TOSHIBA CMOS Linear Integrated Circuit Silicon Monolithic

TCR5FM series

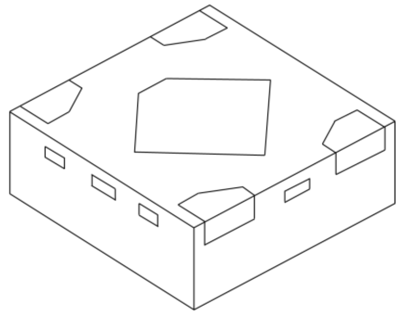
Ultra high Ripple rejection ratio, 500 mA CMOS Low Dropout Regulator in ultra small package

1. Description

The TCR5FM series are CMOS general-purpose single-output voltage regulators with an on/off control input, featuring low dropout voltage and ultra high Ripple rejection ratio.

These voltage regulators are available in fixed output voltages between 0.9 V and 5.0 V and capable of driving up to 500 mA. They feature Overcurrent protection, Thermal shutdown and Auto-discharge.

The TCR5FM series is offered in the ultra small plastic mold package DFN4D (1.0 mm x 1.0 mm; t 0.37 mm (Typ.)) and has a high ripple rejection ratio of 91 dB (f = 1 kHz, 2.8 V output). As small ceramic input and output capacitors 1μF can be used with the TCR5FM series, these devices are ideal for portable applications that require high-density board assembly such as cellular phones.



Weight: 1.1 mg (Typ.)

2. Applications

Power IC developed for portable applications

3. Features

- Ultra Small Package DFN4D (1.0 mm x 1.0 mm; t 0.37 mm (Typ.)).
- High Ripple Rejection Ratio
  91 dB (Typ.) @1 kHz at 2.8 V-output
  89 dB (Typ.) @10 kHz at 2.8 V-output
  67 dB (Typ.) @100 kHz at 2.8 V-output
  59 dB (Typ.) @1 MHz at 2.8 V-output
- Low Output Noise Voltage (V_{NO} = 5 μV_{rms} (Typ.) at 10 Hz ≤ f ≤ 100 kHz)
- Low Quiescent Current (I_B = 10 μA (Typ.) at I_{OUT} = 0 mA)
- Low Dropout Voltage
  V_{DO} = 220 mV (Typ.) at 2.8 V-output, I_{OUT} = 500 mA
- Fast Load Transient Response
  ΔV_{OUT} = -60 mV/+40 mV (Typ.) at I_{OUT} = 1mA ↔ 500 mA, 2.8 V-output
  ΔV_{OUT} = -75 mV/+25 mV (Typ.) at I_{OUT} = 0mA ↔ 100 mA, 2.8 V-output
- Overcurrent Protection
- Slew Rate Control Function aimed at suppressing inrush current
- Thermal Shutdown
- Auto-Discharge
- Wide Range Output Voltage Lineup (V_{OUT} = 0.9 to 5.0 V)
- Pull Down Connection between CONTROL and GND
- Ceramic capacitors can be used (C_{IN} = 1.0 μF, C_{OUT} = 1.0 μF)

Start of commercial production
2025-08

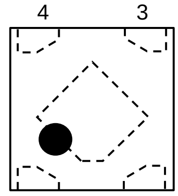
4. Absolute Maximum Ratings (Note) (Ta = 25°C)

Characteristics	Symbol	Rating	Unit
Input voltage	V_{IN}	-0.3 to 6.0	V
Control voltage	V_{CT}	-0.3 to 6.0	V
Output voltage	V_{OUT}	-0.3 to V_{IN} + 0.3 ≤ 6.0	V
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)



Note: Center electrode should be connected to GND or Open

6. Operating Ranges

Characteristics	Symbol	Rating		Unit
Input voltage	V_{IN}	1.55 to 5.5 (Note 2)		V
Control voltage	V_{CT}	0 to 5.5		V
Output voltage	V_{OUT}	0.9 to 5.0		V
Output current	I_{OUT}	DC	500	mA
Operation Temperature	T_{opr}	-40 to 125 (Note 3)		°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.

Note 3: Do not operate at or near the maximum ratings of operating ranges for extended periods of time. Exposure to suchconditions may adversely impact product reliability and results in failures not covered by warranty. Maximum output current of operating ranges table is defined as lifetime average junction temperature of 107°C where maximum output current = lifetime average current to avoid electro migration.

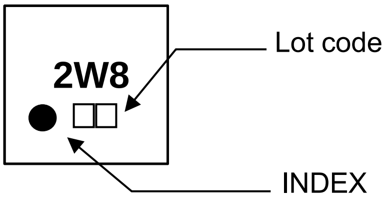
7. List of Products Number, Output voltage and Marking

Product No.	Output voltage(V)	Marking
TCR5FM09A	0.9	0W9
TCR5FM095A*	0.95	0WK
TCR5FM10A*	1.0	1W0
TCR5FM105A*	1.05	1WA
TCR5FM11A*	1.1	1W1
TCR5FM115A*	1.15	1WB
TCR5FM12A	1.2	1W2
TCR5FM125A*	1.25	1WC
TCR5FM13A*	1.3	1W3
TCR5FM15A*	1.5	1W5
TCR5FM16A*	1.6	1W6
TCR5FM17A*	1.7	1W7
TCR5FM18A	1.8	1W8
TCR5FM1825A	1.825	1WL
TCR5FM185A*	1.85	1WJ
TCR5FM19A*	1.9	1W9
TCR5FM20A*	2.0	2W0
TCR5FM22A	2.2	2W2
TCR5FM225A	2.25	2WC
TCR5FM25A*	2.5	2W5
TCR5FM26A*	2.6	2W6
TCR5FM27A*	2.7	2W7
TCR5FM28A	2.8	2W8
TCR5FM285A	2.85	2WJ
TCR5FM29A	2.9	2W9
TCR5FM30A	3.0	3W0
TCR5FM31A*	3.1	3W1
TCR5FM32A*	3.2	3W2
TCR5FM33A*	3.3	3W3
TCR5FM35A*	3.5	3W5
TCR5FM36A*	3.6	3W6
TCR5FM41A*	4.1	4W1
TCR5FM42A*	4.2	4W2
TCR5FM45A*	4.5	4W5
TCR5FM50A	5.0	5W0

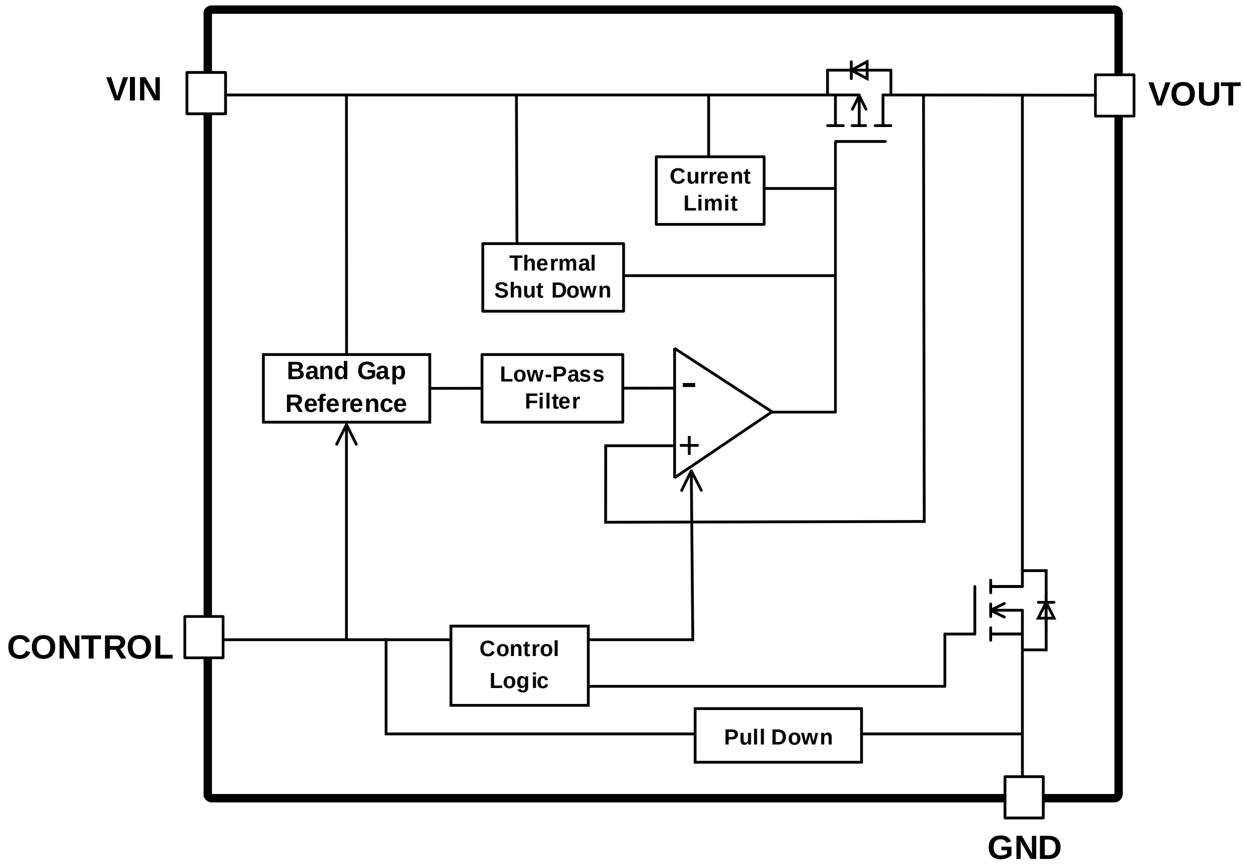
Please ask your local retailer about the devices with (*) or other output voltages.

Top Marking (Top view)

Example: TCR5FM28A (2.8 V output)



8. Block Diagram



9. Electrical Characteristics

(Unless otherwise specified, $V_{IN} = V_{OUT}$ + 0.5 V or 2 V (whichever is greater), $C_{IN} = C_{OUT}$ = 1.0 μF)

Characteristics	Symbol	Test Condition		T_j = 25°C			T_j = -40 to 125°C (Note 8)		Unit
				Min	Typ.	Max	Min	Max	
Output voltage accuracy	V_{OUT}	I_{OUT} = 1 to 500 mA (Note 4)	V_{OUT} ≦ 1.25 V	—	—	—	-45	+45	mV
			1.25 V < V_{OUT} < 1.8 V	—	—	—	-48	+48	mV
			1.8 V ≤ V_{OUT} < 2.2 V	—	—	—	-2.8	+2.8	%
			2.2 V ≤ V_{OUT} < 2.8 V	—	—	—	-2.5	+2.5	%
			2.8 V ≤ V_{OUT}	—	—	—	-2.2	+2.2	%
Line regulation	Reg･line	I_{OUT} = 1 mA (Note 5)		—	1.5	—	—	—	mV
Load regulation	Reg･load	1 mA ≤ I_{OUT} ≤ 500 mA		—	20	—	—	—	mV
Quiescent current	$I_{B(ON)}$	I_{OUT} = 0 mA (Note 6)		—	10	—	—	20	μA
Stand-by current	$I_{B(OFF)}$	V_{CT} = 0 V		—	0.1	—	—	0.8	μA
Control pull down current	I_{CT}	—		—	0.1	—	—	0.2	μA
Drop-out voltage (Note 9)	V_{DO}	I_{OUT} = 500 mA (Note 5)		—	220	—	—	337	mV
Output noise voltage	V_{NO}	I_{OUT} = 10 mA 10 Hz ≤ f ≤ 100 kHz (Note 5)		—	5	—	—	—	$μV_{rms}$
Ripple rejection ratio	R.R.	I_{OUT} = 10 mA, V_{Ripple} = 200 mV_{p-p}, (Note 5)	f = 1 kHz	—	91	—	—	—	dB
			f = 10 kHz	—	89	—	—	—	dB
			f = 100 kHz	—	67	—	—	—	dB
			f = 1 MHz	—	59	—	—	—	dB
Load transient response	$ΔV_{OUT}$	I_{OUT} = 1 mA → 500 mA, t_r = 1 μs (Note 5)		—	-60	—	—	—	mV
		I_{OUT} = 500 mA → 1 mA, t_f = 1 μs (Note 5)		—	+40	—	—	—	mV
		I_{OUT} = 0 mA → 100 mA, t_r = 1 μs (Note 5)		—	-75	—	—	—	mV
		I_{OUT} = 100 mA → 0 mA, t_f = 1 μs (Note 5)		—	+25	—	—	—	mV
Output voltage slew rate	V_{OUTSR}	(Note 5)		—	5	—	—	—	mV/μs
Output current limit	I_{CL}	V_{OUT} = $V_{OUT(NOM)}$*90 % (Note 7)		—	—	—	500	1090	mA
Thermal shutdown threshold	T_{SDH}	T_j rising		—	160	—	—	—	°C
	T_{SDL}	T_j falling		—	140	—	—	—	°C
Control pin voltage (HIGH)	V_{CTH}	Control pin input voltage “HIGH”		—	—	—	0.79	5.5	V
Control pin voltage (LOW)	V_{CTL}	Control pin input voltage “LOW”		—	—	—	0	0.4	V
Fast mode and Low I_B mode switching threshold current	I_{OUTF}	I_{OUT} rising (Low I_B mode to Fast mode)		—	150	—	—	290	μA
	I_{OUTL}	I_{OUT} falling (Fast mode to Low I_B mode)		—	10	—	2	—	μA
Discharge on resistance	R_{SD}	(Note 5)		—	30	—	—	—	Ω

Note 4: stable state with fixed I_{OUT} condition
Note 5: V_{OUT} = 2.8 V
Note 6: except Control pull down current (I_{CT})
Note 7: Pulse measurement
Note 8: This parameter is warranted by design.
Note 9: $V_{DO} = V_{IN1} - (V_{OUT1}$ x 0.97)
V_{OUT1} is the output voltage when $V_{IN} = V_{OUT}$ + 0.5 V.
V_{IN1} is the input voltage at which the output voltage becomes 97% of V_{OUT1} after gradually decreasing the input voltage.

