TOSHIBA CMOS Linear Integrated Circuit Silicon Monolithic

TCR3EM series

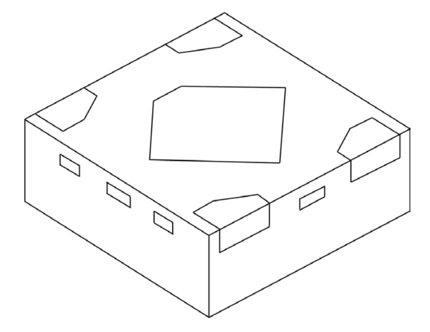
300 mA CMOS Low Dropout Regulator

1. Description

The TCR3EM series are CMOS general-purpose single-output voltage regulators with an on/off control input, featuring low dropout voltage and fast load transient response.

These voltage regulators are available in fixed output voltages between 0.8 V and 5.0 V and capable of driving up to 300 mA. They feature Overcurrent protection, Thermal shutdown and Auto-discharge.

The TCR3EM 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 low dropout voltage of 160 mV (2.5 V output, I_{OUT} = 150 mA). As small ceramic input and output capacitors 1.0 μF can be used with the TCR3EM 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.)).
- Wide range output voltage line up (V_{OUT} = 0.8 to 5.0 V)
- Wide input voltage range (V_{IN} = 1.3 to 5.5 V)
- Low control voltage (HIGH) (V_{CTH} = 0.8 V (min))
- Low dropout voltage
  V_{DO} = 160 mV (typ.) at 2.5 V output, I_{OUT} = 150 mA
- High ripple rejection ratio (68 dB (typ.) at 2.5 V output, I_{OUT} = 10 mA, f = 1 kHz)
- Fast load transient response (-57/+55 mV (typ.) at 2.5 V output, I_{OUT} = 1 mA ⇔ 150 mA)
- Overcurrent protection
- Thermal shutdown
- Auto-discharge
- Inrush current protection circuit
- 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
2024-08

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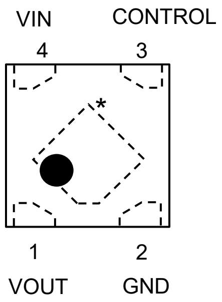
4. Absolute Maximum Ratings (Note) (Ta = 25°C)

Characteristics	Symbol	Rating	Unit
Input voltage	V_{IN}	-0.3 to 6.0	V
Control voltage	V_{CT}	-0.3 to 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%
Through hole: diameter 0.5 mm x 24 pcs

5. Pin Assignment (top view)



*Center electrode should be connected to GND or Open

6. Operating Ranges

Characteristics	Symbol	Rating		Unit
Input voltage	V_{IN}	1.3 to 5.5 (Note 2)		V
Control voltage	V_{CT}	0 to 5.5		V
Output voltage	V_{OUT}	0.8 to 5.0		V
Output current	I_{OUT}	DC	300	mA
Operation 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 and use it within Absolute Maximum Ratings Junction temperature and Operation Temperature Ranges.

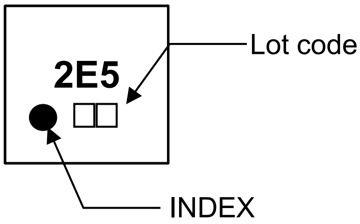
7. List of Products Number, Output voltage and Marking

Product No.	Output voltage(V)	Marking	Product No.	Output voltage(V)	Marking
TCR3EM08A	0.8	0E8	TCR3EM27A*	2.7	2E7
TCR3EM085A*	0.85	0EJ	TCR3EM275A*	2.75	2EM
TCR3EM09A	0.9	0E9	TCR3EM28A	2.8	2E8
TCR3EM095A*	0.95	0EK	TCR3EM285A*	2.85	2ED
TCR3EM10A*	1.0	1E0	TCR3EM29A*	2.9	2E9
TCR3EM105A*	1.05	1EA	TCR3EM295A*	2.95	2EK
TCR3EM11A	1.1	1E1	TCR3EM30A*	3.0	3E0
TCR3EM115A*	1.15	1EB	TCR3EM305A*	3.05	3EA
TCR3EM12A	1.2	1E2	TCR3EM31A*	3.1	3E1
TCR3EM125A*	1.25	1EC	TCR3EM32A*	3.2	3E2
TCR3EM13A*	1.3	1E3	TCR3EM33A	3.3	3E3
TCR3EM135A*	1.35	1ED	TCR3EM335A*	3.35	3ED
TCR3EM14A*	1.4	1E4	TCR3EM34A	3.4	3E4
TCR3EM145A*	1.45	1EL	TCR3EM35A*	3.5	3E5
TCR3EM15A*	1.5	1E5	TCR3EM36A*	3.6	3E6
TCR3EM17A	1.7	1E7	TCR3EM39A*	3.9	3E9
TCR3EM18A	1.8	1E8	TCR3EM40A*	4.0	4E0
TCR3EM185A*	1.85	1EG	TCR3EM41A*	4.1	4E1
TCR3EM19A*	1.9	1E9	TCR3EM42A*	4.2	4E2
TCR3EM20A	2.0	2E0	TCR3EM45A*	4.5	4E5
TCR3EM24A*	2.4	2E4	TCR3EM48A*	4.8	4E8
TCR3EM25A	2.5	2E5	TCR3EM50A	5.0	5E0

* Please contact your local Toshiba representative if you are interested in products with * sign.

Top Marking (top view)

Example: TCR3EM25A (2.5 V output)



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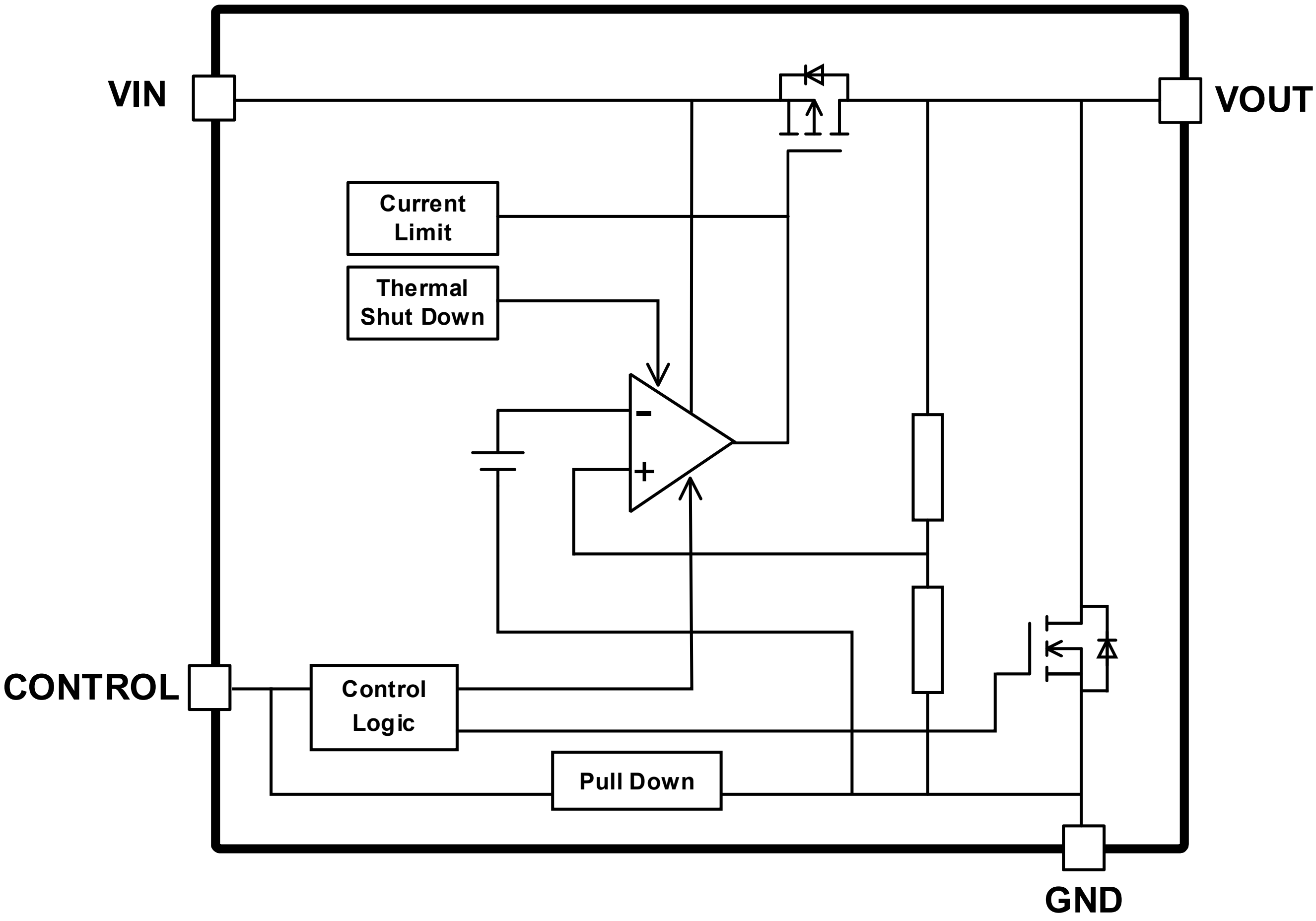
8. Block Diagram



