TOSHIBA CMOS Linear Integrated Circuit Silicon Monolithic

# TCR3RM series

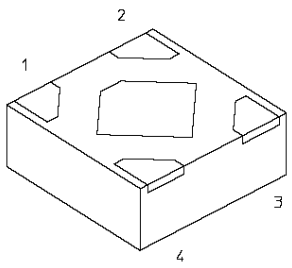
Ultra high Ripple rejection ratio, 300 mA CMOS Low Dropout Regulator in ultra small package

## 1. Description

The TCR3RM series are CMOS general-purpose single-output voltage regulators with an on/off control input, featuring low output voltage noise and ultra-high Ripple rejection ratio.

These voltage regulators are available in fixed output voltages between 0.9 V and 4.5 V and capable of driving up to 300 mA. They feature Overcurrent protection, Thermal shutdown and Auto-discharge.

The TCR3RM series is offered in the ultra small plastic mold package DFN4C/DFN4F (1.0 mm x 1.0 mm; t 0.38 mm (Typ.)) and has a high ripple rejection ratio of 100 dB (f = 1 kHz, 2.8 V output). As small ceramic input and output capacitors 1µF can be used with the TCR3RM series, these devices are ideal for portable applications that require high-density board assembly such as cellular phones.



DFN4C/DFN4F

## 2. Applications

Power IC developed for portable applications

## 3. Features

- Ultra small package DFN4C/DFN4F (1.0 mm x 1.0 mm; t 0.38 mm (Typ.)).
- High Ripple rejection ratio 100 dB (Typ.) @1 kHz ($V_{OUT}$ = 2.8 V)
- High Ripple rejection ratio 93 dB (Typ.) @10 kHz ($V_{OUT}$ = 2.8 V)
- High Ripple rejection ratio 68 dB (Typ.) @100 kHz ($V_{OUT}$ = 2.8 V)
- High Ripple rejection ratio 68 dB (Typ.) @1 MHz ($V_{OUT}$ = 2.8 V)
- Low output noise voltage ($V_{NO}$ = 5 µ$V_{rms}$ (Typ.) at 10 Hz ≤ f ≤ 100 kHz)
- Low quiescent current ($I_B$ = 7 µA (Typ.) at $I_{OUT}$ = 0 mA)
- Overcurrent protection
- Thermal shutdown
- Auto-discharge
- Low Dropout voltage
  $V_{DO}$ = 130 mV (Typ.), $V_{OUT}$ = 2.8 V, $I_{OUT}$ = 300 mA
- Wide range output voltage line up ($V_{OUT}$ = 0.9 to 4.5 V)
- Pull down connection between CONTROL and GND
- Ceramic capacitors can be used ($C_{IN}$ = 1 µF, $C_{OUT}$ =1 µF)

Start of commercial production
2020-09

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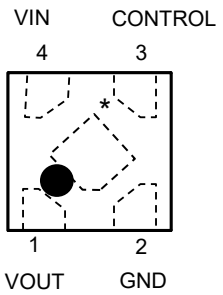
## 4. Absolute Maximum Ratings (Note) (Ta = 25°C)

| Characteristics | Symbol | Rating | Unit |
|---|---|---|---|
| Input voltage | $V_{IN}$ | -0.3 to 6.0 | V |
| Control voltage | $V_{CT}$ | -0.3 to $V_{IN}$ + 0.3 ≤ 6.0 | V |
| Output voltage | $V_{OUT}$ | -0.3 to $V_{IN}$ + 0.3 ≤ 6.0 | V |
| Output current | $I_{OUT}$ | 300 | mA |
| Power dissipation | $P_D$ | 420 (Note1) | mW |
| Junction temperature | $T_j$ | 150 | °C |
| Storage temperature range | $T_{stg}$ | −55 to 150 | °C |

Note: Using continuously under heavy loads (e.g. the application of high temperature/current/voltage and the significant change in temperature, etc.) may cause this product to decrease in the reliability significantly even if the operating conditions (i.e. operating temperature/current/voltage, etc.) are within the absolute maximum ratings and the operating ranges.
Please design the appropriate reliability upon reviewing the Toshiba Semiconductor Reliability Handbook ("Handling Precautions"/"Derating Concept and Methods") and individual reliability data (i.e. reliability test report and estimated failure rate, etc).

Note1: Rating at mounting on a board
Glass epoxy(FR4) board dimension: 40mm x 40mm x 1.6mm, both sides of board.
Metal pattern ratio: a surface approximately 50%, the reverse side approximately 50%

## 5. Pin Assignment (Top view)




*Center electrode should be connected to GND or Open

## 6. Operating Ranges

| Characteristics | Symbol | Ranges | | Unit |
|---|---|---|---|---|
| Input voltage | $V_{IN}$ | 1.8 to 5.5 (Note 2) | | V |
| Control voltage | $V_{CT}$ | 0 to $V_{IN}$ | | V |
| Output voltage | $V_{OUT}$ | 0.9 to 4.5 | | V |
| Output current | $I_{OUT}$ | DC | 300 | mA |
| Operating Temperature | $T_{opr}$ | -40 to 85 | | °C |
| Output Capacitance | $C_{OUT}$ | ≥ 1.0 μF | | — |
| Input Capacitance | $C_{IN}$ | ≥ 1.0 μF | | — |

Note 2: Please refer to Dropout Voltage table(Page 6) and use it within Absolute Maximum Ratings Junction temperature and Operating Temperature Ranges.

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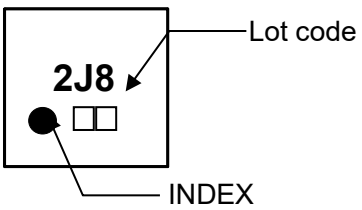
# 7. List of Products Number, Output voltage and Marking

| Product No. | Output voltage(V) | Marking |
|---|---|---|
| TCR3RM09A | 0.9 | 0J9 |
| TCR3RM095A* | 0.95 | 0JB |
| TCR3RM10A | 1.0 | 1J0 |
| TCR3RM105A* | 1.05 | 1JC |
| TCR3RM11A* | 1.1 | 1J1 |
| TCR3RM115A* | 1.15 | 1JD |
| TCR3RM12A | 1.2 | 1J2 |
| TCR3RM13A* | 1.3 | 1J3 |
| TCR3RM15A* | 1.5 | 1J5 |
| TCR3RM16A* | 1.6 | 1J6 |
| TCR3RM17A* | 1.7 | 1J7 |
| TCR3RM18A | 1.8 | 1J8 |
| TCR3RM1825A* | 1.825 | 1JG |
| TCR3RM185A | 1.85 | 1JH |
| TCR3RM19A* | 1.9 | 1J9 |
| TCR3RM20A* | 2.0 | 2J0 |
| TCR3RM22A | 2.2 | 2J2 |
| TCR3RM25A | 2.5 | 2J5 |
| TCR3RM26A* | 2.6 | 2J6 |
| TCR3RM27A* | 2.7 | 2J7 |
| TCR3RM28A | 2.8 | 2J8 |
| TCR3RM285A | 2.85 | 2JJ |
| TCR3RM29A | 2.9 | 2J9 |
| TCR3RM30A | 3.0 | 3J0 |
| TCR3RM31A* | 3.1 | 3J1 |
| TCR3RM32A* | 3.2 | 3J2 |
| TCR3RM33A | 3.3 | 3J3 |
| TCR3RM35A* | 3.5 | 3J5 |
| TCR3RM36A* | 3.6 | 3J6 |
| TCR3RM40A* | 4.0 | 4J0 |
| TCR3RM41A | 4.1 | 4J1 |
| TCR3RM42A* | 4.2 | 4J2 |
| TCR3RM43A* | 4.3 | 4J3 |
| TCR3RM45A* | 4.5 | 4J5 |

Please ask your local retailer about the devices with (*) or other output voltages.

## Top Marking (Top view)

Example: TCR3RM28A (2.8 V output)



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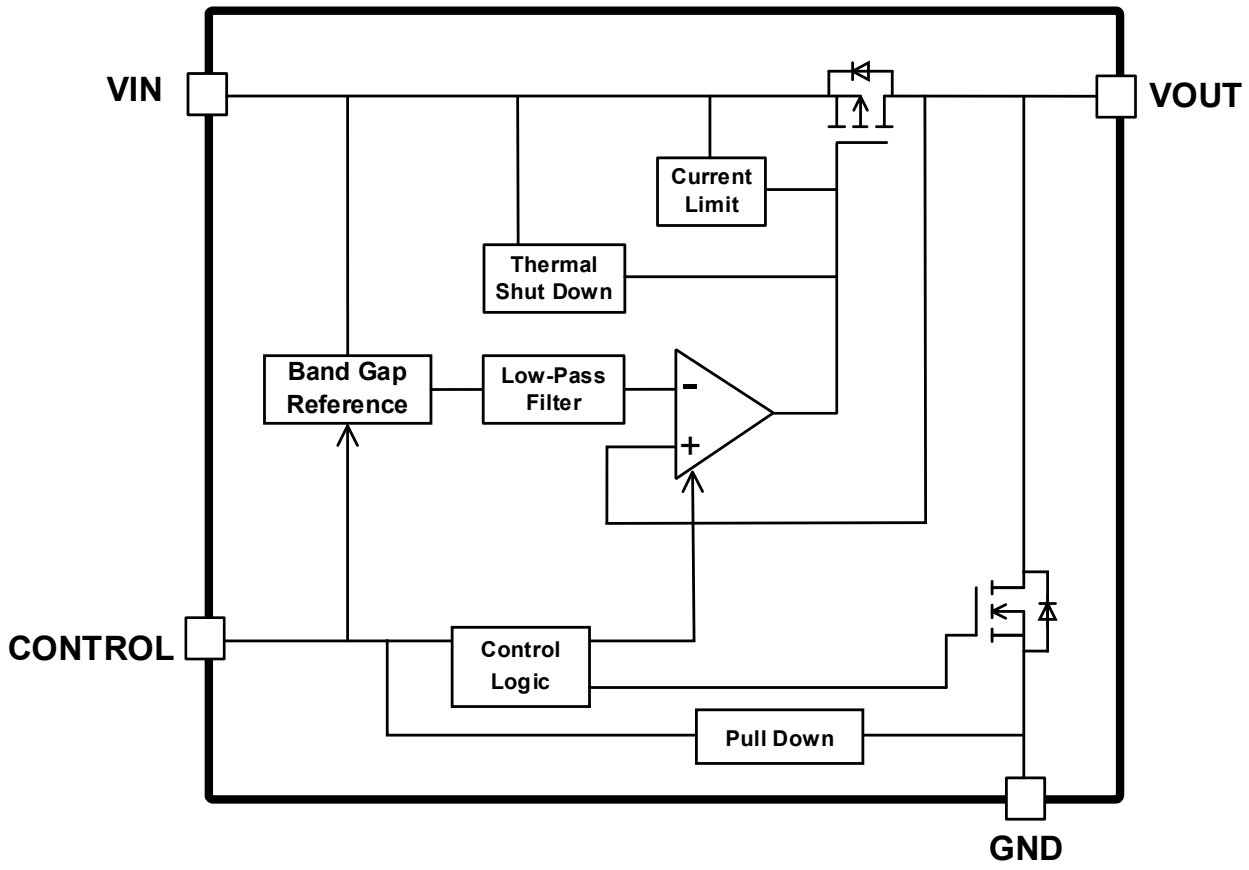
## Block Diagram



