only for products with output shutdown function.

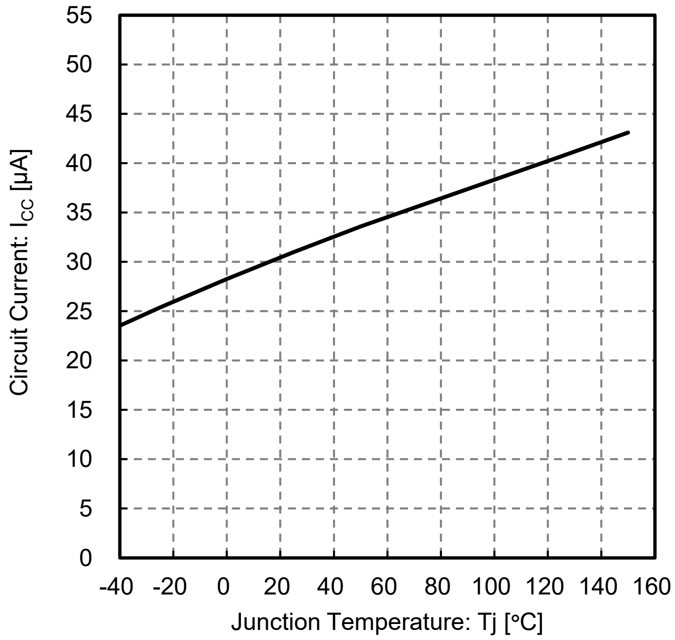



Figure 44. Circuit Current vs Junction Temperature (3.3 V Output)

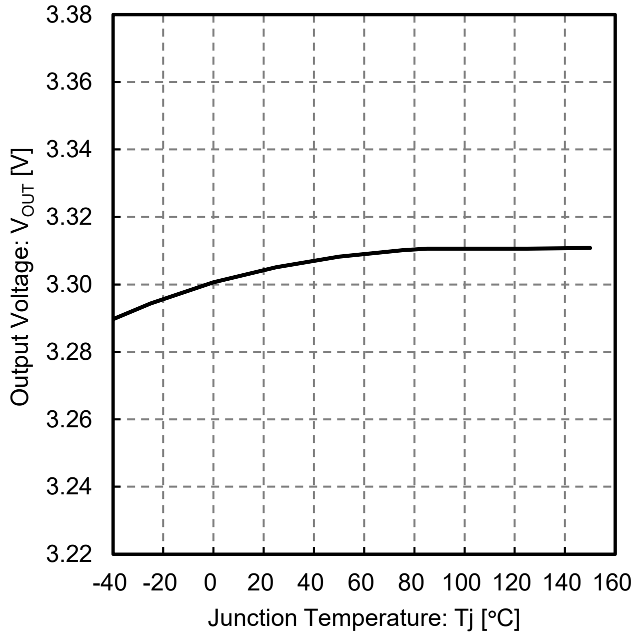



Figure 45. Output Voltage vs Junction Temperature (3.3 V Output)

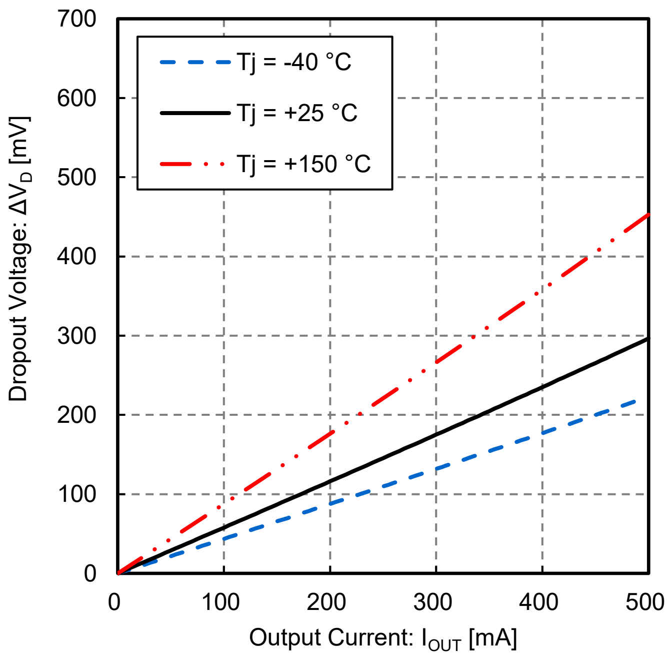



Figure 46. Dropout Voltage vs Output Current (3.3 V Output, $V_{IN}$ = 3.135 V)

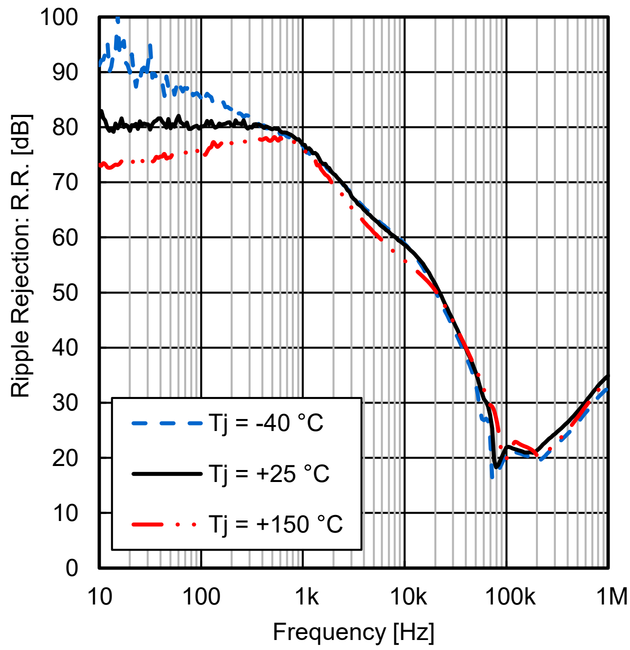



Figure 47. Ripple Rejection vs Frequency (3.3 V Output, $V_{Ripple}$ = 1 Vrms, $I_{OUT}$ = 100 mA)

## Typical Performance Curves 3.3 V Output - continued

Unless otherwise specified, Tj = -40 °C to +150 °C, $V_{IN}$ = 13.5 V, $V_{EN}$ = 5 V*(Note 1)*, $I_{OUT}$ = 0 mA, $C_{OUT}$ = 1 µF

*(Note 1)* Only for products with output shutdown function.

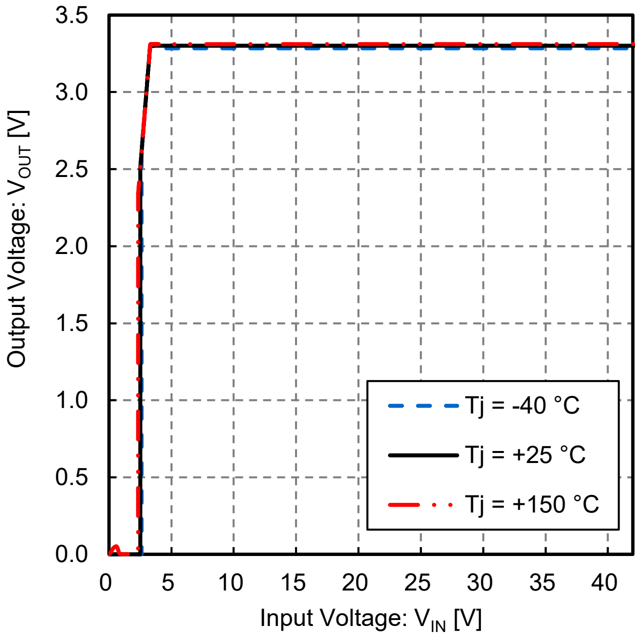



Figure 48. Output Voltage vs Input Voltage
(3.3 V Output)

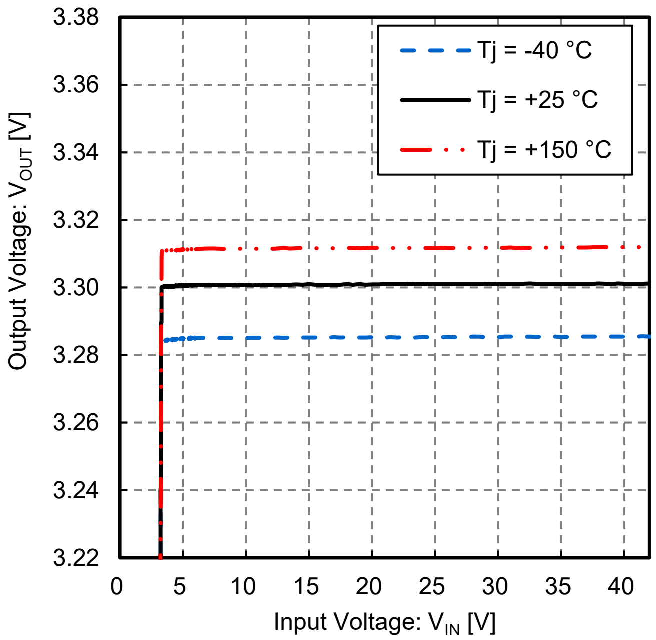



Figure 49. Output Voltage vs Input Voltage;
Enlarged view of Figure 48 at narrow Output Voltage range
(3.3 V Output, Line Regulation)

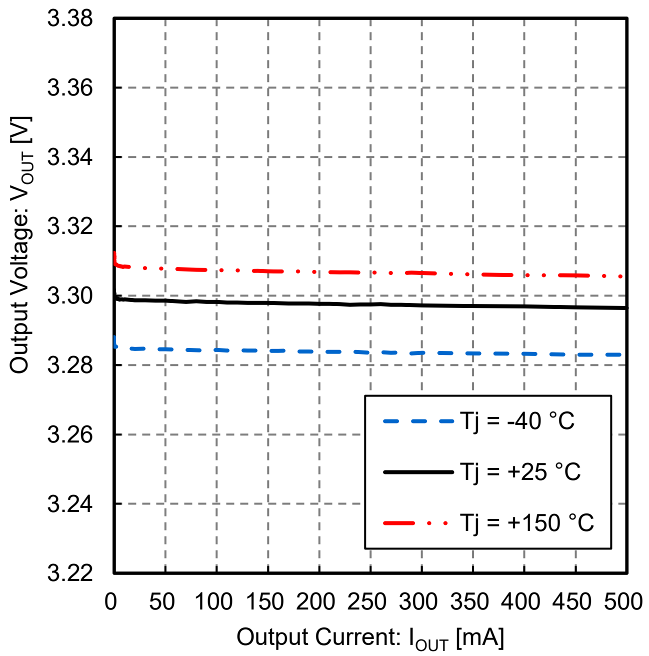



Figure 50. Output Voltage vs Output Current
(3.3 V Output, Load Regulation)

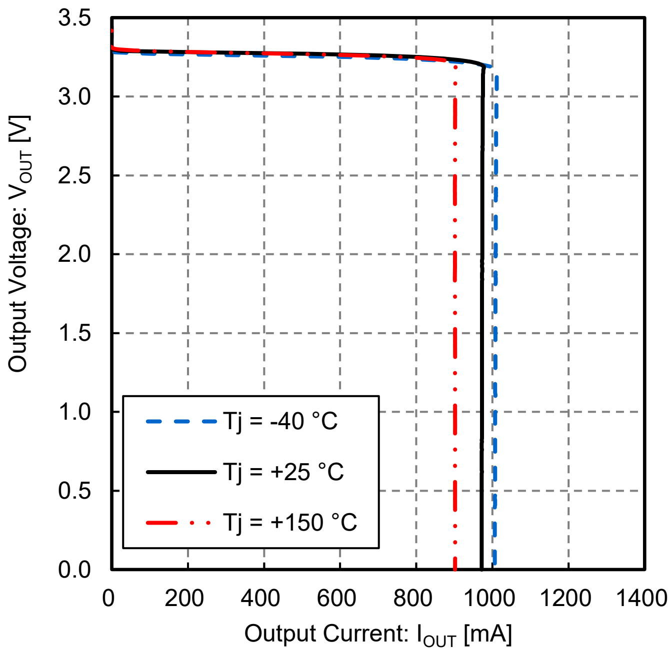



Figure 51. Output Voltage vs Output Current
(3.3 V Output, Over Current Protection)

### Typical Performance Curves 3.3 V Output - continued

Unless otherwise specified, Ta = 25 °C, $V_{IN}$ = 13.5 V, $V_{EN}$ = 5 V*(Note 1)*, $I_{OUT}$ = 0 mA, $C_{OUT}$ = 1 µF

*(Note 1)* Only for products with output shutdown function.