10. Dropout voltage table

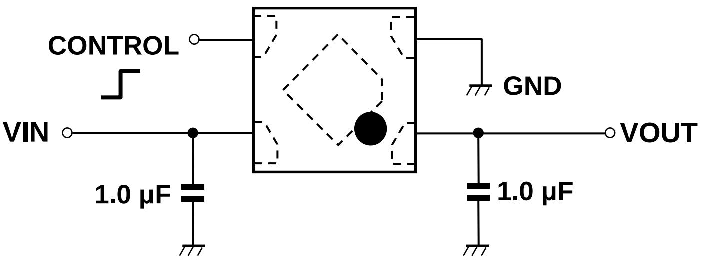
(C_{IN} = 1.0 μF, C_{OUT} = 1.0 μF)

Output voltages	I_{OUT} = 500 mA			Unit
	Min	Typ.	Max (Note 10)	
0.9 V, 0.95 V	—	860 (Note 11)	982 (Note 11)	mV
1.0 V, 1.05 V	—	790 (Note 11)	929 (Note 11)	mV
1.1 V, 1.15 V	—	730 (Note 11)	876 (Note 11)	mV
1.2 V, 1.25 V	—	670	822	mV
1.3 V	—	610	768	mV
1.5 V	—	490	659	mV
1.6 V	—	440	603	mV
1.7 V	—	390	547	mV
1.8 V, 1.825 V, 1.85 V	—	340	491	mV
1.9 V	—	320	471	mV
2.0 V	—	310	451	mV
2.2 V, 2.25 V	—	300	411	mV
2.5 V	—	250	372	mV
2.6 V	—	240	361	mV
2.7 V	—	230	349	mV
2.8 V ≤ V_{OUT} ≤ 3.0 V	—	220	337	mV
3.1 V ≤ V_{OUT} ≤ 3.6 V	—	210	328	mV
4.1 V ≤ V_{OUT} ≤ 4.5 V	—	180	297	mV
5.0 V	—	160	264	mV

Note 10: T_j = -40 to 125 °C. This parameter is warranted by design.
Note 11: Operating Voltage of V_{IN} should be over 2.0 V.

11. Application Note

11.1. Recommended Application Circuit



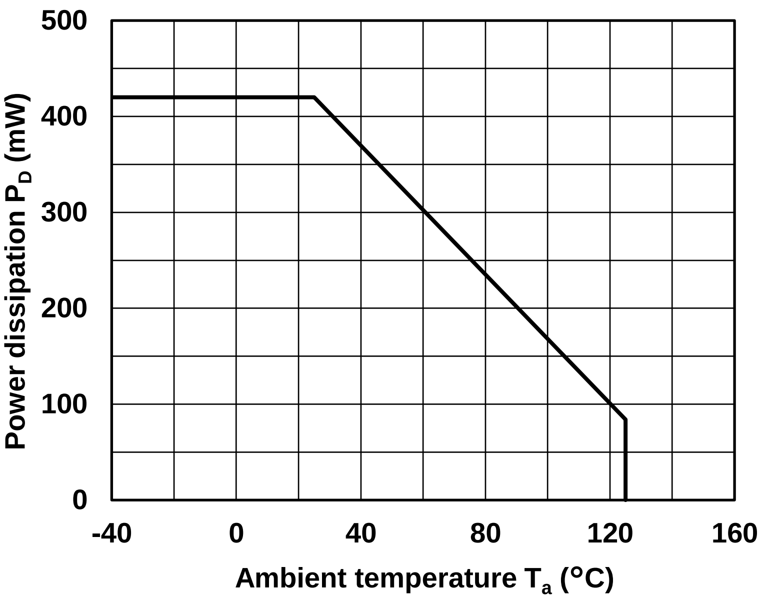
CONTROL voltage	Output voltage
HIGH	ON
LOW	OFF
OPEN	OFF

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).

11.2. Power Dissipation

Board-mounted power dissipation ratings for TCR5FM 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: 40 mm x 40 mm (both sides of board), t = 1.6 mm
Metal pattern ratio: a surface approximately 50%, the reverse side approximately 50%



11.3. Attention in Use

- Output Capacitors
  Toshiba recommends using ceramic capacitors for these devices. However, because of the type of the capacitors, there might be greatly affected by thermal features and DC bias depending. Please secure an effective capacitance of 0.5 μF or more by considering application condition for selecting capacitors.

- Bias current characteristics
  TCR5FM series has two modes (Low I_B mode, Fast mode). These modes are controlled by mode switching threshold current, I_{OUTF} and I_{OUTL}. When the output current required is very low, TCR5FM series operates with low $I_{B(ON)}$ (Low I_B mode). In this state, ripple rejection ratio characteristic and load transient response characteristic are inferior to Fast mode. Regarding two mode switches depending on I_{OUT}, it has hysteresis. When output current is increased, good Ripple rejection ratio characteristics and good load transient response characteristics are provided with $I_{B(ON)}$ becoming high (Fast mode). In the case of decreasing the I_{OUT}, TCR5FM 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 assurance by impedance in wire and inductor. For stable power supply, output capacitor needs 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, and 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.

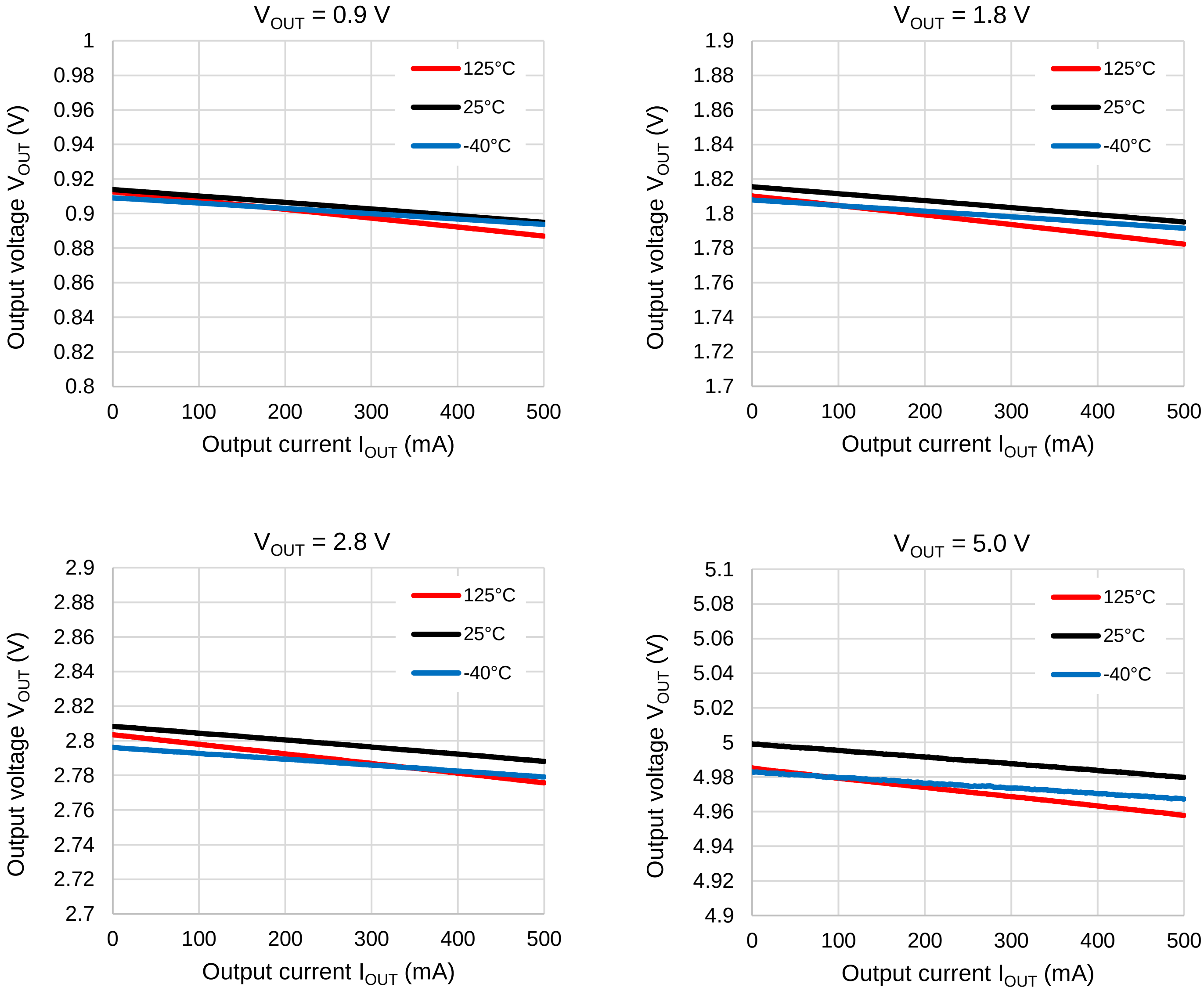
- High ripple rejection ratio and low output noise voltage characteristics
  TCR5FM series has low-pass filter which contributes high ripple rejection ratio and low output noise voltage. This low-pass filter turns on after V_{OUT} becomes near the nominal V_{OUT}, and the filter turn on time changes depend on usage condition, surrounding circuit and surrounding temperature. Therefore, please design with full consideration of usage condition. For example, the filter turn on time is approximately 10 ms in $V_{IN} = V_{OUT} + 0.5$ V, Ta = 25°C condition. 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.

- Line Transient Response
  V_{OUT} may fluctuate when a sudden V_{IN} change is input. If V_{OUT} fluctuation is problem for usage, please consider measures such as adjusting C_{IN} to reduce V_{IN} change.

12. Representative Typical Characteristics (Note)

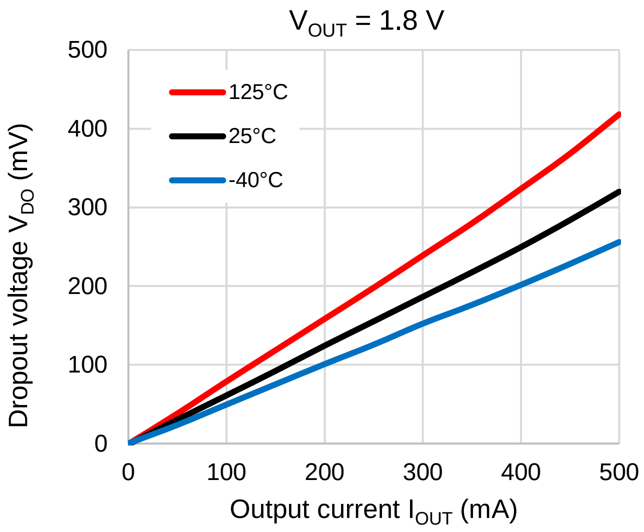
12.1. Output Voltage vs. Output Current

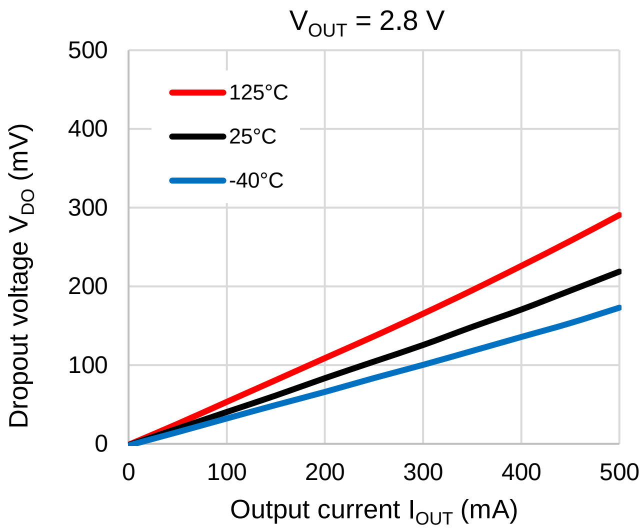
(V_{IN} = 2.0 V or V_{OUT} + 0.5 V (whichever is greater))

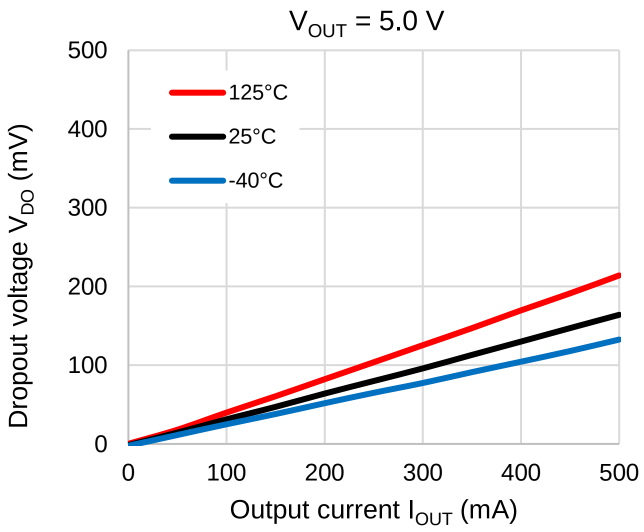


Note: The above characteristics curves are presented for reference only and not guaranteed by production test, unless otherwise noted.