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# 8. Electrical Characteristics

**(Unless otherwise specified, $V_{IN} = V_{OUT} + 1$ V ($V_{OUT} \geq 1$ V), $V_{IN} = 2$ V ($V_{OUT} \leq 1$ V), $C_{IN} = C_{OUT} = 1$ μF)**

| Characteristics | Symbol | Test Condition | | $T_j$ = 25°C | | | $T_j$ = -40 to 85°C (Note 6) | | Unit |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Min | Typ. | Max | Min | Max | |
| Output voltage accuracy | $V_{OUT}$ | $I_{OUT}$ = 1 to 300 mA<br>$V_{IN} = V_{OUT}$+ 1 V to 5.5 V<br>(Note 3) | $V_{OUT}$ < 1.8 V | — | — | — | -36 | +36 | mV |
| | | | 1.8V ≤ $V_{OUT}$ | — | — | — | -2 | +2 | % |
| Line regulation | Reg·line | $V_{OUT}$ + 1 V ≤ $V_{IN}$ ≤ 5.5 V<br>$I_{OUT}$ = 1 mA | | — | 0.025 | — | — | — | %/V |
| Load regulation | Reg·load | 1 mA ≤ $I_{OUT}$ ≤ 300 mA | | — | 12 | — | — | — | mV |
| Quiescent current | $I_{B(ON)}$ | $I_{OUT}$ = 0 mA (Note 5) | | — | 7 | — | — | 12 | μA |
| Stand-by current | $I_{B\ (OFF)}$ | $V_{CT}$ = 0 V | | — | 0.1 | — | — | 1.0 | μA |
| Control pull down current | $I_{CT}$ | — | | — | 0.1 | — | — | 0.2 | μA |
| Drop-out voltage (Note 7) | $V_{DO}$ | $I_{OUT}$ = 300 mA | $V_{OUT}$ = 1.8 V | — | 180 | — | — | 220 | mV |
| | | | $V_{OUT}$ = 2.8 V | — | 130 | — | — | 150 | mV |
| | | | $V_{OUT}$ = 4.5 V | — | 98 | — | — | 125 | mV |
| Output noise voltage | $V_{NO}$ | $I_{OUT}$ = 10 mA<br>10 Hz ≤ f ≤ 100 kHz, Ta = 25°C (Note 4) | | — | 5 | — | — | — | $\mu V_{rms}$ |
| Ripple rejection ratio | R.R. | $I_{OUT}$ = 10 mA,<br>$V_{Ripple}$ = 200 $mV_{p-p}$,<br>Ta = 25°C (Note 4) | f = 1 kHz | — | 100 | — | — | — | dB |
| | | | f = 10 kHz | — | 93 | — | — | — | dB |
| | | | f = 100 kHz | — | 68 | — | — | — | dB |
| | | | f = 1 MHz | — | 68 | — | — | — | dB |
| Load transient response | ⊿$V_{OUT}$ | $I_{OUT}$ = 1 mA → 300 mA, $t_r$ = 1 μs | | — | -30 | — | — | — | mV |
| | | $I_{OUT}$ = 300 mA → 1 mA, $t_f$ = 1 μs | | — | +30 | — | — | — | mV |
| Output voltage slew rate | $V_{OUTSR}$ | (Note 4) | | — | 4 | — | — | — | mV/μs |
| Output current limit | $I_{CL}$ | — | | — | — | — | 400 | 700 | mA |
| Thermal shutdown threshold | $T_{SDH}$ | $T_j$ rising | | — | 160 | — | — | — | °C |
| | $T_{SDL}$ | $T_j$ falling | | — | 140 | — | — | — | °C |
| Control voltage (HIGH) | $V_{CTH}$ | Control pin input voltage "HIGH" | | — | — | — | 1.0 | $V_{IN}$ | V |
| Control voltage (LOW) | $V_{CTL}$ | Control pin input voltage "LOW" | | — | — | — | 0 | 0.4 | V |
| Discharge on resistance | $R_{SD}$ | (Note 4) | | — | 20 | — | — | — | Ω |

Note 3: stable state with fixed $I_{OUT}$ condition
Note 4: $V_{OUT}$ = 2.8 V
Note 5: except Control pull down current ($I_{CT}$)
Note 6: This parameter is warranted by design.
Note 7: $V_{DO} = V_{IN1} - (V_{OUT1} \times 0.97)$
$V_{OUT1}$ is the nominal output voltage.
$V_{IN1}$ is the input voltage at which the output voltage becomes 97% of $V_{OUT1}$ after gradually decreasing the input voltage.

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## Dropout voltage table

**( $C_{IN}$ = 1.0 μF, $C_{OUT}$ = 1.0 μF)**

| Output voltages | $I_{OUT}$ = 300 mA | | | Unit |
|---|---|---|---|---|
| | Min | Typ. | Max (Note 8) | |
| 0.9 V ≤ $V_{OUT}$ ≤ 1.5 V | — | (Note 9) | (Note 9) | mV |
| 1.5 V | — | 225 (Note 9) | 280 (Note 9) | mV |
| 1.6 V | — | 210 | 255 | mV |
| 1.7 V | — | 190 | 235 | mV |
| 1.8 V, 1.825 V, 1.85 V | — | 180 | 220 | mV |
| 1.9 V | — | 175 | 210 | mV |
| 2.0 V | — | 170 | 200 | mV |
| 2.2 V | — | 160 | 185 | mV |
| 2.5 V, 2.6 V | — | 140 | 165 | mV |
| 2.7 V | — | 130 | 155 | mV |
| 2.8 V | — | 130 | 150 | mV |
| 2.85 V, 2.9 V | — | 125 | 150 | mV |
| 3.0 V, 3.1 V, 3.2 V | — | 120 | 145 | mV |
| 3.3 V | — | 115 | 140 | mV |
| 3.5 V, 3.6 V | — | 110 | 140 | mV |
| 4.0 V | — | 100 | 138 | mV |
| 4.1 V | — | 100 | 135 | mV |
| 4.2 V, 4.3 V | — | 100 | 133 | mV |
| 4.5 V | — | 98 | 125 | mV |

Note 8: $T_j$ = -40 to 85 °C. This parameter is guaranteed by design
Note 9: Operating Voltage of $V_{IN}$ should be over 1.8 V.

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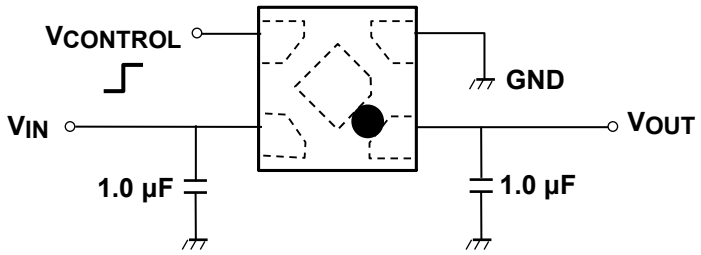
# 9. Application Note

## 9.1. Recommended Application Circuit



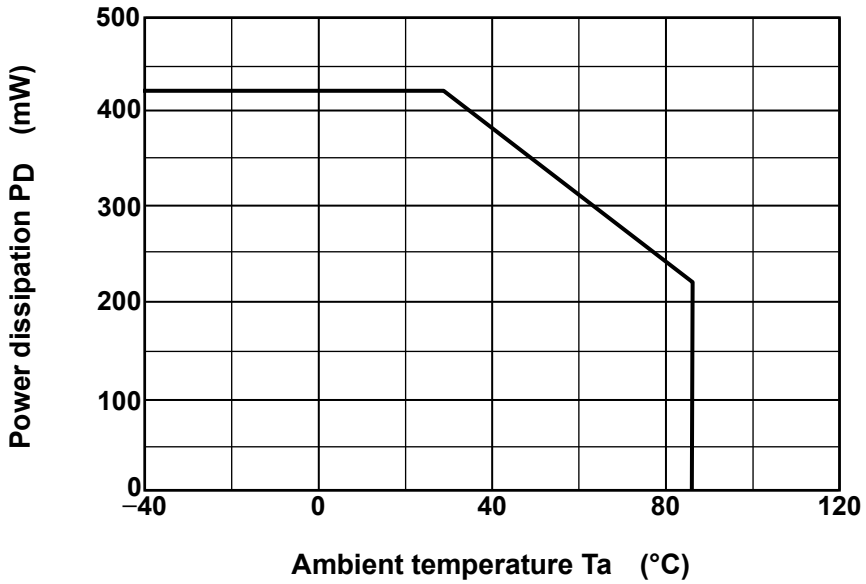

| CONTROL voltage | Output voltage |
|---|---|
| HIGH | ON |
| LOW | OFF |
| OPEN | OFF |

The figure above shows the recommended configuration for using a Low-Dropout regulator. Insert a capacitor at VOUT and VIN pins for stable input/output operation. (Ceramic capacitors can be used.)