9. Electrical Characteristics

(Unless otherwise specified, V_{IN} = 2.5 V or V_{OUT} + 1 V (whichever is greater), V_{IN} = 5.5 V (V_{OUT} > 4.5 V), C_{IN} = C_{OUT} = 1.0 μF)

Characteristics	Symbol	Test Condition		T_j = 25°C			T_j = -40 to 85°C (Note 8)		Unit
				Min	Typ.	Max	Min	Max	
Output voltage accuracy	V_{OUT}	I_{OUT} = 50 mA V_{IN} = V_{OUT} + 1 V (Note 3)	V_{OUT} < 1.8 V	-18	—	+18	—	—	mV
			1.8 V ≤ V_{OUT}	-1	—	+1	—	—	%
Line regulation	Reg·line	V_{OUT} + 0.5 V ≤ V_{IN} ≤ 5.5 V I_{OUT} = 1 mA		—	1	—	—	10	mV
Load regulation	Reg·load	1 mA ≤ I_{OUT} ≤ 300 mA		—	17	—	—	59	mV
Quiescent current	$I_{B(ON)}$	I_{OUT} = 0 mA, V_{IN} = 5.5 V (Note 5)		—	35	—	—	55	μA
Stand-by current	$I_{B\ (OFF)}$	V_{CT} = 0 V, V_{IN} = 5.5 V (Note 5)		—	0.1	—	—	1.0	μA
Control pull down current	I_{CT}	—		—	0.1	—	—	0.2	μA
Drop-out voltage (Note 9)	V_{DO}	I_{OUT} = 150 mA (Note 4)		—	160	—	—	218	mV
		I_{OUT} = 300 mA (Note 4)		—	330	—	—	417	mV
Output noise voltage	V_{NO}	I_{OUT} = 10 mA 10 Hz ≤ f ≤ 100 kHz, Ta = 25°C (Note 4)		—	50	—	—	—	μV_{rms}
Ripple rejection ratio	R.R.	V_{IN} = 3.5 V V_{OUT} = 2.5 V I_{OUT} = 10 mA, V_{Ripple} = 500 m$V_{p\text{-}p}$, Ta = 25°C (Note 4)	f = 100 Hz	—	80	—	—	—	dB
			f = 1 kHz	—	68	—	—	—	
			f = 10 kHz	—	55	—	—	—	
			f = 100 kHz	—	43	—	—	—	
			f = 1 MHz	—	43	—	—	—	
Load transient response	⊿V_{OUT}	I_{OUT} = 1 mA → 150 mA (Note 4) (Note 6)		—	-57	—	—	—	mV
		I_{OUT} = 150 mA → 1 mA (Note 4) (Note 6)		—	+55	—	—	—	
		I_{OUT} = 1 mA → 300 mA (Note 4) (Note 6)		—	-95	—	—	—	
		I_{OUT} = 300 mA → 1 mA (Note 4) (Note 6)		—	+100	—	—	—	
Output current limit	I_{CL}	V_{OUT} = $V_{OUT(NOM)}$*90% (Note 7)		—	—	—	310	550	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"		—	—	—	0.8	5.5	V
Control voltage (LOW)	V_{CTL}	Control pin input voltage "LOW"		—	—	—	—	0.4	V
Discharge on resistance	R_{SD}	(Note 4)		—	25	—	—	—	Ω

Note 3: stable state with fixed I_{OUT} condition
Note 4: V_{OUT} = 2.5 V
Note 5: except Control pull down current (I_{CT})
Note 6: t_r = t_f = 1.5 μs
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} (nominal voltage) + 1.0 V

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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10. Drop-out voltage table

(C_{IN} = 1.0 μF, C_{OUT} = 1.0 μF)

Output voltages	Symbol	I_{OUT} = 150 mA					I_{OUT} = 300 mA					Unit
		T_j = 25°C			T_j = -40 to 85°C (Note 10)		T_j = 25°C			Tj = -40 to 85°C (Note 10)		
		Min	Typ.	Max	Min	Max	Min	Typ.	Max	Min	Max	
0.8 V ≤ V_{OUT} ≤ 1.15 V	V_{IN}-V_{OUT}	—	687	—	—	773	—	1050 (Note 11)	—	—	1165 (Note 11)	mV
1.2 V ≤ V_{OUT} ≤ 1.45 V		—	434	—	—	505	—	755 (Note 11)	—	—	858 (Note 11)	
1.5 V ≤ V_{OUT} ≤ 1.7 V		—	371	—	—	439	—	655	—	—	756	
1.8 V ≤ V_{OUT} ≤ 1.9 V		—	309	—	—	373	—	559	—	—	655	
2.0 V ≤ V_{OUT} ≤ 2.4 V		—	267	—	—	328	—	493	—	—	587	
2.5 V ≤ V_{OUT} ≤ 2.75 V		—	160	—	—	218	—	330	—	—	417	
2.8 V ≤ V_{OUT} ≤ 2.95 V		—	156	—	—	210	—	315	—	—	401	
3.0 V ≤ V_{OUT} ≤ 3.2 V		—	151	—	—	205	—	305	—	—	390	
3.3 V ≤ V_{OUT} ≤ 3.5 V		—	144	—	—	198	—	290	—	—	373	
3.6 V ≤ V_{OUT} ≤ 4.1 V		—	137	—	—	190	—	275	—	—	357	
4.2 V ≤ V_{OUT} ≤ 5.0V		—	122	—	—	174	—	245	—	—	324	

Note 10: This parameter is warranted by design.
Note 11: Operating Voltage of V_{IN} should be over 2.5 V.