12.2. Dropout Voltage vs. Output Current

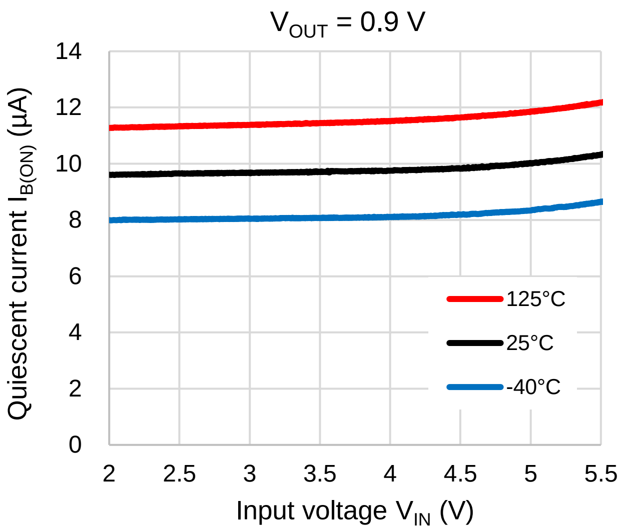


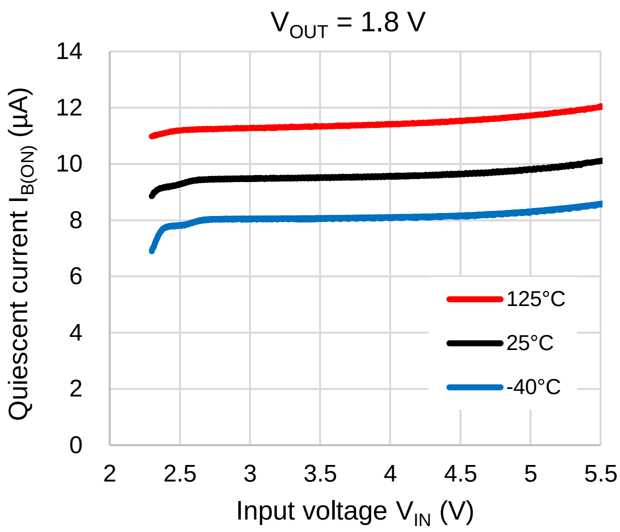


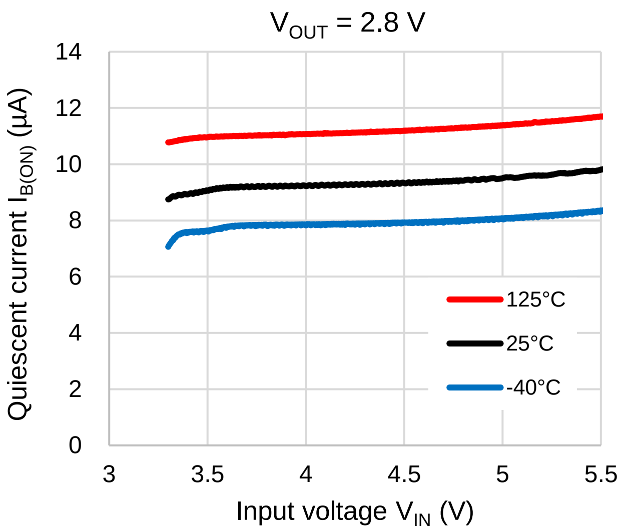


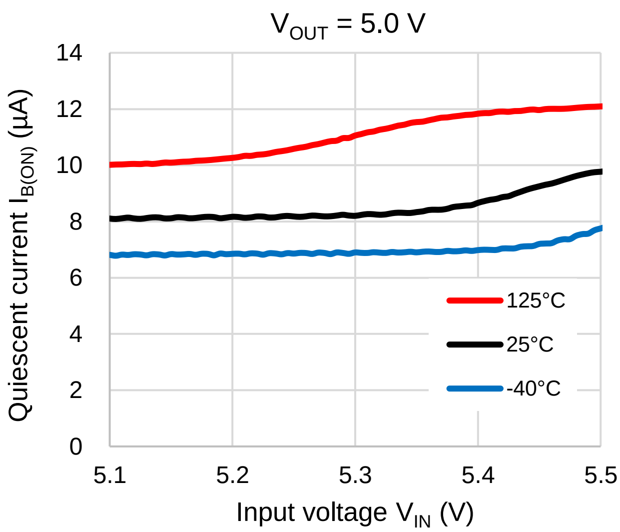
Note: The above characteristics curves are presented for reference only and not guaranteed by production test, unless otherwise noted.

12.3. Quiescent Current vs. Input Voltage (I_{OUT} = 0 mA)





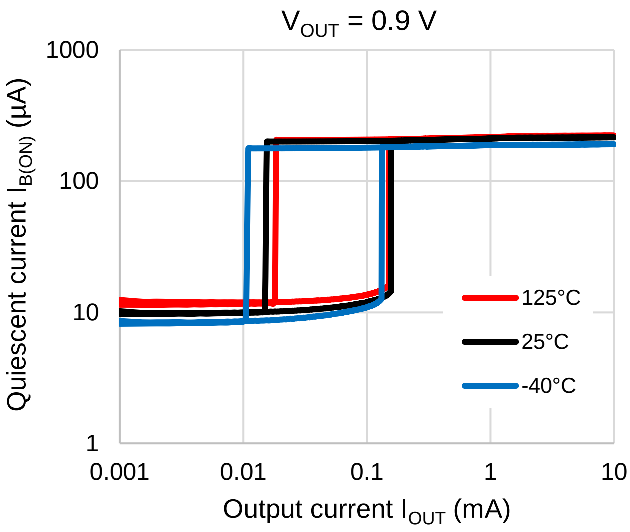


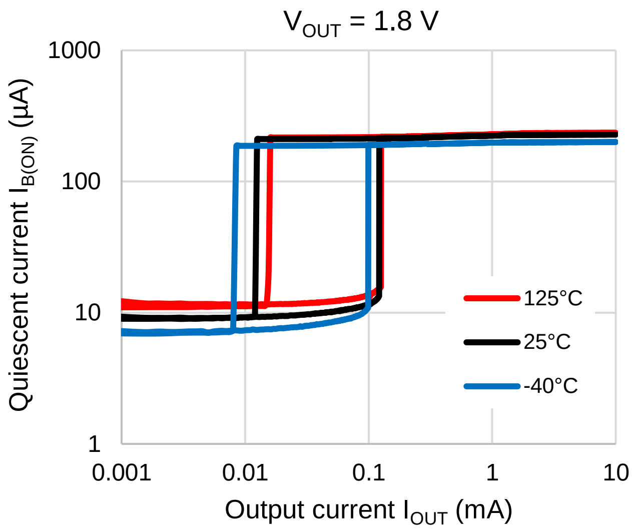


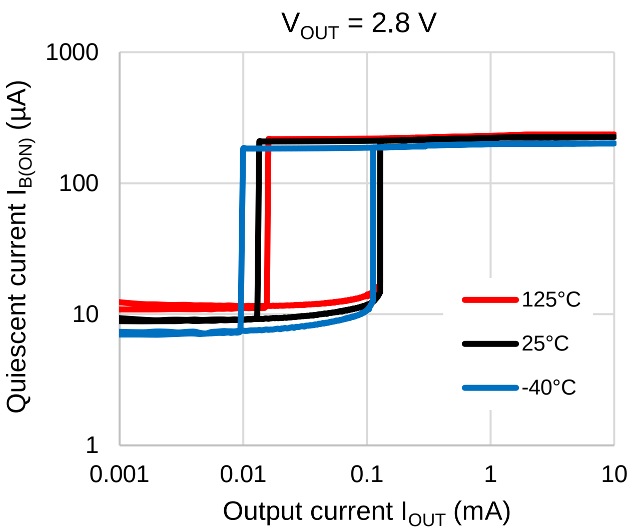
Note: The above characteristics curves are presented for reference only and not guaranteed by production test, unless otherwise noted.

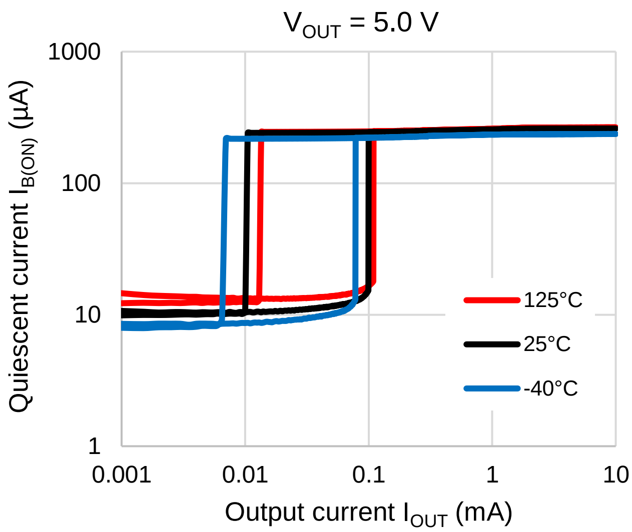
12.4. Quiescent Current vs. Output Current

(V_{IN} = 2.0 V or V_{OUT} + 0.5 V (whichever is greater))





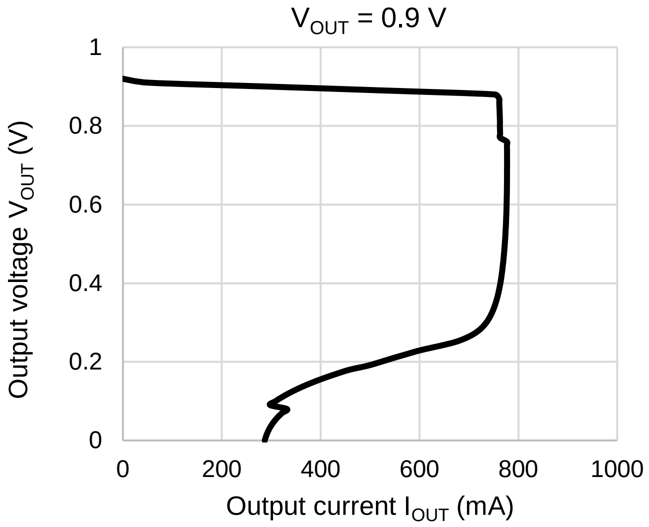


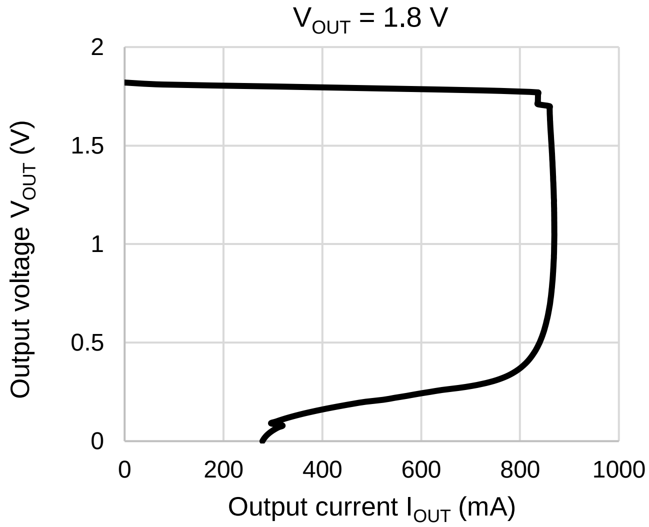


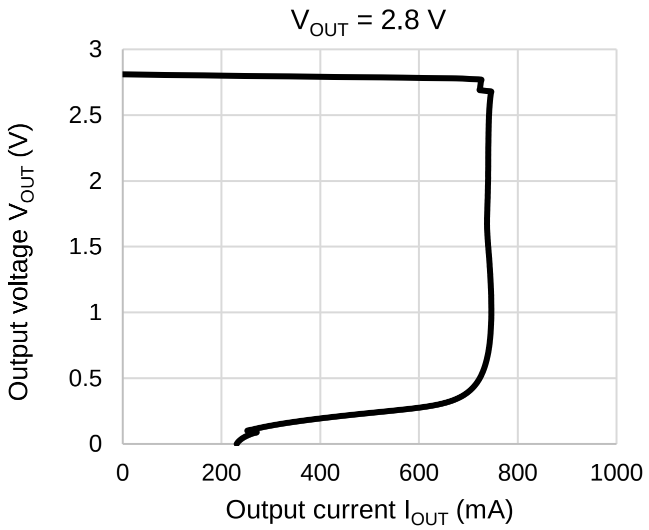
Note: The above characteristics curves are presented for reference only and not guaranteed by production test, unless otherwise noted.

