# SNE2402 Automotive 150-mA, High-Voltage, Ultra-Low-IQ Low-Dropout Regulator

## Features

- AEC-Q100 qualified for automotive applications:
  - Temperature grade 0: −40°C ≤ $T_A$ ≤ 150°C
- Extended junction temperature range:
  - Grade 0: −40°C ≤ $T_J$ ≤ 165°C
- Low quiescent current $I_Q$:
  - 300nA typical shutdown $I_Q$
  - 3.5μA typical at light loads
- 3V to 40V wide $V_{IN}$ input voltage range with up to 42V transient
- Maximum output current: 150mA
- Output-voltage accuracy: 2%
- Typ. dropout voltage: 250mV@150mA load current for fixed 5V output version
- Stable with low-ESR (0.001Ω to 1Ω) ceramic output-stability capacitor (2.2μF to 200μF)
- Fixed 2.5V, 3.3V, and 5V output voltage

## Typical Application



**Typical Application Circuit**

## General Description

In automotive battery-connected applications, low quiescent current (IQ) is important to save power and extend battery lifetime. Ultra-low IQ must be included for always-on systems.

The SNE2402 is a low-dropout linear regulator designed to operate with a wide input-voltage range from 3V to 40V (45V load dump protection). Operation down to 3V allows the SNE2402 to continue operating during cold-crank and start and stop conditions. With only 3.5μA typical quiescent current at light load, this device is an optimal solution for powering microcontrollers (MCUs) and CAN/LIN transceivers in standby systems.

The device features integrated short-circuit and overcurrent protection. Additionally, this device uses a thermally conductive package to enable sustained operation despite significant dissipation across the device. Because of these features, the device is designed as a power supply for various automotive applications.
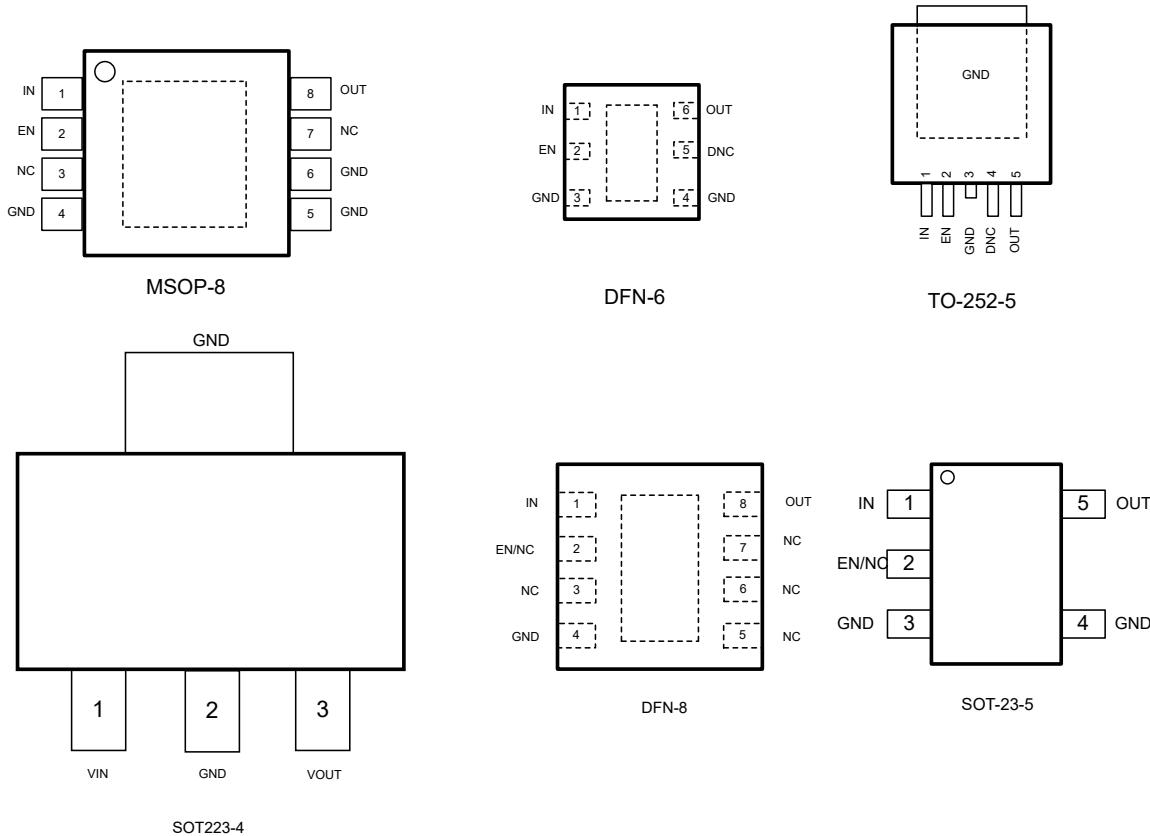
## Applications

- Automotive head units
- Telematics control units
- Headlights
- Body control modules
- Inverter and motor controls

# Contents

# 1    Pin Description



MSOP-8



DFN-6



TO-252-5



SOT223-4



DFN-8



SOT-23-5

| Pin | | | | | | Name | Function |
|---|---|---|---|---|---|---|---|
| MSOP-8 | DFN-6 | TO-252-5 | SOT223-4 | DFN-8 | SOT-23-5 | | |
|  | 5 | 4 |  |  |  | DNC | Do not connect to a biased voltage. Tie this pin to ground or leave floating. |
| 2 | 2 | 2 |  | 2 |  | EN | Enable input pin |
| 4/5/6 | 3/4 | 3 | 2 | 4 | 3/4 | GND | Ground. |
| 1 | 1 | 1 | 1 | 1 | 1 | IN | Input power-supply pin |
| 3/7 |  |  |  | 3/5/6/7 | 2 | NC | Not Connected. |
| 8 | 6 | 5 | 3 | 8 | 5 | OUT | Regulated output voltage pin |
| Thermal pad | | | | | | | Connect the thermal pad to a large-area GND plane for improved thermal performance. |