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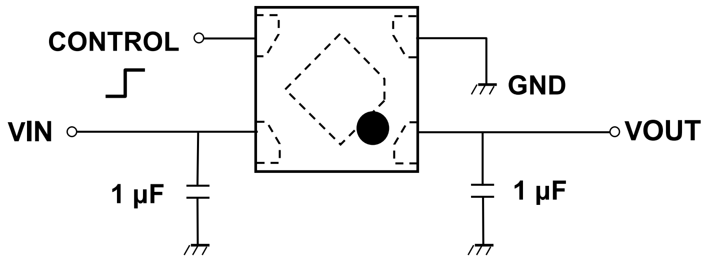
11. Application Note

11.1. Recommended Application Circuit



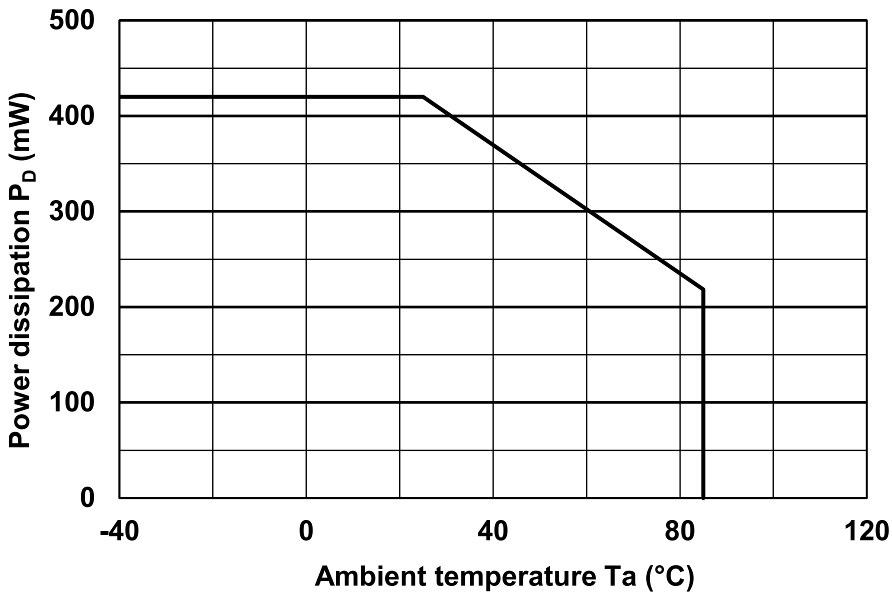
CONTROL voltage	Output voltage
HIGH	ON
LOW	OFF
OPEN	OFF

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

11.2. Power Dissipation

Board-mounted power dissipation ratings for TCR3EM 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%
Through hole: diameter 0.5 mm x 24 pcs



11.3. 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 recommend ceramic capacitor.

- V_{OUT} rise time
  Due to the circuit for inrush current reduction, V_{OUT} rise time changes depends on usage condition, surrounding circuit, and surrounding temperature. Therefore, please design with full consideration of usage condition. For example, V_{OUT} becomes stable approximately after 200 μs from V_{CT} apply timing in C_{OUT} = 1.0 μF, Ta = 25°C condition.

- 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 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, 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 shut down function
  Over current protection and Thermal shut down 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 recommend inserting failsafe system into the design.

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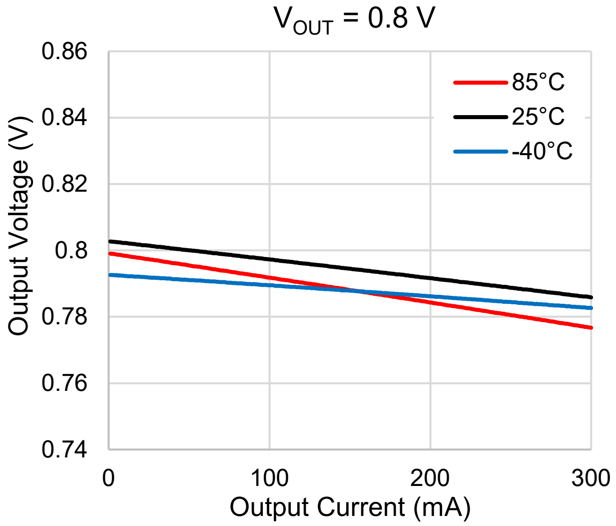
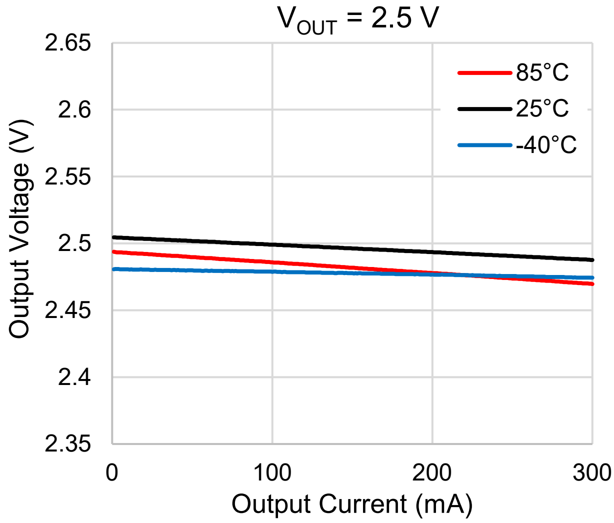
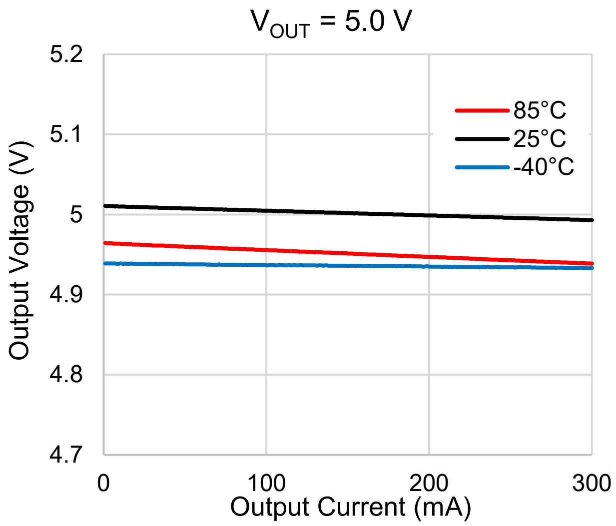
12. Representation Typical Characteristics (Note)

12.1. Output Voltage vs. Output Current

(V_{IN} = 2.5 V (V_{OUT} = 0.8 V) or 3.5 V (V_{OUT} = 2.5 V) or 5.5 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.

