



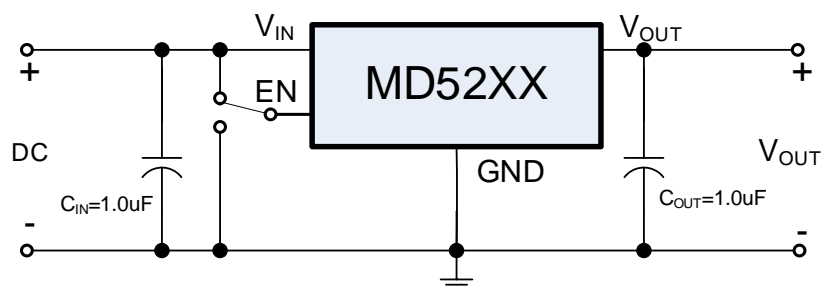
MD52XX is ultra-low power consumption low dropout voltage regulator (LDO) manufactured in CMOS processes. It can deliver up to 500mA of current while consuming only 0.6 $\mu$ A of quiescent current. It consists of a reference voltage generator, an error amplifier, a current foldback circuit, and a phase compensation circuit plus a driver transistor. The MD52XX is designed specifically for applications where very-low  $I_Q$  is a critical parameter. This device maintains low quiescent current consumption even in dropout mode to further increase the battery life.

**■ Features:**

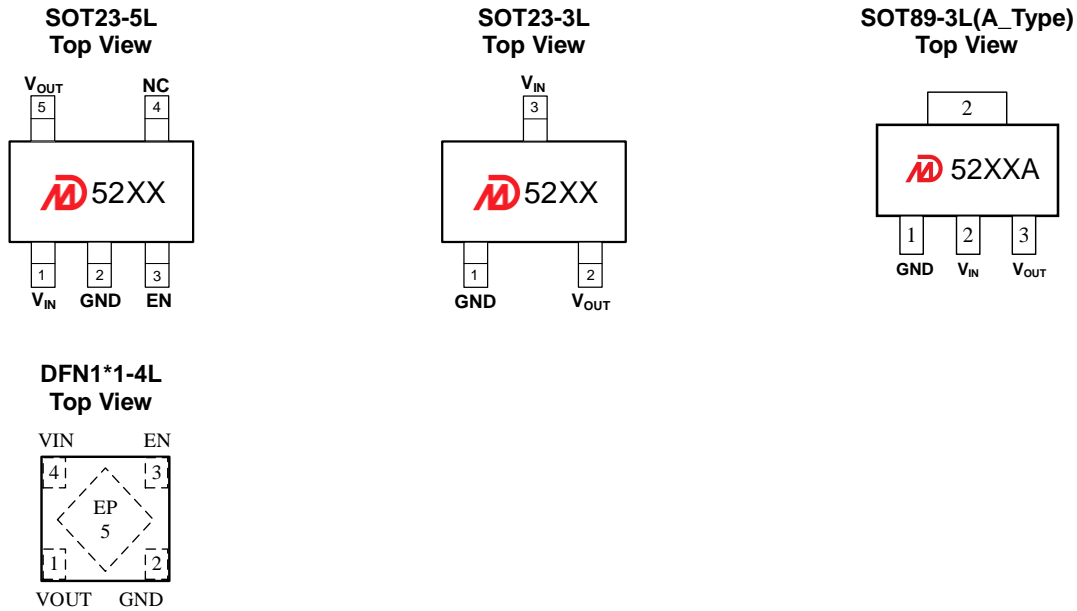
- Ultra-low Quiescent Current: 0.6 $\mu$ A
- Highly Accurate:  $\pm 2\%$
- Dropout Voltage: 230mV@ $I_{OUT}=500$ mA
- Maximum Output Current: 500mA
- Input Voltage Range: 2.2V~7.0V
- Temperature Stability:  $\pm 50$ ppm/ $^{\circ}$ C
- ON/OFF Logic = Enable High
- Standby Current: 10nA
- $C_{OUT}$  Discharge Circuit when EN Disable is Active
- Protections Circuits: Current Limiter, Short Circuit, Foldback
- Output Capacitor: Low ESR Ceramic Capacitor Compatible

**■ Applications:**

- Smart wearer
- Long-life battery-powered devices
- Portable mobile devices, such as mobile phones, cameras, and so on
- Wireless communication equipment










**■ Typical Applications:**

■ Pin Configuration:



■ Product Selections:

| Product Name | V <sub>OUT</sub> (V) | Package  | Ordering Name | Marking | Package Information       |
|--------------|----------------------|----------|---------------|---------|---------------------------|
| MD5212       | 1.2                  | SOT23-5L | MD52E12QC3    | 5212    | Tape and Reel,<br>3000pcs |
| MD5215       | 1.5                  | SOT23-5L | MD52E15QC3    | 5215    |                           |
| MD5218       | 1.8                  | SOT23-5L | MD52E18QC3    | 5218    |                           |
| MD5221       | 2.1                  | SOT23-5L | MD52E21QC3    | 5221    |                           |
| MD5225       | 2.5                  | SOT23-5L | MD52E25QC3    | 5225    |                           |
| MD5228       | 2.8                  | SOT23-5L | MD52E28QC3    | 5228    |                           |
| MD5230       | 3.0                  | SOT23-5L | MD52E30QC3    | 5230    |                           |
| MD5233       | 3.3                  | SOT23-5L | MD52E33QC3    | 5233    |                           |
| MD5236       | 3.6                  | SOT23-5L | MD52E36QC3    | 5236    |                           |
| MD5237       | 3.7                  | SOT23-5L | MD52E37QC3    | 5237    |                           |
| MD5240       | 4.0                  | SOT23-5L | MD52E40QC3    | 5240    |                           |
| MD5250       | 5.0                  | SOT23-5L | MD52E50QC3    | 5250    |                           |
| MD5212       | 1.2                  | SOT23-3L | MD52E12QA3    | 5212    |                           |
| MD5215       | 1.5                  | SOT23-3L | MD52E15QA3    | 5215    |                           |
| MD5218       | 1.8                  | SOT23-3L | MD52E18QA3    | 5218    |                           |
| MD5221       | 2.1                  | SOT23-3L | MD52E21QA3    | 5221    |                           |
| MD5225       | 2.5                  | SOT23-3L | MD52E25QA3    | 5225    |                           |
| MD5228       | 2.8                  | SOT23-3L | MD52E28QA3    | 5228    |                           |
| MD5230       | 3.0                  | SOT23-3L | MD52E30QA3    | 5230    |                           |
| MD5233       | 3.3                  | SOT23-3L | MD52E33QA3    | 5233    |                           |
| MD5236       | 3.6                  | SOT23-3L | MD52E36QA3    | 5236    |                           |
| MD5237       | 3.7                  | SOT23-3L | MD52E37QA3    | 5237    |                           |
| MD5240       | 4.0                  | SOT23-3L | MD52E40QA3    | 5240    |                           |
| MD5250       | 5.0                  | SOT23-3L | MD52E50QA3    | 5250    |                           |
| MD5212A      | 1.2                  | SOT89-3L | MD52A12PA1    | 5212A   |                           |
| MD5215A      | 1.5                  | SOT89-3L | MD52A15PA1    | 5215A   |                           |
| MD5218A      | 1.8                  | SOT89-3L | MD52A18PA1    | 5218A   |                           |