## 9.2. Power Dissipation

Board-mounted power dissipation ratings for TCR3RM series are available in the Absolute Maximum Ratings table. Power dissipation is measured on the board condition shown below.

[The Board Condition]
Board material: Glass epoxy(FR4)
Board dimension: 40mm x 40mm (both sides of board), t= 1.6 mm
Metal pattern ratio: a surface approximately 50%, the reverse side approximately 50%



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## 9.3. **Attention in Use**

- Output Capacitors
  Ceramic capacitors can be used for these devices. However, because of the type of the capacitors, there might be unexpected thermal features. Please consider application condition for selecting capacitors. And Toshiba recommends ceramic capacitor.

- Bias current characteristics
  TCR3RM series has Bias current; $I_{B(ON)}$ characteristic that controlled depending on $I_{OUT}$.
  When the output current required is very low, TCR3RM series operates with low $I_{B(ON)}$. In this state, PSRR characteristic and load transient response characteristic are inferior than normal characteristics.
  Regarding output current that switches $I_{B(ON)}$ state, TCR3RM series has hysteresis to control. When output current is increased, good PSRR characteristics and good load transient response characteristics are provided with $I_{B(ON)}$ becoming high. In the case of decreasing the $I_{OUT}$, TCR3RM series keeps good characteristics until the $I_{B(ON)}$ switches to a low state.

- Mounting
  The long distance between IC and output capacitor might affect phase compensation by impedance in wire and inductor. For stable power supply, output capacitor need to mount near IC as much as possible. Also VIN and GND pattern need to be large and make the wire impedance small as possible.

- Permissible Loss
  Please have enough design patterns for expected maximum permissible loss. And under consideration of surrounding temperature, input voltage, output current etc., we recommend proper dissipation ratings for maximum permissible loss; in general maximum dissipation rating is 70 to 80%.

- Over current Protection and Thermal shutdown function
  Over current protection and Thermal shutdown function are designed in these products, but these are not designed to constantly ensure the suppression of the device within operation limits. Depending on the condition during actual usage, it could affect the electrical characteristic specification and reliability. Also note that if output pins and GND pins are not completely shorted out, these products might be break down. When using these products, please read through and understand the concept of dissipation for absolute maximum ratings from the above mention or our ‘Semiconductor Reliability Handbook’. Then use these products under absolute maximum ratings in any condition. Furthermore, Toshiba recommends inserting failsafe system into the design.

- High ripple rejection ratio and low output noise voltage characteristics
  TCR3RM series has low-pass filter which contributes high ripple rejection ratio and low output noise voltage.
  This low-pass filter turns on after $V_{OUT}$ becomes near the nominal $V_{OUT}$.
  Therefore, before and when the low-pass filter is turned on, please be careful about the increase and decrease of $V_{OUT}$ such as CONTROL voltage from low to high and load transient response.
  It affects significantly especially when the voltage difference between $V_{IN}$ and $V_{OUT}$ is small.

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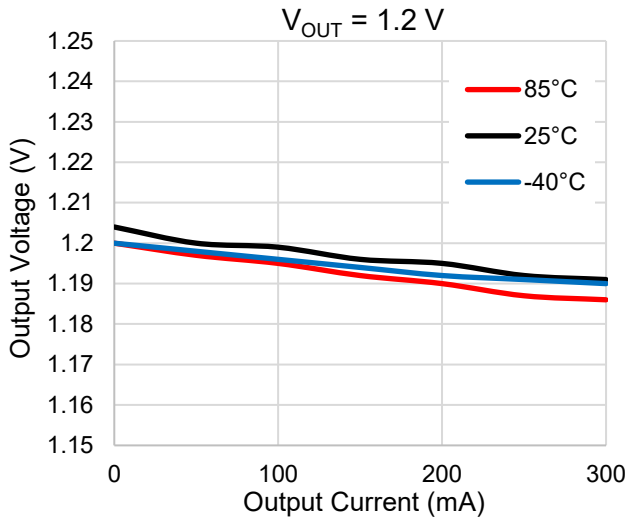
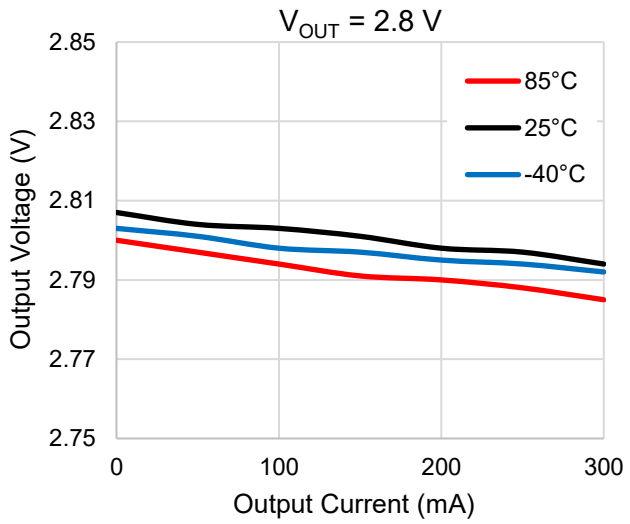
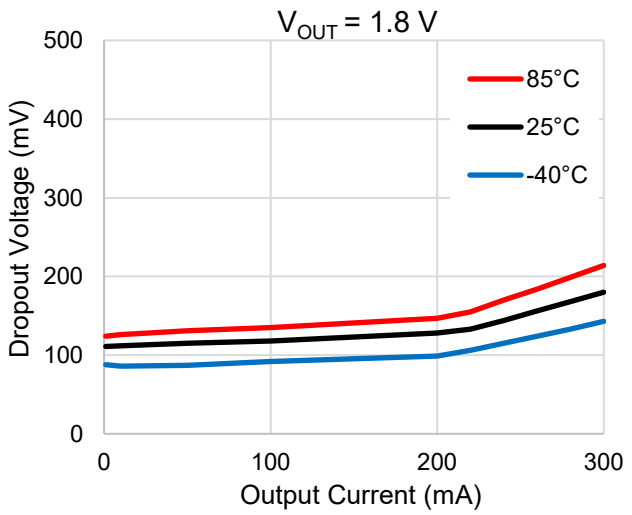
# 10. Representative Typical Characteristics (Note)

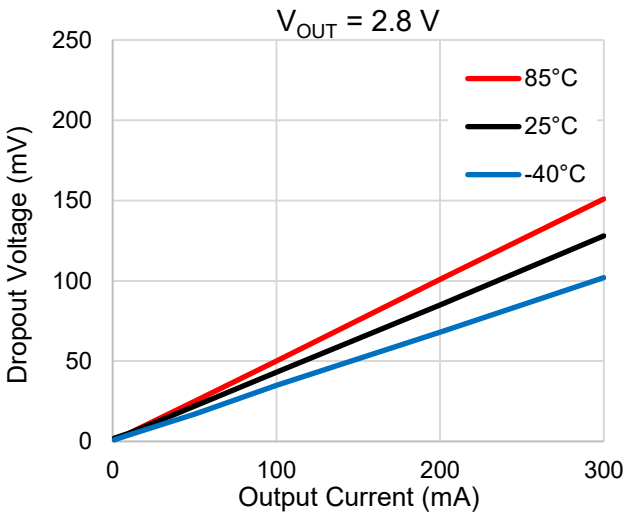
## 10.1. Output Voltage vs. Output Current ($V_{IN} = V_{OUT} + 1$ V)