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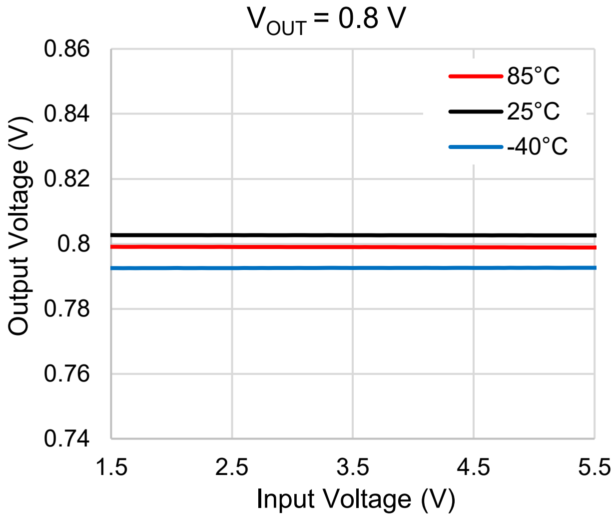
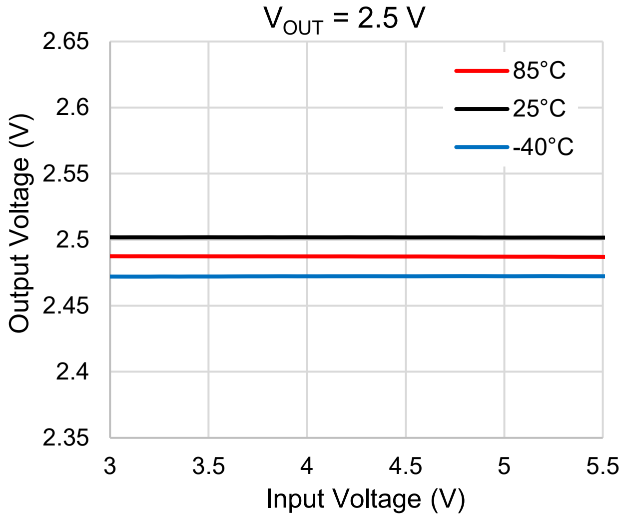
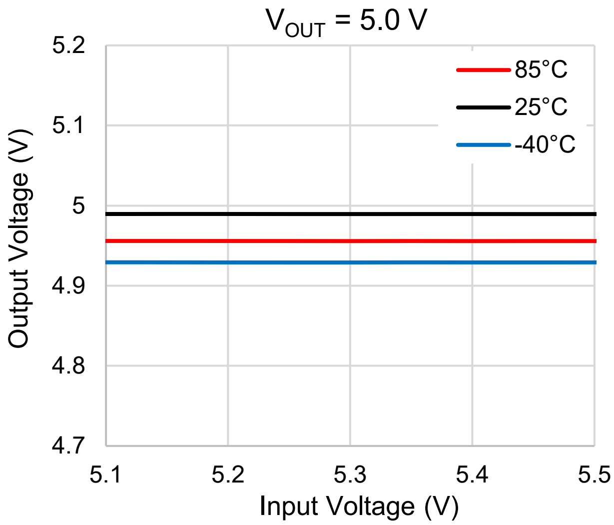
12.2. Output Voltage vs. Input Voltage

(I_{OUT} = 1 mA)







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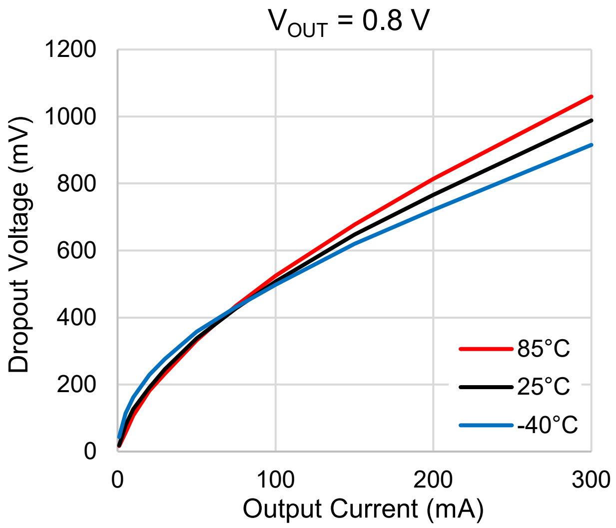
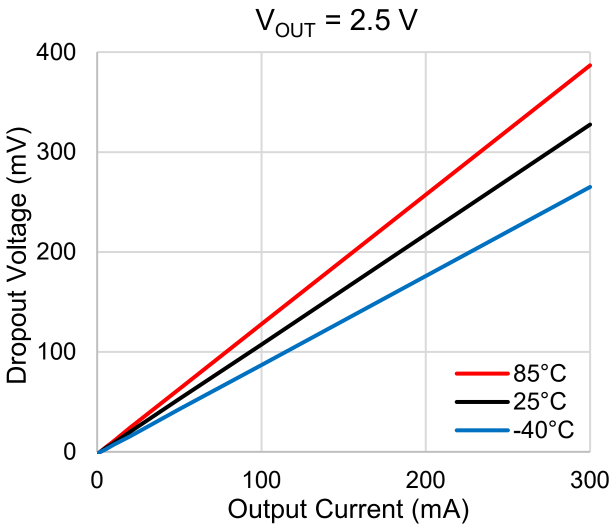
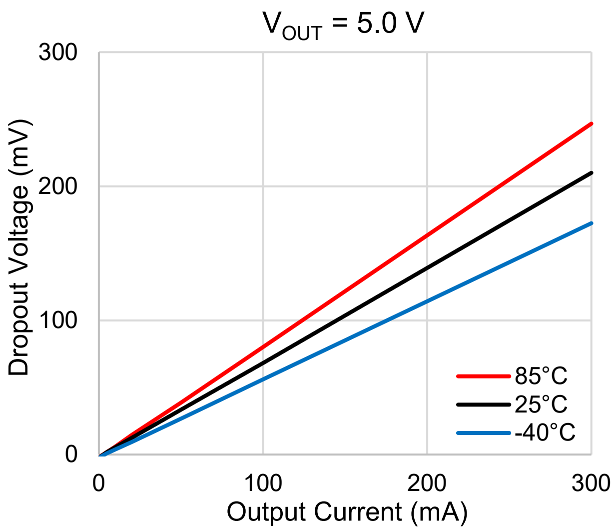
12.3. Dropout Voltage vs. Output Current







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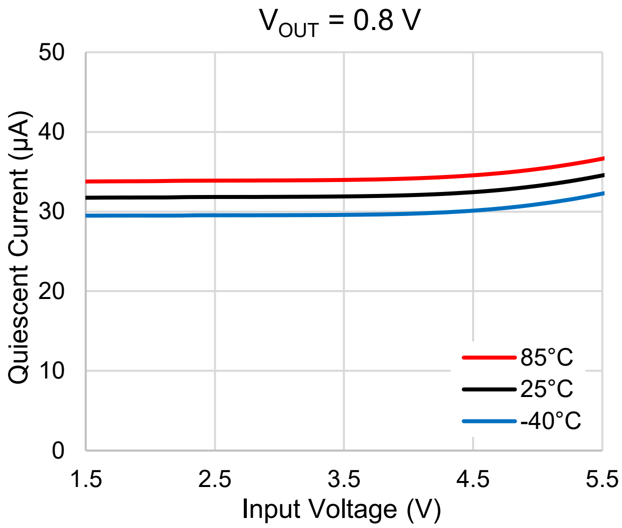
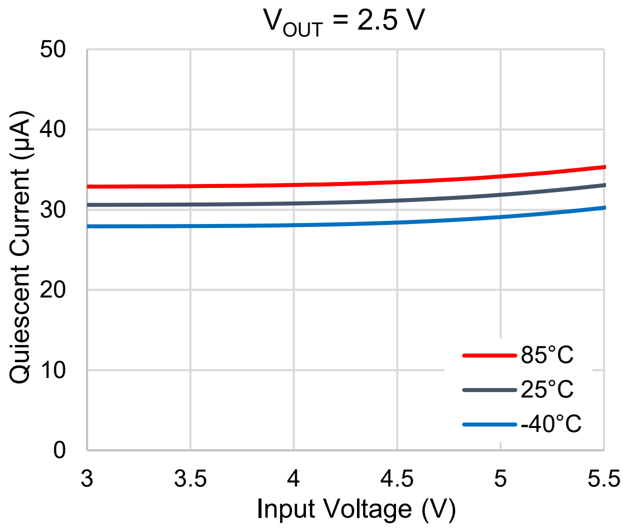
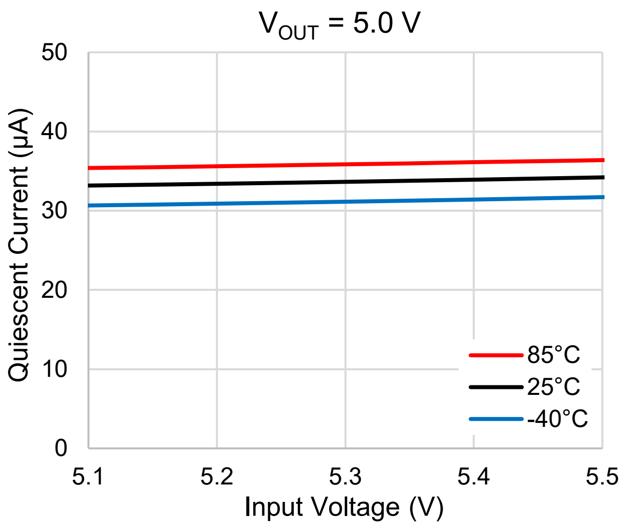
12.4. Quiescent Current vs. Input Voltage