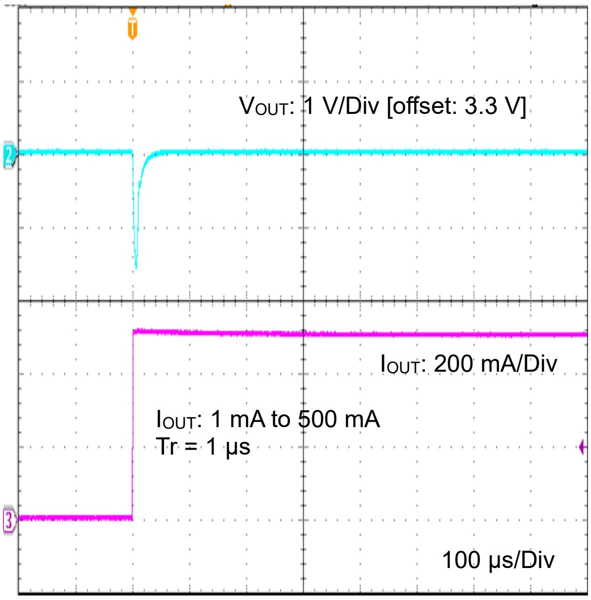



Figure 52. Load Transient 1 mA to 500 mA
(3.3 V Output, Tr = 1 µs, $C_{OUT}$ = 1 µF)

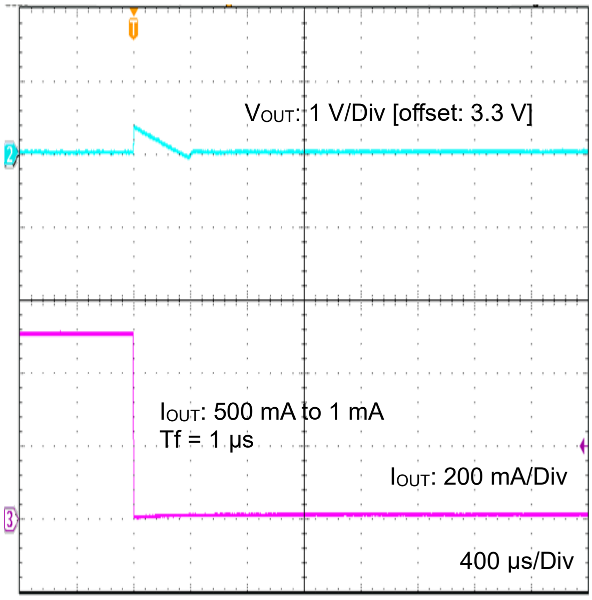



Figure 53. Load Transient 500 mA to 1 mA
(3.3 V Output, Tf = 1 µs, $C_{OUT}$ = 1 µF)

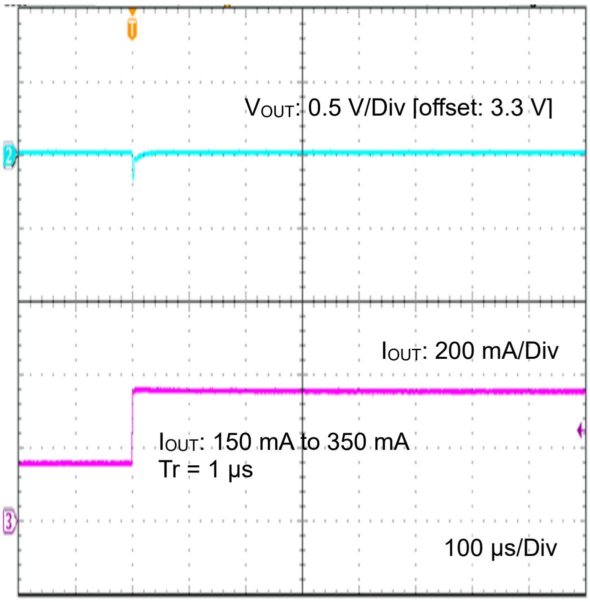



Figure 54. Load Transient 150 mA to 350 mA
(3.3 V Output, Tr = 1 µs, $C_{OUT}$ = 1 µF)

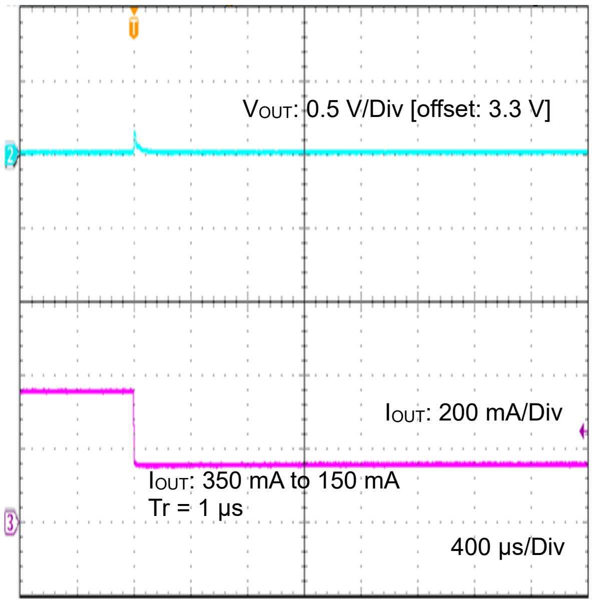



Figure 55. Load Transient 350 mA to 150 mA
(3.3 V Output, Tr = 1 µs, $C_{OUT}$ = 1 µF)

## Typical Performance Curves 3.3 V Output - continued

Unless otherwise specified, Ta = 25 °C, $V_{IN}$ = 13.5 V, $V_{EN}$ = 5 V(Note 1), $I_{OUT}$ = 0 mA, $C_{OUT}$ = 2.2 µF

*(Note 1)* Only for products with output shutdown function.

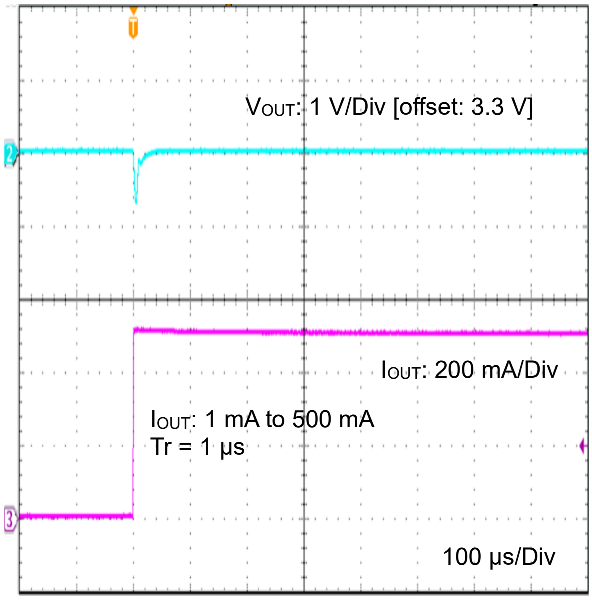



Figure 56. Load Transient 1 mA to 500 mA
(3.3 V Output, Tr = 1 µs, $C_{OUT}$ = 2.2 µF)

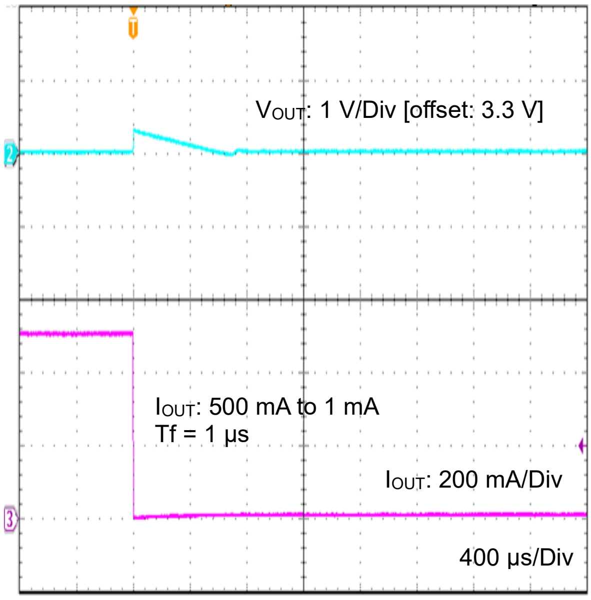



Figure 57. Load Transient 500 mA to 1 mA
(3.3 V Output, Tf = 1 µs, $C_{OUT}$ = 2.2 µF)

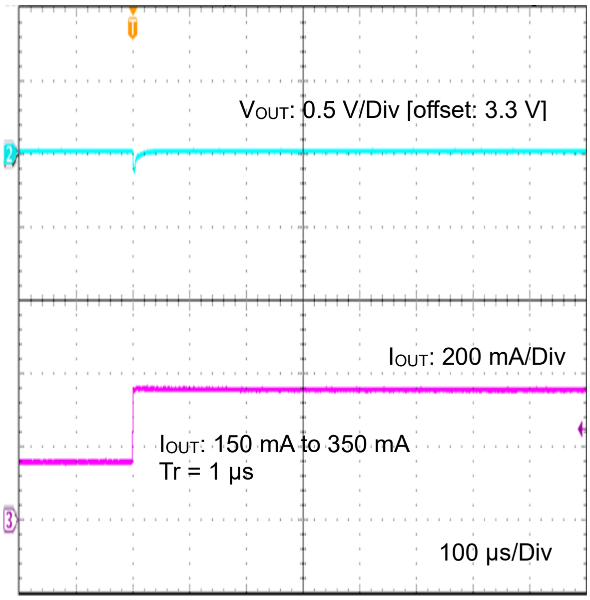



Figure 58. Load Transient 150 mA to 350 mA
(3.3 V Output, Tr = 1 µs, $C_{OUT}$ = 2.2 µF)

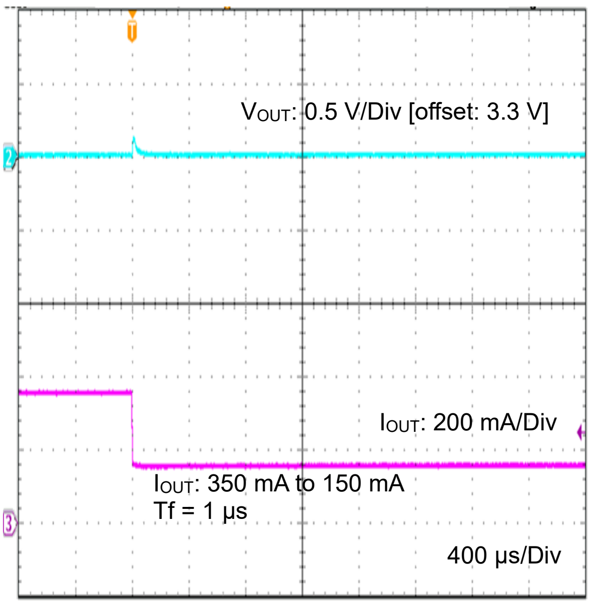



Figure 59. Load Transient 350 mA to 150 mA
(3.3 V Output, Tr = 1 µs, $C_{OUT}$ = 2.2 µF)

## Typical Performance Curves 3.3 V Output - continued

Unless otherwise specified, Ta = 25 °C, $V_{IN}$ = 13.5 V, $V_{EN}$ = 5 V*(Note 1)*, $I_{OUT}$ = 0 mA, $C_{OUT}$ = 4.7 µF

*(Note 1)* Only for products with output shutdown function.