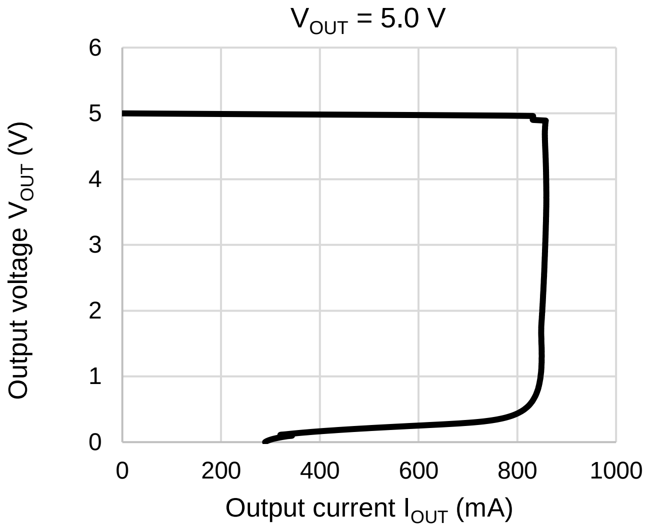
12.5. Output Current Limit

(V_{IN} = 2.0 V or V_{OUT} + 0.5 V (whichever is greater), T_a = 25°C)





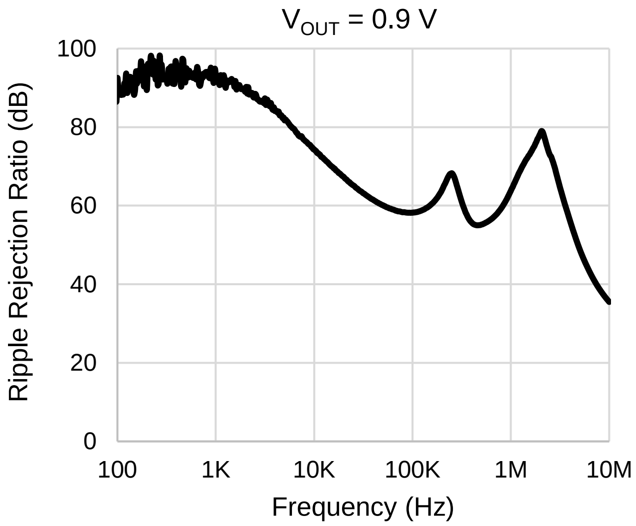


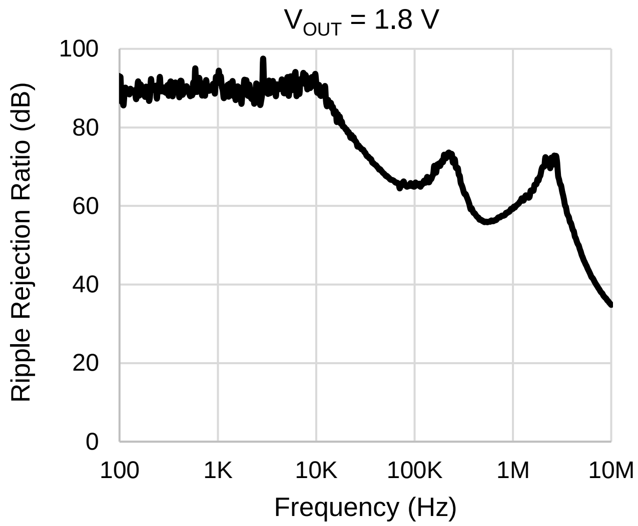


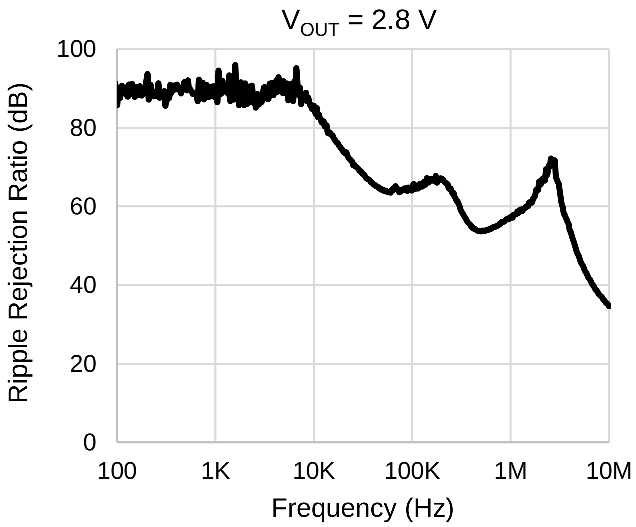
Note: The above characteristics curves are presented for reference only and not guaranteed by production test, unless otherwise noted.

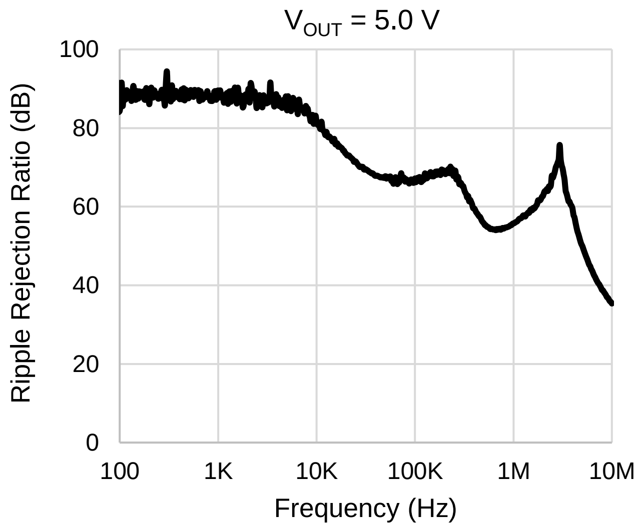
12.6. Ripple rejection Ratio vs. Frequency

(C_{IN} = none, C_{OUT} = 1.0 μF, V_{IN} = 2.0 V or V_{OUT} + 0.5 V (whichever is greater), $V_{IN\ Ripple}$ = 200 mV_{p-p}, I_{OUT} = 10 mA, T_a = 25°C)





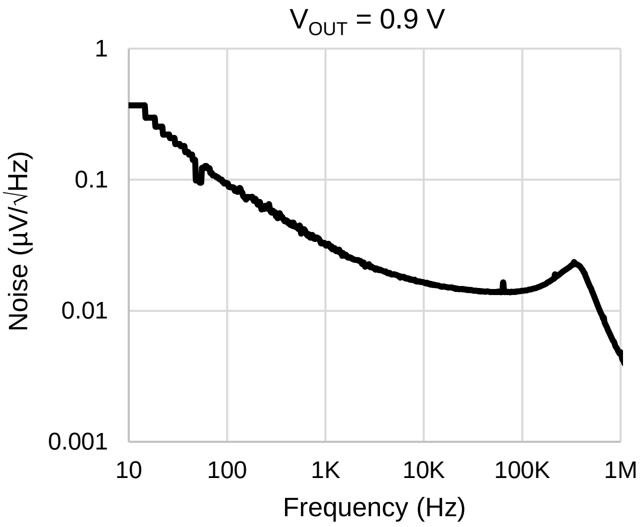


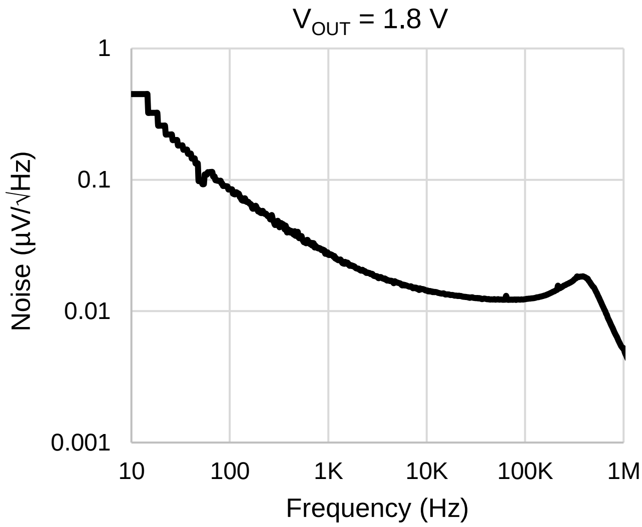


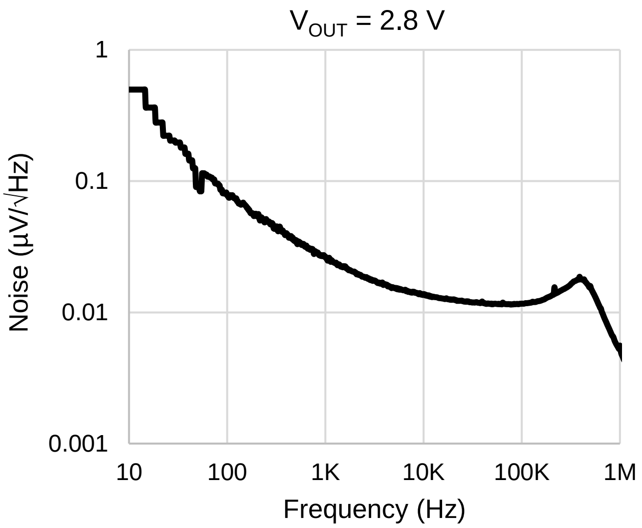
Note: The above characteristics curves are presented for reference only and not guaranteed by production test, unless otherwise noted.

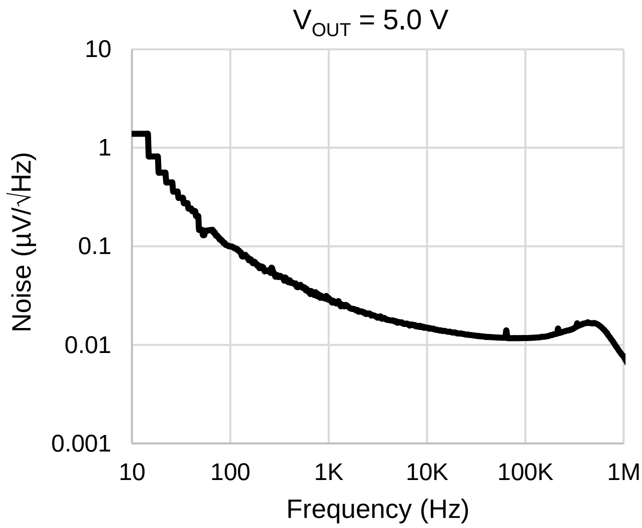
12.7. Output noise Voltage

(C_{IN} = 1.0 µF, C_{OUT} = 1.0 µF, V_{IN} = 2.0 V or V_{OUT} + 0.5 V (whichever is greater), I_{OUT} = 10 mA, T_a = 25°C)









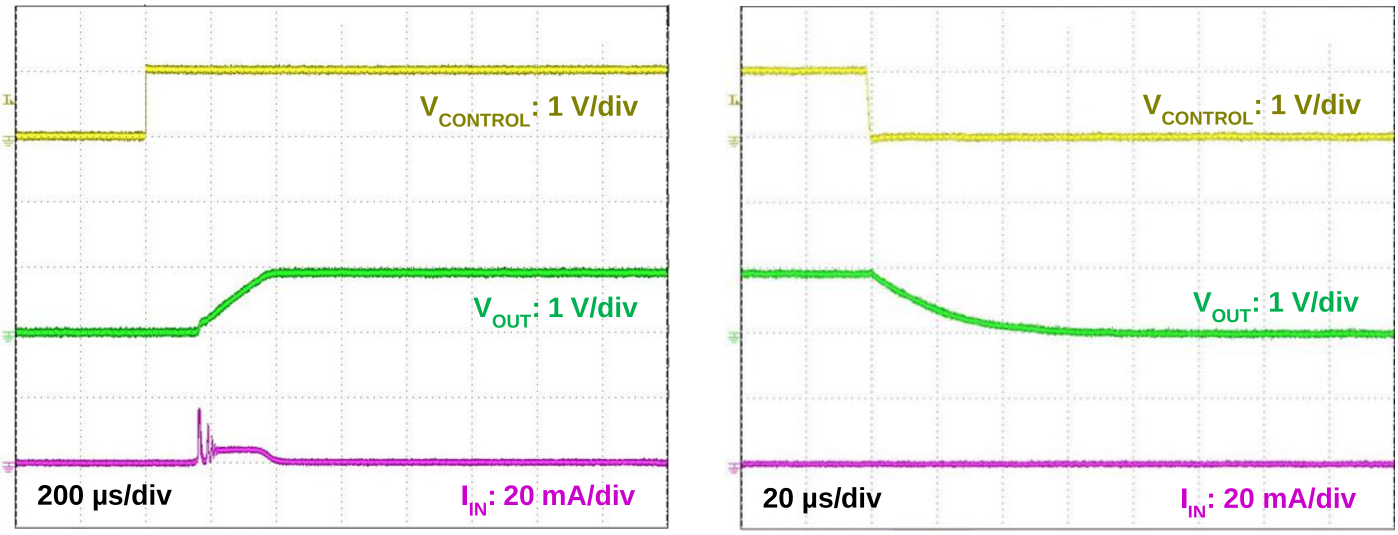
Note: The above characteristics curves are presented for reference only and not guaranteed by production test, unless otherwise noted.