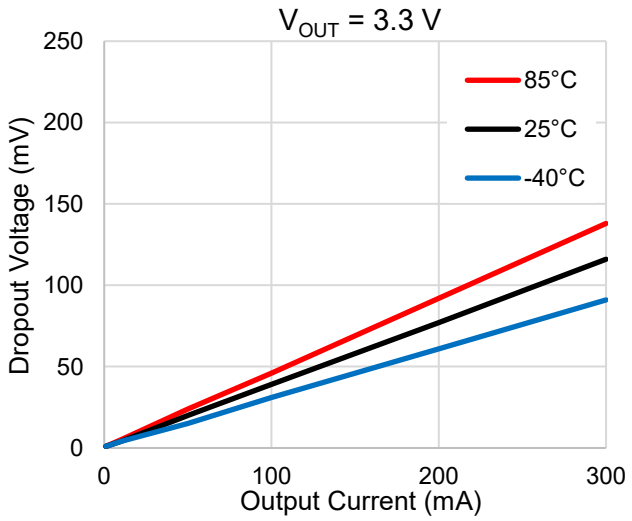


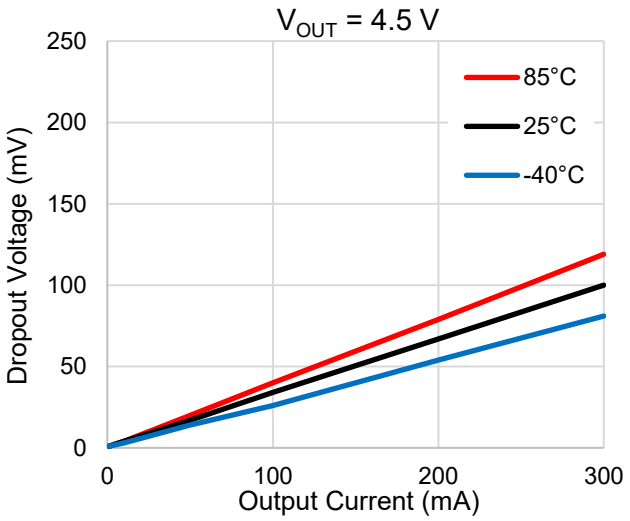




## 10.2. Dropout Voltage vs. Output Current



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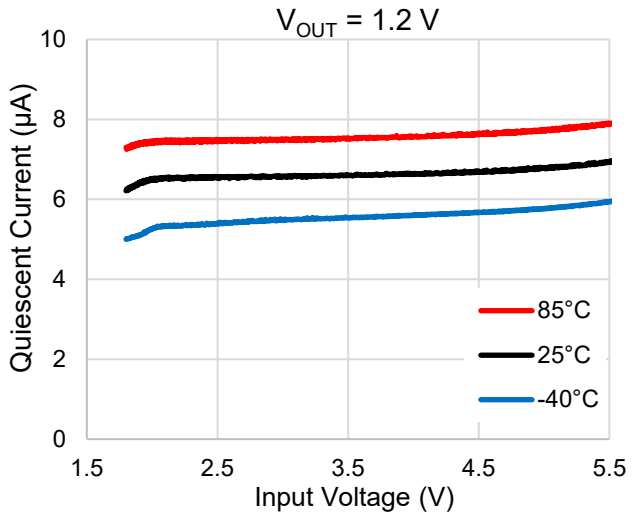
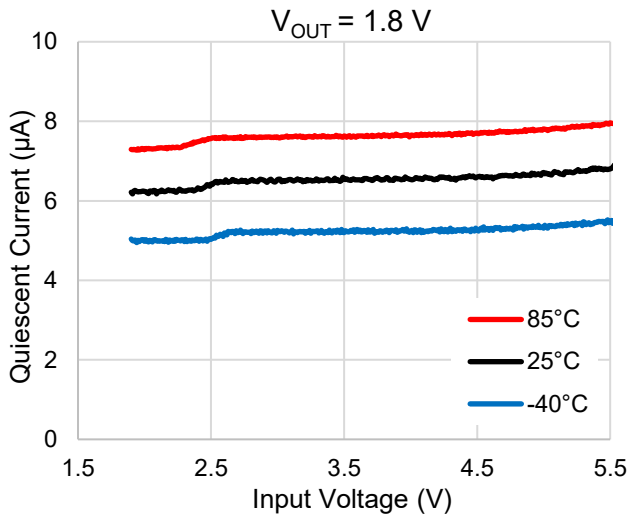
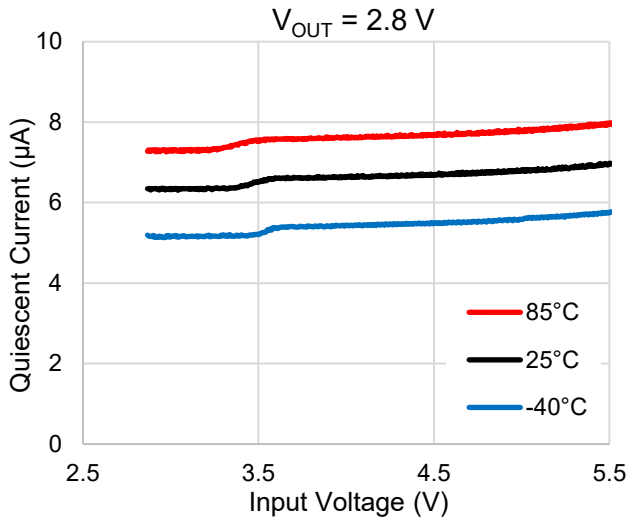
## 10.3. **Quiescent Current vs. Input Voltage ($I_{OUT}$ = 0mA)**



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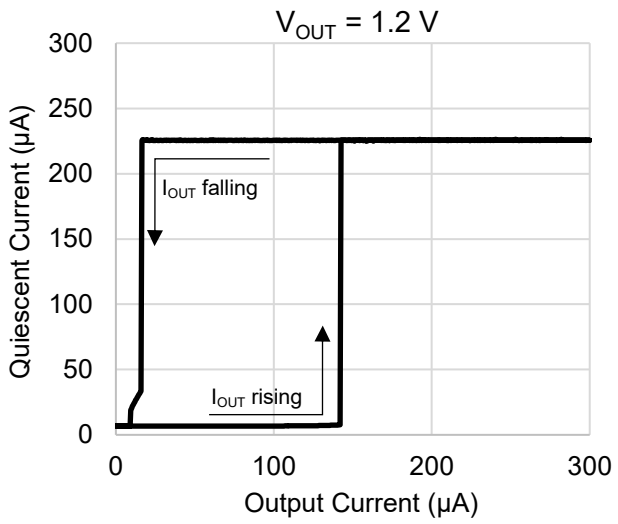
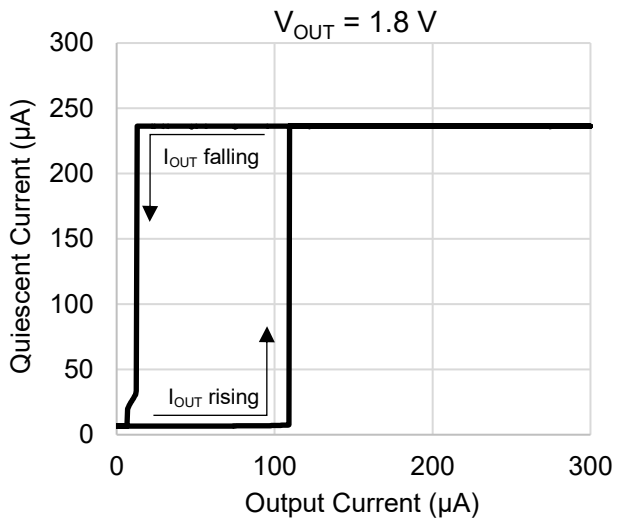
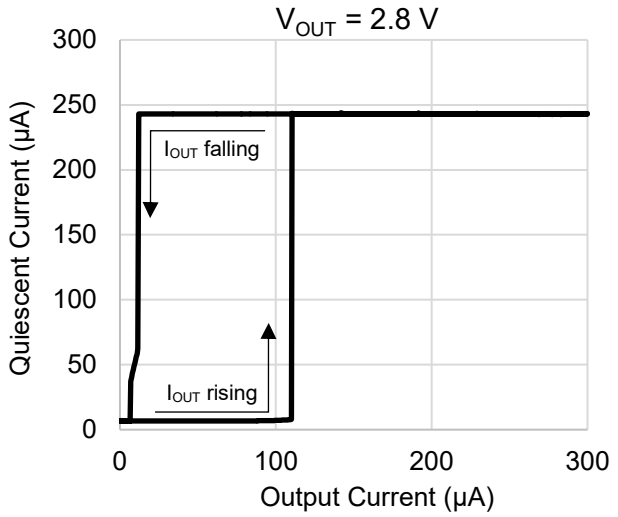
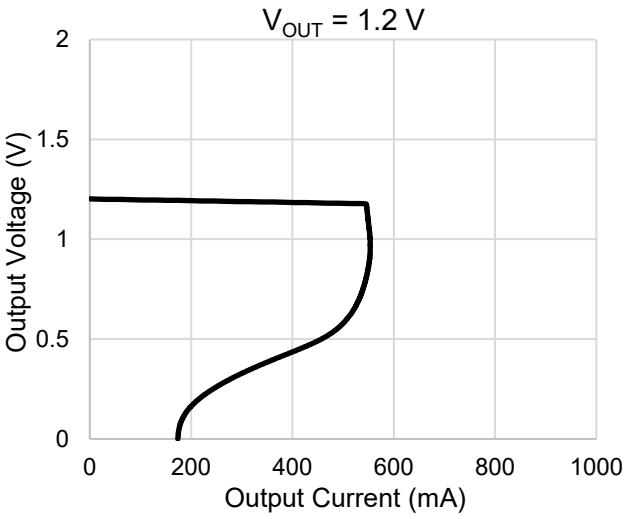
## 10.4. **Quiescent Current vs. Output Current ($V_{IN}$ = $V_{OUT}$ + 1 V, $I_{OUT}$ = 0 ↔ 300 μA, Ta=25°C)**