# 2    Specifications

## 2.1    Absolute Maximum Ratings

Over operating ambient temperature range (unless otherwise noted)[1][2].

| Parameter | Symbol | Rating | Unit |
|---|---|---|---|
| VIN to GND[3] | $V_{IN}$ | -0.3 ~ 42 | V |
| EN to GND[3] | $V_{EN}$ | -0.3 ~ $V_{IN}$ | V |
| OUT to GND | $V_{OUT}$ | -0.3 ~7 | V |
| Junction Temperature (grade 0) | $T_J$ | -40 ~165 | °C |
| Storage Temperature Range | $T_{STG}$ | -40 ~ 150 | °C |

> **Note:**
> [1] Stresses greater than those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "Recommended Operating Conditions" is not implied. Exposure to "Absolute Maximum Ratings" for extended periods may affect device reliability;
> [2] All voltage values are with respect to GND;
> [3] Absolute maximum voltage, withstand 45V for 200ms.

## 2.2    ESD Ratings

| Parameter | Symbol | | | Value | Unit |
|---|---|---|---|---|---|
| Electrostatic discharge | $V_{ESD}$ | Human-body model (HBM), per AEC Q100-002 HBM ESD classification level H2 | | ±2000 | V |
| | | Charged-device model (CDM), per AEC Q100-011 CDM ESD classification level C3B | Corner pins (1, 4, 5, and 8) | ±750 | |
| | | | Other pins | ±500 | |

## 2.3    Recommanded Operating Range

Over operating ambient temperature range (unless otherwise noted).

| Parameter | Symbol | Value | Unit |
|---|---|---|---|
| Unregulated input | $V_{in}$ | 3~40 | V |
| Enable input | $V_{EN}$ | 0~$V_{in}$ | V |
| Output capacitor requirements[1] | $C_{OUT}$ | 2.2~200 | µF |
| Output capacitor ESR requirements[2] | ESR | 0.001~1 | Ω |
| Ambient temperature (grade 0) | $T_A$ | -40~150 | °C |
| Junction temperature (grade 0) | $T_J$ | -40~165 | °C |

> **Note:**
> [1] The output capacitance range specified in the table is the effective value;
> [2] Relevant equivalent series resistance (ESR) value at f = 10 kHz.

## 2.4 Thermal Information

| Thermal Metric | Symbol | MSOP-8 | DFN-6 | TO-252-5 | DFN-8 | UNIT |
|---|---|---|---|---|---|---|
| Junction-to-ambient thermal resistance | $R_{\theta JA}$ | 63.9 | 72.8 | 31.1 | 52.6 | °C/W |
| Junction-to-case (top) thermal resistance | $R_{\theta JC(top)}$ | 50.2 | 85.8 | 39.9 | 66.2 | °C/W |
| Junction-to-board thermal resistance | $R_{\theta JB}$ | 22.6 | 37.4 | 9.9 | 16.7 | °C/W |
| Junction-to-top characterization parameter | $\psi_{JT}$ | 1.8 | 2.7 | 4.2 | 1.9 | °C/W |
| Junction-to-board characterization parameter | $\psi_{JB}$ | 22.3 | 37.3 | 9.9 | 16.7 | °C/W |
| Junction-to-case (bottom) thermal resistance | $R_{\theta JC(bot)}$ | 12.1 | 13.8 | 2.8 | 11.1 | °C/W |

## 2.5 Electrical Characteristics: Grade 0 Options

$V_{IN}$= 14V, 10µF ceramic output capacitor, grade 0 options (PWP package) , $T_J$= –40°C to +150°C, over operating ambient temperature range (unless otherwise noted) .

| Parameter | Symbol | Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| **SUPPLY VOLTAGE AND CURRENT (IN)** | | | | | | | |
| Input Voltage | $V_{IN}$ | | | $V_{OUT(NOM)}$ +$V_{(Dropout)}$ | | 40 | V |
| Shutdown current | $I_{SD}$ | EN = 0 V | | | 0.3 | 1 | µA |
| Quiescent current | $I_Q$ | $V_{IN}$=6 to 40 V, EN ≥ 2 V, $I_{OUT}$=0 mA | | | 3.5 | 6 | µA |
| | | $V_{IN}$=6 to 40 V, EN ≥ 2 V, $I_{OUT}$=0.2 mA | | | 5 | 7 | µA |
| $V_{IN}$ undervoltage detection | $V_{(IN, UVLO)}$ | Ramp $V_{IN}$ down until the output turns OFF | | | 2.45 | 2.85 | V |
| | | Hysteresis | | | 100 | | mV |
| **ENABLE INPUT (EN)** | | | | | | | |
| Logic-input low level | $V_{IL}$ | | | | | 0.7 | V |
| Logic-input high level | $V_{IH}$ | | | 2 | | | V |
| **REGULATED OUTPUT (OUT)** | | | | | | | |
| Regulated output | $V_{OUT}$ | $V_{IN}$=$V_{OUT}$+$V_{(Dropout)}$ to 14 V, $I_{OUT}$=1 mA to 300 mA | | –2% | | 2% | |
| Line regulation | $V_{(Line-Reg)}$ | $V_{IN}$=6 V to 40 V, $I_{OUT}$=10 mA | | | 5 | 10 | mV |
| Load regulation | $V_{(Load-Reg)}$ | $V_{IN}$=14 V, $I_{OUT}$=1 mA to 300 mA | | | | 20 | mV |
| Dropout voltage | $V_{(Dropout)}$ | $V_{OUT(NOM)}$ =5 V | $I_{OUT}$ =150mA | | 250 | 350 | mV |
| | | | $I_{OUT}$ =100mA | | 165 | 220 | mV |
| | | $V_{OUT}$ =3.3 V | $I_{OUT}$ =150mA | | 320 | 440 | mV |
| | | | $I_{OUT}$=100 mA | | 180 | 290 | mV |
| Output current | $I_{OUT}$ | $V_{OUT}$ in regulation | | 0 | | 150 | mA |
| Output current limit | $I_{(CL)}$ | $V_{OUT}$ short to 90% × $V_{OUT}$ | | | 286 | | mA |
| Power-supply ripple rejection | PSRR | $V_{(Ripple)}$=0.5 VPP, $I_{OUT}$=1mA, frequency=100 Hz, $C_{OUT}$=10 µF | | | 90 | | dB |
| **OPERATING TEMPERATURE RANGE** | | | | | | | |
| Junction shutdown temperature | $T_{(SD)}$ | | | | 185 | | °C |
| Hysteresis of thermal shutdown | $T_{(HYST)}$ | | | | 20 | | °C |