|         |     |           |            |  |  |
|---------|-----|-----------|------------|--|--|
| MD5221A | 2.1 | SOT89-3L  | MD52A21PA1 |  5221A |  |
| MD5225A | 2.5 | SOT89-3L  | MD52A25PA1 |  5225A |  |
| MD5228A | 2.8 | SOT89-3L  | MD52A28PA1 |  5228A |  |
| MD5230A | 3.0 | SOT89-3L  | MD52A30PA1 |  5230A |  |
| MD5233A | 3.3 | SOT89-3L  | MD52A33PA1 |  5233A |  |
| MD5236A | 3.6 | SOT89-3L  | MD52A36PA1 |  5236A |  |
| MD5237A | 3.7 | SOT89-3L  | MD52A37PA1 |  5237A |  |
| MD5240A | 4.0 | SOT89-3L  | MD52A40PA1 |  5240A |  |
| MD5250A | 5.0 | SOT89-3L  | MD52A50PA1 |  5250A |  |
| MD5212  | 1.2 | DFN1*1-4L | MD52E12WB6 | 5212   |  |
| MD5215  | 1.5 | DFN1*1-4L | MD52E15WB6 | 5215   |  |
| MD5218  | 1.8 | DFN1*1-4L | MD52E18WB6 | 5218   |  |
| MD5221  | 2.1 | DFN1*1-4L | MD52E21WB6 | 5221   |  |
| MD5225  | 2.5 | DFN1*1-4L | MD52E25WB6 | 5225   |  |
| MD5228  | 2.8 | DFN1*1-4L | MD52E28WB6 | 5228   |  |
| MD5230  | 3.0 | DFN1*1-4L | MD52E30WB6 | 5230   |  |
| MD5233  | 3.3 | DFN1*1-4L | MD52E33WB6 | 5233   |  |
| MD5236  | 3.6 | DFN1*1-4L | MD52E36WB6 | 5236   |  |
| MD5237  | 3.7 | DFN1*1-4L | MD52E37WB6 | 5237   |  |
| MD5240  | 4.0 | DFN1*1-4L | MD52E40WB6 | 5240   |  |
| MD5250  | 5.0 | DFN1*1-4L | MD52E50WB6 | 5250   |  |

**Notes:** 1\* Customer can request to customize the output voltage ranged from 1.2V to 5V if desired voltage is not found in the selections.

2\* Customer can request customization of package choice.

3\* Please pay attention to the MARKING of the product package type.

■ **Absolute Maximum Ratings:** (Unless otherwise indicated:  $T_a=25^{\circ}\text{C}$ )

| PARAMETER                     | SYMBOL                | RATINGS                       |      | UNITS                       |
|-------------------------------|-----------------------|-------------------------------|------|-----------------------------|
| Input Voltage                 | $V_{IN}$              | -0.3 ~ 8                      |      | V                           |
| Output Voltage                | $V_{OUT}$             | $V_{SS}-0.3 \sim V_{IN}+0.3V$ |      |                             |
| Power Dissipation             | $P_D$                 | SOT23-5                       | 250  | mW                          |
|                               |                       | SOT23-3                       | 250  |                             |
|                               |                       | SOT89-3                       | 1000 |                             |
|                               |                       | DFN1*1-4L                     | 200  |                             |
| Thermal Resistance            | $R_{\theta JB}^{(1)}$ | SOT23-5                       | 180  | $^{\circ}\text{C}/\text{W}$ |
|                               |                       | SOT23-3                       | 200  |                             |
|                               |                       | SOT89-3                       | 100  |                             |
|                               |                       | DFN1*1-4L                     | 160  |                             |
| Operating Ambient Temperature | $T_{opr}$             | -40 ~ +85                     |      | $^{\circ}\text{C}$          |
| Storage Temperature           | $T_{stg}$             | -40 ~ +125                    |      |                             |
| ESD Protection                | ESD HBM               | 6000                          |      | V                           |

**Note:** Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device.

<sup>(1)</sup> Mounted on JEDEC standard 4layer (2s2p) PCB test board

■ **Notes on Use:**

Input Capacitor ( $C_{IN}$ ): 1.0 $\mu\text{F}$  above

Output Capacitor ( $C_{OUT}$ ): 1.0 $\mu\text{F}$  above

**■ Electrical Characteristics:**

MD52XX Series

(Unless otherwise indicated:  $T_a=25^{\circ}\text{C}$ )