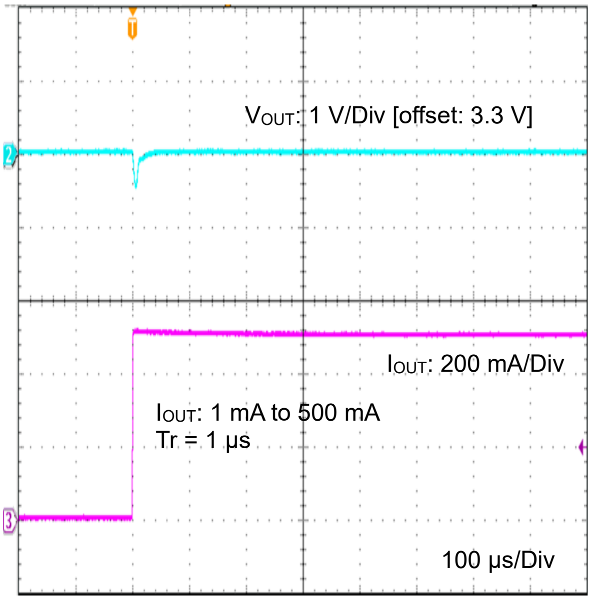



Figure 60. Load Transient 1 mA to 500 mA
(3.3 V Output, Tr = 1 µs, $C_{OUT}$ = 4.7 µF)

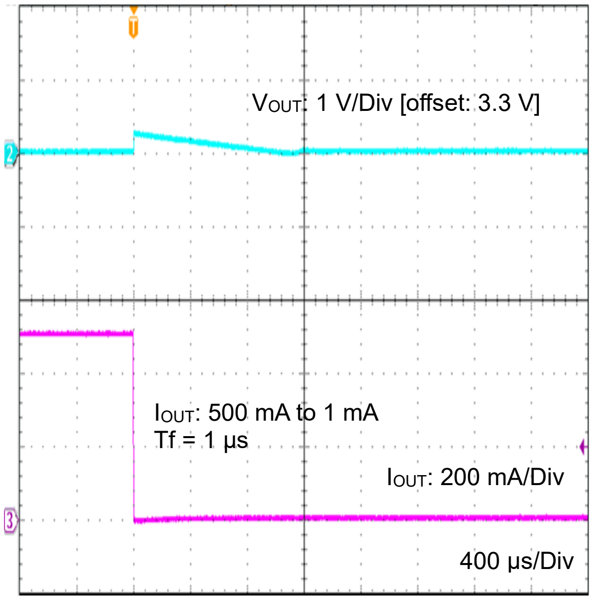



Figure 61. Load Transient 500 mA to 1 mA
(3.3 V Output, Tf = 1 µs, $C_{OUT}$ = 4.7 µF)

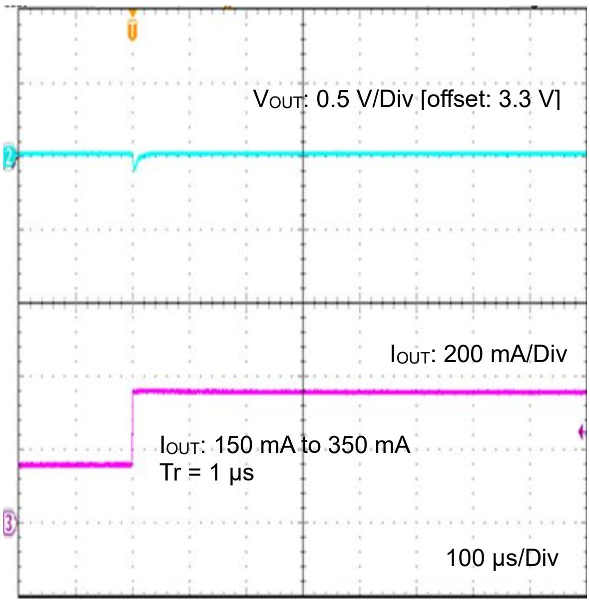



Figure 62. Load Transient 150 mA to 350 mA
(3.3 V Output, Tr = 1 µs, $C_{OUT}$ = 4.7 µF)

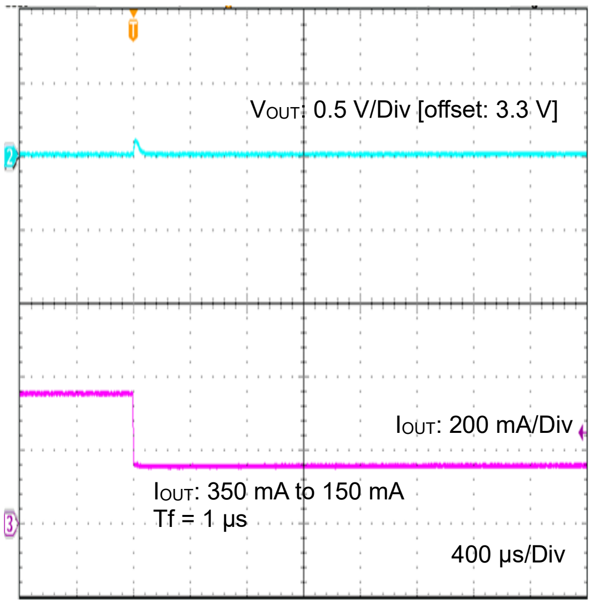



Figure 63. Load Transient 350 mA to 150 mA
(3.3 V Output, Tr = 1 µs, $C_{OUT}$ = 4.7 µF)

### Typical Performance Curves 3.3 V Output - continued

Unless otherwise specified, Ta = 25 °C, $V_{IN}$ = 13.5 V, $V_{EN}$ = 5 V*(Note 1)*, $I_{OUT}$ = 0 mA, $C_{OUT}$ = 1 μF

*(Note 1)* Only for products with output shutdown function.

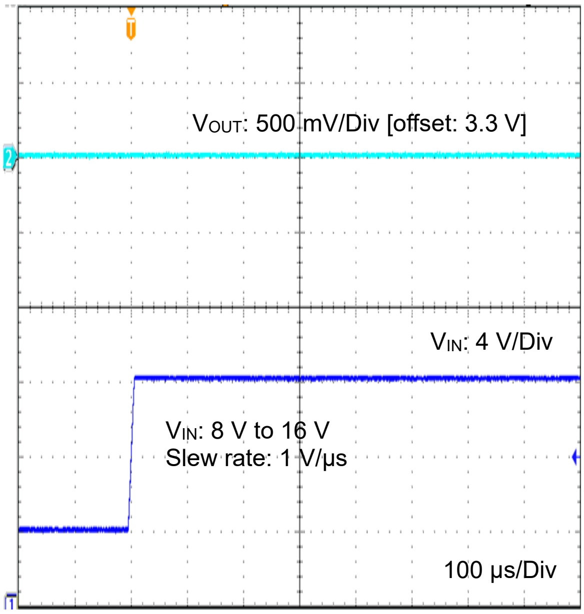



Figure 64. Line Transient 8 V to 16 V
(3.3 V Output, Slew rate = 1 V/μs, $I_{OUT}$ = 0 mA)

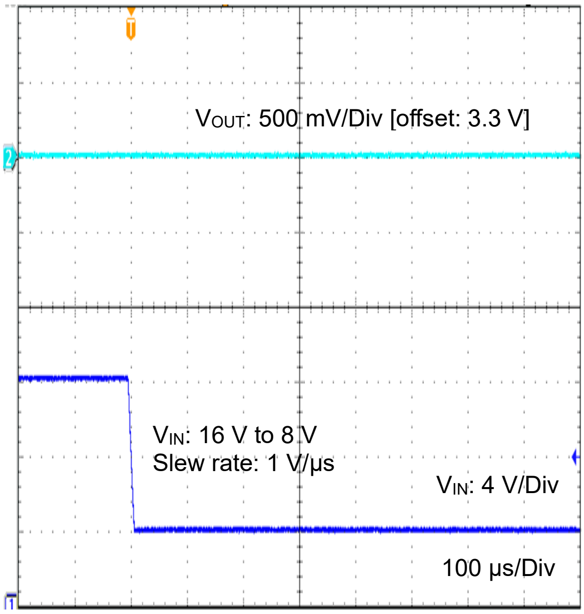



Figure 65. Line Transient 16 V to 8 V
(3.3 V Output, Slew rate = 1 V/μs, $I_{OUT}$ = 0 mA)

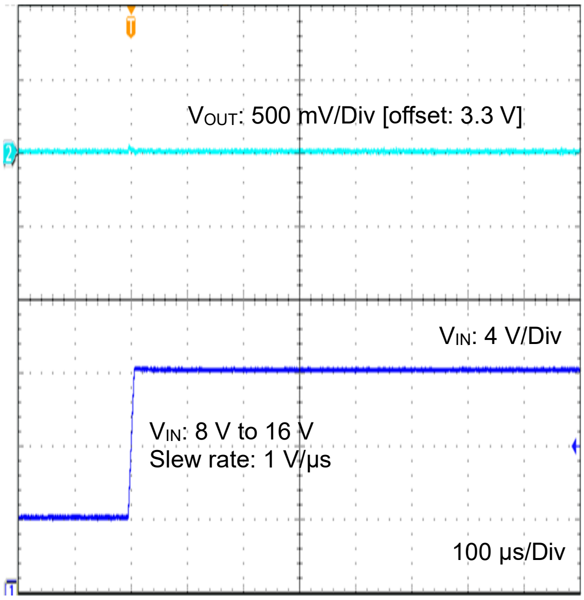



Figure 66. Line Transient 8 V to 16 V
(3.3 V Output, Slew rate = 1 V/μs, $I_{OUT}$ = 500 mA)

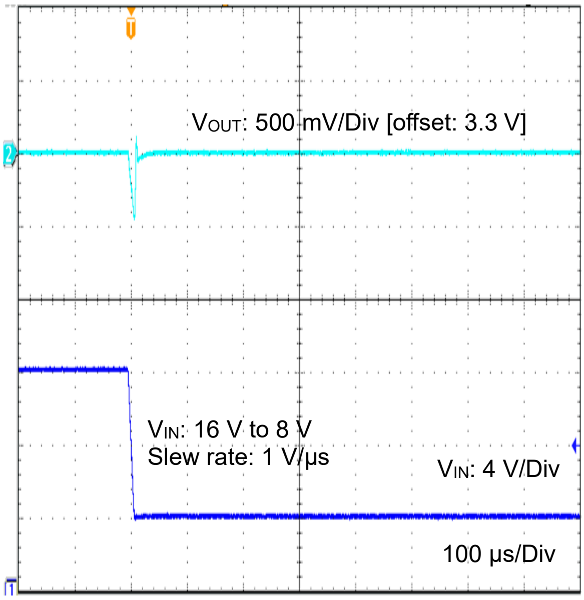



Figure 67. Line Transient 16 V to 8 V
(3.3 V Output, Slew rate = 1 V/μs, $I_{OUT}$ = 500 mA)

### Typical Performance Curves 3.3 V Output - continued

Unless otherwise specified, Ta = 25 °C, $V_{IN}$ = 13.5 V, $V_{EN}$ = 5 V*(Note 1)*, $I_{OUT}$ = 0 mA, $C_{OUT}$ = 1 μF

*(Note 1)* Only for products with output shutdown function.