# 3 Performance Characteristics

$V_{IN}$=14V, $V_{OUT}$=5V, $C_{IN}$=2.2μF, $C_{OUT}$=10μF, $T_A$=-40~150°C,unless otherwise noted.
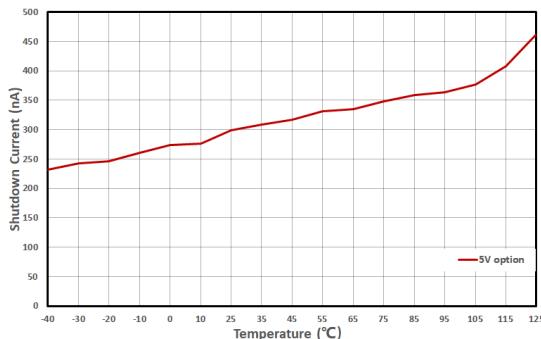


**Figure 3-1 Shutdown Current VS Ambient Temperature**
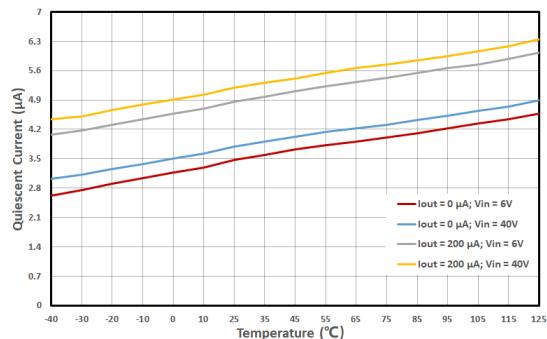


**Figure 3-2 Quiescent Current VS Ambient Temperature**
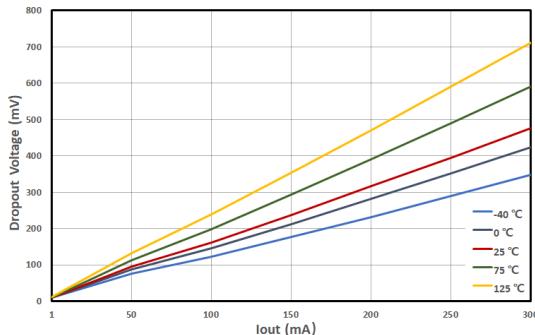


**Figure 3-3 Dropout Voltage VS Output Current**
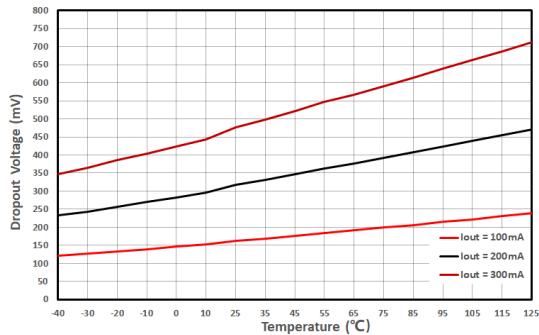


**Figure 3-4 Dropout Voltage VS Ambient Temperature**
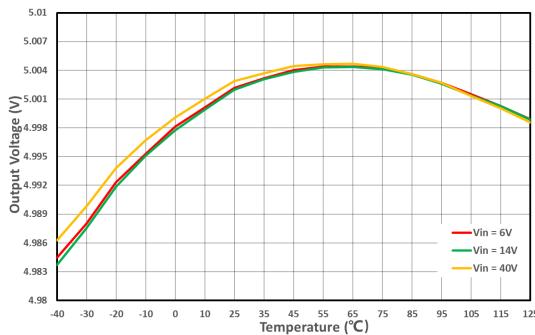


**Figure 3-5 Output Voltage VS Ambient Temperature**
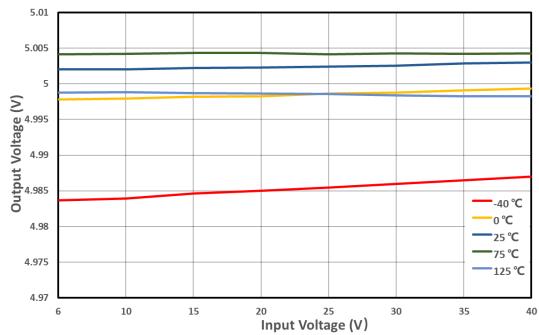


**Figure 3-6 Output Voltage VS Input Voltage**
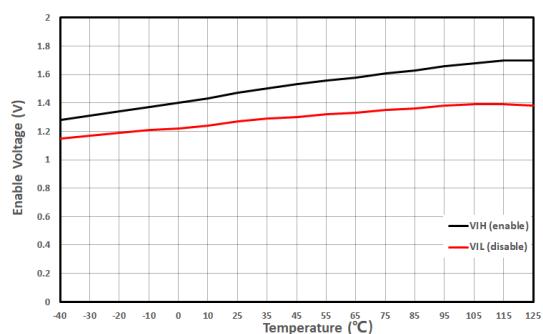
Figure 3-7 Enable Voltage VS Ambient Temperature
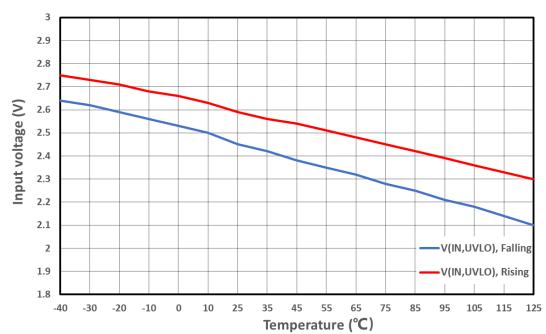