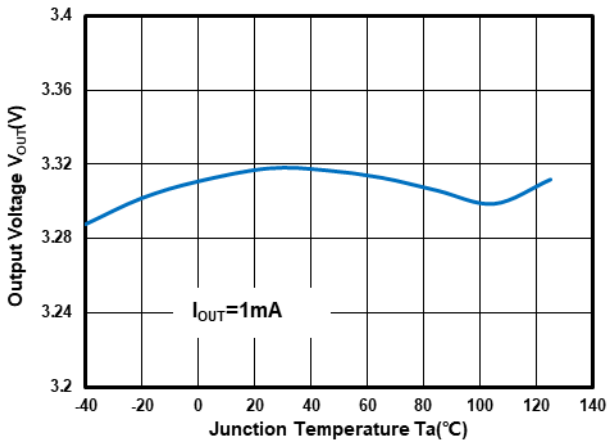
| PARAMETER                          | SYMBOL  | CONDITIONS  | MIN.                    | TYP.         | MAX.                    | UNIT                       |
|------------------------------------|---|---|-------------------------|--------------|-------------------------|----------------------------|
| Output Voltage*1                   | $V_{OUT(S)}$  | $V_{IN}=V_{OUT(S)}+2.0\text{V}$<br>$I_{OUT}=10\text{mA}$ , $V_{OUT(S)}<2.0\text{V}$                                     | $V_{OUT(S)}-0.03$       | $V_{OUT(S)}$ | $V_{OUT(S)}+0.03$       | V                          |
|                                    |   | $V_{IN}=V_{OUT(S)}+1.0\text{V}$<br>$I_{OUT}=10\text{mA}$ ,<br>$V_{OUT(S)}\geq 2.0\text{V}$                              | $V_{OUT(S)}\times 0.98$ |              | $V_{OUT(S)}\times 1.02$ |                            |
| Dropout Voltage*2                  | $V_{DROP}$  | $V_{EN}=V_{IN}$ , $V_{OUT}<3\text{V}$<br>$I_{OUT}=500\text{mA}$   |                         | 240          |                         | mV                         |
|                                    |   | $V_{EN}=V_{IN}$ , $V_{OUT}\geq 3\text{V}$<br>$I_{OUT}=500\text{mA}$   |                         | 230          |                         |                            |
| Line Regulation*3                  | $\frac{\Delta V_{OUT}}{\Delta V_{IN} \cdot V_{OUT(S)}}$ | $V_{OUT(S)}+0.5\text{V}\leq V_{IN}=V_{EN}\leq 7\text{V}$<br>$I_{OUT}=10\text{mA}$                                       |                         | 0.05         | 0.1                     | %/V                        |
| Load Regulation                    | $\Delta V_{OUT2}$                                       | $V_{IN}=V_{EN}=V_{OUT(S)}+1.0\text{V}$<br>$1\text{mA}\leq I_{OUT}\leq 500\text{mA}$                                     |                         | 50           | 90                      | mV                         |
| Temperature Stability              | $\frac{\Delta V_{OUT}}{\Delta T_a \cdot V_{OUT(S)}}$    | $V_{IN}=V_{EN}=V_{OUT(S)}+1.0\text{V}$<br>$I_{OUT}=1\text{mA}$<br>$-40^{\circ}\text{C}\leq T_a\leq 125^{\circ}\text{C}$ |                         | $\pm 50$     |                         | ppm/<br>$^{\circ}\text{C}$ |
| GND Current<br>( $V_{EN}=V_{IN}$ ) | $I_{GND}$   | no load   |                         | 0.6          | 0.9                     | $\mu\text{A}$              |
|                                    |   | $I_{OUT}=500\text{mA}$  |                         | 210          |                         | $\mu\text{A}$              |
| Shutdown Current<br>( $V_{EN}=0$ ) | $I_{SHUT}$  | $V_{IN}=7.0\text{V}$ , $V_{EN}=0$   |                         | 0.01         | 0.1                     | $\mu\text{A}$              |
| Input Voltage                      | $V_{IN}$  | ---   | 2.2                     |              | 7                       | V                          |
| Maximum Output Current             | $I_{OUTMAX}$  |   | 450                     | 500          |                         | mA                         |
| Current Limit*4                    | $I_{LIM}$   | $V_{IN}=V_{EN}=V_{OUT(S)}+1.0\text{V}$<br>$V_{OUT} = 0.95 \times V_{OUT(S)}$  |                         | 750          |                         | mA                         |
| Short Circuit Current              | $I_{SHORT}$   | $V_{IN}=V_{EN}=V_{OUT(S)}+1.0\text{V}$<br>$V_{OUT}=0\text{V}$   |                         | 50           |                         | mA                         |
| $C_{OUT}$ Auto Discharge           | $R_{DCHG}$  | $V_{EN}=0$ , $V_{OUT}=V_{OUT(S)}$   | 280                     | 450          | 640                     | $\Omega$                   |
| Power Supply Rejection Ratio       | PSRR  | $f=10\text{Hz}$ , $I_{OUT}=10\text{mA}$   |                         | 64           |                         | dB                         |
|                                    |   | $f=100\text{Hz}$ , $I_{OUT}=10\text{mA}$  |                         | 51           |                         |                            |
|                                    |   | $f=1\text{kHz}$ , $I_{OUT}=10\text{mA}$   |                         | 34           |                         |                            |
| EN 'H' Level Voltage               | $V_{ENH}$   | ---   | 1.0                     |              | 7.0                     | V                          |
| EN 'L' Level Voltage               | $V_{ENL}$   | ---   | 0                       |              | 0.38                    |                            |
| EN 'H' Level Current               | $I_{ENH}$   | $V_{IN}=7.0\text{V}$ , $V_{EN}=V_{IN}$  | -0.1                    |              | 0.1                     | $\mu\text{A}$              |
| EN 'L' Level Current               | $I_{ENL}$   | $V_{IN}=7.0\text{V}$ , $V_{EN}=0$   | -0.1                    |              | 0.1                     |                            |

Notes:

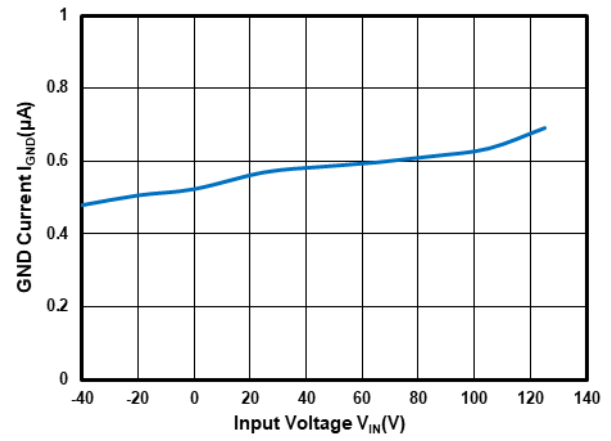
- $V_{OUT(S)}$ : Output voltage when  $V_{IN}=V_{OUT}+1\text{V}$ ,  $I_{OUT}=1\text{mA}$ .
- $V_{DROP}=V_{IN1} - (V_{OUT(S)}\times 0.98)$  where  $V_{IN1}$  is the input voltage when  $V_{OUT} = V_{OUT(S)}\times 0.98$ .
- Minimum  $V_{IN}=V_{OUT}+0.5\text{V}$  or  $2.2\text{V}$ , whichever is greater.
- $I_{LIM}$ : Output current when  $V_{IN}=V_{OUT(S)}+1\text{V}$  and  $V_{OUT} = 0.95 \times V_{OUT(S)}$ .

■ Typical Performance Characteristics:

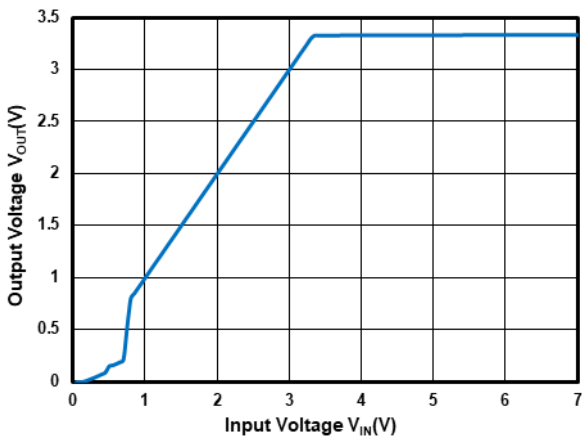
Test Conditions:  $V_{IN}=V_{OUT}+1.0V$ ,  $C_{IN}=1.0\mu F$ ,  $C_{OUT}=1.0\mu F$ ,  $T_a=25^\circ C$ , unless otherwise indicated.



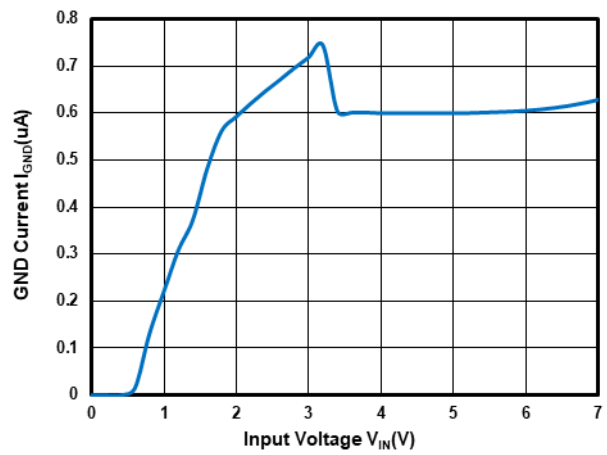
Output Voltage vs. Temperature at  $V_{OUT}=3.3V$