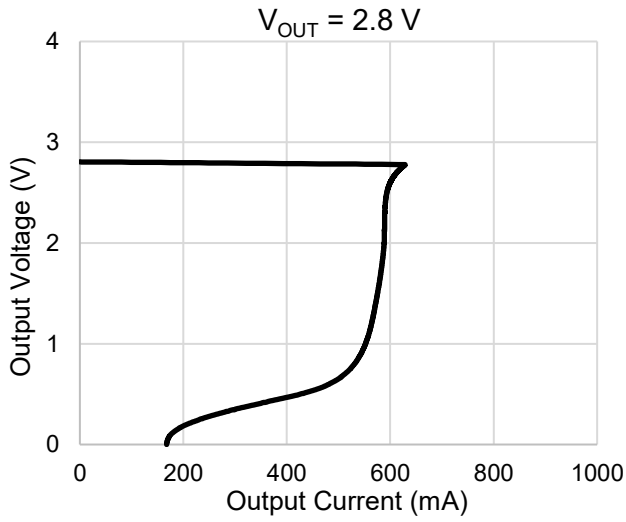



## 10.5. **Output Current Limit ($V_{IN}$ = $V_{OUT}$ + 1 V, Ta = 25°C)**



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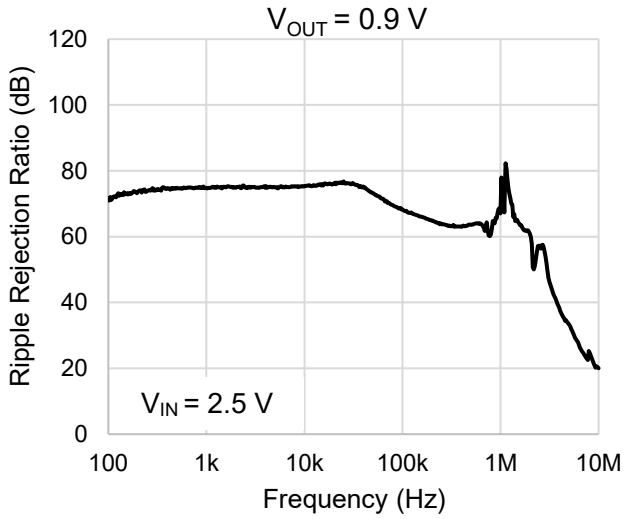
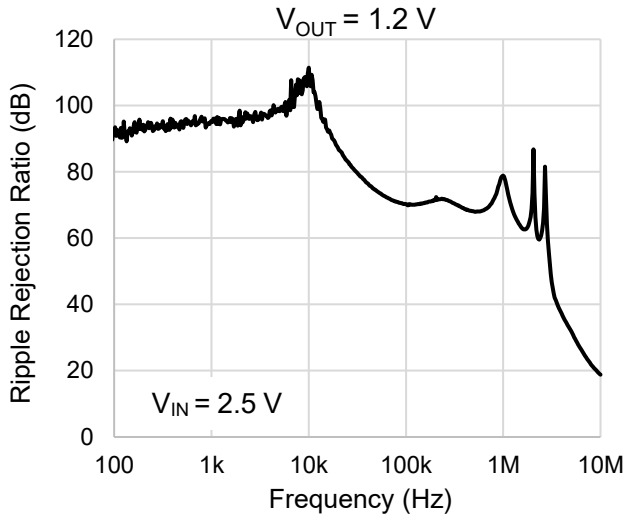
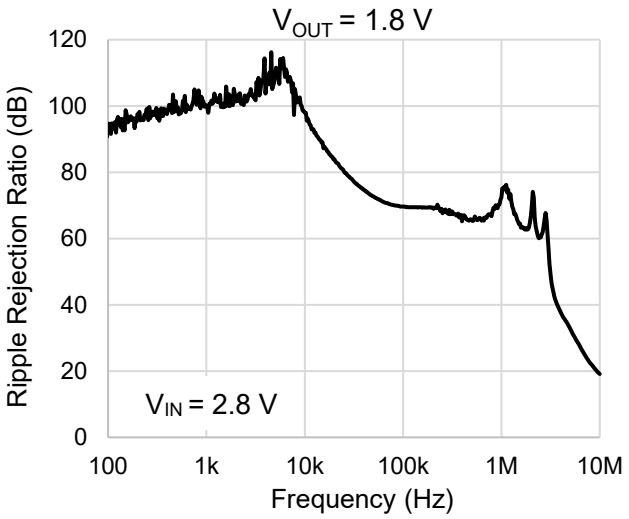
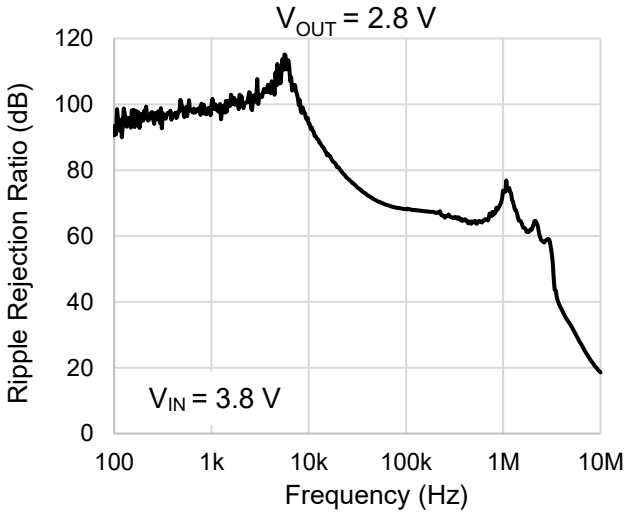
## 10.6. **Ripple rejection Ratio vs. Frequency**

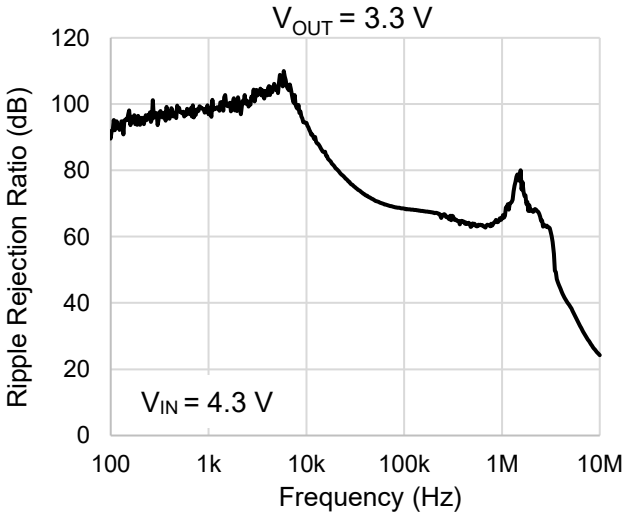
**($C_{IN}$ = none, $C_{OUT}$ = 1 μF, $V_{IN\ Ripple}$ = 200 $mV_{p-p}$, $I_{OUT}$ = 10 mA, Ta = 25°C)**

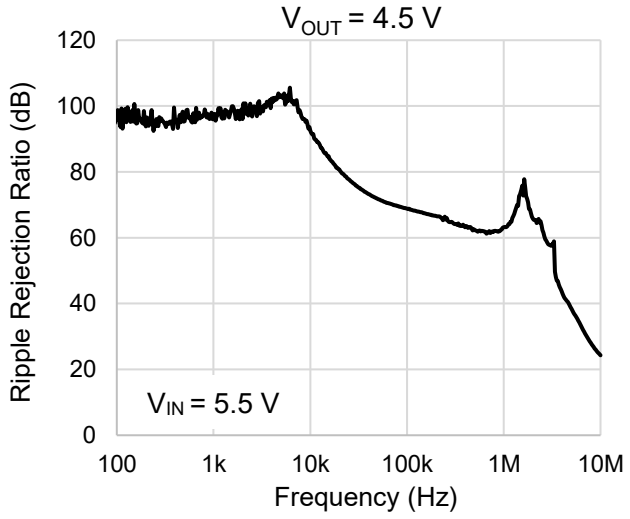
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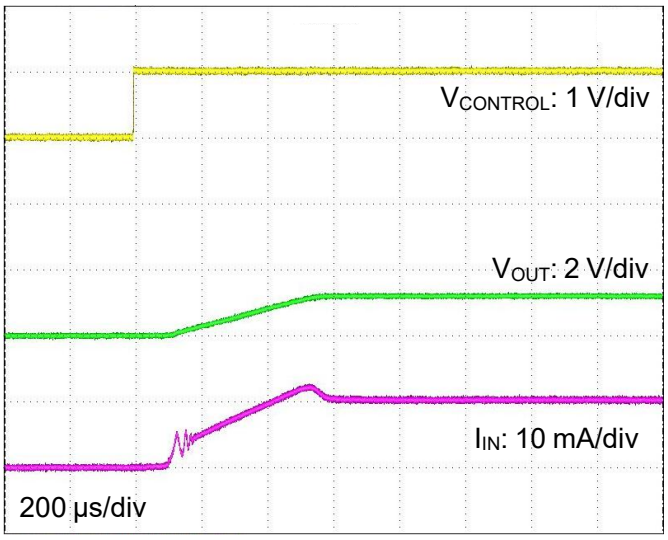
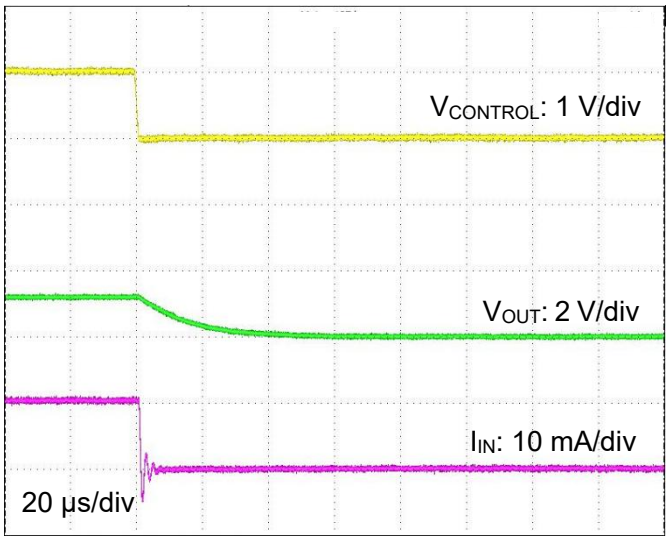
## 10.7. $t_{ON}$ / $t_{OFF}$ Response ($C_{IN}$ = 1 μF, $V_{IN}$ = $V_{OUT}$ + 1 V, $V_{CONTROL}$ = 0 V ↔ 1 V, Ta = 25°C)

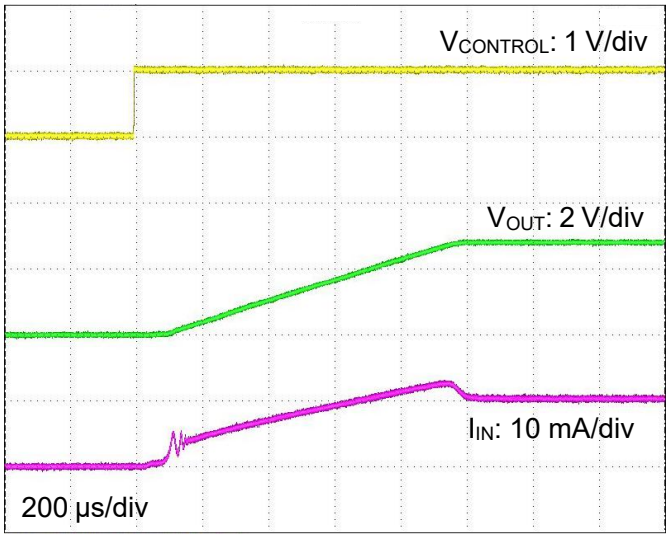
- **$C_{OUT}$ = 1 μF, $I_{OUT}$ = 10 mA**