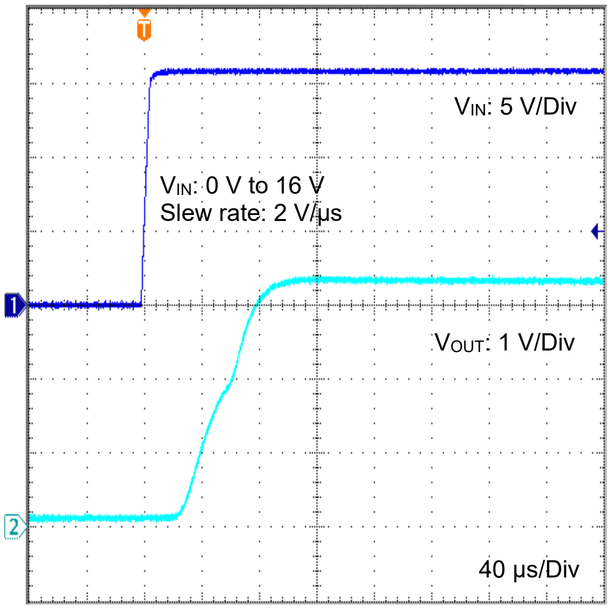



Figure 68. VIN Startup Waveform
$V_{IN}$: 0 V to 16 V
(3.3 V Output, Slew rate = 2 V/μs, $I_{OUT}$ = 0 mA)

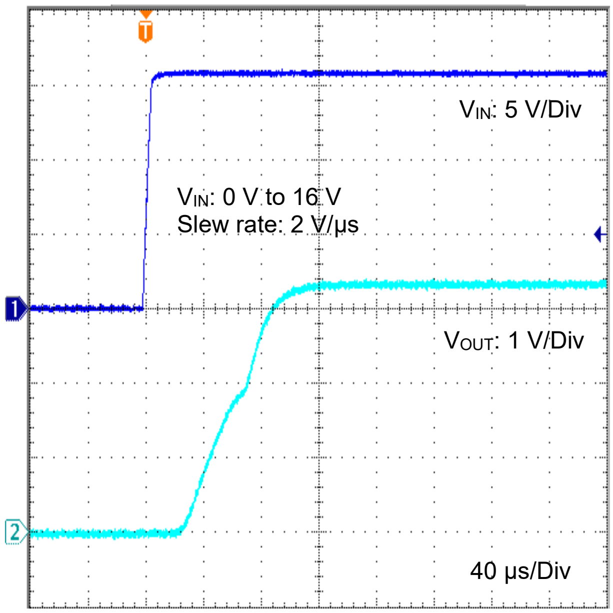



Figure 69. VIN Startup Waveform
$V_{IN}$: 0 V to 16 V
(3.3 V Output, Slew rate = 2 V/μs, $I_{OUT}$ = 500 mA)

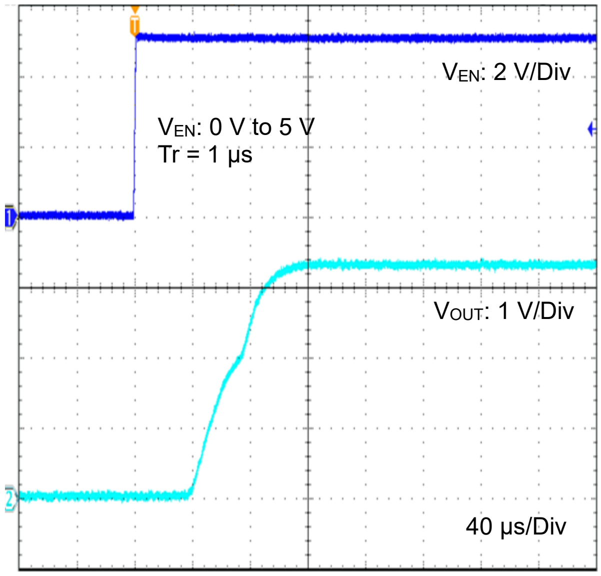



Figure 70. EN Startup Waveform
(3.3 V Output, Tr = 1 μs, $I_{OUT}$ = 1 mA)

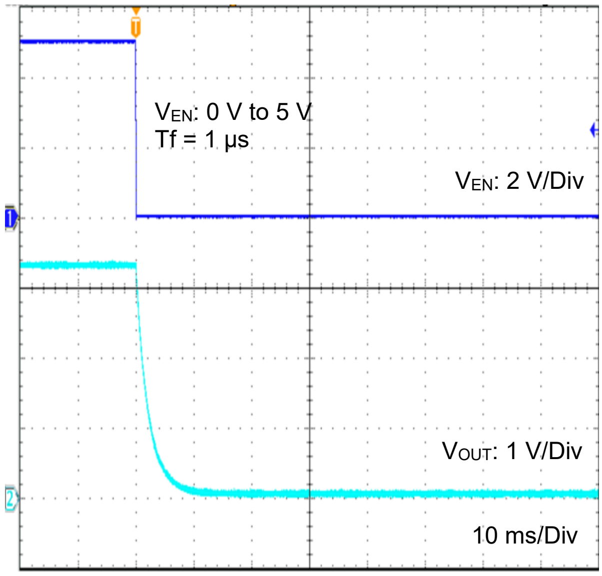
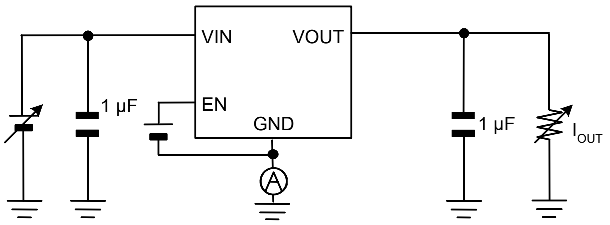
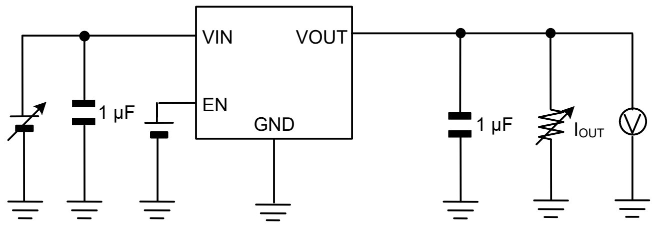



Figure 71. EN Shutdown Waveform
(3.3 V Output, Tf = 1 μs, $I_{OUT}$ = 1 mA)

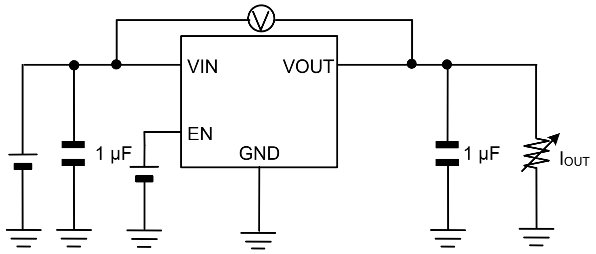
## Measurement Circuit for Typical Performance Curves



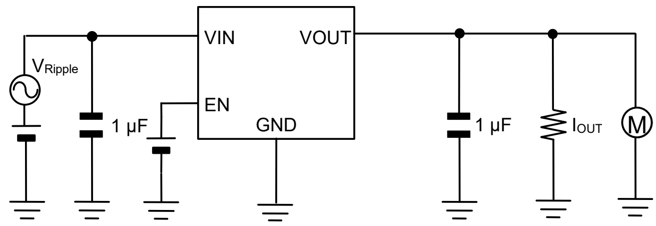

Measurement Setup for
Figure 1 to 5, 16, 40 to 44



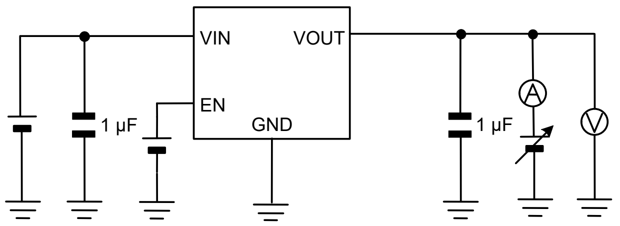

Measurement Setup for
Figure 6, 9 to 12, 14, 45, 48 to 50



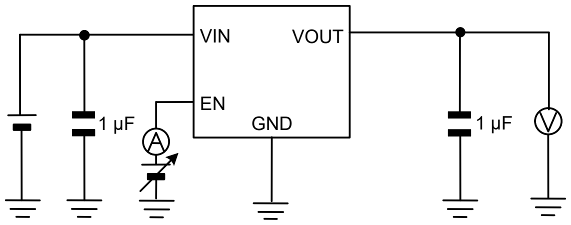

Measurement Setup for
Figure 7, 46



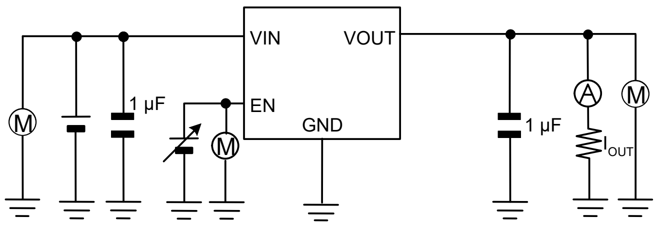

Measurement Setup for
Figure 8, 47



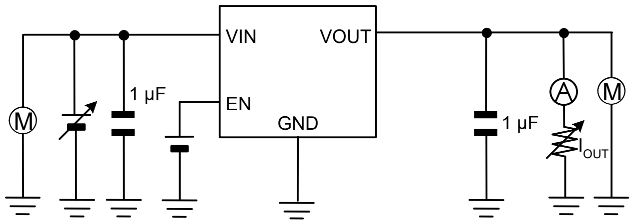

Measurement Setup for
Figure 13, 51




Measurement Setup for
Figure 17, 18, 19

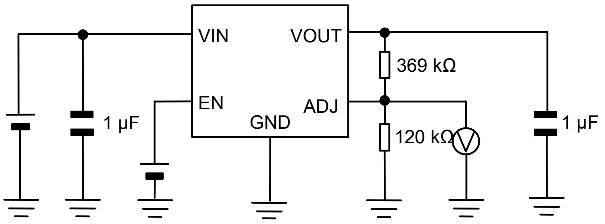



Measurement Setup for
Figure 38, 39, 70, 71




Measurement Setup for
Figure 20 to 37, 52 to 69

**Measurement Circuit for Typical Performance Curves - continued**




Measurement Setup for
Figure 15

## Application and Implementation

***Notice:*** The following information is given as a reference or hint for the application and the implementation. Therefore, it does not guarantee its operation on the specific function, accuracy or external components in the application. In the application, it should be designed with sufficient margin by enough understanding about characteristics of the external components, e.g. capacitors, and also by appropriate verification in the actual operating conditions.