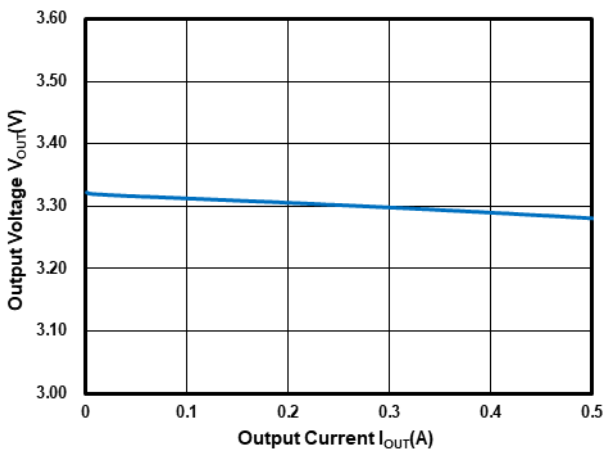
GND Current vs. Temperature at  $V_{OUT}=3.3V$



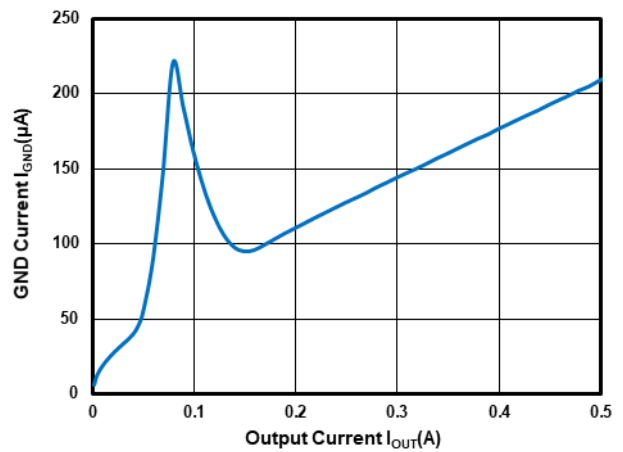
Output Voltage vs. Input Voltage at  $V_{OUT}=3.3V$



GND Current vs. Input Voltage at  $V_{OUT}=3.3V$



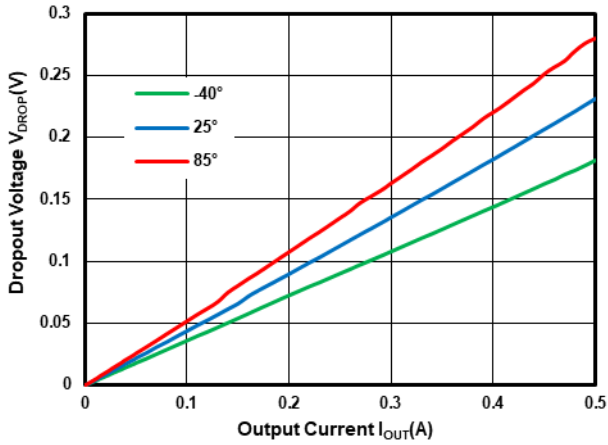
Output Voltage vs Output Current at  $V_{OUT}=3.3V$



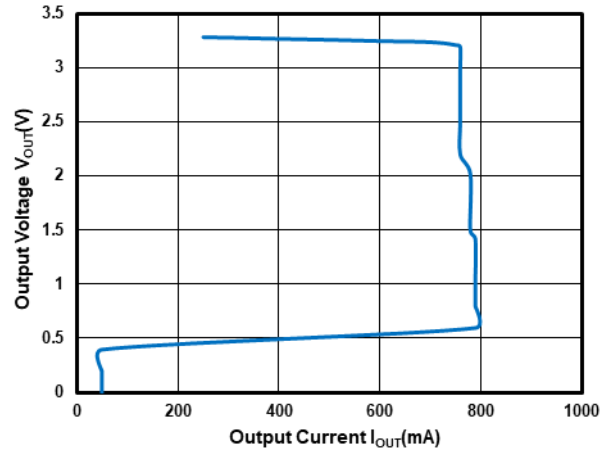
GND Current vs Output Current at  $V_{OUT}=3.3V$

■ Typical Performance Characteristics (Continued):

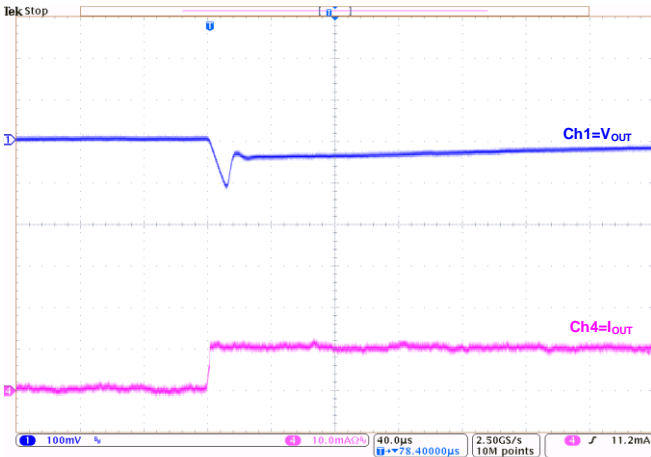
Test Conditions:  $V_{IN}=V_{OUT}+1.0V$ ,  $C_{IN}=1.0\mu F$ ,  $C_{OUT}=1.0\mu F$ ,  $T_a=25^\circ C$ , unless otherwise indicated.



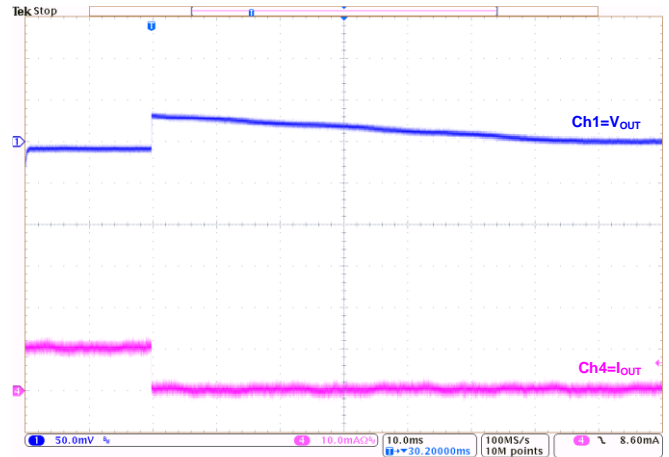
Dropout Voltage vs. Output Current at  $V_{OUT}=3.3V$



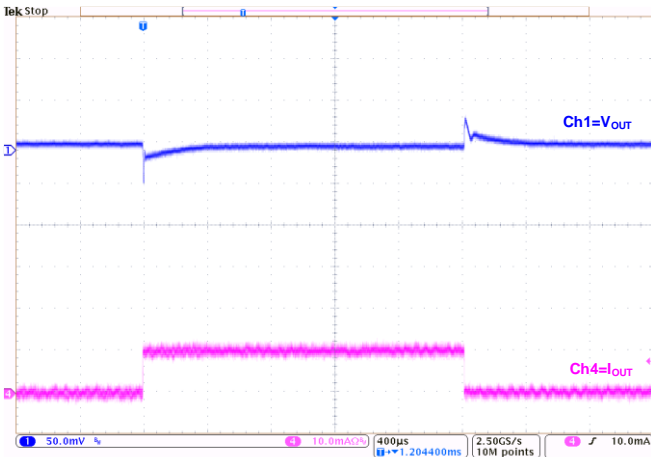
Output Current Fold-back at  $V_{OUT}=3.3V$