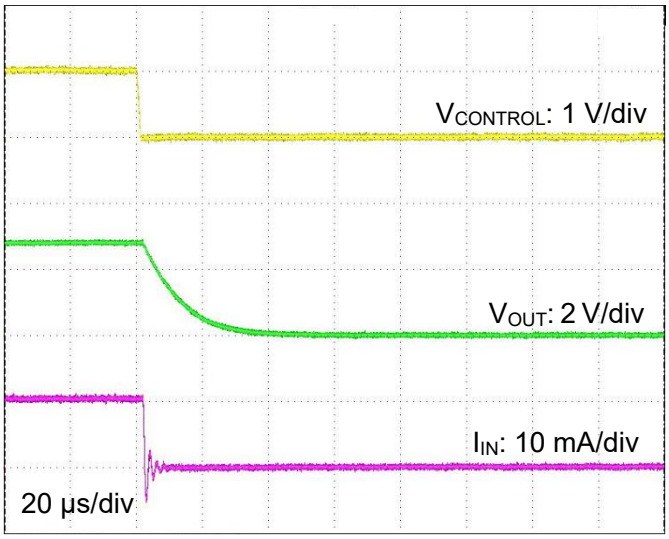
$V_{OUT}$ = 1.2 V




$V_{OUT}$ = 2.8 V



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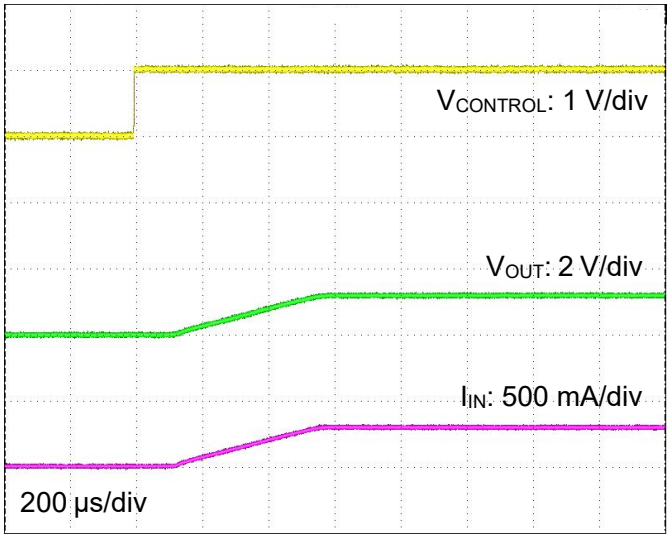
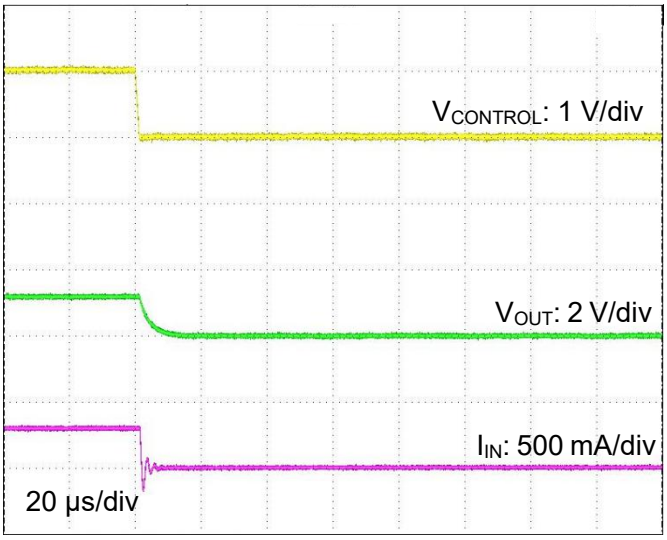
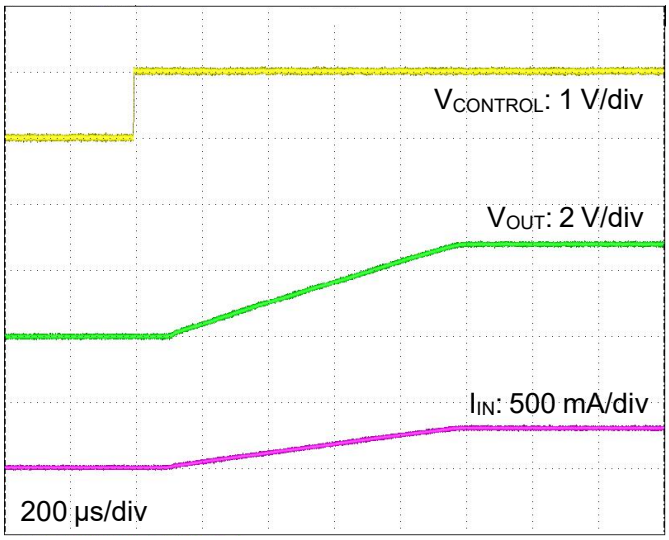
- **$C_{OUT}$ = 1 μF, $I_{OUT}$ = 300 mA**

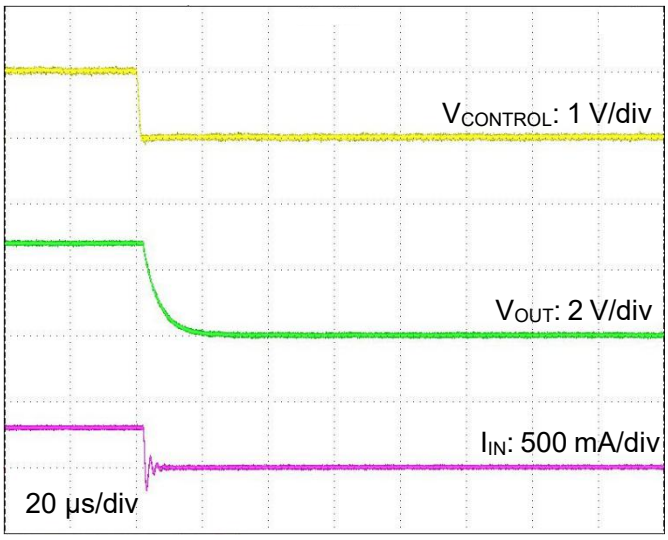
$V_{OUT}$ = 1.2 V




$V_{OUT}$ = 2.8 V



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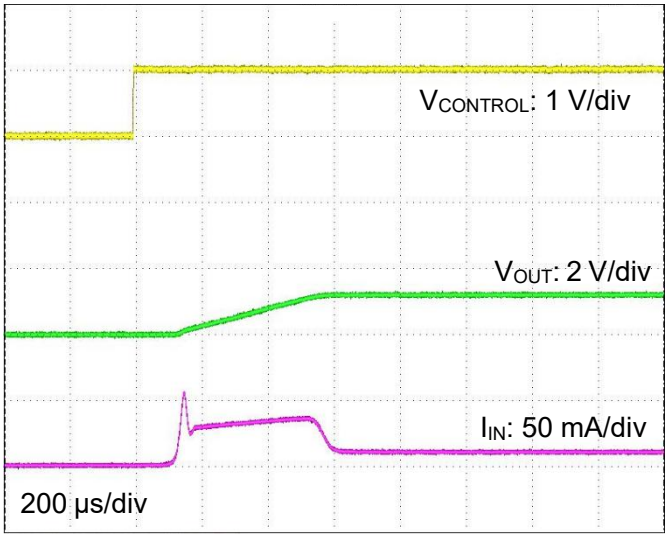
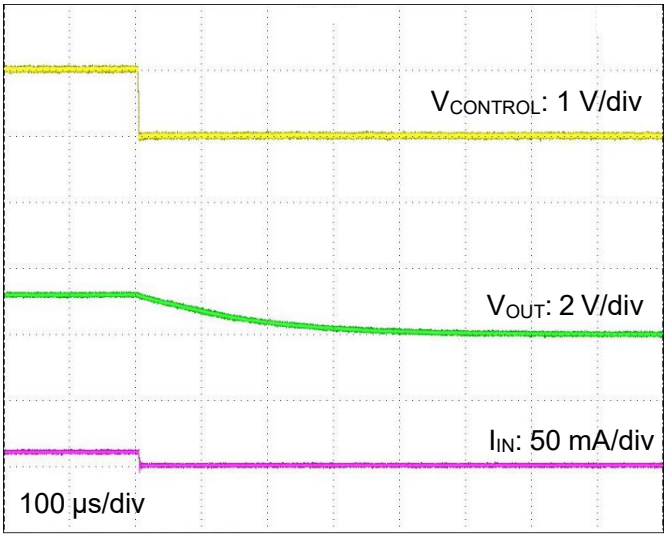
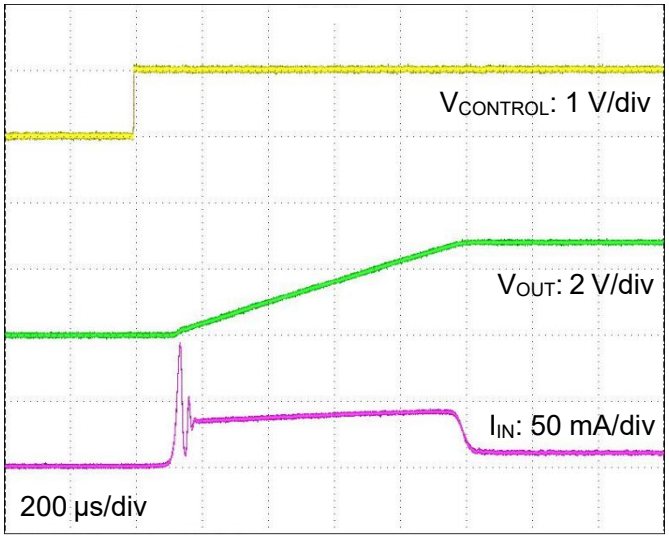
- **$C_{OUT}$ = 10 μF, $I_{OUT}$ = 10 mA**