Figure 3-8 UVLO VS Ambient Temperature
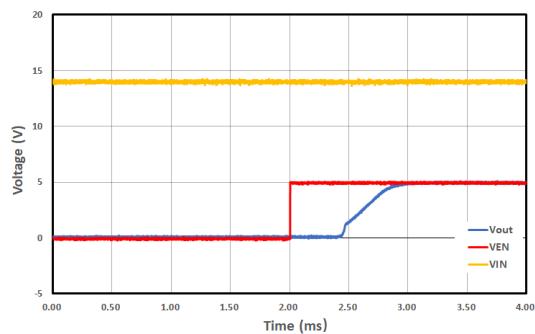

Figure 3-9 Startup with Enable
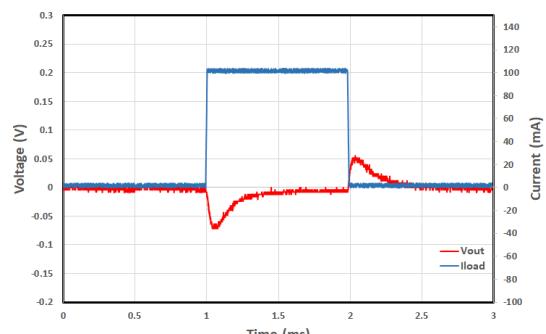

Figure 3-10 Load Transient
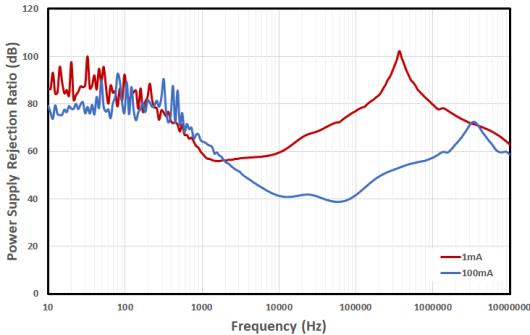

Figure 3-11 PSRR VS Frequency
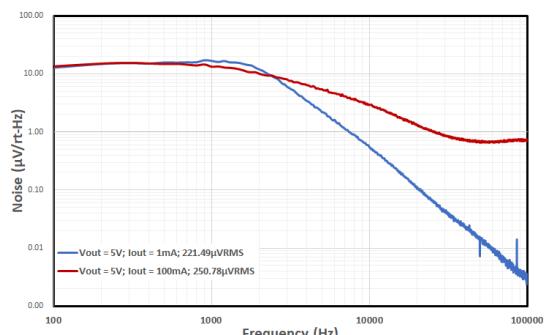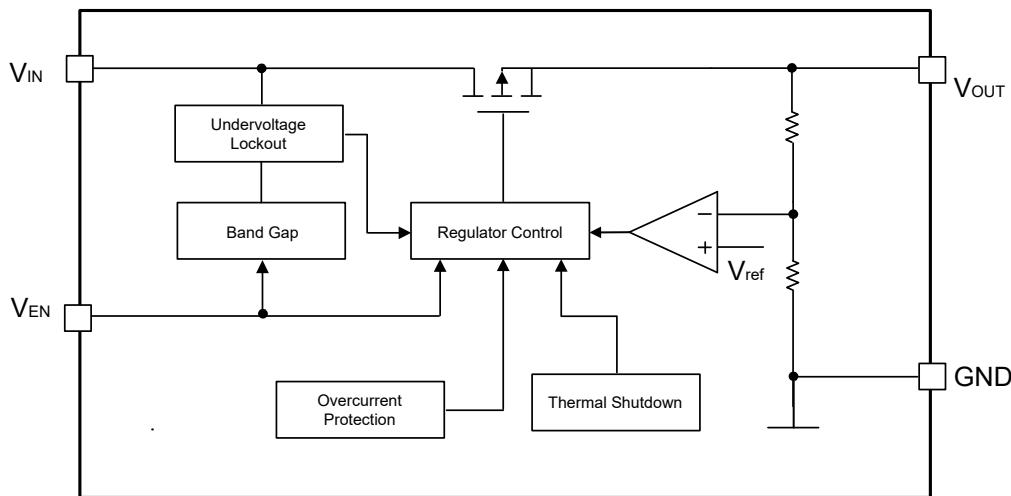

Figure 3-12 Noise VS Frequency

# 4    Detail Description

## 4.1    Overview

The SNE2402 is a 40V, 150mA low-dropout (LDO) linear regulator with ultra-low quiescent current. This voltage regulator consumes only 3.5µA of quiescent current at light load, and is designed for the automotive always-on application.

## 4.2    Functional Block Diagram



## 4.3    Feature Description

### 4.3.1    Device Enable (EN)

The EN pin is a high-voltage-tolerant pin. A high input activates the device and turns the regulation ON. Connect this pin to an external microcontroller or a digital circuit to enable and disable the device, or connect to the IN pin for self-bias applications.

### 4.3.2    Undervoltage Shutdown

This device has an integrated undervoltage lockout (UVLO) circuit to shut down the output if the input voltage ($V_{IN}$) falls below an internal UVLO threshold ($V_{(UVLO)}$). This threshold limit ensures that the regulator does not latch into an unknown state during low-input-voltage conditions. If the input voltage has a negative transient that drops below the UVLO threshold and recovers, the regulator shuts down and powers up with a normal power-up sequence when the input voltage is above the required level.