12.8. t_{ON} / t_{OFF} Response

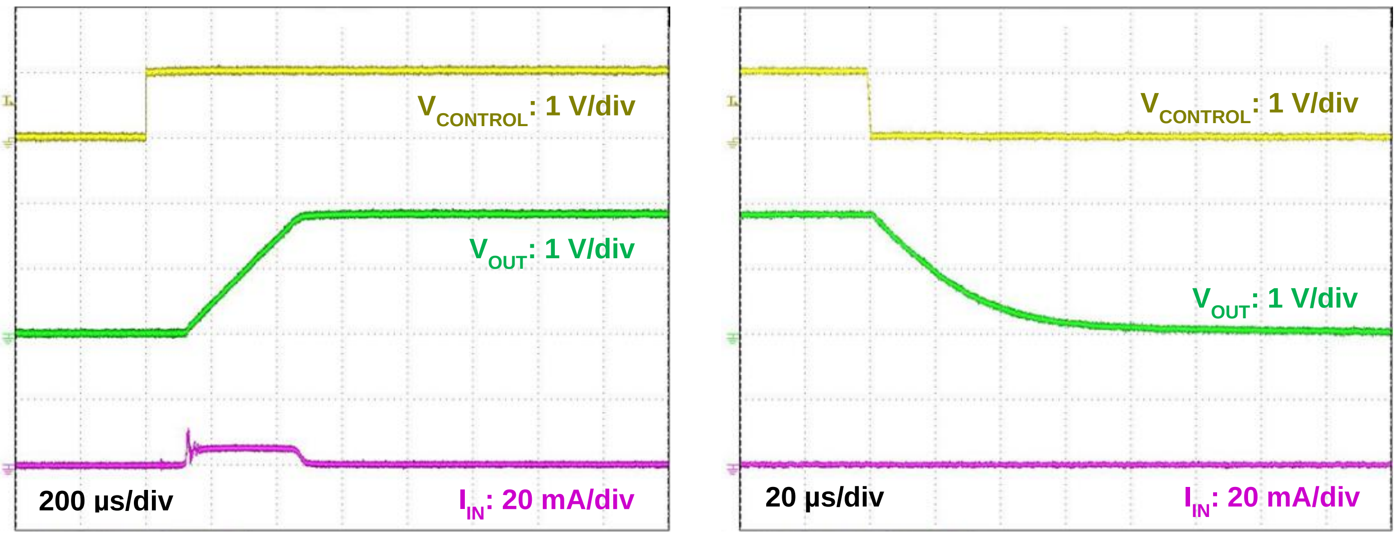
(C_{IN} = 1.0 μF, V_{IN} = 2.0 V or V_{OUT} + 0.5 V (whichever is greater), $V_{CONTROL}$ = 0 V↔1.0 V, T_a = 25°C)

- **C_{OUT} = 1.0 μF, I_{OUT} = 0 mA**

V_{OUT} = 0.9 V



V_{OUT} = 1.8 V



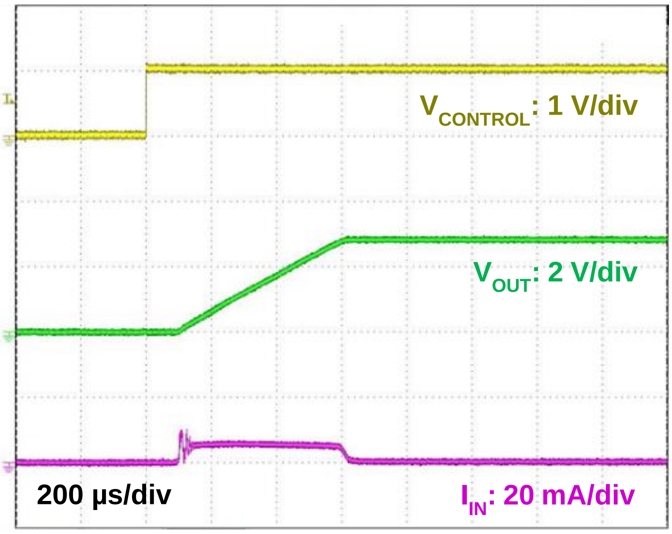
Note: The above characteristics curves are presented for reference only and not guaranteed by production test, unless otherwise noted.

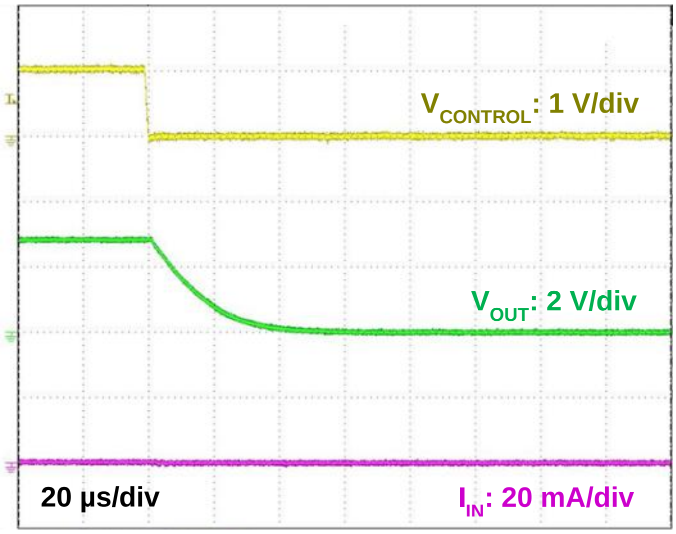
t_{ON} / t_{OFF} Response

(C_{IN} = 1.0 μF, V_{IN} = 2.0 V or V_{OUT} + 0.5 V (whichever is greater), $V_{CONTROL}$ = 0 V↔1.0 V, T_a = 25°C)

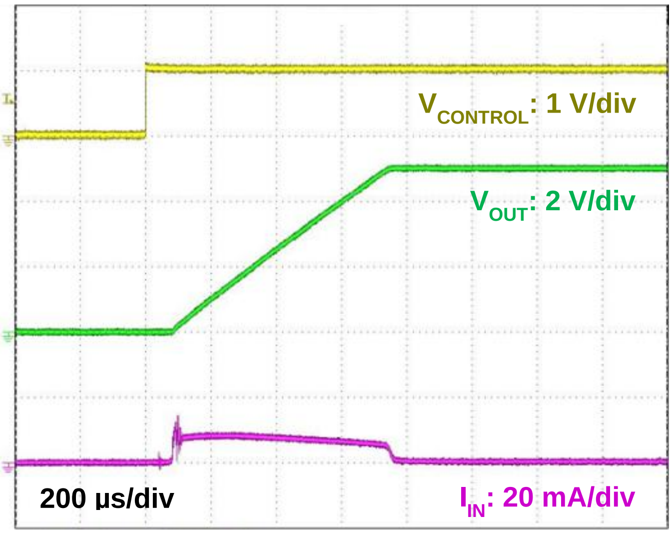
- **C_{OUT} = 1.0 μF, I_{OUT} = 0 mA**

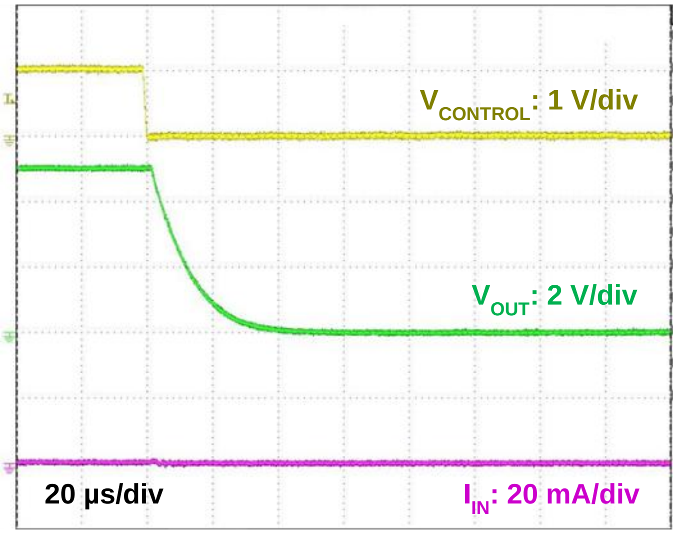
V_{OUT} = 2.8 V





V_{OUT} = 5.0 V





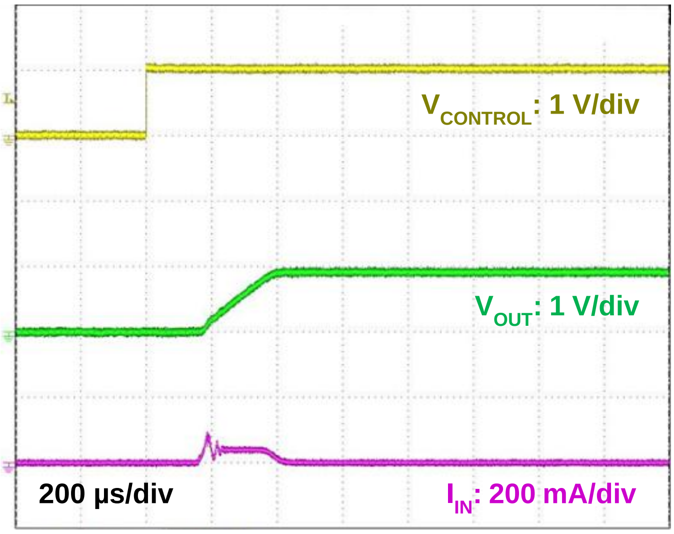
Note: The above characteristics curves are presented for reference only and not guaranteed by production test, unless otherwise noted.

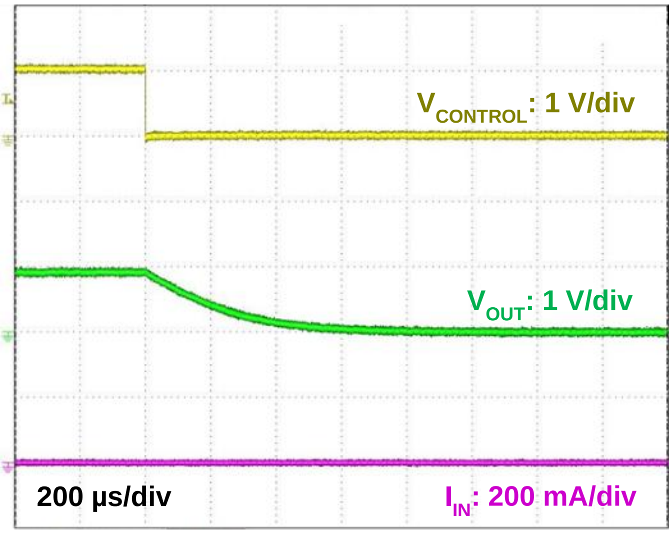
t_{ON} / t_{OFF} Response

(C_{IN} = 1.0 μF, V_{IN} = 2.0 V or V_{OUT} + 0.5 V (whichever is greater), $V_{CONTROL}$ = 0 V↔1.0 V, T_a = 25°C)