(I_{OUT} = 0 mA)



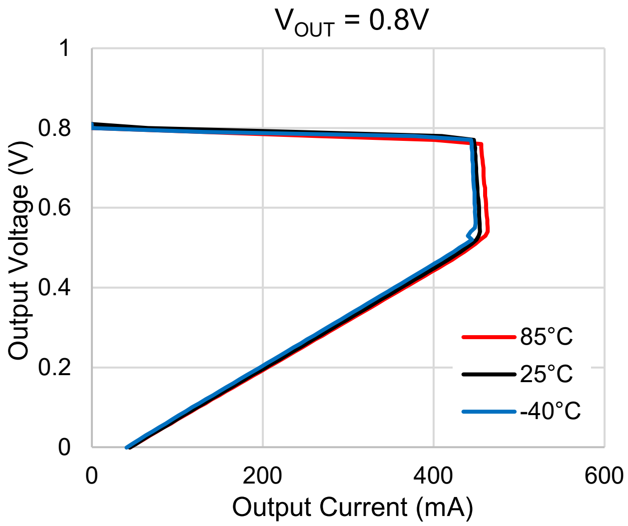


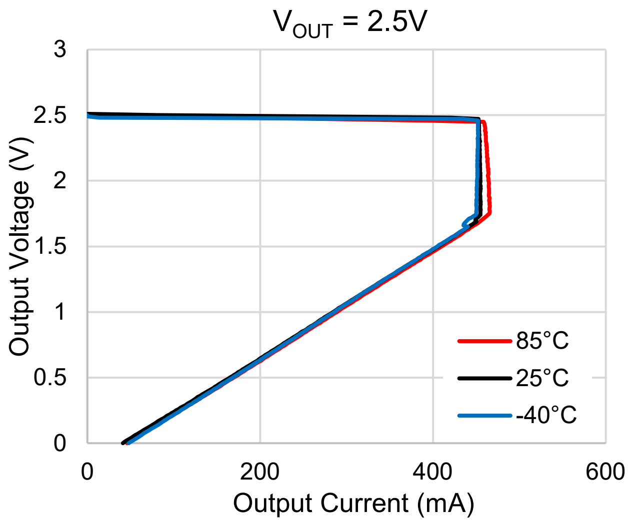


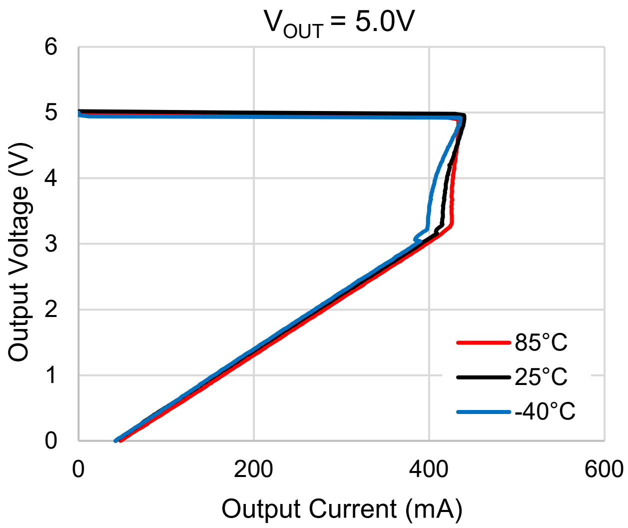
Note: The above characteristics curves are presented for reference only and not guaranteed by production test, unless otherwise noted.

12.5. Output Current Limit

(V_{IN} = 2.5 V (V_{OUT} = 0.8 V) or 3.5 V (V_{OUT} = 2.5 V) or 5.5 V (V_{OUT} = 5.0 V))







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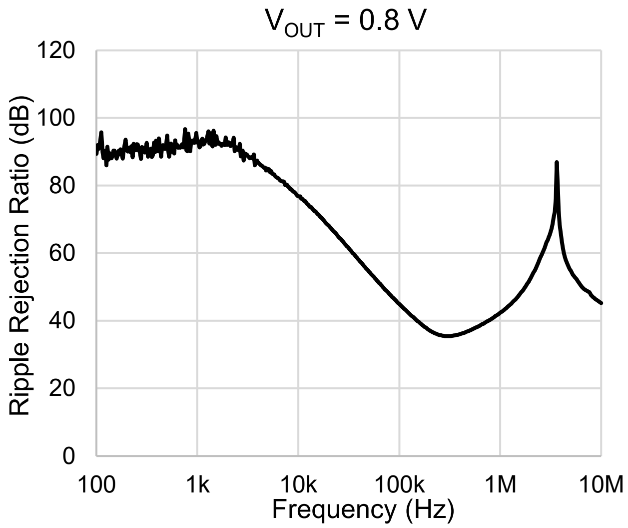
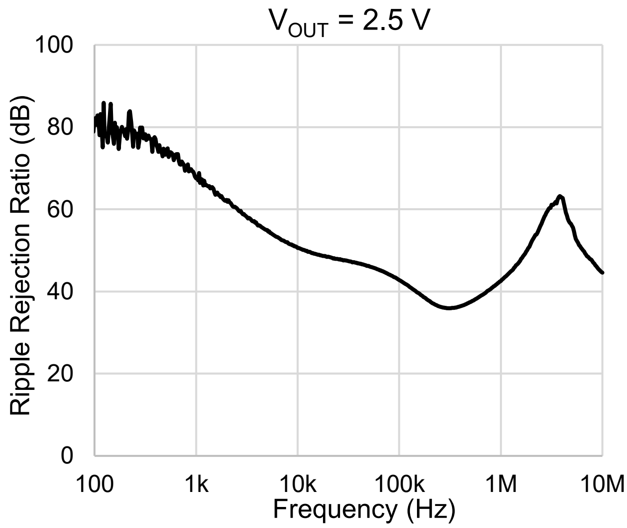
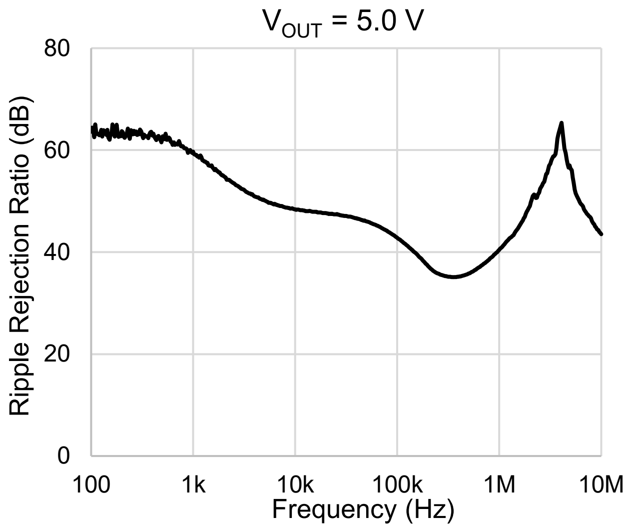
12.6. Ripple rejection Ratio vs. Frequency