### 4.3.3    Current Limit

This device features current-limit protection to keep the device in a safe operating area when an overload or output short-to-ground condition occurs. This limit protects the device from excessive power dissipation. For example, during a short-circuit condition on the output, fault protection limits the current through the pass element to $I_{(LIM)}$ to protect the device from excessive power dissipation.

### 4.3.4  Thermal Shutdown

This device incorporates a thermal shutdown (TSD) circuit as a protection from overheating. For continuous normal operation, the junction temperature must not exceed the TSD trip point. The junction temperature exceeding the TSD trip point causes the output to turn off. When the junction temperature falls below the TSD trip point minus thermal shutdown hysteresis, the output turns on again.

## 4.4  Device Functional Modes

### 4.4.1  Operation With $V_{IN}$ Lower Than 3V
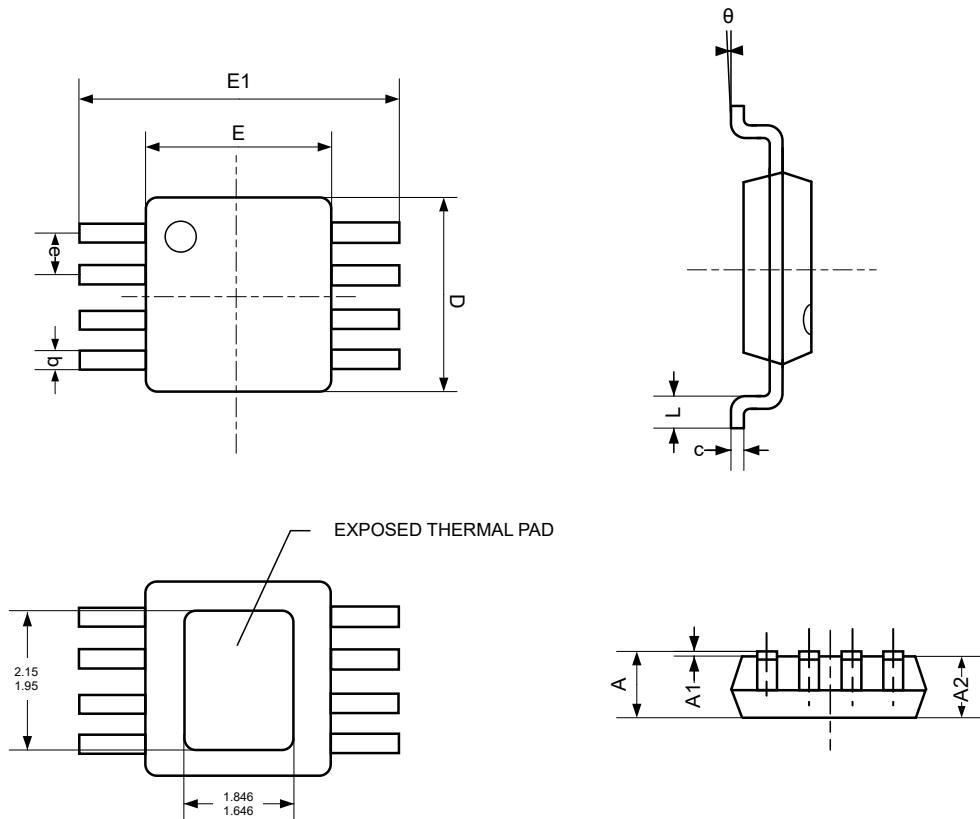
The device normally operates with input voltages above 3V. The device can also operate at lower input voltages; the maximum UVLO voltage is 2.85V. At input voltages below the actual UVLO voltage, the device does not operate.

### 4.4.2  Operation With $V_{IN}$ Larger Than 3V

When $V_{IN}$ is greater than 3 V, if $V_{IN}$ is also higher than the output set value plus the device dropout voltage, $V_{OUT}$ is equal to the set value. Otherwise, $V_{OUT}$ is equal to VIN minus the dropout voltage.
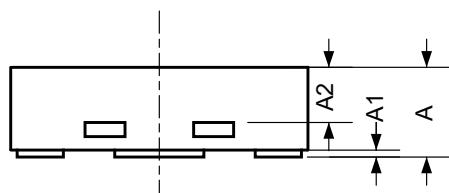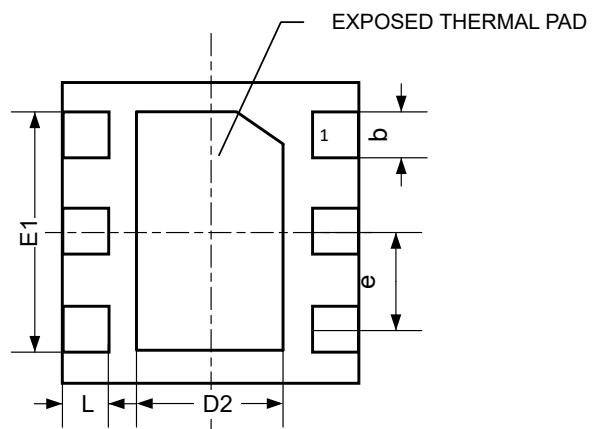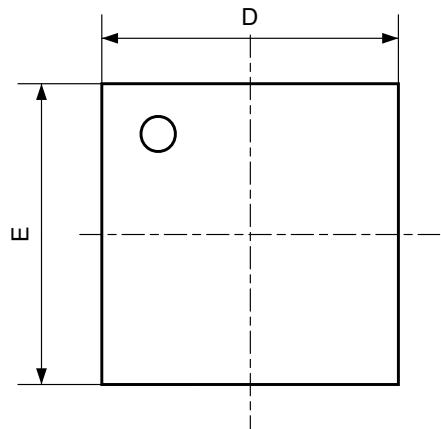
# 5 Package Outline