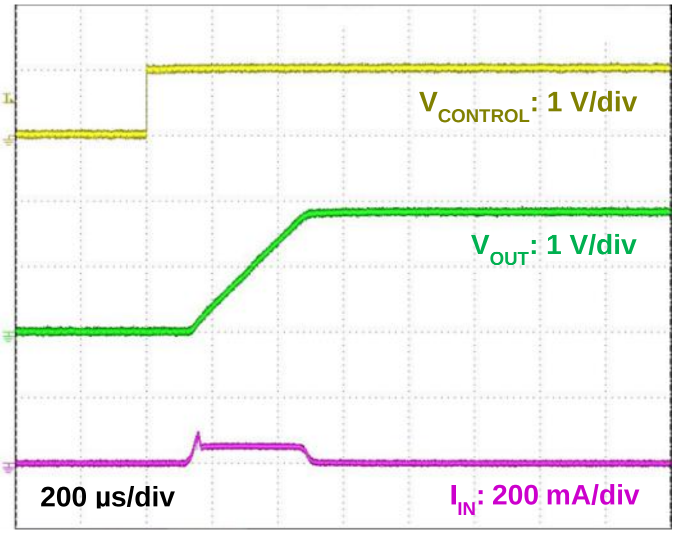
- **C_{OUT} = 10 μF, I_{OUT} = 0 mA**

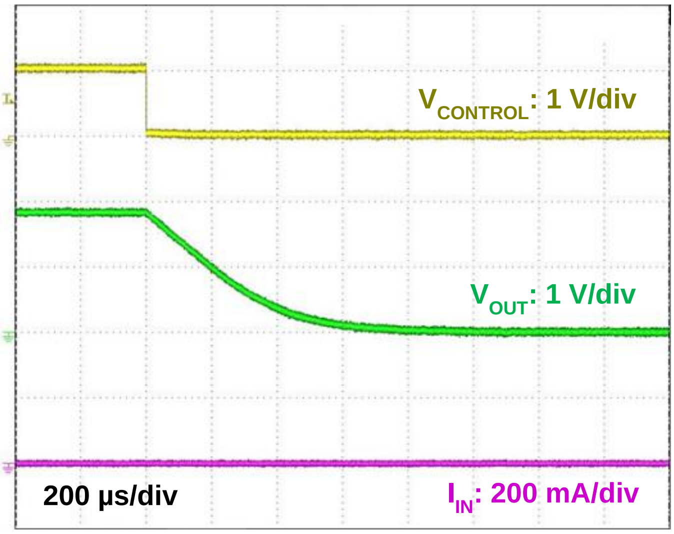
V_{OUT} = 0.9 V





V_{OUT} = 1.8 V





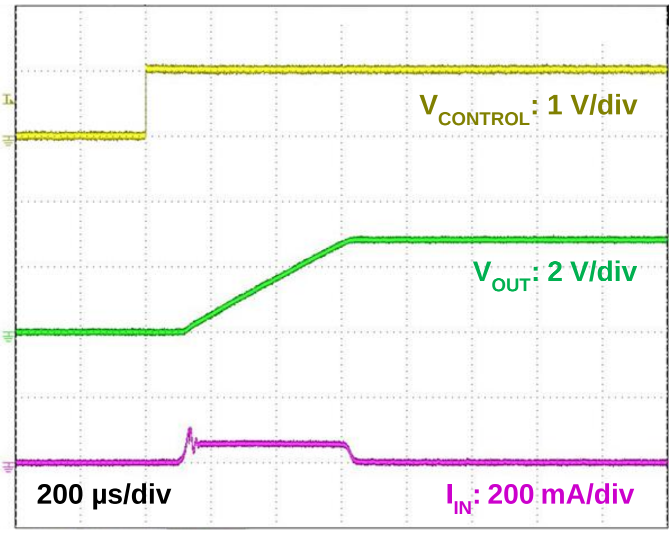
Note: The above characteristics curves are presented for reference only and not guaranteed by production test, unless otherwise noted.

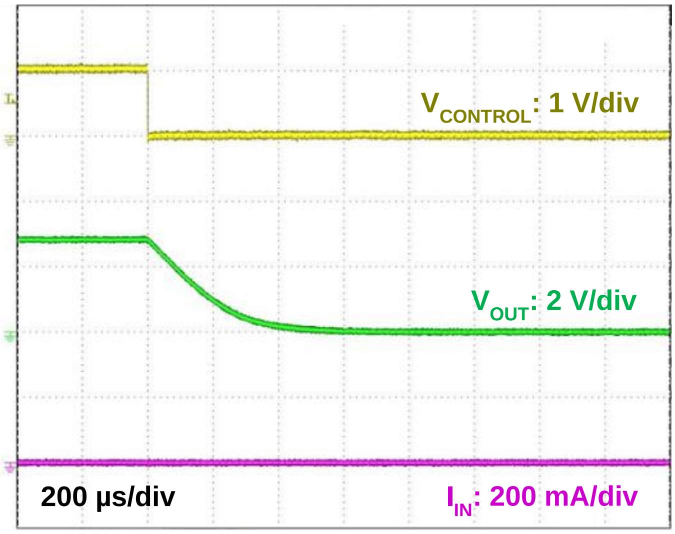
t_{ON} / t_{OFF} Response

(C_{IN} = 1.0 μF, V_{IN} = 2.0 V or V_{OUT} + 0.5 V (whichever is greater), $V_{CONTROL}$ = 0 V↔1.0 V, T_a = 25°C)

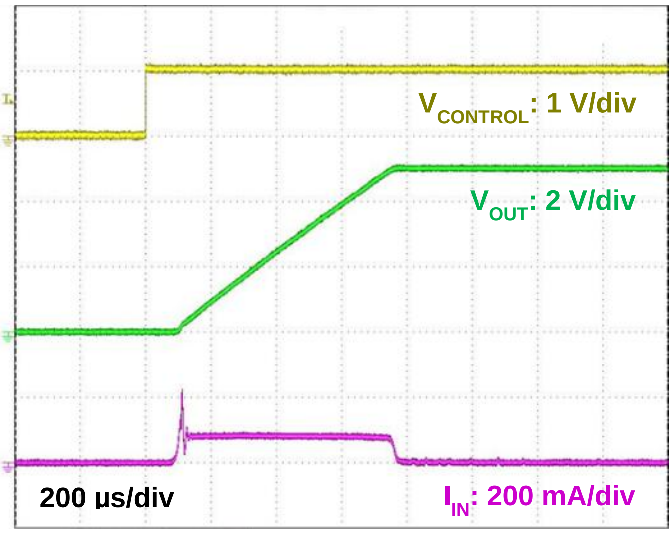
- **C_{OUT} = 10 μF, I_{OUT} = 0 mA**

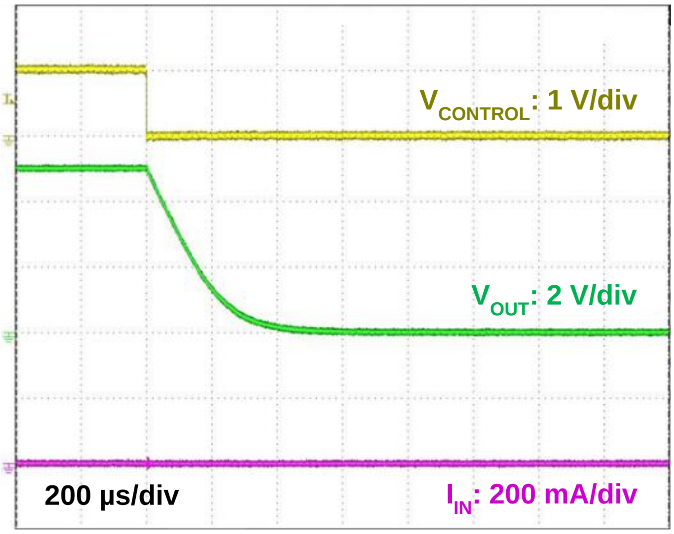
V_{OUT} = 2.8 V





V_{OUT} = 5.0 V





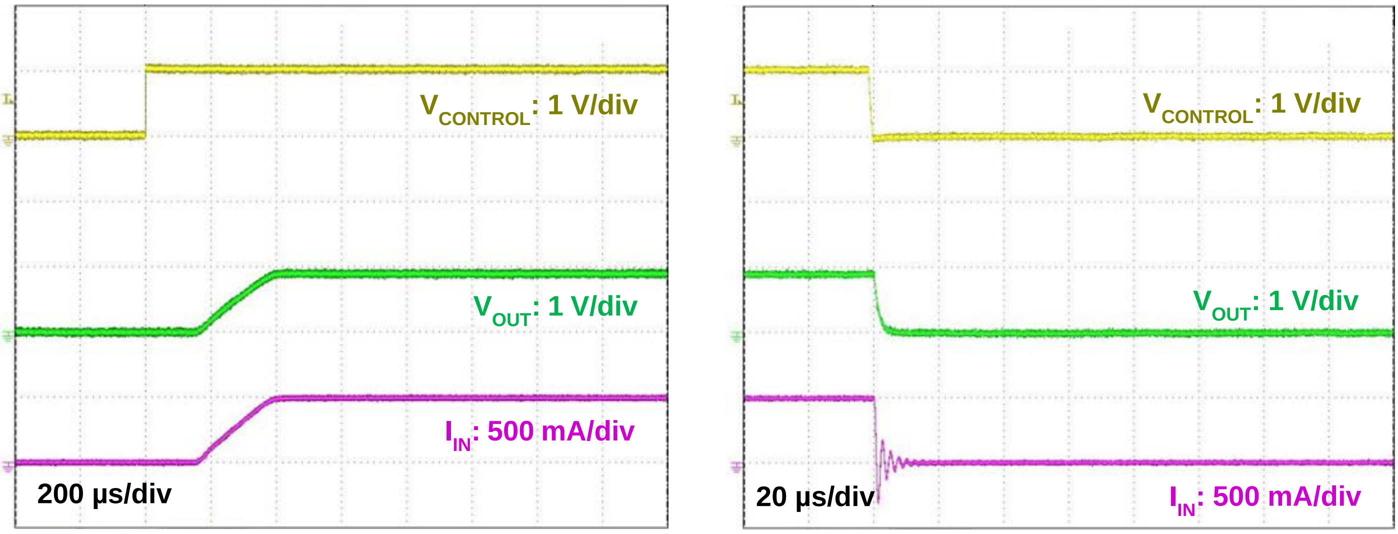
Note: The above characteristics curves are presented for reference only and not guaranteed by production test, unless otherwise noted.

t_{ON} / t_{OFF} Response

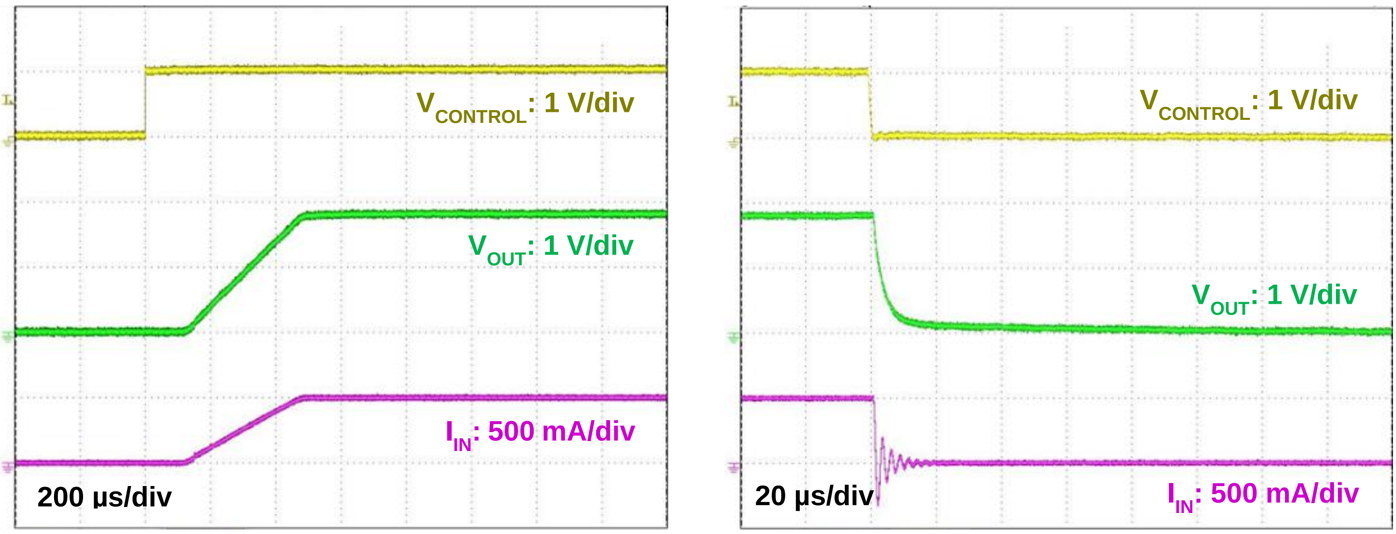
(C_{IN} = 1.0 µF, V_{IN} = 2.0 V or V_{OUT} + 0.5 V (whichever is greater), $V_{CONTROL}$ = 0 V↔1.0 V, T_a = 25°C)

- **C_{OUT} = 1.0 µF, I_{OUT} = 500 mA**

V_{OUT} = 0.9 V



V_{OUT} = 1.8 V



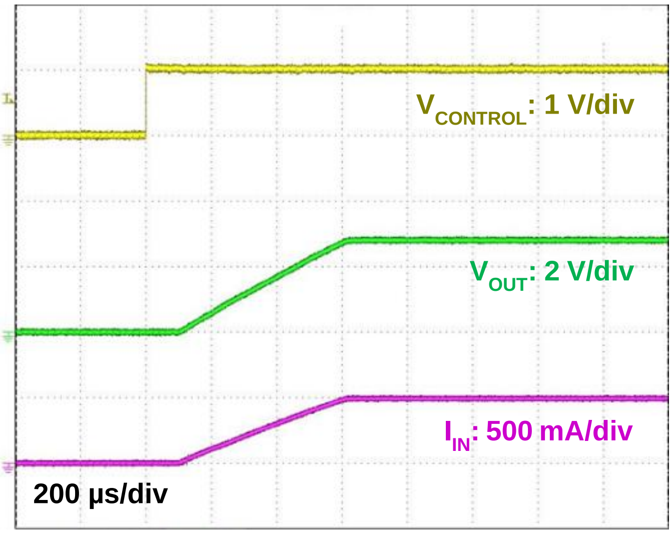
Note: The above characteristics curves are presented for reference only and not guaranteed by production test, unless otherwise noted.