(C_{IN} = none, C_{OUT} = 1.0 μF, V_{IN} = 2.5 V (V_{OUT} = 0.8 V) or 3.5 V (V_{OUT} = 2.5 V) or 5.5 V (V_{OUT} = 5.0 V), $V_{IN\ Ripple}$ = 500 $mV_{p\text{-}p}$, I_{OUT} = 10 mA, Ta = 25°C)







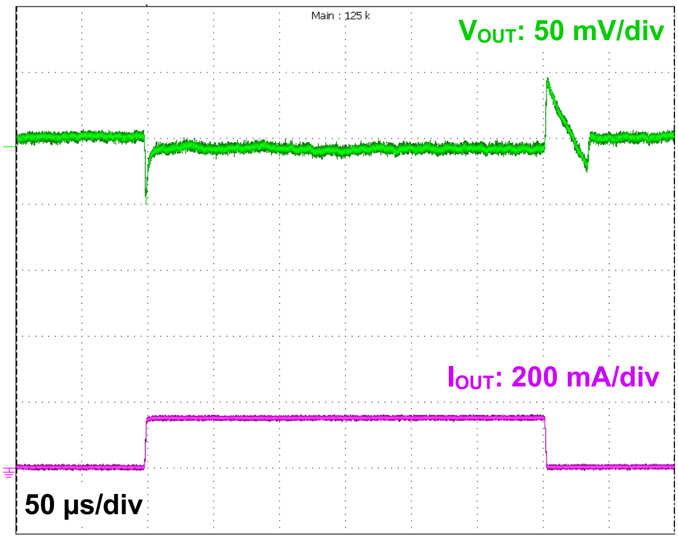
Note: The above characteristics curves are presented for reference only and not guaranteed by production test, unless otherwise noted.

12.7. Load Transient Response

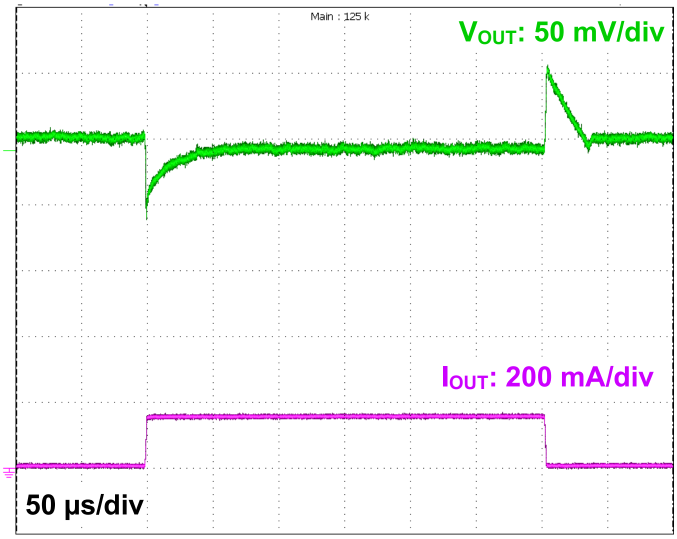
(C_{IN} = 1.0 μF, C_{OUT} = 1.0 μF, V_{IN} = 2.5 V (V_{OUT} = 0.8 V) or 3.5 V (V_{OUT} = 2.5 V) or 5.5 V (V_{OUT} = 5.0 V), t_r = 1.5 μs, t_f = 1.5 μs, Ta = 25°C)

- **I_{OUT} = 1 mA ⇔ 150 mA**

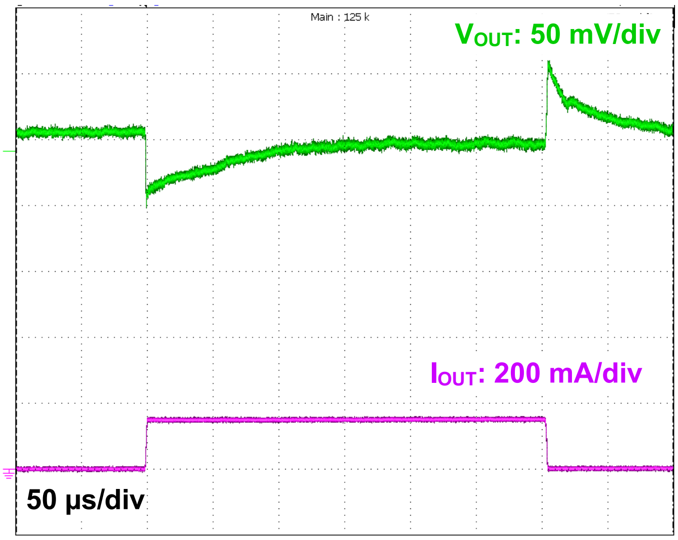
V_{OUT} = 0.8 V



V_{OUT} = 2.5 V



V_{OUT} = 5.0 V



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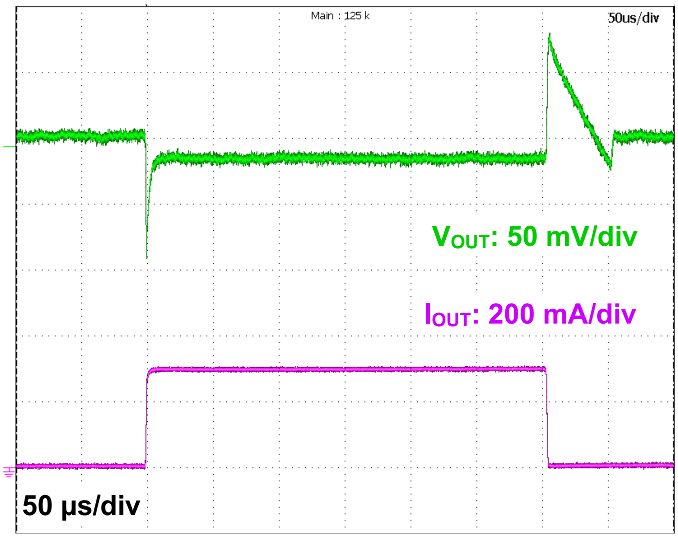
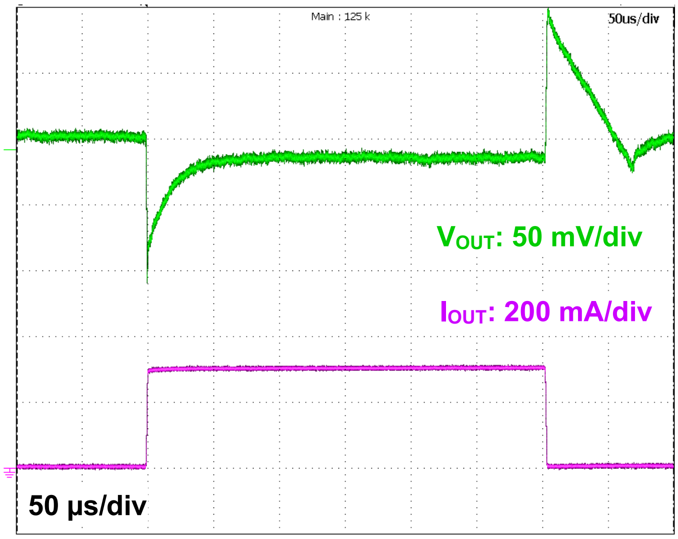
- I_{OUT} = 1 mA ⇔ 300 mA