## 5.1 MSOP-8



EXPOSED THERMAL PAD
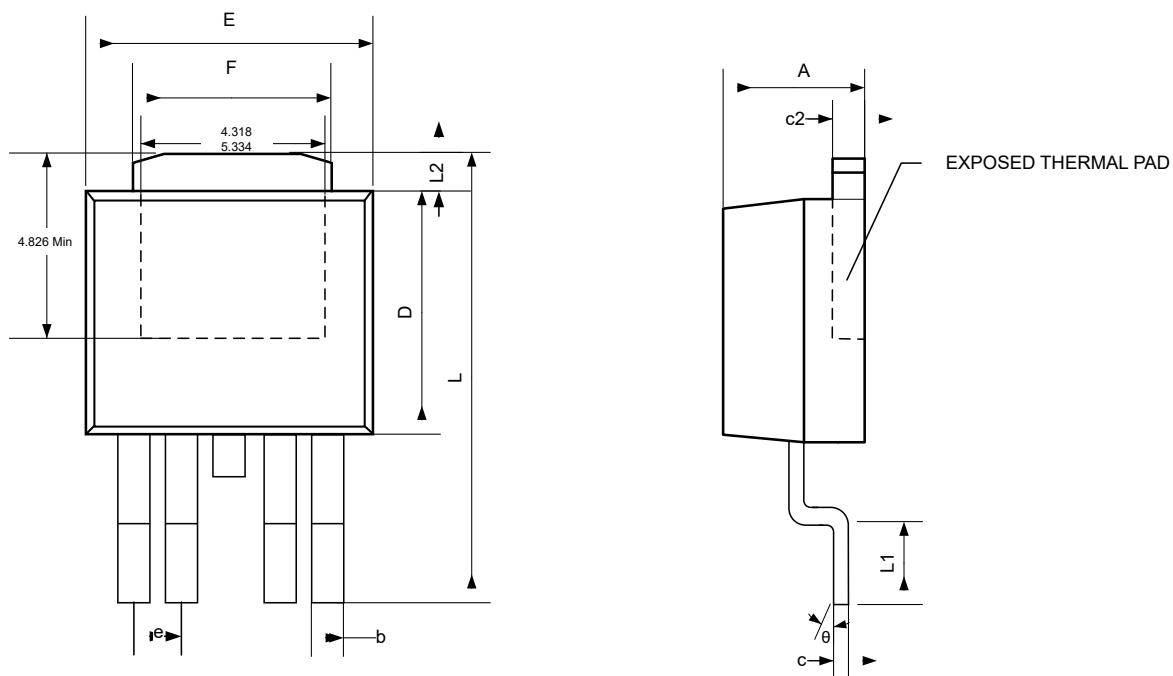
| Symbol | Dimensions in Millimeters | | Dimensions in Inches | |
|---|---|---|---|---|
| | Min | Max | Min | Max |
| A | 0.820 | 1.100 | 0.032 | 0.043 |
| A1 | 0.020 | 0.150 | 0.001 | 0.006 |
| A2 | 0.750 | 0.950 | 0.030 | 0.037 |
| b | 0.250 | 0.380 | 0.010 | 0.015 |
| c | 0.090 | 0.230 | 0.004 | 0.009 |
| D | 2.900 | 3.100 | 0.114 | 0.122 |
| E | 2.900 | 3.100 | 0.114 | 0.122 |
| E1 | 4.750 | 5.050 | 0.187 | 0.199 |
| e | 0.650 BSC | | 0.026 BSC | |
| L | 0.400 | 0.800 | 0.016 | 0.031 |
| θ | 0° | 6° | 0° | 6° |

## 5.2 DFN-6



TOP VIEW

BOTTOM VIEW

EXPOSED THERMAL PAD

SIDE VIEW
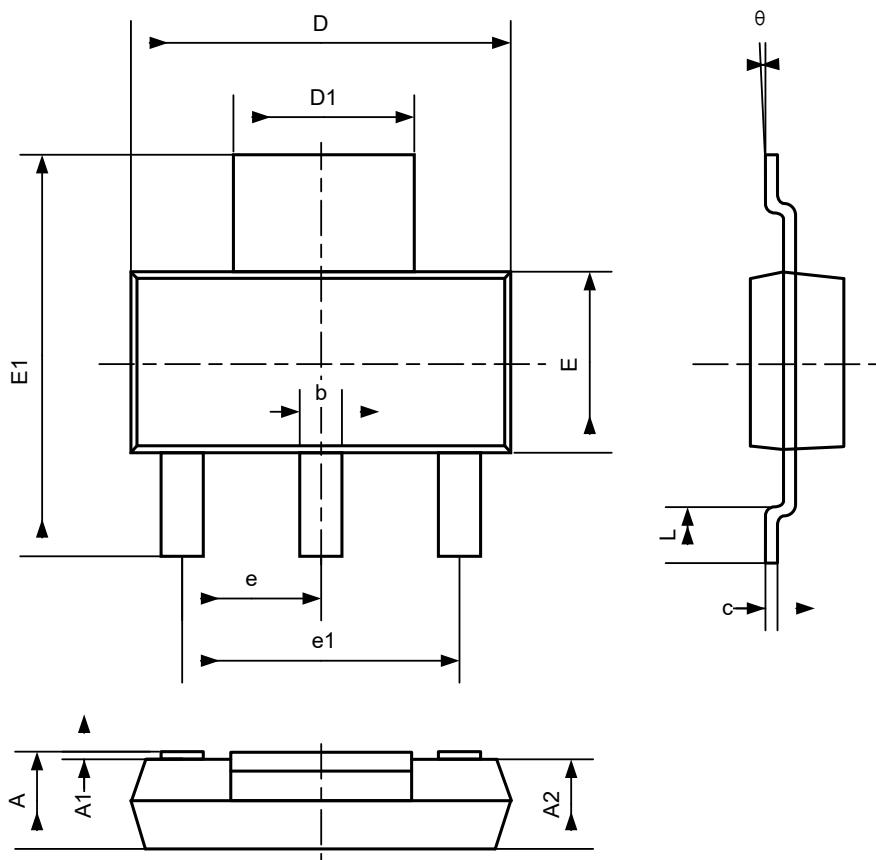
| Symbol | Dimensions in Millimeters | | Dimensions in Inches | |
|---|---|---|---|---|
| | Min | Max | Min | Max |
| A | 0.700 | 0.800 | 0.028 | 0.031 |
| A1 | 0.000 | 0.050 | 0.000 | 0.002 |
| A2 | 0.500 | 0.600 | 0.020 | 0.024 |
| b | 0.250 | 0.350 | 0.001 | 0.014 |
| D2 | 0.900 | 1.100 | 0.035 | 0.043 |
| D | 1.900 | 2.100 | 0.075 | 0.083 |
| E | 1.900 | 2.100 | 0.075 | 0.083 |
| E1 | 1.500 | 1.700 | 0.059 | 0.067 |
| e | 0.650 BSC | | 0.026 BSC | |
| L | 0.200 | 0.300 | 0.008 | 0.0012 |