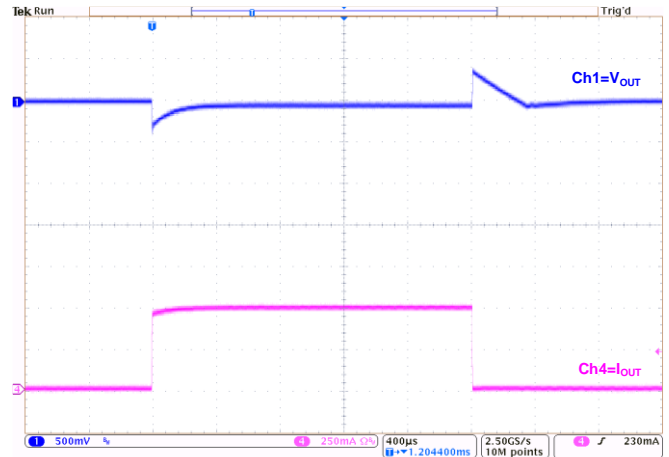
Load Transient at  $V_{OUT}=3.3V$ :  
( $I_{OUT}=0mA\sim 10mA$ )



Load Transient at  $V_{OUT}=3.3V$ :  
( $I_{OUT}=10mA\sim 0mA$ )



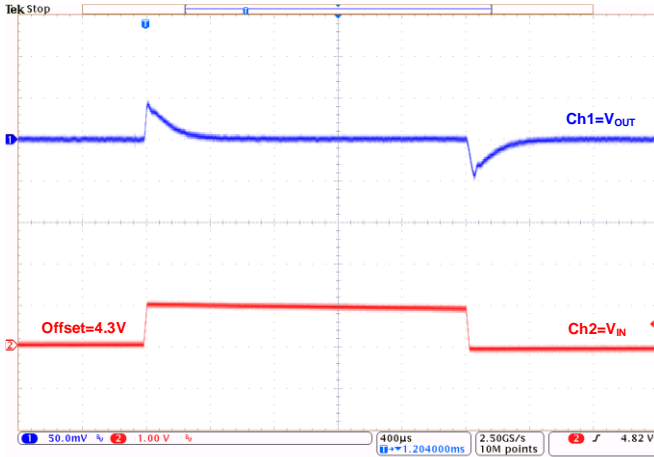
Load Transient at  $V_{OUT}=3.3V$ :  
( $I_{OUT}=1mA\sim 10mA\sim 1mA$ )



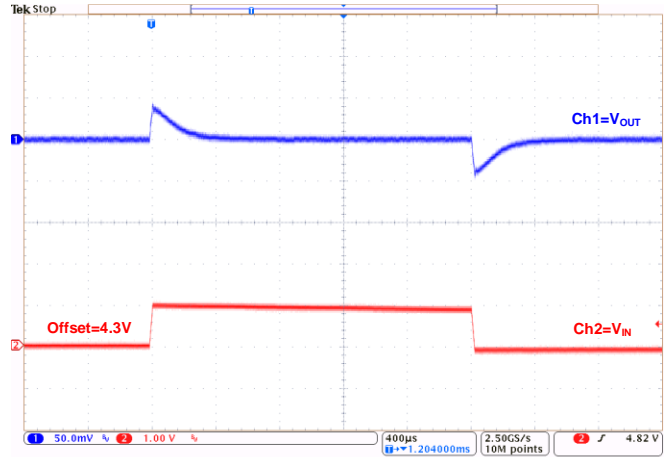
Load Transient at  $V_{OUT}=3.3V$ :  
( $I_{OUT}=1mA\sim 500mA\sim 1mA$ )

■ Typical Performance Characteristics (Continued):

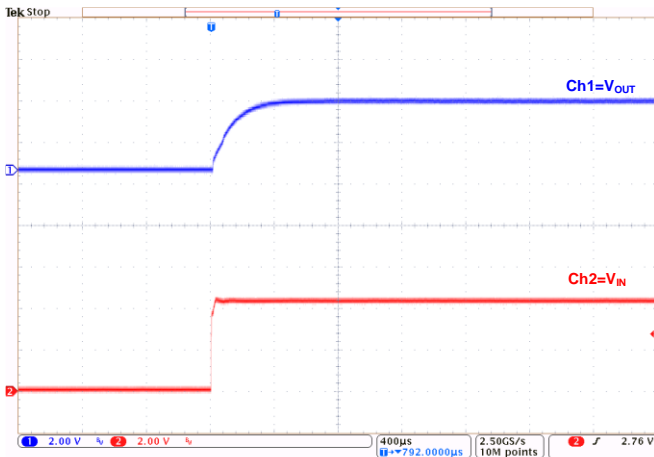
Test Conditions:  $V_{IN}=V_{OUT}+1.0V$ ,  $C_{IN}=1.0\mu F$ ,  $C_{OUT}=1.0\mu F$ ,  $T_a=25^\circ C$ , unless otherwise indicated.



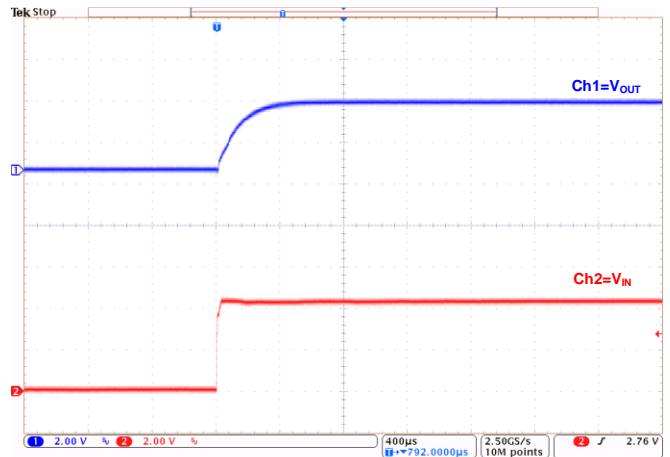
Line Transient at  $V_{OUT}=3.3V$ :  
( $I_{OUT}=1mA$ )



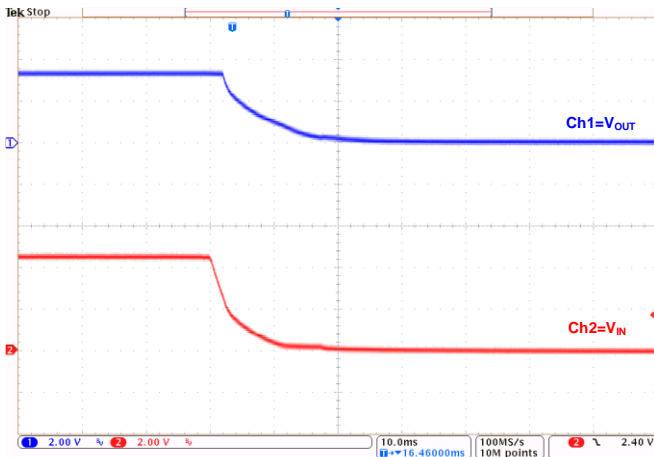
Line Transient at  $V_{OUT}=3.3V$ :  
( $I_{OUT}=10mA$ )