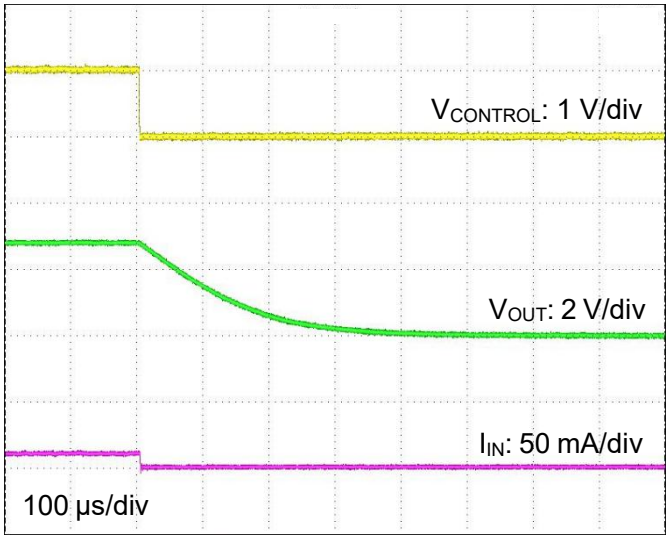
$V_{OUT}$ = 1.2 V




$V_{OUT}$ = 2.8 V



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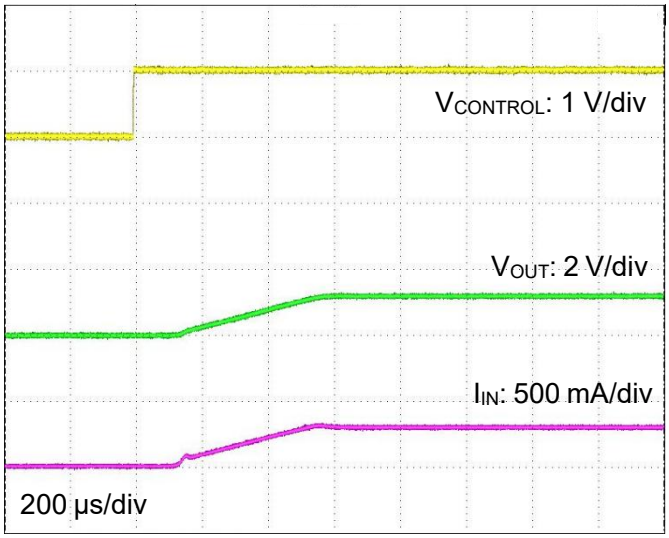
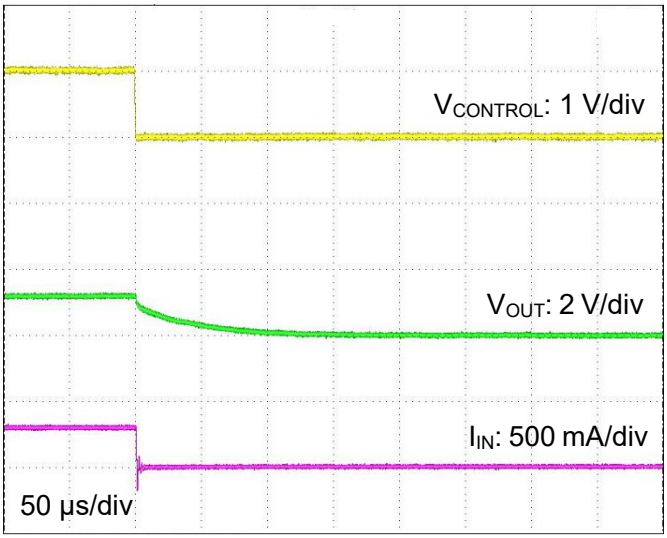
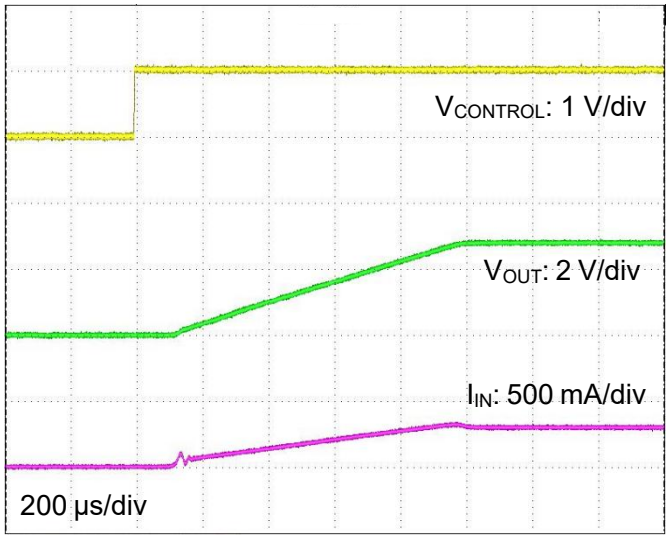
- **$C_{OUT}$ = 10 μF, $I_{OUT}$ = 300 mA**

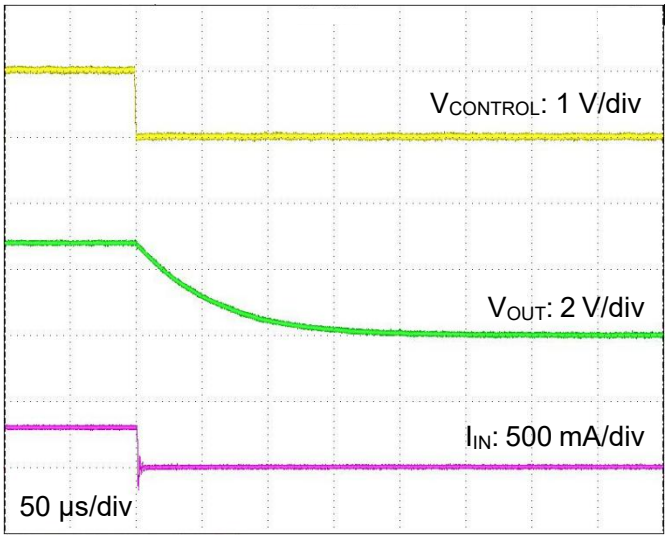
$V_{OUT}$ = 1.2 V




$V_{OUT}$ = 2.8 V



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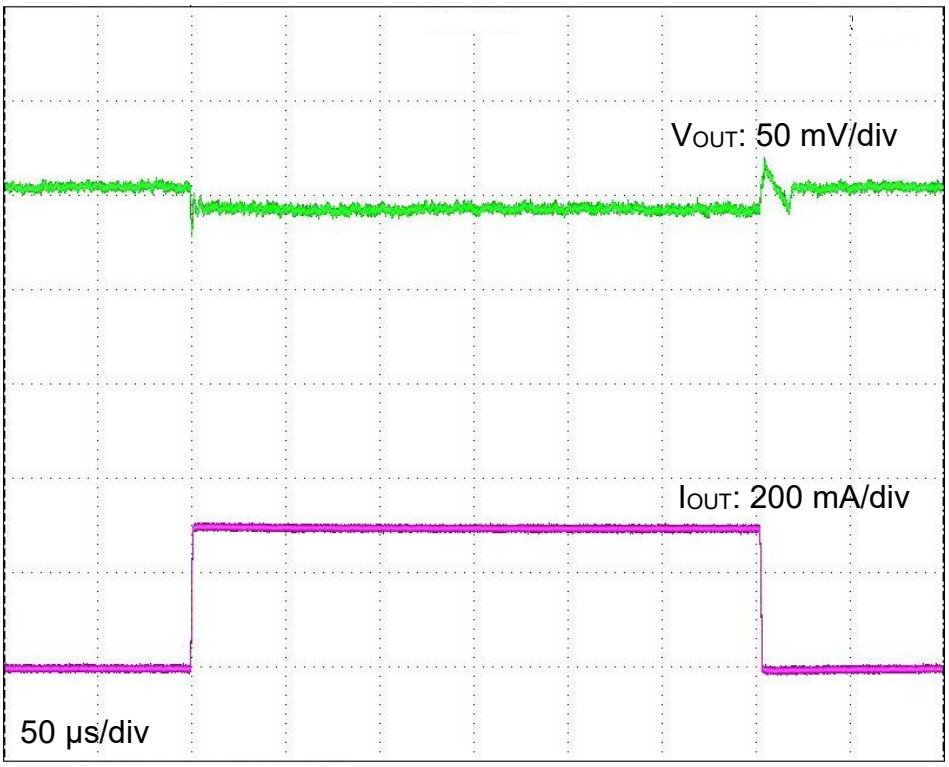
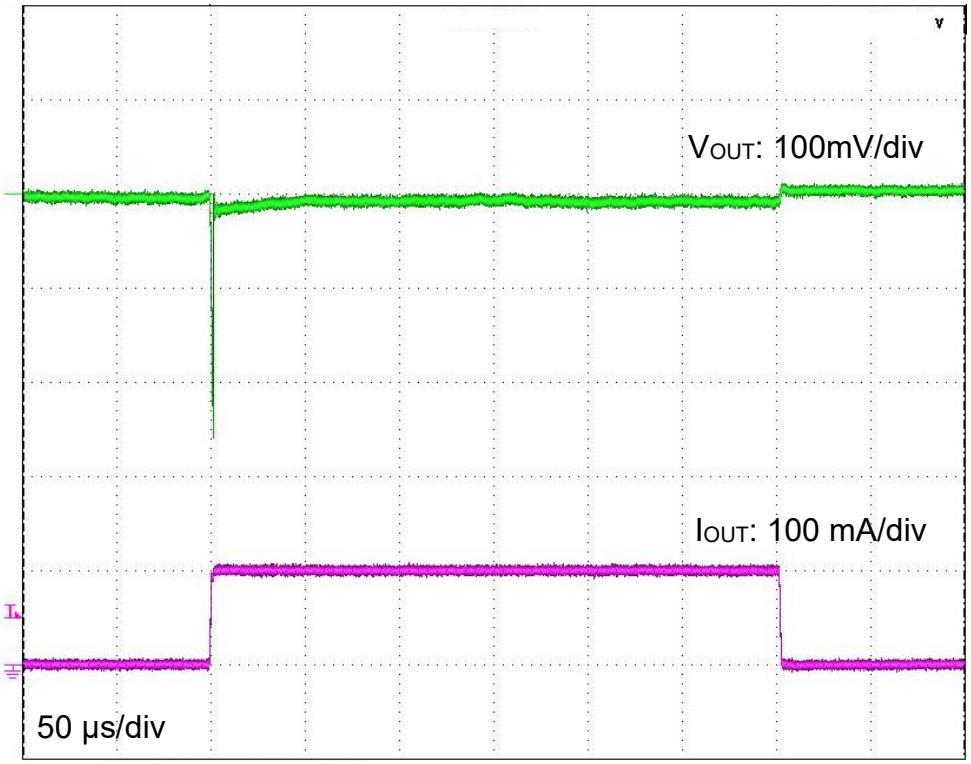
## 10.8. **Load Transient Response**