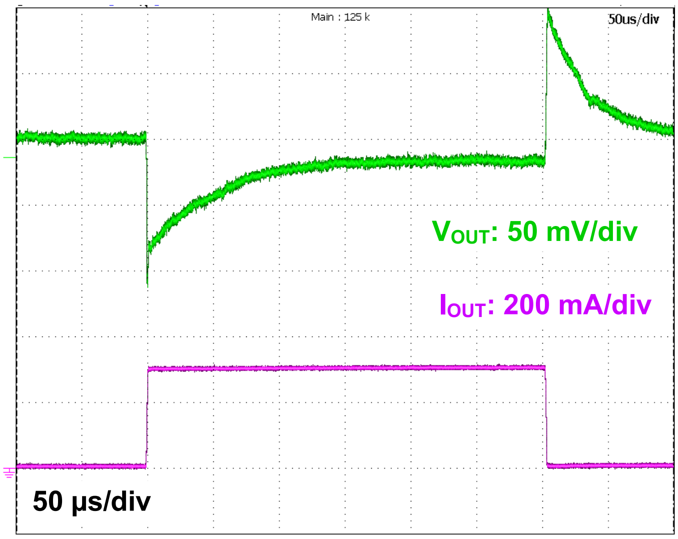
V_{OUT} = 0.8 V



V_{OUT} = 2.5 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.

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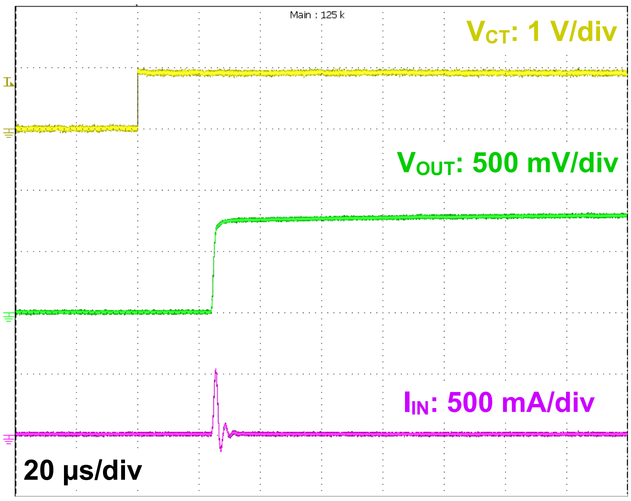
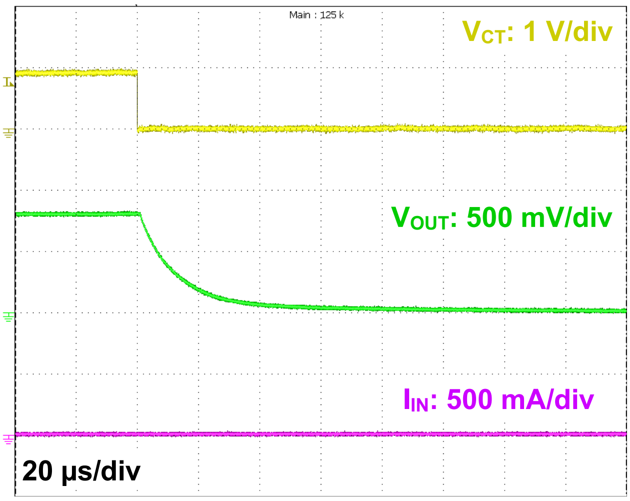
12.8. t_{ON} / t_{OFF} Response

(C_{IN} = 1.0 µF, C_{OUT} = 1.0 µF, V_{IN} = 2.5 V (V_{OUT} = 0.8 V) or 3.5 V (V_{OUT} = 2.5 V) or 5.5 V (V_{OUT} = 5.0 V), V_{CT} = 0 V ⇔ 1.0 V, Ta = 25°C)