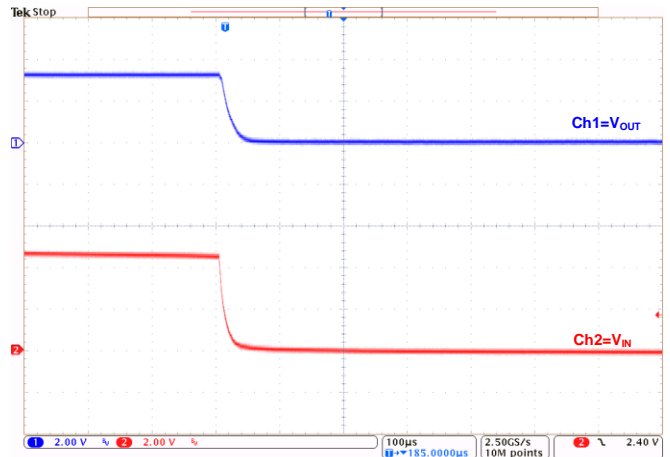
Power Up at  $V_{OUT}=3.3V$ :  
( $I_{OUT}=1mA$ )



Power Up at  $V_{OUT}=3.3V$ :  
( $I_{OUT}=500mA$ )



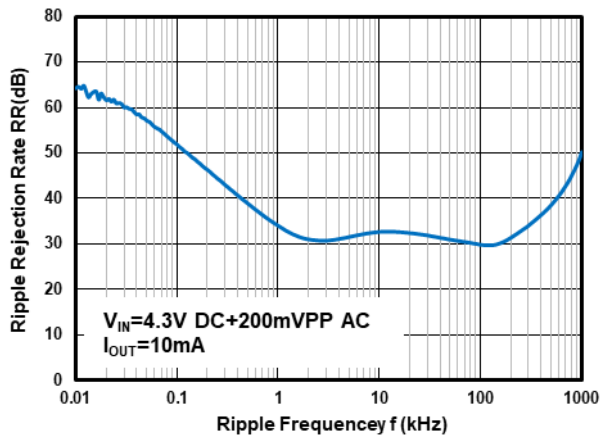
Power Down at  $V_{OUT}=3.3V$ :  
( $I_{OUT}=1mA$ )



Power Down at  $V_{OUT}=3.3V$ :  
( $I_{OUT}=500mA$ )

■ **Typical Performance Characteristics (Continued):**

Test Conditions:  $V_{IN}=V_{OUT}+1.0V$ ,  $C_{IN}=1.0\mu F$ ,  $C_{OUT}=1.0\mu F$ ,  $T_a=25^\circ C$ , unless otherwise indicated.



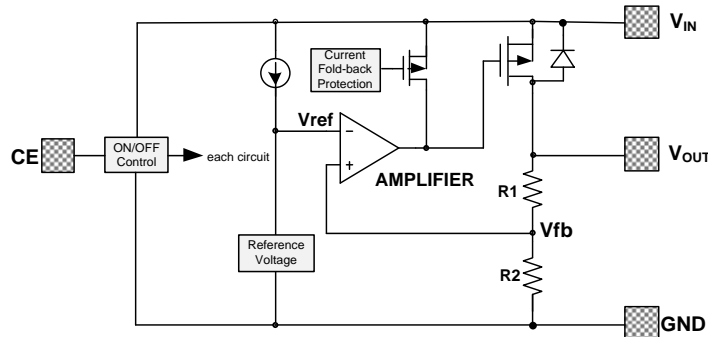
Power Supply Rejection Ratio at  $V_{OUT}=3.3V$



■ **Operational Explanation:**

1. Output voltage control

The voltage divided by resistors R1 and R2 is compared with the internal reference voltage by the error amplifier. The amplifier output then drives the P-channel MOSFET connected to the V<sub>OUT</sub> pin. The output voltage at the V<sub>OUT</sub> pin is regulated by this negative feedback system. The current limit circuit and short protect circuit operate in relation to output current level. Further, the IC's internal circuitry can be in operation or shutdown modes controlled by the EN pin's signal.



2. Pass transistor

The pass transistor with low turn-on resistance used in MD52XX is a P-channel MOSFET. If the potential on V<sub>OUT</sub> pin is higher than V<sub>IN</sub>, it is possible that IC will be destroyed due to reverse current which is caused by parasitic diodes between V<sub>IN</sub> and V<sub>OUT</sub>. Therefore, the V<sub>OUT</sub> pin potential exceeds V<sub>IN</sub>+0.3V is not allowed.

3. Current foldback and short circuit protection

The MD52XX series includes a combination of a fixed current limiter circuit and a foldback circuit, which aid the operations of the current limiter and circuit protection. When the load current reaches the current limit level, the fixed current limiter circuit operates and output voltage drops. As a result of this drop in output voltage, the foldback circuit operates, output voltage drops further and output current decreases. The short circuit current is about 65mA (typical value). This design can prevent the chip be damaged due to over temperature, moreover, the heat dissipation is limited by the package type.

Special attention should be paid to that the product of the dropout voltage on the chip and the output current must be smaller than the heat dissipation.

4. C<sub>OUT</sub> Auto-Discharge Function

The MD52XX series can quickly discharge the electric charge at the output capacitor (C<sub>OUT</sub>), when a low signal is set to the EN pin, which puts the whole IC into OFF state. The discharge function is achieved by an internal switch located between the V<sub>OUT</sub> pin and the GND pin. In this state, the application is protected from a glitch operation caused by the electric charge at the output capacitor (C<sub>OUT</sub>).

Moreover, discharge time of the output capacitor (C<sub>OUT</sub>) is set by the C<sub>OUT</sub> auto-discharge resistance (R<sub>DCHG</sub>) and the output capacitor (C<sub>OUT</sub>). By setting time constant of a C<sub>OUT</sub> auto-discharge resistance value (R<sub>DCHG</sub>) and an output capacitor value (C<sub>OUT</sub>) as  $\tau(\tau = C_{OUT} \times R_{DCHG})$ , the output voltage after discharge via the internal switch is calculated by the following formulas.