## 5.3    TO-252-5
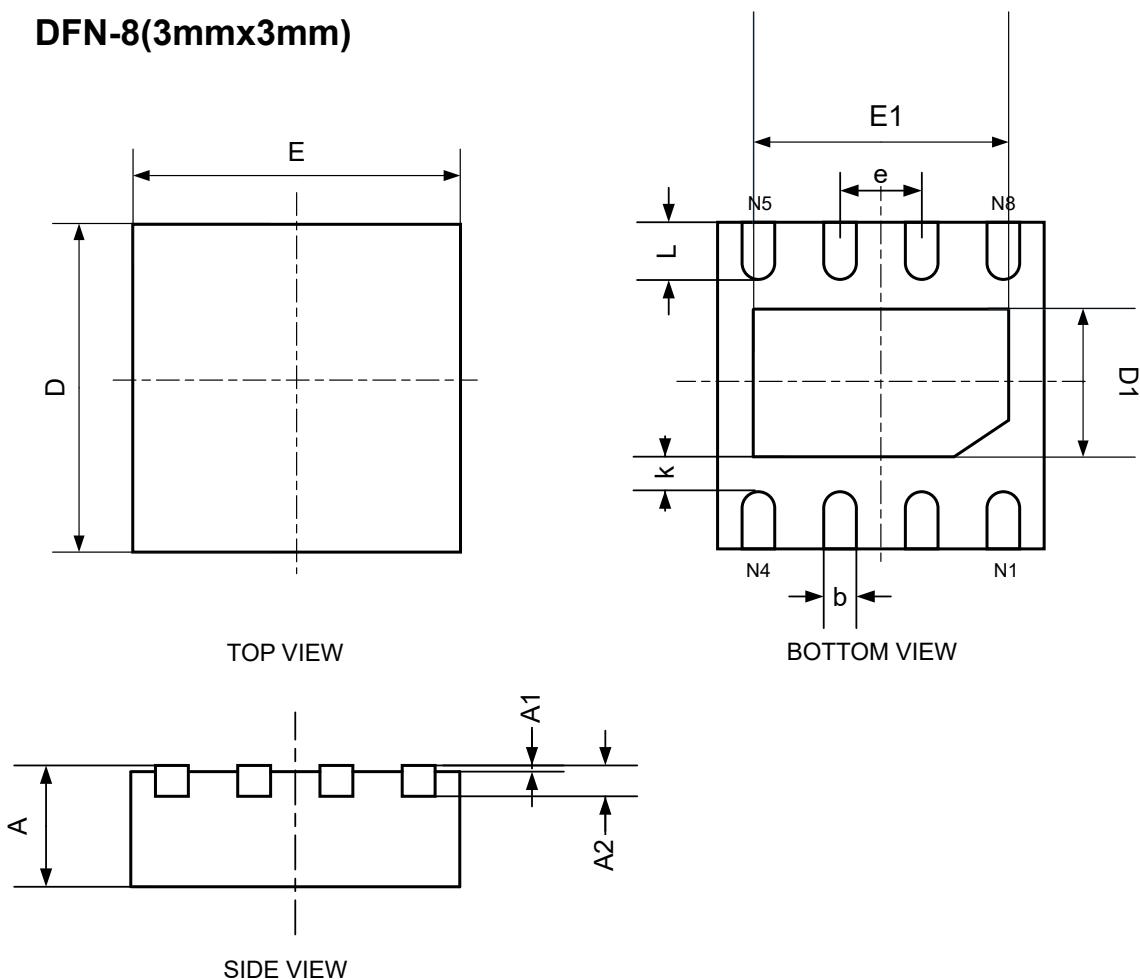


| Symbol | Dimensions in Millimeters | | Dimensions in Inches | |
|---|---|---|---|---|
| | Min | Max | Min | Max |
| **A** | 2.18 | 2.39 | 0.086 | 0.094 |
| **c2** | 0.46 | 0.61 | 0.018 | 0.024 |
| **L1** | 1.40 | 1.78 | 0.055 | 0.070 |
| **b** | 0.51 | 0.71 | 0.020 | 0.028 |
| **L2** | 0.89 | 1.27 | 0.035 | 0.050 |
| **D** | 5.97 | 6.22 | 0.235 | 0.245 |
| **L** | 9.80 | 10.41 | 0.386 | 0.410 |
| **E** | 6.50 | 6.70 | 0.256 | 0.264 |
| **F** | 4.32 | 5.46 | 0.170 | 0.215 |
| **e** | 1.14 BSC | | 0.045 BSC | |
| **c** | 0.51 TYP | | 0.020 TYP | |
| **θ** | 0° | 8° | 0° | 8° |