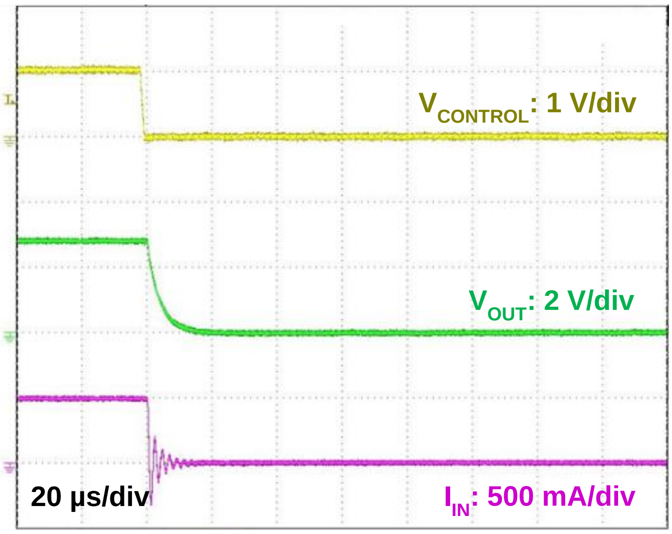
t_{ON} / t_{OFF} Response

(C_{IN} = 1.0 μF, V_{IN} = 2.0 V or V_{OUT} + 0.5 V (whichever is greater), $V_{CONTROL}$ = 0 V↔1.0 V, T_a = 25°C)

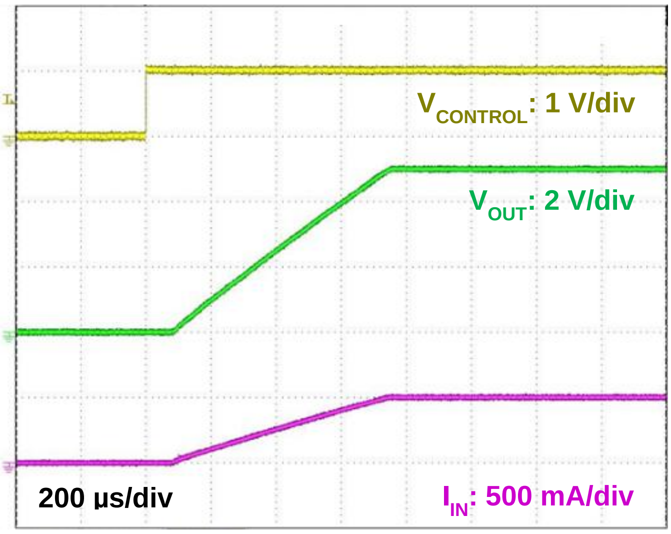
- **C_{OUT} = 1.0 μF, I_{OUT} = 500 mA**

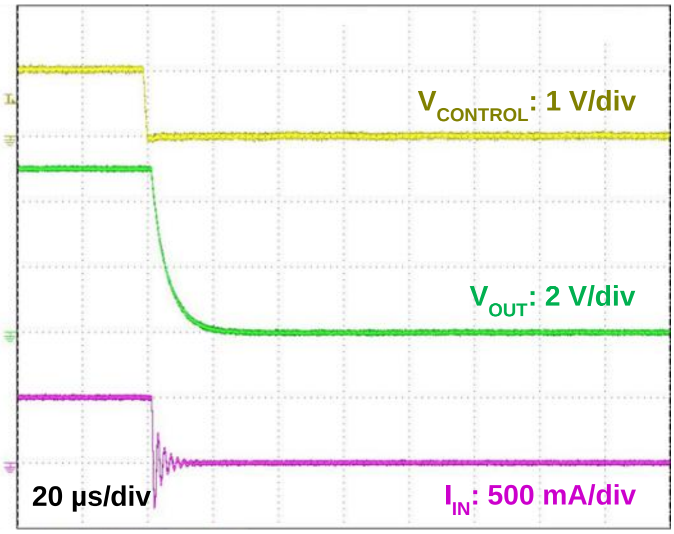
V_{OUT} = 2.8 V





V_{OUT} = 5.0 V





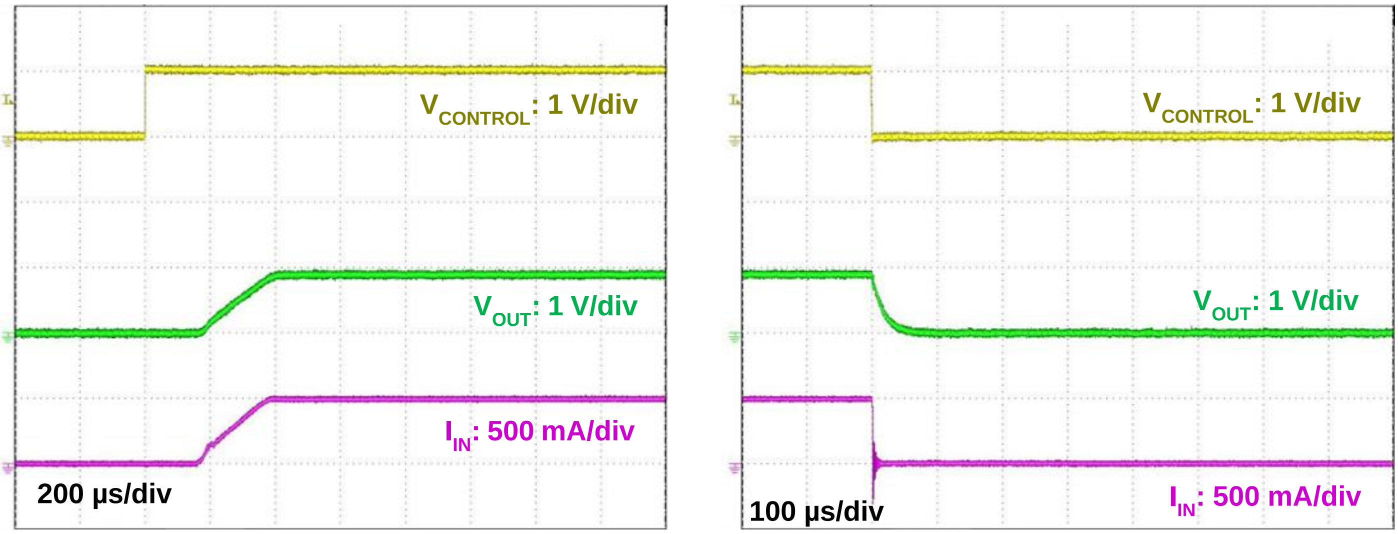
Note: The above characteristics curves are presented for reference only and not guaranteed by production test, unless otherwise noted.

t_{ON} / t_{OFF} Response

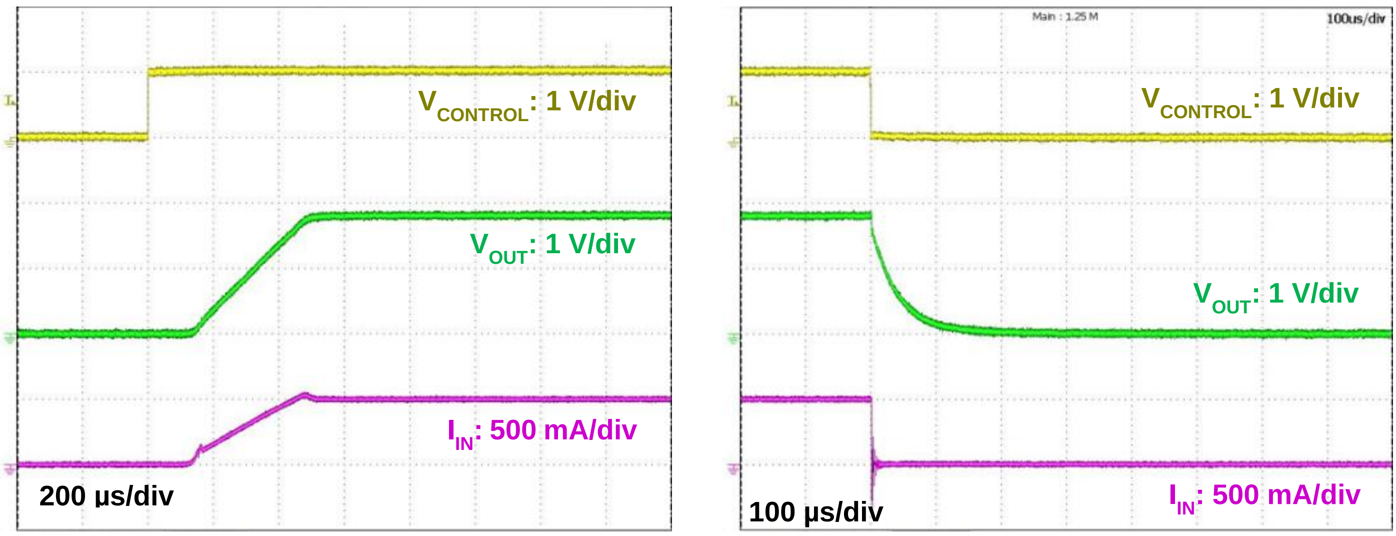
(C_{IN} = 1.0 μF, V_{IN} = 2.0 V or V_{OUT} + 0.5 V (whichever is greater), $V_{CONTROL}$ = 0 V↔1.0 V, T_a = 25°C)

- **C_{OUT} = 10 μF, I_{OUT} = 500 mA**

V_{OUT} = 0.9 V



V_{OUT} = 1.8 V



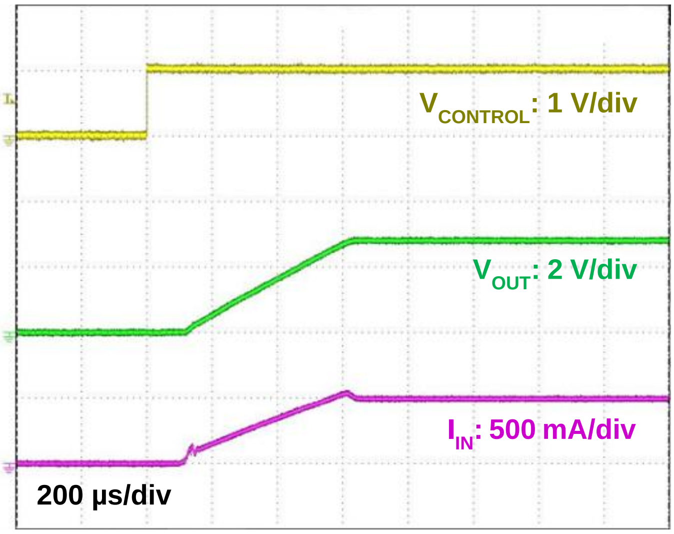
Note: The above characteristics curves are presented for reference only and not guaranteed by production test, unless otherwise noted.