$$V = V_{OUT(S)} \times e^{-t/\tau} \text{ or } t = \tau \ln(V_{OUT(S)} / V)$$

V: Output voltage after discharge

V<sub>OUT(S)</sub>: Output voltage

t: Discharge time

$$\tau: C_{OUT} \times R_{DCHG}$$

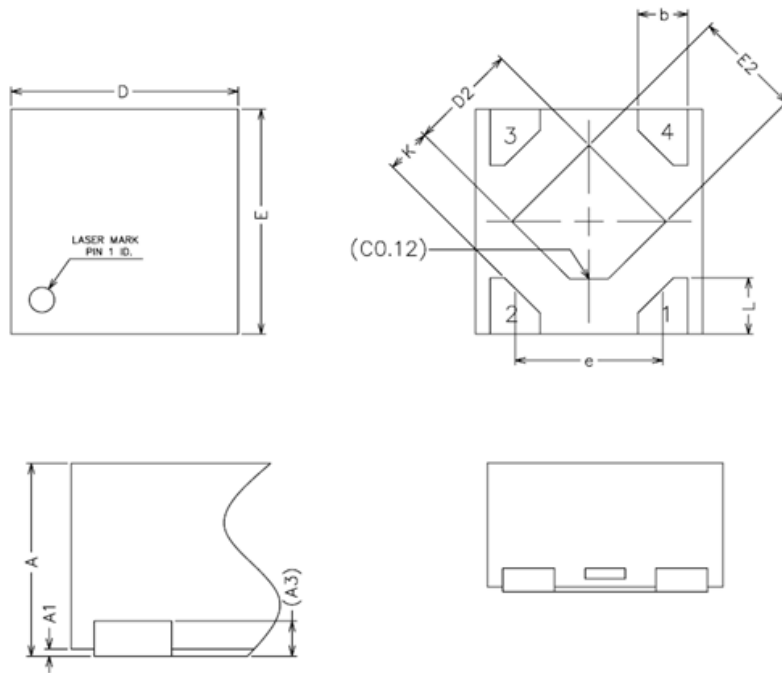
Please also note  $R_{DCHG}$  is depended on  $V_{IN}$  and When  $V_{IN}$  is high,  $R_{DCHG}$  is low.

■ **Notes:**

1. The input and output capacitors should be placed as close as possible to the IC.
2. If the impedance of the power supply is high, which is caused by forgetting installing input capacitor or installing too small value capacitor, the oscillation may occur.
3. Pay attention to the operation conditions of input and output voltage and load current, such that the power consumption in the IC should not exceed the allowable power consumption of the package even though the chip has short circuit protection.
4. IC has a built-in anti-static protection (ESD) circuit, but please do not add excessive stress to the IC.

■ Packaging Information:

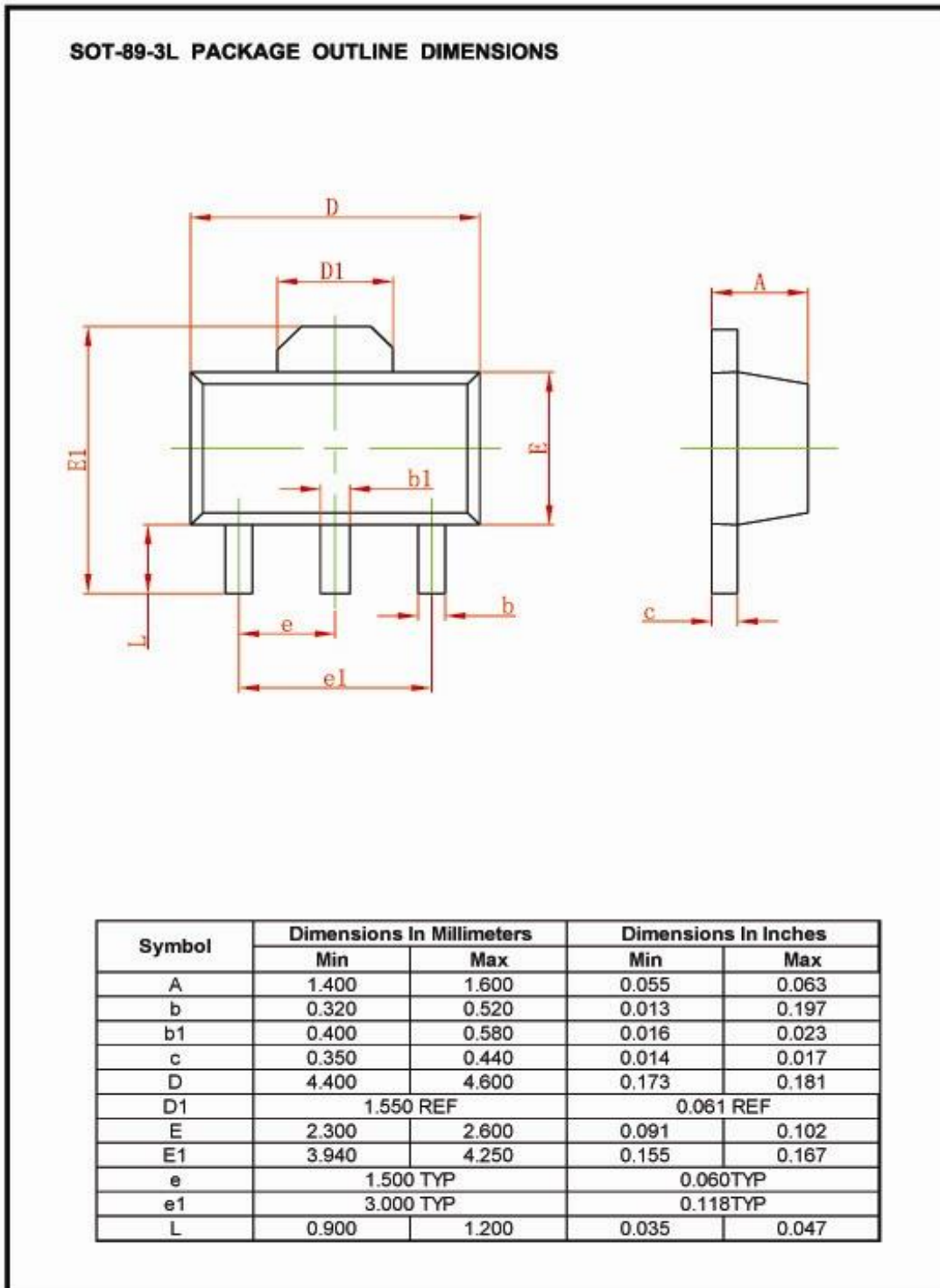
DFN(1\*1)-4L PACKAGE OUTLINE DIMENSIONS



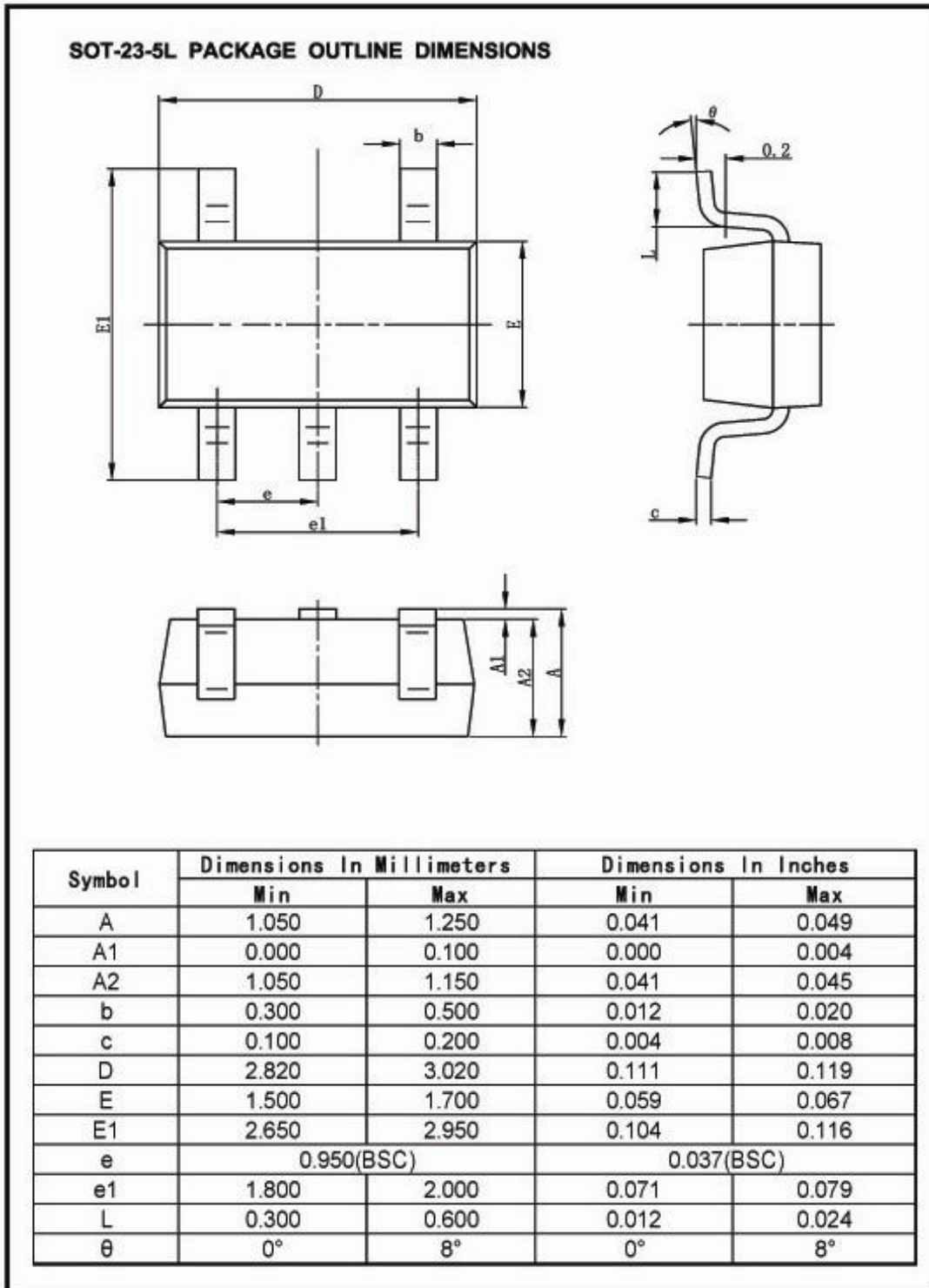
COMMON DIMENSIONS  
(UNITS OF MEASURE=MILLIMETER)

| SYMBOL | MIN      | NOM  | MAX  |
|--------|----------|------|------|
| A      | 0.50     | 0.55 | 0.60 |
| A1     | 0.00     | 0.02 | 0.05 |
| A3     | 0.100REF |      |      |
| b      | 0.17     | 0.22 | 0.27 |
| D      | 0.95     | 1.00 | 1.05 |
| E      | 0.95     | 1.00 | 1.05 |
| D2     | 0.43     | 0.48 | 0.53 |
| E2     | 0.43     | 0.48 | 0.53 |
| L      | 0.20     | 0.25 | 0.30 |
| e      | 0.60     | 0.65 | 0.70 |
| K      | 0.15     | -    | -    |

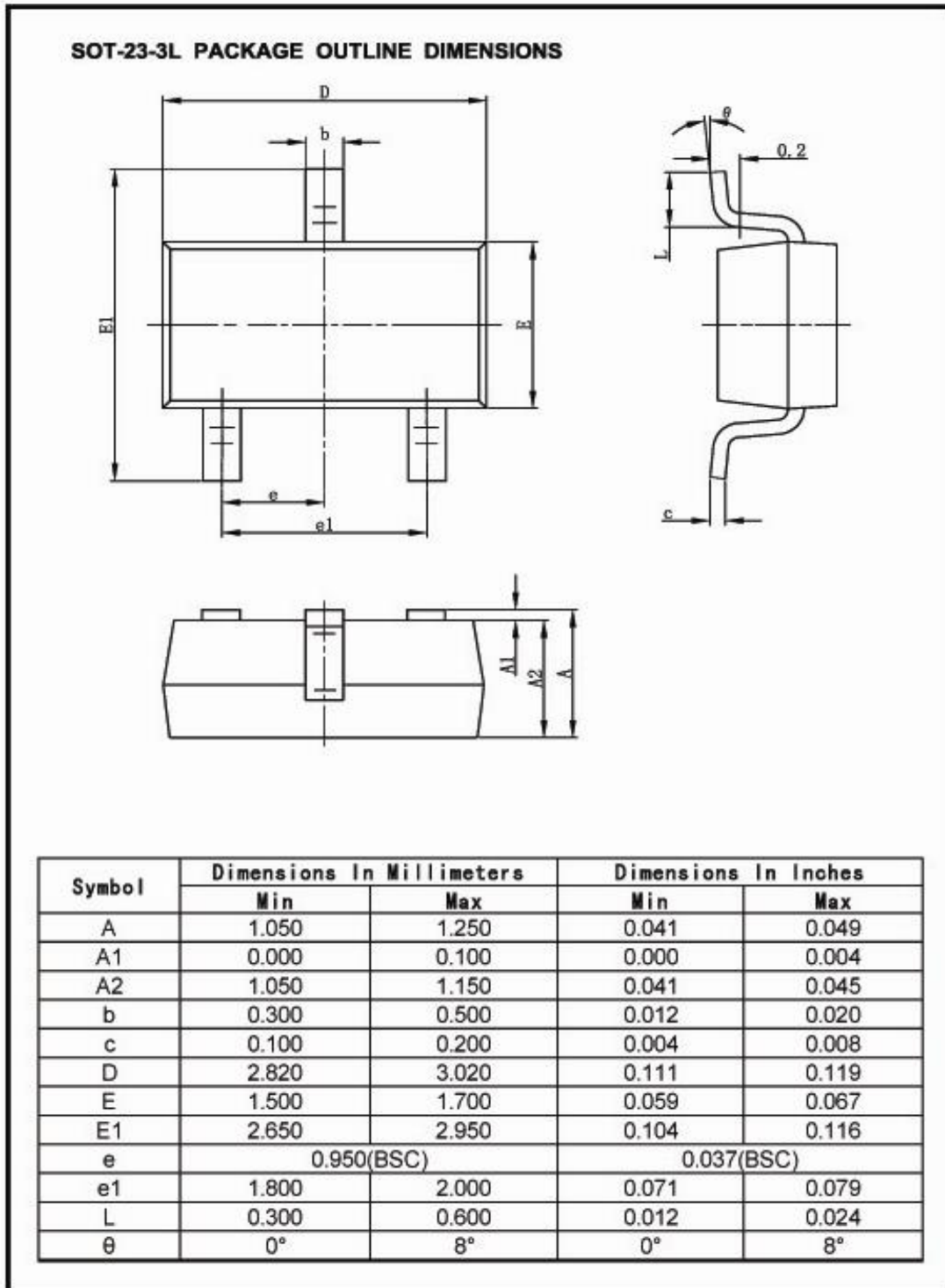
■ PACKAGING INFORMATION(Continued):



■ PACKAGING INFORMATION(Continued):



■ PACKAGING INFORMATION(Continued):



For the newest datasheet, please see the website:

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