## 5.4 SOT223-4
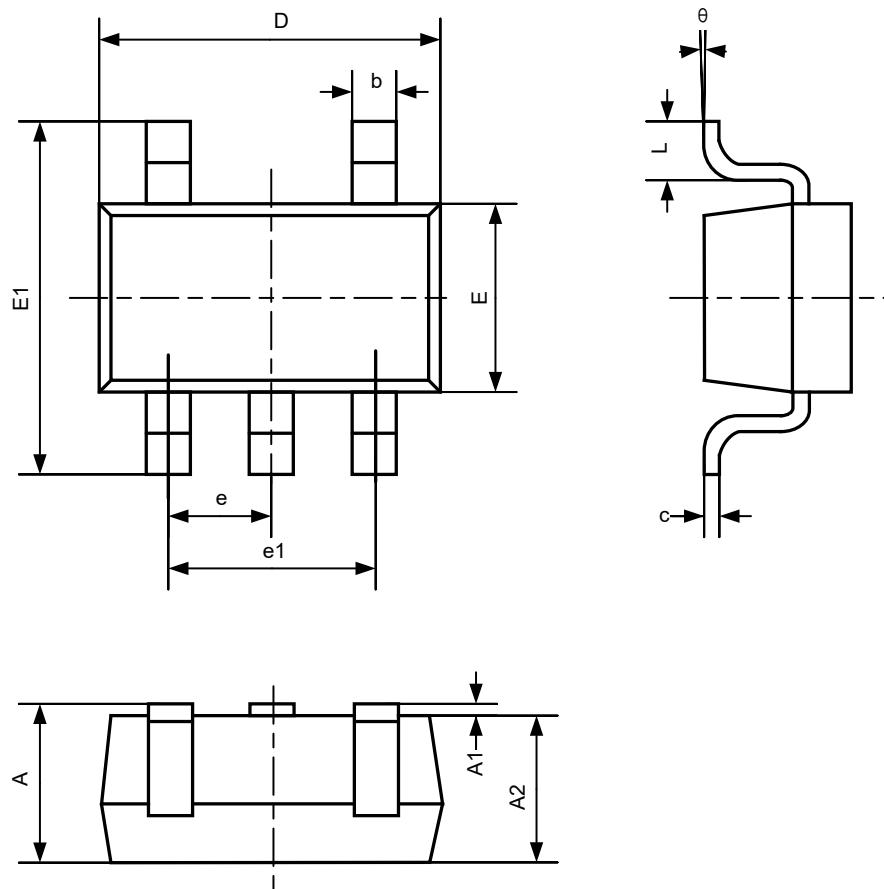
| Symbol | Dimensions in Millimeters | | Dimensions in Inches | |
|---|---|---|---|---|
| | Min | Max | Min | Max |
| A | 1.520 | 1.800 | 0.060 | 0.071 |
| A1 | 0.000 | 0.100 | 0.000 | 0.004 |
| A2 | 1.500 | 1.700 | 0.059 | 0.067 |
| b | 0.660 | 0.820 | 0.026 | 0.032 |
| c | 0.250 | 0.350 | 0.010 | 0.014 |
| D | 6.200 | 6.400 | 0.244 | 0.252 |
| D1 | 2.900 | 3.100 | 0.114 | 0.122 |
| E | 3.300 | 3.700 | 0.130 | 0.146 |
| E1 | 6.830 | 7.070 | 0.269 | 0.278 |
| e | 2.300 BSC | | 0.091 BSC | |
| e1 | 4.500 | 4.700 | 0.177 | 0.185 |
| L | 0.900 | 1.150 | 0.035 | 0.045 |
| θ | 0° | 10° | 0° | 10° |

## 5.5 DFN-8(3mmx3mm)

TOP VIEW

BOTTOM VIEW

SIDE VIEW

| Symbol | Dimensions in Millimeters | | | Dimensions in Inches | | |
|---|---|---|---|---|---|---|
| | Min | Nom | Max | Min | Nom | Max |
| A | 0.800 | 0.900 | 1.000 | 0.031 | 0.035 | 0.039 |
| A1 | 0.000 | 0.020 | 0.050 | 0.000 | 0.001 | 0.002 |
| A2 | 0.200 REF | | | 0.008 REF | | |
| b | 0.250 | 0.300 | 0.350 | 0.010 | 0.012 | 0.014 |
| D | 2.900 | 3.000 | 3.100 | 0.114 | 0.118 | 0.122 |
| E | 2.900 | 3.000 | 3.100 | 0.114 | 0.118 | 0.122 |
| D1 | 1.550 | 1.650 | 1.750 | 0.061 | 0.065 | 0.069 |
| E1 | 2.250 | 2.400 | 2.550 | 0.089 | 0.094 | 0.100 |
| e | 0.650 BSC | | | 0.026 BSC | | |
| k | 0.280 REF | | | 0.011 REF | | |
| L | 0.300 | 0.400 | 0.500 | 0.012 | 0.016 | 0.020 |

## 5.6 SOT23-5



| Symbol | Dimensions in Millimeters | | Dimensions in Inches | |
|--------|-----|-----|-----|-----|
| | Min | Max | Min | Max |
| A | 1.050 | 1.250 | 0.041 | 0.049 |
| A1 | 0.000 | 0.100 | 0.000 | 0.004 |
| A2 | 1.050 | 1.150 | 0.041 | 0.045 |
| b | 0.300 | 0.500 | 0.012 | 0.020 |
| c | 0.100 | 0.200 | 0.004 | 0.008 |
| D | 2.820 | 3.020 | 0.111 | 0.119 |
| E | 1.500 | 1.700 | 0.059 | 0.067 |
| E1 | 2.650 | 2.950 | 0.104 | 0.116 |
| e | 0.950 BSC | | 0.037 BSC | |
| e1 | 1.900 BSC | | 0.075 BSC | |
| L | 0.300 | 0.600 | 0.012 | 0.024 |
| θ | 0° | 8° | 0° | 8° |

# 6    Revision History

| Version | Date | Description |
|---------|------|-------------|
| 0.1 | 2022/08/26 | Initial release |
| 0.2 | 2023/03/10 | Add Package: SOT223-4,DFN-8,SOT-23-5 |
| 1.0 | 2023/09/21 | Official version |