### Selection of External Components

#### Input Pin Capacitor

In order to fully demonstrate the performance of this IC, it is recommended that the input capacitor be placed as close as possible to the input pin and the GND pin without being affected by mounting impedance, etc., and that it be laid out on the same mounting surface. In this case, a capacitor with a capacitance value of 0.1 µF (Min) or higher is recommended.

Depending on the layout of the peripheral components, including this IC, from the input power supply, if the distance from the input power supply is too far or the impedance of the input side is too high, for example, the current supply due to the load response of the IC cannot be withstood, and the output voltage may become unstable due to fluctuations in the input voltage. In such a case, it is necessary to use a large capacitor to prevent the input voltage from dropping. Select the capacitance of the input pin capacitor according to the line impedance between the power smoothing circuit and the input pin, and the load response required by the application.

In addition, the consideration should be taken as the input pin capacitor, to prevent an influence to the regulator’s characteristic from the deviation or the variation of the input capacitor’s characteristic. All input capacitors mentioned above are recommended to have a good DC bias characteristic and a temperature characteristic (approximately ±15 %, e.g. X7R, X8R) with being satisfied high absolute maximum voltage rating based on EIA standard.

#### Output Pin Capacitor

The output capacitor is mandatory for the regulator in order to realize stable operation. The output capacitor with capacitance value of 0.6 µF (Min) or higher and ESR up to 10 Ω (Max) must be required between the output pin and the GND pin.

A proper selection of appropriate both the capacitance value and ESR for the output capacitor can improve the transient behavior of the regulator and can also keep the stability with better regulation loop. The correlation of the output capacitance value and ESR is shown in the graph on the next page as the **output capacitor’s capacitance value and the stability region for ESR**. As described in this graph, this regulator is designed to be stable with ceramic capacitors as of MLCC, with the capacitance value from 0.6 µF to 1000 µF and with ESR value within almost 0 Ω to 10 Ω. The frequency range of ESR can be generally considered at around 10 kHz to around 100 kHz.

Note that the provided the stable area of the capacitance value and ESR in the graph is obtained under a specific set of conditions which is based on the measurement result in single IC on our board with a resistive load. In the actual environment, the stability is affected by wire impedance on the board, input power supply impedance and also loads impedance. Therefore, note that a careful evaluation of the actual application, the actual usage environment and the actual conditions should be done to confirm the actual stability of the system.

Generally, in the transient event which is caused by the input voltage fluctuation or the load fluctuation beyond the gain bandwidth of the regulation loop, the transient response ability of the regulator depends on the capacitance value of the output capacitor. Basically the capacitance value of 0.6 µF (Min) or higher for the output capacitor is recommended as shown in the table on **Output Capacitance $C_{OUT}$, ESR Available Area**. Using bigger capacitance value can be expected to improve better the transient response ability in a high frequency. Various types of capacitors can be used for the output capacitor with high capacity which includes electrolytic capacitor, electro-conductive polymer capacitor and tantalum capacitor. Noted that, depending on the type of capacitors, its characteristics such as ESR (≤ 10 Ω) absolute value range, a temperature dependency of capacitance value and increased ESR at cold temperature needs to be taken into consideration.

In addition, the same consideration should be taken as the input pin capacitor, to prevent an influence to the regulator’s characteristic from the deviation or the variation of the external capacitor’s characteristic. All output capacitors mentioned above are recommended to have a good DC bias characteristic and a temperature characteristic (approximately ±15 %, e.g. X7R, X8R) with being satisfied high absolute maximum voltage rating based on EIA standard. These capacitors should be placed close to the output pin and mounted on the same board side of the regulator not to be influenced by implement impedance.

## Application and Implementation - continued

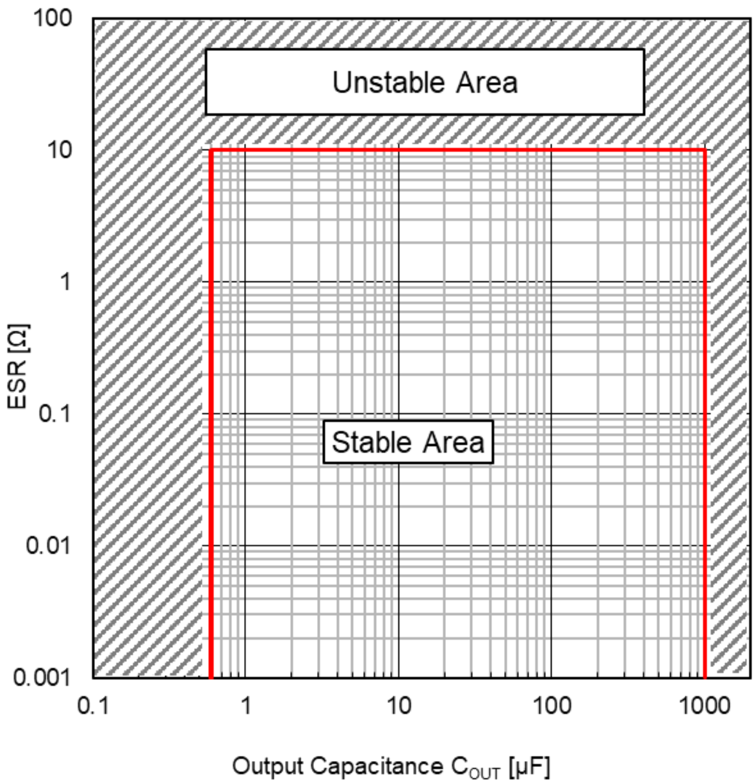



Figure 72. Output Capacitance $C_{OUT}$, ESR Available Area
($V_{IN}$ = 3 V to 42 V, $V_{OUT}$ = 1.5 V*(Note 1)* , -40 °C ≤ Tj ≤ +150 °C, $I_{OUT}$ = 0 mA to 500 mA)
*(Note 1)* The most strict condition from the stability theory for the control loop of regulator.

### Typical Application

| Parameter | Symbol | Reference Value for Application |
|---|---|---|
| Output Current Range | $I_{OUT}$ | $I_{OUT}$ ≤ 500 mA |
| Output Capacitor | $C_{OUT}$ | 1 μF |
| Input Voltage | $V_{IN}$ | 13.5 V |
| Input Capacitor*(Note 2)* | $C_{IN}$ | 1 μF |
| Feedback Resistor ADJ vs GND*(Note 3)* | $R_1$ | 120 kΩ |
| Feedback Resistor ADJ vs VOUT*(Note 3)* | $R_2$ | 369 kΩ |

*(Note 2)* If the impedance, inductance of power supply line is high, please adjust input capacitor value.
To avoid any malfunctions by input voltage drop of power supply line, please consider to adjust the impedance of power supply line to small as much as possible.
*(Note 3)* Applicable for product output adjustable type.
Place the feedback resistor close to the pins as much as possible to avoid the effect by parasitic capacitance on the board, etc.

## Application and Implementation - continued

### Surge Voltage Protection for Linear Regulators

The following shows some helpful tips to protect ICs from possible inputting surge voltage which exceeds absolute maximum ratings.

#### Positive Surge to the Input

If there is any potential risk that positive surges higher than absolute maximum ratings is applied to the input, a Zener Diode should be inserted between the VIN pin and the GND to protect the device as shown in Figure 73.

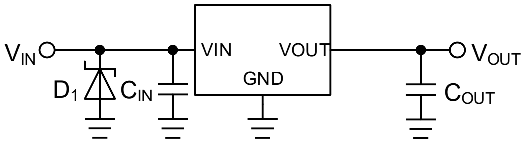



Figure 73. Surges Higher than Absolute Maximum Ratings is Applied to the Input

#### Negative Surge to the Input

If there is any potential risk that negative surges below the absolute maximum ratings, (e.g.) -0.3 V, is applied to the input, a Schottky Diode should be inserted between the VIN and the GND to protect the device as shown in Figure 74.

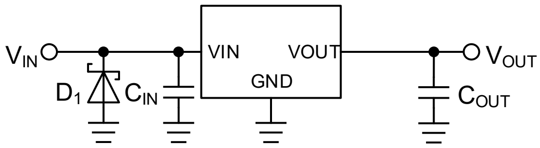



Figure 74. Surges Lower than -0.3 V is Applied to the Input

### Reverse Voltage Protection for Linear Regulators

A linear regulator which is one of the integrated circuit (IC) operates normally in the condition that the input voltage is higher than the output voltage. However, it is possible to happen the abnormal situation in specific conditions which is the output voltage becomes higher than the input voltage. A reverse polarity connection between the input and the output might be occurred or a certain inductor component can also cause a polarity reverse conditions. If the countermeasure is not implemented, it may cause damage to the IC. The following shows some helpful tips to protect ICs from the reverse voltage occasion.

#### Protection against Reverse Input/Output Voltage

In the case that MOSFET is used for the pass transistor, a parasitic body diode between the drain-source generally exists. If the output voltage becomes higher than the input voltage and if its voltage difference exceeds $V_F$ of the body diode, a reverse current flows from the output to the input through the body diode as shown in Figure 75. The current flows in the parasitic body diode is not limited in the protection circuit because it is the parasitic element, therefore too much reverse current may cause damage to degrade or destroy the semiconductor elements of the regulator.

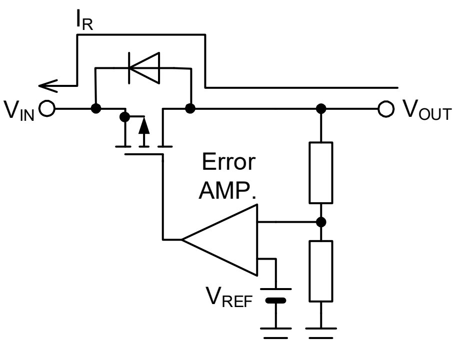



Figure 75. Reverse Current Path in a MOS Linear Regulator

**Protection against Reverse Input/Output Voltage - continued**

An effective solution for this problem is to implement an external bypass diode in order to prevent the reverse current flow inside the IC as shown in Figure 76. Especially in applications where the output voltage setting is high and a large output capacitor is connected, be sure to consider countermeasures for large reverse current values. Note that the bypass diode must be turned on prior to the internal body diode of the IC. This external bypass diode should be chosen as being lower forward voltage $V_F$ than the internal body diode. It should to be selected a diode which has a rated reverse voltage greater than the IC's input maximum voltage and also which has a rated forward current greater than the anticipated reverse current in the actual application.

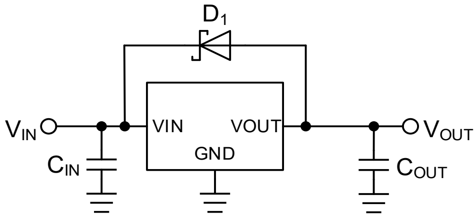



Figure 76. Bypass Diode for Reverse Current Diversion

A Schottky Barrier Diode which has a characteristic of low forward voltage ($V_F$) can meet to the requirement for the external diode to protect the IC from the reverse current. However, it also has a characteristic that the leakage ($I_R$) caused by the reverse voltage is bigger than other diodes. Therefore, it should be taken into the consideration to choose it because if $I_R$ is large, it may cause increase of the current consumption, or raise of the output voltage in the light-load current condition. $I_R$ characteristic of Schottky Diode has positive temperature characteristic, which the details shall be checked with the datasheet of the products, and the careful confirmation of behavior in the actual application is mandatory.

Even in the condition when the input/output voltage is inverted, if the VIN pin is open as shown in Figure 77, or if the VIN pin becomes high-impedance condition as designed in the system, it cannot damage or degrade the parasitic element. It's because a reverse current via the pass transistor becomes extremely low. In this case, therefore, the protection external diode is not necessary.