**($C_{IN}$ = 1 μF, $C_{OUT}$ = 1 μF, $V_{IN}$ = 3.8 V, $V_{OUT}$ = 2.8 V, $t_r$ = 1μs, $t_f$ = 1μs, Ta = 25°C)**

$I_{OUT}$ = 1 mA ↔ 300 mA




$I_{OUT}$ = 0 mA ↔ 100 mA




Note: The above characteristics curves are presented for reference only and not guaranteed by production test, unless otherwise noted.



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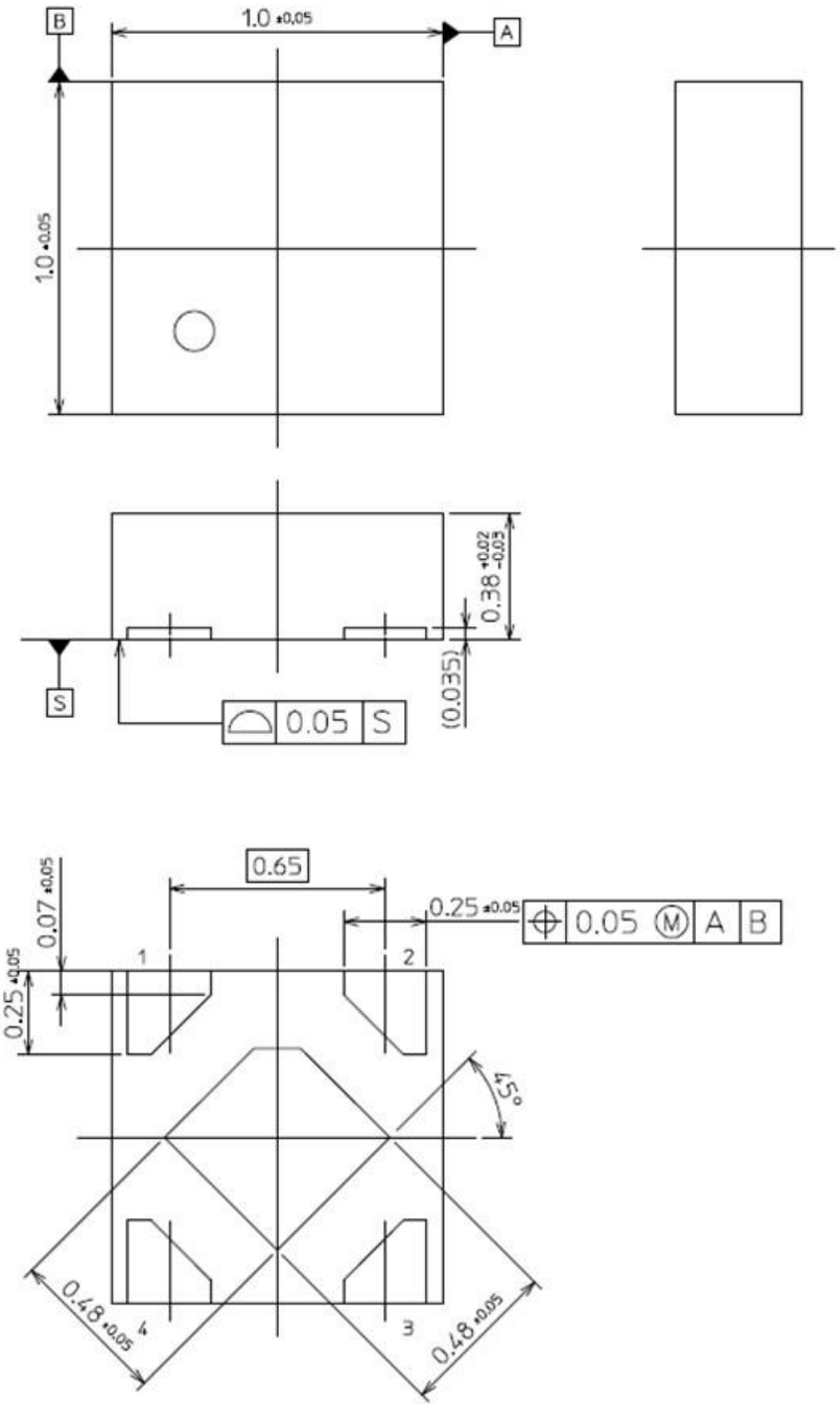
# 11. Package Information

## 11.1. DFN4C

Unit : mm




Weight : 0.93 mg ( typ.)

**Figure 11.1 Package Dimensions**



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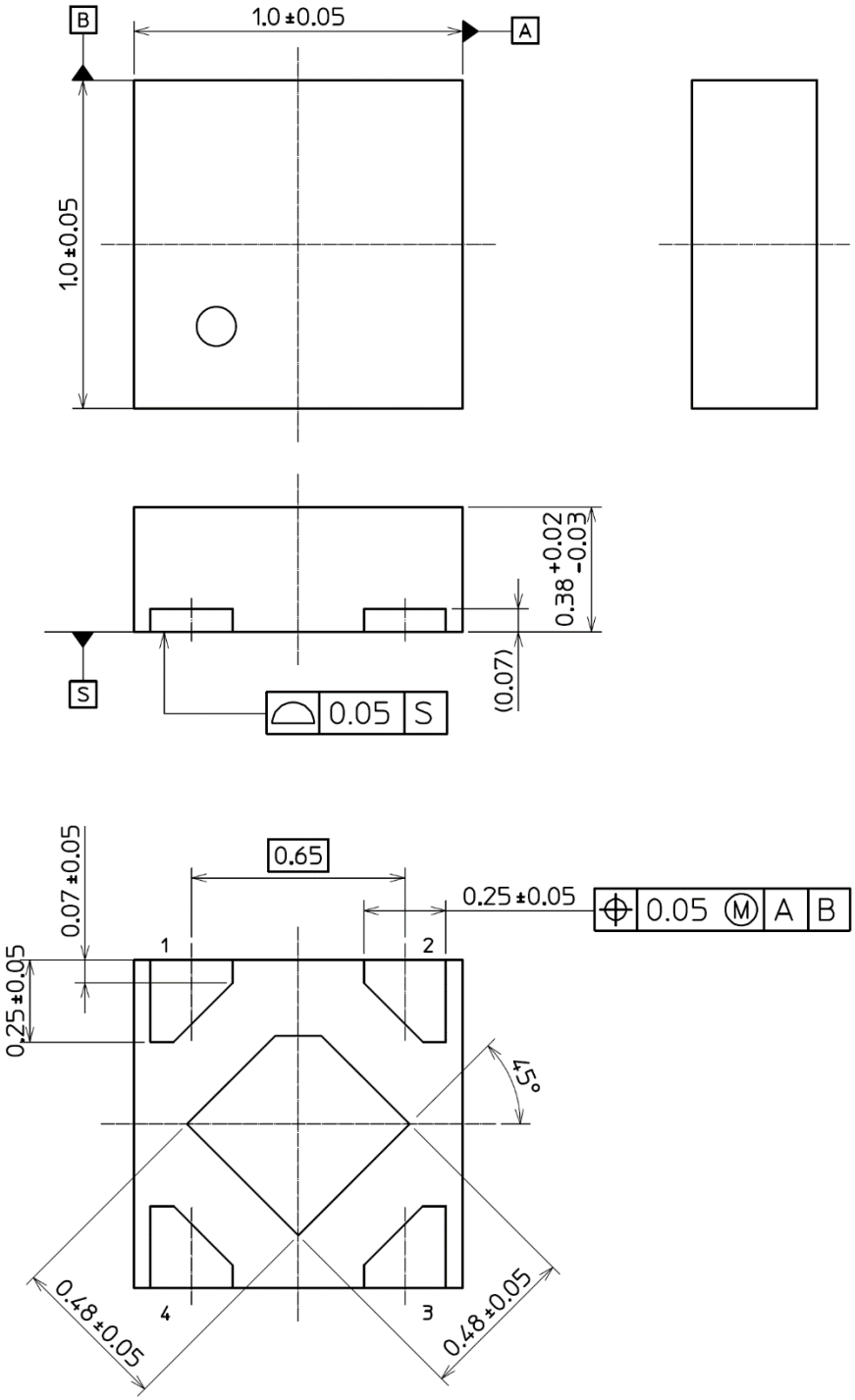
## 11.2. **DFN4F**

Unit : mm




Weight : 0.93 mg ( typ.)

**Figure 11.2 Package Dimensions**



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