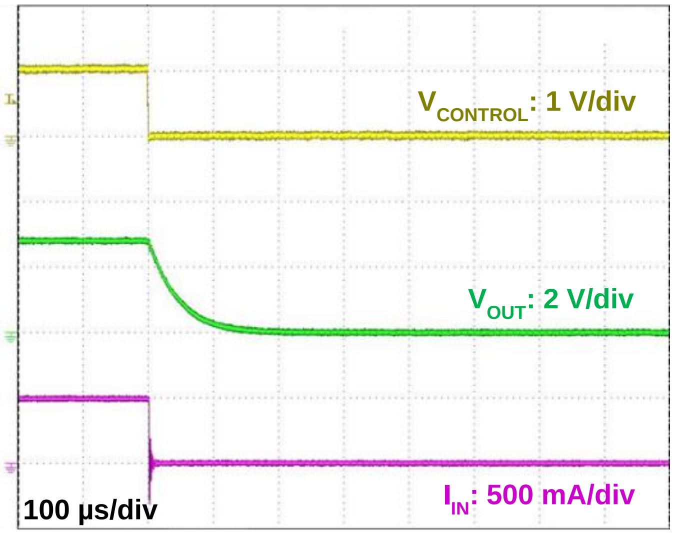
t_{ON} / t_{OFF} Response

(C_{IN} = 1.0 μF, V_{IN} = 2.0 V or V_{OUT} + 0.5 V (whichever is greater), $V_{CONTROL}$ = 0 V↔1.0 V, T_a = 25°C)

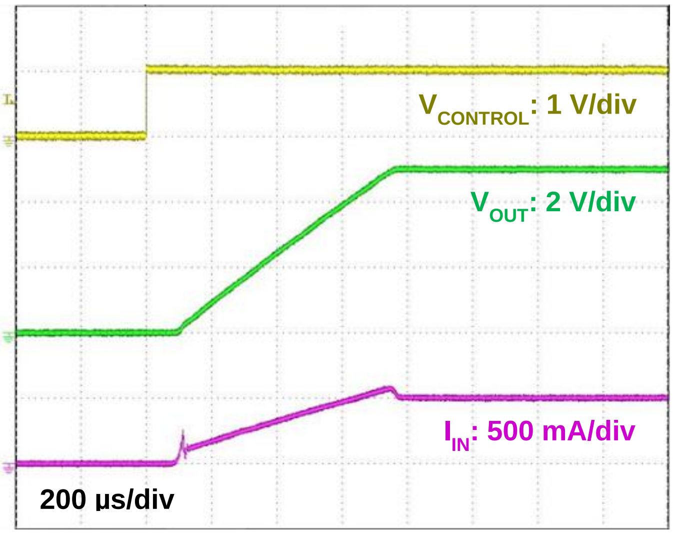
- **C_{OUT} = 10 μF, I_{OUT} = 500 mA**

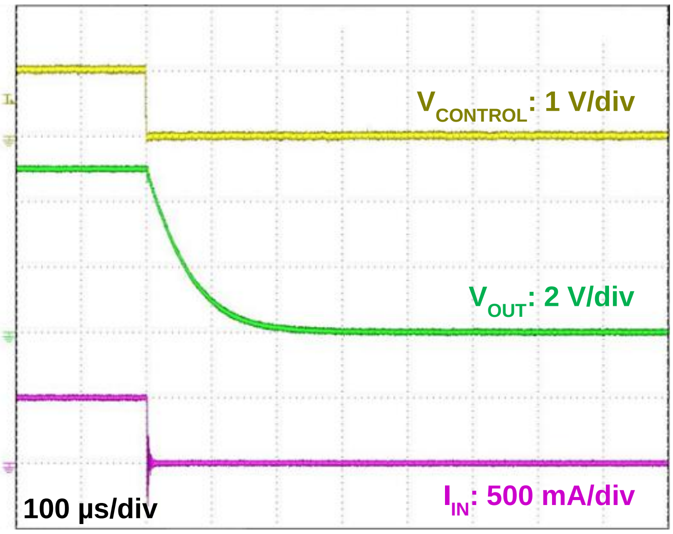
V_{OUT} = 2.8 V





V_{OUT} = 5.0 V



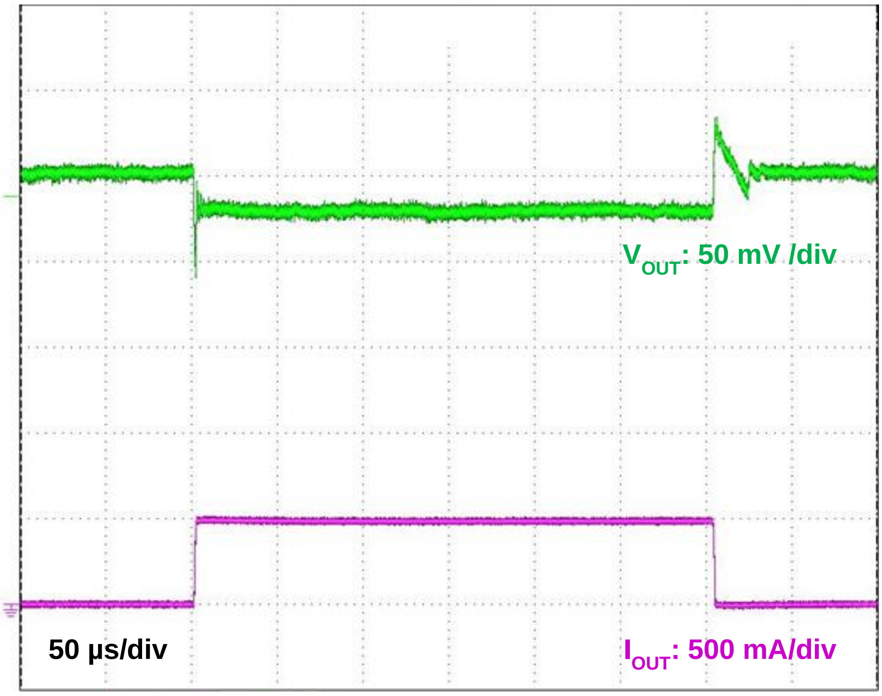


Note: The above characteristics curves are presented for reference only and not guaranteed by production test, unless otherwise noted.

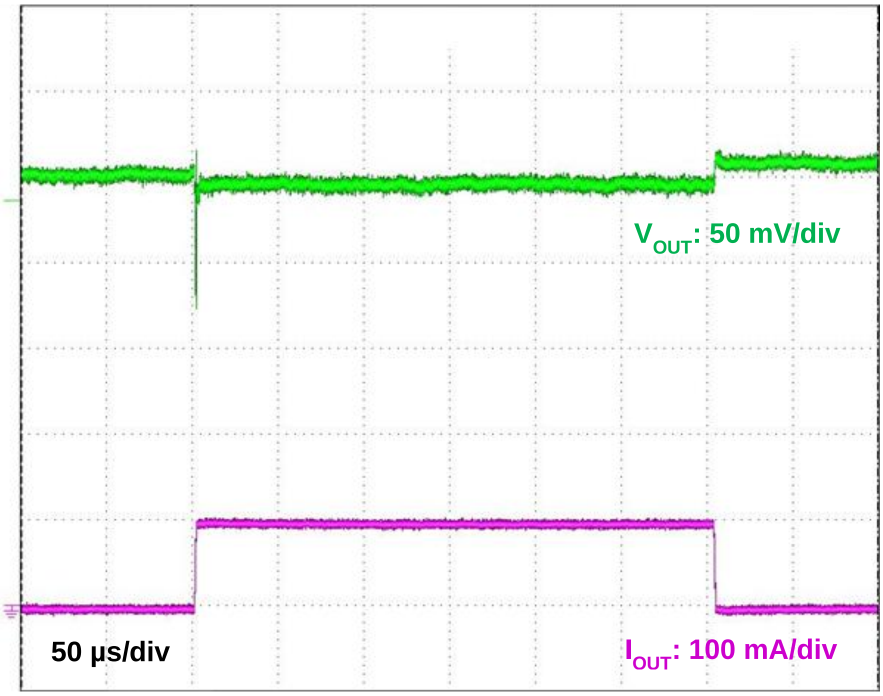
12.9. Load Transient Response

(C_{IN} = 1.0 μF, C_{OUT} = 1.0 μF, V_{IN} = 3.3 V, V_{OUT} = 2.8 V, t_r = 1.0 μs, t_f = 1.0 μs, T_a = 25°C)

I_{OUT} = 1 mA ↔ 500 mA



I_{OUT} = 0 mA ↔ 100 mA

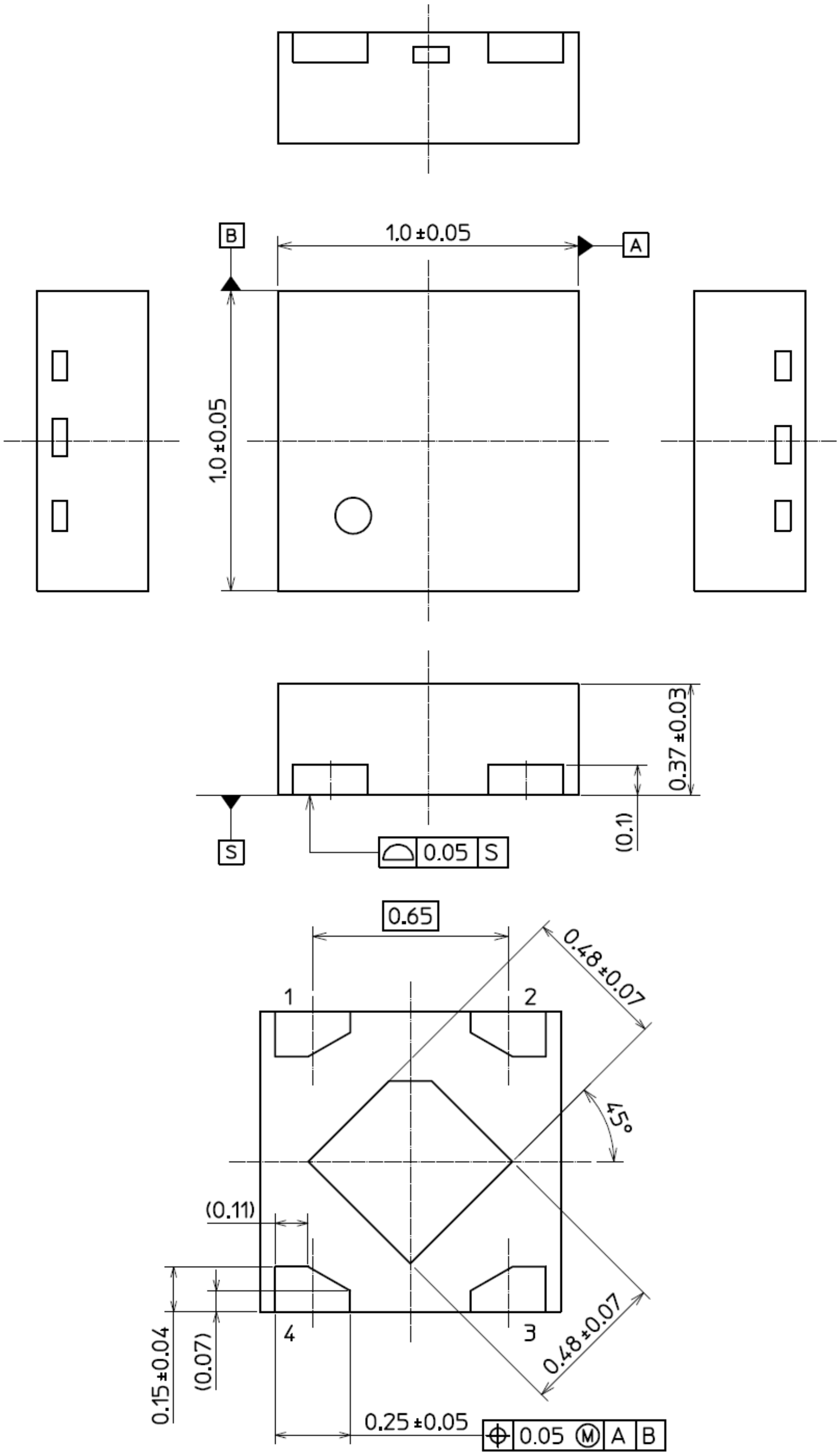


Note: The above characteristics curves are presented for reference only and not guaranteed by production test, unless otherwise noted.

13. Package Information

DFN4D

Unit: mm

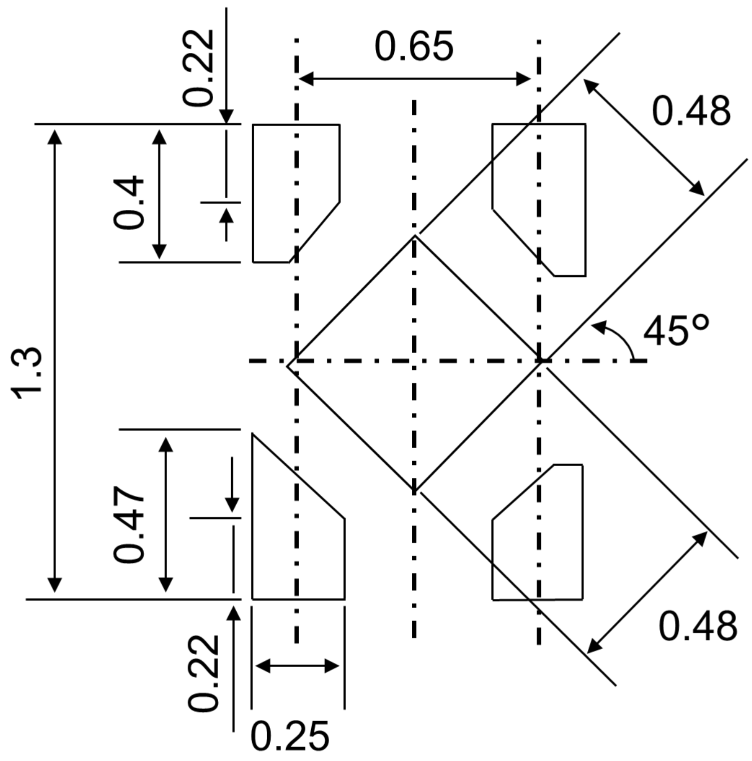


Weight: 1.1 mg (Typ.)

Figure 10.1 Package Dimensions

14. Land pattern Dimensions (for reference only)

Unit: mm



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