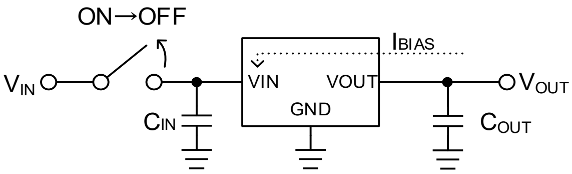



Figure 77. Open VIN

**Protection against Input Reverse Voltage**

When the input of the IC is connected to the power supply, accidentally if plus and minus are routed in reverse, or if there is a possibility that the input may become lower than the GND pin, it may cause to destroy the IC because a large current passes via the internal electrostatic breakdown prevention diode between the VIN pin and the GND pin inside the IC as shown in Figure 78.

The simplest solution to avoid this problem is to connect a Schottky Barrier Diode or a rectifier diode in series to the power supply line as shown in Figure 79. However, it increases a power loss calculated as $V_F$ x $I_{CC}$, and it also causes the voltage drop by a forward voltage $V_F$ at the supply voltage while normal operation.
Generally, since the Schottky Barrier Diode has lower $V_F$, so it contributes to rather smaller power loss than rectifier diodes. If IC has load currents, the required input current to the IC is also bigger. In this case, this external diode generates heat more, therefore select a diode with enough margin in power dissipation. On the other hand, a reverse current passes this diode in the reverse connection condition, however, it is negligible because its small amount.

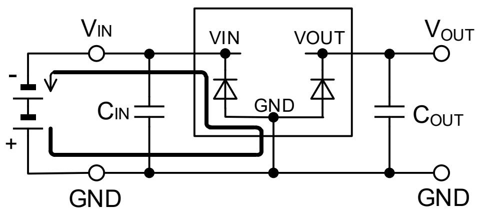



Figure 78. Current Path in Reverse Input Connection

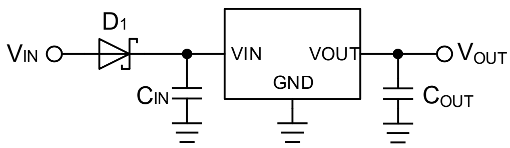



Figure 79. Protection against Reverse Polarity 1

**Protection against Input Reverse Voltage - continued**

Figure 80 shows a circuit in which a P-channel MOSFET is connected in series to the power. The body diode (parasitic element) is located in the drain-source junction area of the MOSFET. The drop voltage in a forward connection is calculated from the on state resistance of the MOSFET and the output current $I_{OUT}$. It is smaller than the drop voltage by the diode as shown in Figure 79 and results in less of a power loss. No current flows in a reverse connection where the MOSFET remains off in Figure 80.

If the gate-source voltage exceeds maximum rating of MOSFET gate-source junction with derating curve in consideration, reduce the gate-source junction voltage by connecting resistor voltage divider as shown in Figure 81.

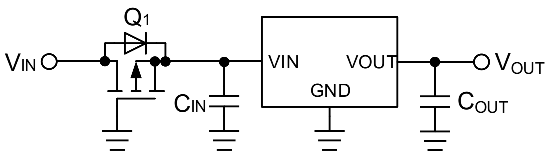



Figure 80. Protection against Reverse Polarity 2

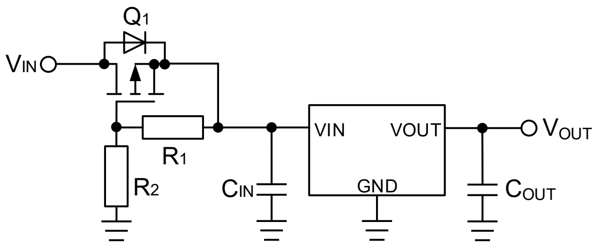



Figure 81. Protection against Reverse Polarity 3

**Protection against Reverse Output Voltage when Output Connect to an Inductor**

If the output load is inductive, electrical energy accumulated in the inductive load is released to the ground at the moment that the output voltage is turned off. IC integrates ESD protection diodes between the IC output and ground pins. A large current may flow in such condition finally resulting on destruction of the IC. To prevent this situation, connect a Schottky Barrier Diode in parallel to the integrated diodes as shown in Figure 82.

Further, if a long wire is in use for the connection between the output pin of the IC and the load, confirm that the negative voltage is not generated at the VOUT pin when the output voltage is turned off by observation of the waveform on an oscilloscope, since it is possible that the load becomes inductive. An additional diode is required for a motor load that is affected by its counter electromotive force, as it produces an electrical current in a similar way.

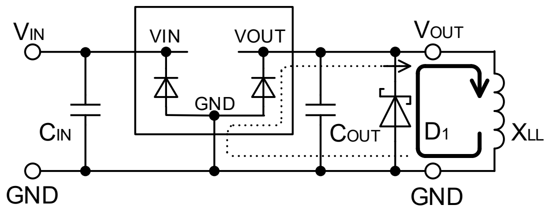
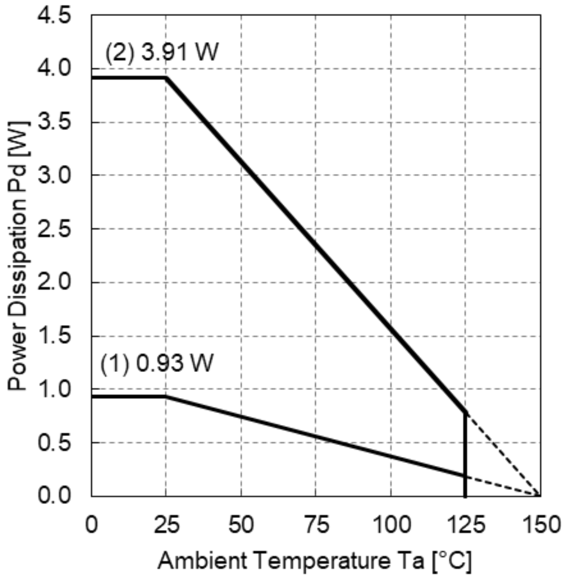



Figure 82. Current Path in Inductive Load (Output: Off)

## Power Dissipation

### HTSOP-J8




(1): 1-layer PCB
(Copper foil area on the reverse side of PCB: 0 mm x 0 mm)
Board material: FR-4
Board size: 114.3 mm x 76.2 mm x 1.57 mmt
Top copper foil: Mounted land pattern + wiring to measure, 70 µm. copper.

(2): 4-layer PCB
(Copper foil area on the reverse side of PCB: 74.2 mm x 74.2 mm)
Board material: FR-4
Board size: 114.3 mm x 76.2 mm x 1.60 mmt
Top copper foil: Mounted land pattern + wiring to measure, 70 µm. copper.
2 inner layers copper foil area of PCB:
74.2 mm x 74.2 mm, 35 µm. copper.
Copper foil area on the reverse side of PCB:
74.2 mm x 74.2 mm, 70 µm. copper.

Condition (1) : $\theta_{JA}$ = 134.2 °C/W, $\Psi_{JT}$ (top center) = 14 °C/W
Condition (2) : $\theta_{JA}$ = 31.9 °C/W, $\Psi_{JT}$ (top center) = 5 °C/W

Figure 83. Power Dissipation Graph (HTSOP-J8)

## Thermal Design

This product exposes a frame on the back side of the package for thermal efficiency improvement. The power consumption of the IC is decided by the dropout voltage condition, the load current and the current consumption. Refer to power dissipation curves illustrated in Figure 83 when using the IC in an environment of Ta ≥ 25 °C. Even if the ambient temperature Ta is at 25 °C, chip junction temperature (Tj) can be very high depending on the input voltage and the load current. Consider the design to be Tj ≤ Tjmax = 150 °C in whole operating temperature range.
Should by any condition the maximum junction temperature Tjmax = 150 °C rating be exceeded by the temperature increase of the chip, it may result in deterioration of the properties of the chip. The thermal impedance in this specification is based on recommended PCB and measurement condition by JEDEC standard. Therefore, need to be careful because it might be different from the actual use condition. Verify the application and allow sufficient margins in the thermal design by the following method to calculate the junction temperature Tj. Tj can be calculated by either of the two following methods.

1. The following method is used to calculate the junction temperature Tj with ambient temperature Ta.

$$Tj = Ta + P_C \times \theta_{JA} \text{ [°C]}$$

Where:

- $Tj$ is the Junction Temperature
- $Ta$ is the Ambient Temperature
- $P_C$ is the Power Consumption
- $\theta_{JA}$ is the Thermal Resistance (Junction to Ambient)

2. The following method is also used to calculate the junction temperature Tj with top center of case's (mold) temperature $T_T$.

$$Tj = T_T + P_C \times \Psi_{JT} \text{ [°C]}$$

Where:

- $Tj$ is the Junction Temperature
- $T_T$ is the Top Center of Case's (mold) Temperature
- $P_C$ is the Power Consumption
- $\Psi_{JT}$ is the Thermal Resistance (Junction to Top Center of Case)

The following method is used to calculate the power consumption Pc (W).

$$Pc = (V_{IN} - V_{OUT}) \times I_{OUT} + V_{IN} \times I_{CC} \text{ [W]}$$

Where:

- $P_C$ is the Power Consumption
- $V_{IN}$ is the Input Voltage
- $V_{OUT}$ is the Output Voltage
- $I_{OUT}$ is the Load Current
- $I_{CC}$ is the Current Consumption

## Thermal Design - continued

### Calculation Example (HTSOP-J8)

If $V_{IN}$ = 13.5 V, $V_{OUT}$ = 5.0 V, $I_{OUT}$ = 200 mA, $I_{CC}$ = 350 µA, the power consumption Pc can be calculated as follows:

$$\begin{aligned} P_C &= (V_{IN} - V_{OUT}) \times I_{OUT} + V_{IN} \times I_{CC} \\ &= (13.5\,V - 5.0\,V) \times 200\,mA + 13.5\,V \times 350\,\mu A \\ &= 1.7\,W \end{aligned}$$

At the ambient temperature Ta = 85 °C,
the thermal impedance (Junction to Ambient) $\theta_{JA}$ = 31.9 °C/W (4-layer PCB)

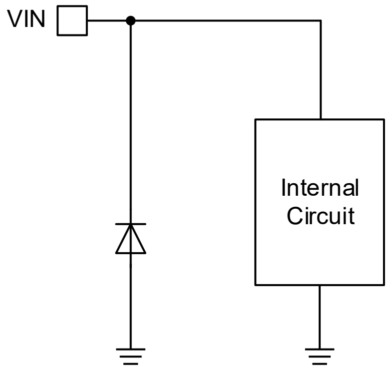
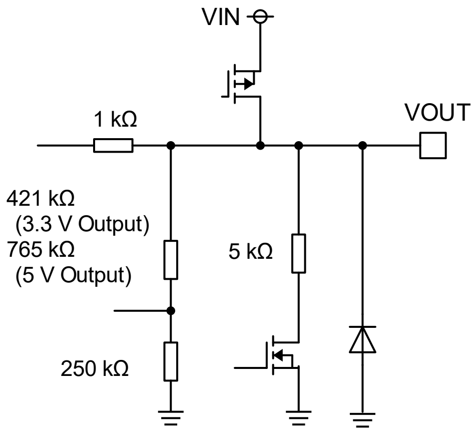
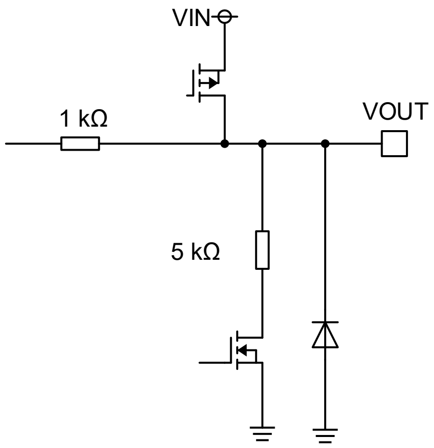
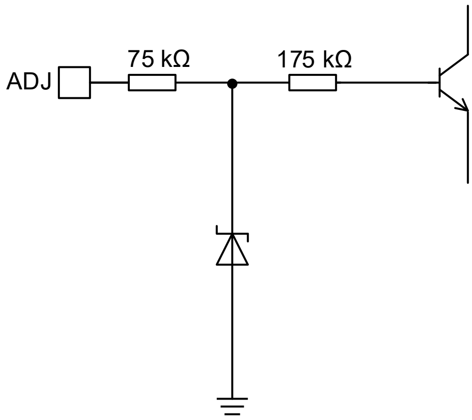
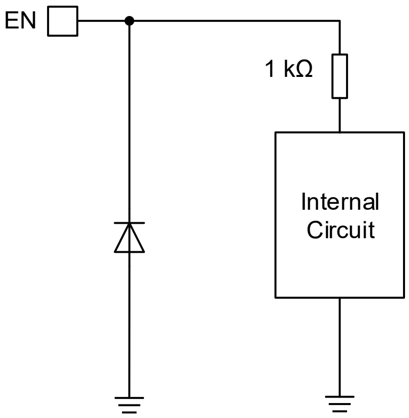
$$\begin{aligned} Tj &= Ta + P_C \times \theta_{JA} \\ &= 85\,°C + 1.7\,W \times 31.9\,°C/W \\ &= 139.2\,°C \end{aligned}$$

When operating the IC, the top center of case's (mold) temperature $T_T$ = 100 °C,
the Thermal Resistance (Junction to Top Center of Case) $\Psi_{JT}$ = 14 °C/W (1-layer PCB)

$$\begin{aligned} Tj &= T_T + P_C \times \Psi_{JT} \\ &= 100\,°C + 1.7\,W \times 14\,°C/W \\ &= 123.8\,°C \end{aligned}$$

If it is difficult to ensure the margin by the calculations above, it is recommended to expand the copper foil area of the board, increasing the layer and thermal via between thermal land pad for optimum thermal performance.

## I/O Equivalence Circuit

<table>
<tr><th>VIN</th><th>VOUT(Note 1)</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><th>VOUT(Note 2)</th><th>ADJ(Note 2)</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><th>EN(Note 3)</th><th></th></tr>
<tr><td>
</td><td></td></tr>
</table>

*(Note 1)* Applicable for product output Fixed type.
*(Note 2)* Applicable for product output adjustable type.
*(Note 3)* Applicable for product with output shutdown function.

## Operational Notes

1. **Reverse Connection of Power Supply**
   Connecting the power supply in reverse polarity can damage the IC. Take precautions against reverse polarity when connecting the power supply, such as mounting an external diode between the power supply and the IC's power supply pins.

2. **Power Supply Lines**
   Design the PCB layout pattern to provide low impedance supply lines. Furthermore, connect a capacitor to ground at all power supply pins. Consider the effect of temperature and aging on the capacitance value when using electrolytic capacitors.

3. **Ground Voltage**
   Ensure that no pins are at a voltage below that of the ground pin at any time, even during transient condition.

4. **Ground Wiring Pattern**
   When using both small-signal and large-current ground traces, the two ground traces should be routed separately but connected to a single ground at the reference point of the application board to avoid fluctuations in the small-signal ground caused by large currents. Also ensure that the ground traces of external components do not cause variations on the ground voltage. The ground lines must be as short and thick as possible to reduce line impedance.

5. **Operating Conditions**
   The function and operation of the IC are guaranteed within the range specified by the recommended operating conditions. The characteristic values are guaranteed only under the conditions of each item specified by the electrical characteristics.

6. **Inrush Current**
   When power is first supplied to the IC, it is possible that the internal logic may be unstable and inrush current may flow instantaneously due to the internal powering sequence and delays, especially if the IC has more than one power supply. Therefore, give special consideration to power coupling capacitance, power wiring, width of ground wiring, and routing of connections.

7. **Thermal Consideration**
   The power dissipation under actual operating conditions should be taken into consideration and a sufficient margin should be allowed in the thermal design. On the reverse side of the package this product has an exposed heat pad for improving the heat dissipation. The amount of heat generation depends on the voltage difference between the input and output, load current, and bias current. Therefore, when actually using the chip, ensure that the generated heat does not exceed the Pd rating. If Junction temperature is over Tjmax (= 150 °C), IC characteristics may be worse due to rising chip temperature. Heat resistance in specification is measurement under PCB condition and environment recommended in JEDEC. Ensure that heat resistance in specification is different from actual environment.

8. **Testing on Application Boards**
   When testing the IC on an application board, connecting a capacitor directly to a low-impedance output pin may subject the IC to stress. Always discharge capacitors completely after each process or step. The IC's power supply should always be turned off completely before connecting or removing it from the test setup during the inspection process. To prevent damage from static discharge, ground the IC during assembly and use similar precautions during transport and storage.

9. **Inter-pin Short and Mounting Errors**
   Ensure that the direction and position are correct when mounting the IC on the PCB. Incorrect mounting may result in damaging the IC. Avoid nearby pins being shorted to each other especially to ground, power supply and output pin. Inter-pin shorts could be due to many reasons such as metal particles, water droplets (in very humid environment) and unintentional solder bridge deposited in between pins during assembly to name a few.

10. **Unused Input Pins**
    Input pins of an IC are often connected to the gate of a MOS transistor. The gate has extremely high impedance and extremely low capacitance. If left unconnected, the electric field from the outside can easily charge it. The small charge acquired in this way is enough to produce a significant effect on the conduction through the transistor and cause unexpected operation of the IC. So unless otherwise specified, unused input pins should be connected to the power supply or ground line.

## Operational Notes - continued

**11. Regarding the Input Pin of the IC**

This monolithic IC contains P+ isolation and P substrate layers between adjacent elements in order to keep them isolated. P-N junctions are formed at the intersection of the P layers with the N layers of other elements, creating a parasitic diode or transistor. For example, (refer to figure below):

When GND > Pin A and GND > Pin B, the P-N junction operates as a parasitic diode.
When GND > Pin B, the P-N junction operates as a parasitic transistor.

Parasitic diodes inevitably occur in the structure of the IC. The operation of parasitic diodes can result in mutual interference among circuits, operational faults, or physical damage. Therefore, conditions that cause these diodes to operate, such as applying a voltage lower than the GND voltage to an input pin (and thus to the P substrate) should be avoided.

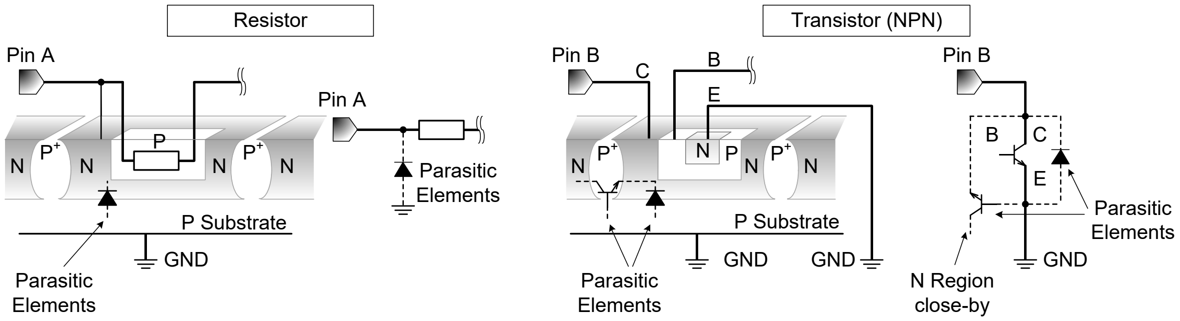



Figure 84. Example of Monolithic IC Structure

**12. Ceramic Capacitor**

When using a ceramic capacitor, determine a capacitance value considering the change of capacitance with temperature and the decrease in nominal capacitance due to DC bias and others.

**13. Thermal Shutdown Protection Circuit (TSD)**

This IC has a built-in thermal shutdown protection circuit that prevents heat damage to the IC. Normal operation should always be within the IC's maximum junction temperature rating. If however the rating is exceeded for a continued period, the junction temperature (Tj) will rise which will activate the TSD circuit that will turn OFF power output pins. When the Tj falls below the TSD threshold, the circuits are automatically restored to normal operation.
Note that the TSD circuit operates in a situation that exceeds the absolute maximum ratings and therefore, under no circumstances, should the TSD circuit be used in a set design or for any purpose other than protecting the IC from heat damage.

**14. Over Current Protection Circuit (OCP)**

This IC incorporates an integrated overcurrent protection circuit that is activated when the load is shorted. This protection circuit is effective in preventing damage due to sudden and unexpected incidents. However, the IC should not be used in applications characterized by continuous operation or transitioning of the protection circuit.

**15. Enable Pin**

The EN pin is for controlling ON/OFF the output voltage. Do not make voltage level of chip enable keep floating level, or between $V_{ENH}$ and $V_{ENL}$. Otherwise, the output voltage would be unstable or indefinite.

**16. Functional Safety**

"ISO 26262 Process Compliant to Support ASIL-*"
A product that has been developed based on an ISO 26262 design process compliant to the ASIL level described in the datasheet.
"Safety Mechanism is Implemented to Support Functional Safety (ASIL-*)"
A product that has implemented safety mechanism to meet ASIL level requirements described in the datasheet.
"Functional Safety Supportive Automotive Products"
A product that has been developed for automotive use and is capable of supporting safety analysis with regard to the functional safety.
Note: "ASIL-*" is stands for the ratings of "ASIL-A", "-B", "-C" or "-D" specified by each product's datasheet.

## Ordering Information

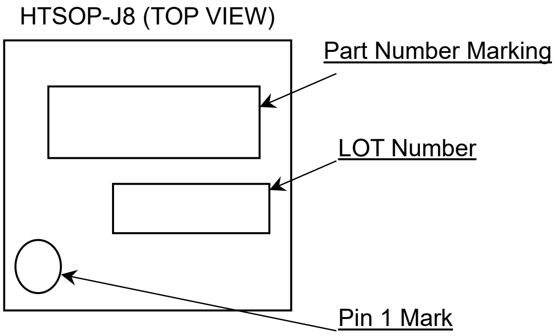
B D 6 x x M 5 W x x x - C E 2

- Product Name
- Output Voltage
  00: Adjustable
  33: 3.3 V
  50: 5.0 V
- Output Current
  5: 500 mA
- Output Shutdown Function
  W: Include Function
  None: Without Function
- Package
  EFJ: HTSOP-J8
- Product Rank
  C: for Automotive
- Packaging and Forming Specification
  E2: Embossed Tape and Reel

## Lineup

| Output Current Capability | Output Voltage (Typ) | Output Shut-down Function | Package | Ordering |
|---|---|---|---|---|
| 500 mA | 3.3 V | not available | HTSOP-J8 | BD633M5EFJ-CE2 |
| | | available | | BD633M5WEFJ-CE2 |
| | 5.0 V | not available | | BD650M5EFJ-CE2 |
| | | available | | BD650M5WEFJ-CE2 |
| | Adjustable | not available | | BD600M5EFJ-CE2 |
| | | available | | BD600M5WEFJ-CE2 |

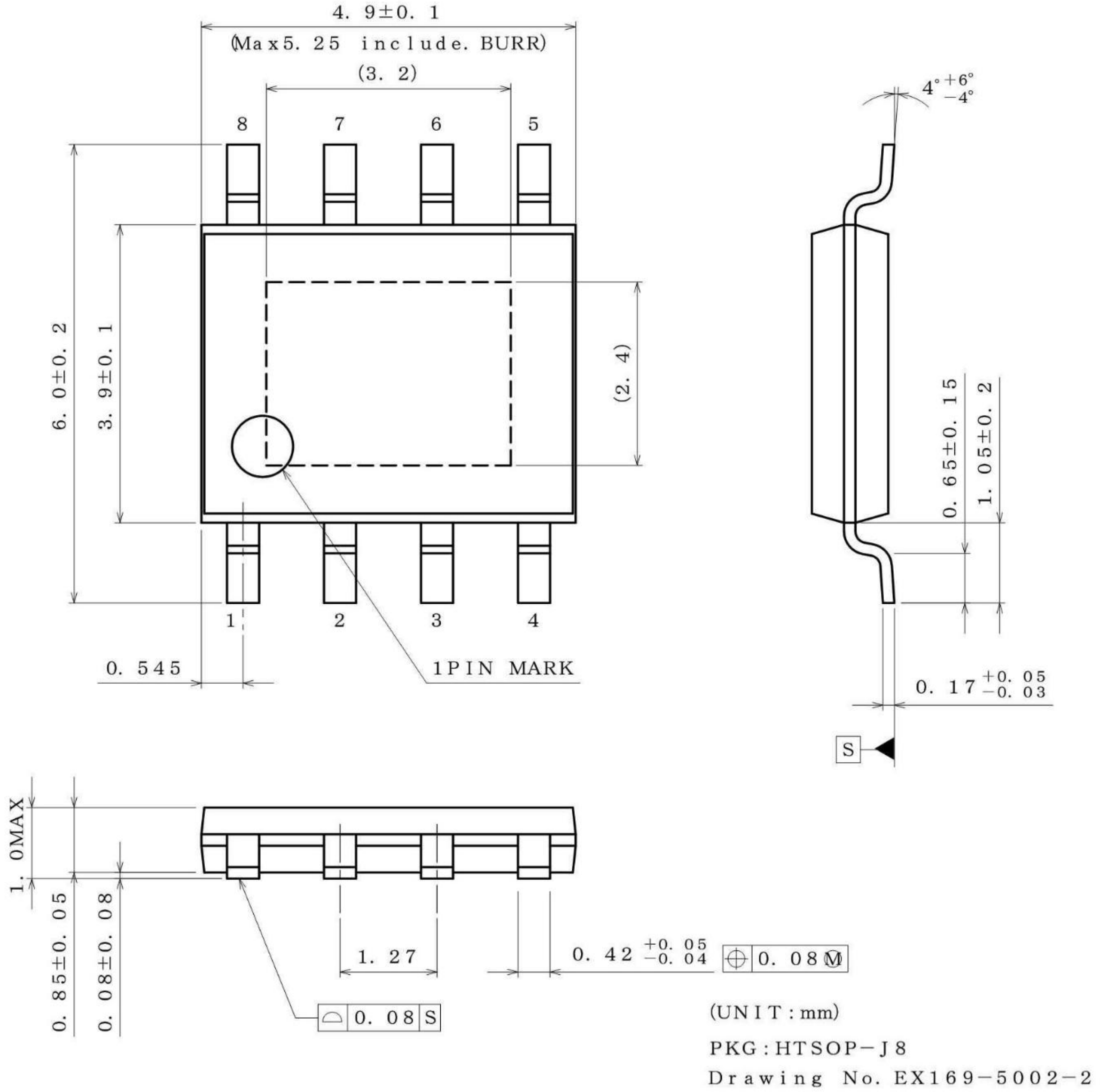
## Marking Diagrams




| Part Number | Part Number Marking | Output Voltage [V] | Output Shutdown Function |
|---|---|---|---|
| BD633M5EFJ-CE2 | 633M5 | 3.3 V | not available |
| BD650M5EFJ-CE2 | 650M5 | 5.0 V | not available |
| BD600M5EFJ-CE2 | 600M5 | Adjustable | not available |
| BD633M5WEFJ-CE2 | 633M5W | 3.3 V | available |
| BD650M5WEFJ-CE2 | 650M5W | 5.0 V | available |
| BD600M5WEFJ-CE2 | 600M5W | Adjustable | available |

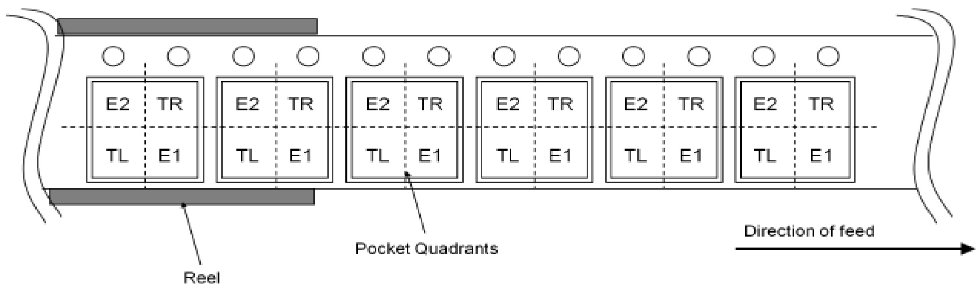
## Physical Dimension and Packing Information

| Package Name | HTSOP-J8 |
|---|---|




<Tape and Reel information>

| | |
|---|---|
| Tape | Embossed carrier tape |
| Quantity | 2500pcs |
| Direction of feed | E2<br>( The direction is the 1pin of product is at the upper left when you hold reel on the left hand and you pull out the tape on the right hand ) |



## Revision History

| Date | Revision | Changes |
|---|---|---|
| 21.Jan.2026 | 001 | New Release |

# Notice

## Precaution on using ROHM Products

1. If you intend to use our Products in devices requiring extremely high reliability (such as medical equipment (Note 1), aircraft/spacecraft, nuclear power controllers, etc.) and whose malfunction or failure may cause loss of human life, bodily injury or serious damage to property (“Specific Applications”), please consult with the ROHM sales representative in advance. Unless otherwise agreed in writing by ROHM in advance, ROHM shall not be in any way responsible or liable for any damages, expenses or losses incurred by you or third parties arising from the use of any ROHM’s Products for Specific Applications.

(Note1) Medical Equipment Classification of the Specific Applications

| JAPAN | USA | EU | CHINA |
|---|---|---|---|
| CLASSⅢ | CLASSⅢ | CLASSⅡb | CLASSⅢ |
| CLASSⅣ | | CLASSⅢ | |

2. ROHM designs and manufactures its Products subject to strict quality control system. However, semiconductor products can fail or malfunction at a certain rate. Please be sure to implement, at your own responsibilities, adequate safety measures including but not limited to fail-safe design against the physical injury, damage to any property, which a failure or malfunction of our Products may cause. The following are examples of safety measures:
   [a] Installation of protection circuits or other protective devices to improve system safety
   [b] Installation of redundant circuits to reduce the impact of single or multiple circuit failure

3. Our Products are not designed under any special or extraordinary environments or conditions, as exemplified below. Accordingly, ROHM shall not be in any way responsible or liable for any damages, expenses or losses arising from the use of any ROHM’s Products under any special or extraordinary environments or conditions. If you intend to use our Products under any special or extraordinary environments or conditions (as exemplified below), your independent verification and confirmation of product performance, reliability, etc, prior to use, must be necessary:
   [a] Use of our Products in any types of liquid, including water, oils, chemicals, and organic solvents
   [b] Use of our Products outdoors or in places where the Products are exposed to direct sunlight or dust
   [c] Use of our Products in places where the Products are exposed to sea wind or corrosive gases, including $Cl_2$, $H_2S$, $NH_3$, $SO_2$, and $NO_2$
   [d] Use of our Products in places where the Products are exposed to static electricity or electromagnetic waves
   [e] Use of our Products in proximity to heat-producing components, plastic cords, or other flammable items
   [f] Sealing or coating our Products with resin or other coating materials
   [g] Use of our Products without cleaning residue of flux (Exclude cases where no-clean type fluxes is used. However, recommend sufficiently about the residue.); or Washing our Products by using water or water-soluble cleaning agents for cleaning residue after soldering
   [h] Use of the Products in places subject to dew condensation

4. The Products are not subject to radiation-proof design.

5. Please verify and confirm characteristics of the final or mounted products in using the Products.

6. In particular, if a transient load (a large amount of load applied in a short period of time, such as pulse, is applied, confirmation of performance characteristics after on-board mounting is strongly recommended. Avoid applying power exceeding normal rated power; exceeding the power rating under steady-state loading condition may negatively affect product performance and reliability.

7. De-rate Power Dissipation depending on ambient temperature. When used in sealed area, confirm that it is the use in the range that does not exceed the maximum junction temperature.

8. Confirm that operation temperature is within the specified range described in the product specification.

9. ROHM shall not be in any way responsible or liable for failure induced under deviant condition from what is defined in this document.

## Precaution for Mounting / Circuit board design

1. When a highly active halogenous (chlorine, bromine, etc.) flux is used, the residue of flux may negatively affect product performance and reliability.

2. In principle, the reflow soldering method must be used on a surface-mount products, the flow soldering method must be used on a through hole mount products. If the flow soldering method is preferred on a surface-mount products, please consult with the ROHM representative in advance.

For details, please refer to ROHM Mounting specification

## Precautions Regarding Application Examples and External Circuits

1. If change is made to the constant of an external circuit, please allow a sufficient margin considering variations of the characteristics of the Products and external components, including transient characteristics, as well as static characteristics.

2. You agree that application notes, reference designs, and associated data and information contained in this document are presented only as guidance for Products use. Therefore, in case you use such information, you are solely responsible for it and you must exercise your own independent verification and judgment in the use of such information contained in this document. ROHM shall not be in any way responsible or liable for any damages, expenses or losses incurred by you or third parties arising from the use of such information.

## Precaution for Electrostatic

This Product is electrostatic sensitive product, which may be damaged due to electrostatic discharge. Please take proper caution in your manufacturing process and storage so that voltage exceeding the Products maximum rating will not be applied to Products. Please take special care under dry condition (e.g. Grounding of human body / equipment / solder iron, isolation from charged objects, setting of Ionizer, friction prevention and temperature / humidity control).

## Precaution for Storage / Transportation

1. Product performance and soldered connections may deteriorate if the Products are stored in the places where:
    [a] the Products are exposed to sea winds or corrosive gases, including $Cl_2$, $H_2S$, $NH_3$, $SO_2$, and $NO_2$
    [b] the temperature or humidity exceeds those recommended by ROHM
    [c] the Products are exposed to direct sunshine or condensation
    [d] the Products are exposed to high Electrostatic

2. Even under ROHM recommended storage condition, solderability of products out of recommended storage time period may be degraded. It is strongly recommended to confirm solderability before using Products of which storage time is exceeding the recommended storage time period.

3. Store / transport cartons in the correct direction, which is indicated on a carton with a symbol. Otherwise bent leads may occur due to excessive stress applied when dropping of a carton.

4. Use Products within the specified time after opening a humidity barrier bag. Baking is required before using Products of which storage time is exceeding the recommended storage time period.

## Precaution for Product Label

A two-dimensional barcode printed on ROHM Products label is for ROHM's internal use only.

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When disposing Products please dispose them properly using an authorized industry waste company.

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