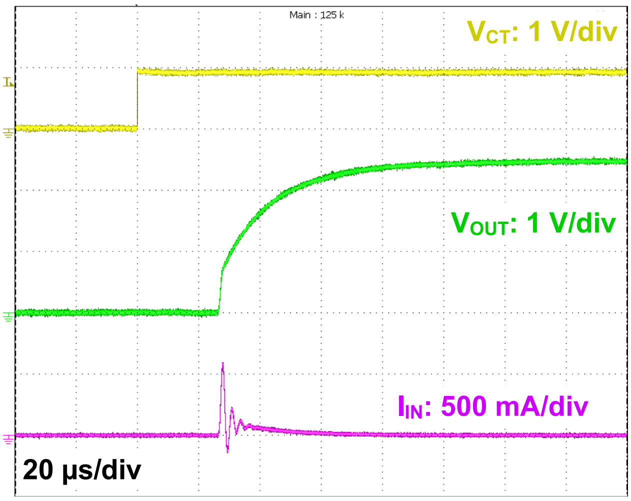
- **I_{OUT} = 0 mA**

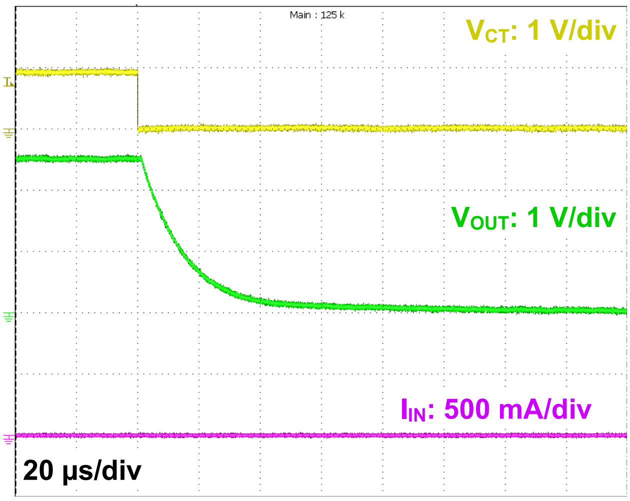
V_{OUT} = 0.8 V



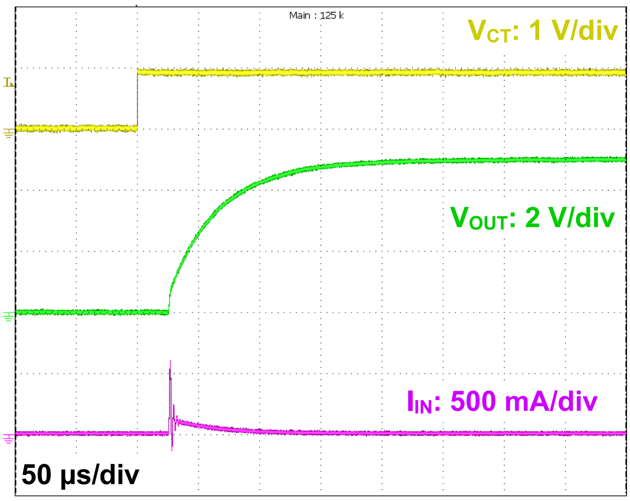


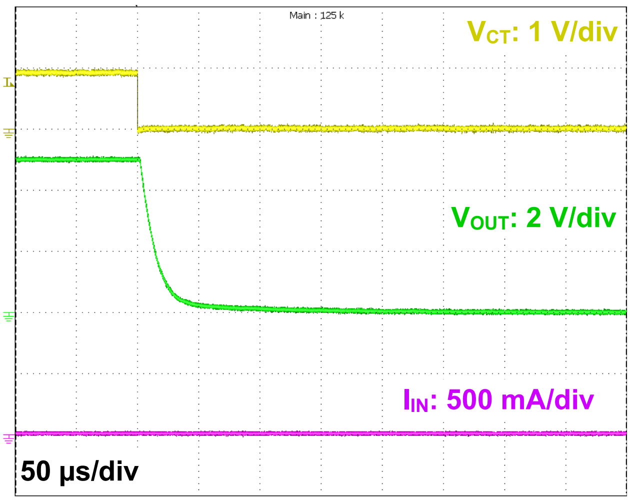
V_{OUT} = 2.5 V





V_{OUT} = 5.0 V

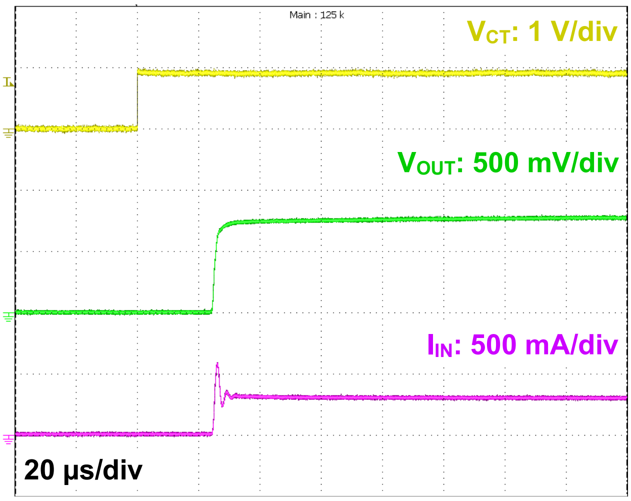


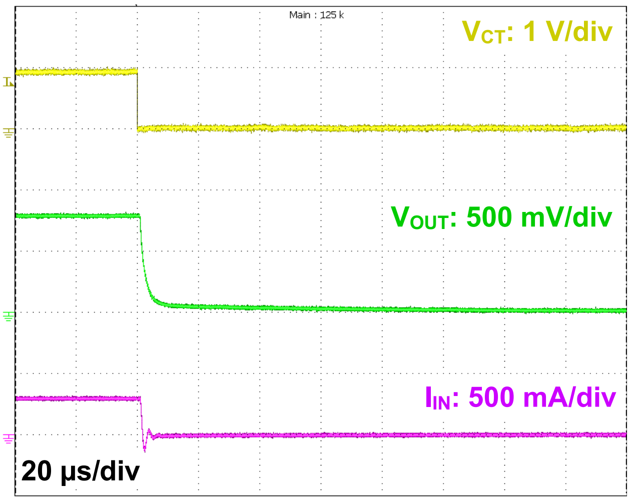


Note: The above characteristics curves are presented for reference only and not guaranteed by production test, unless otherwise noted.

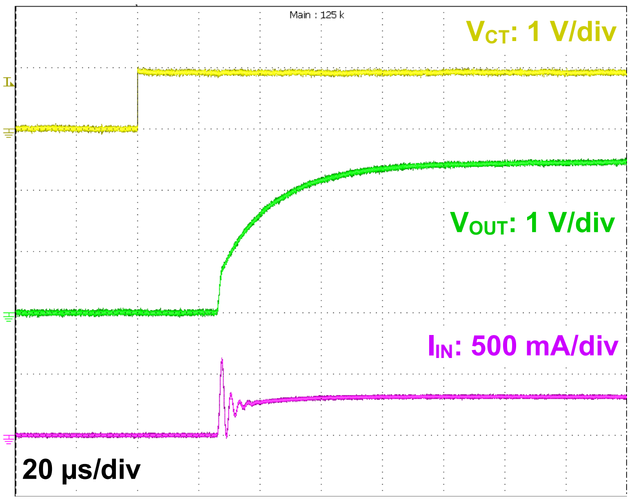
- I_{OUT} = 300 mA

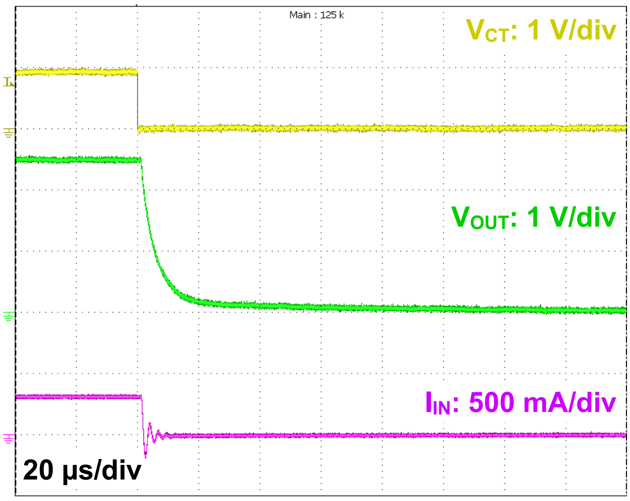
V_{OUT} = 0.8 V



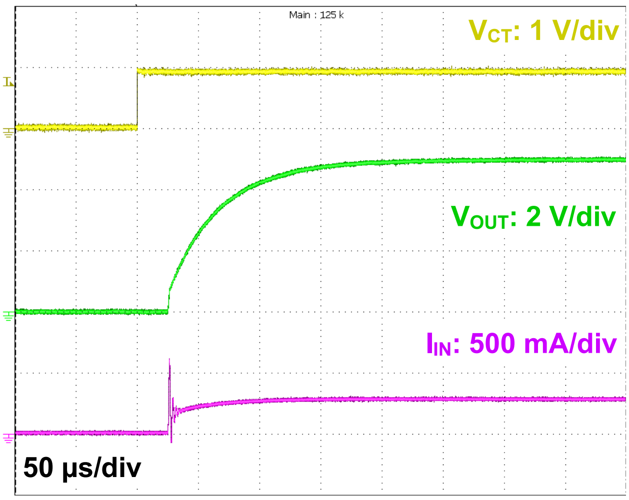


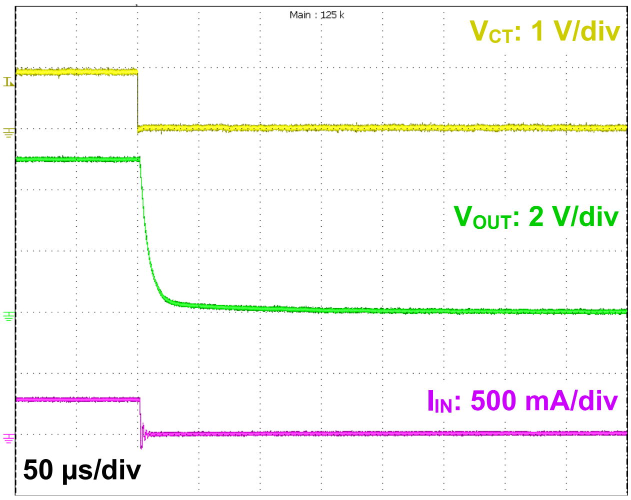
V_{OUT} = 2.5 V





V_{OUT} = 5.0 V





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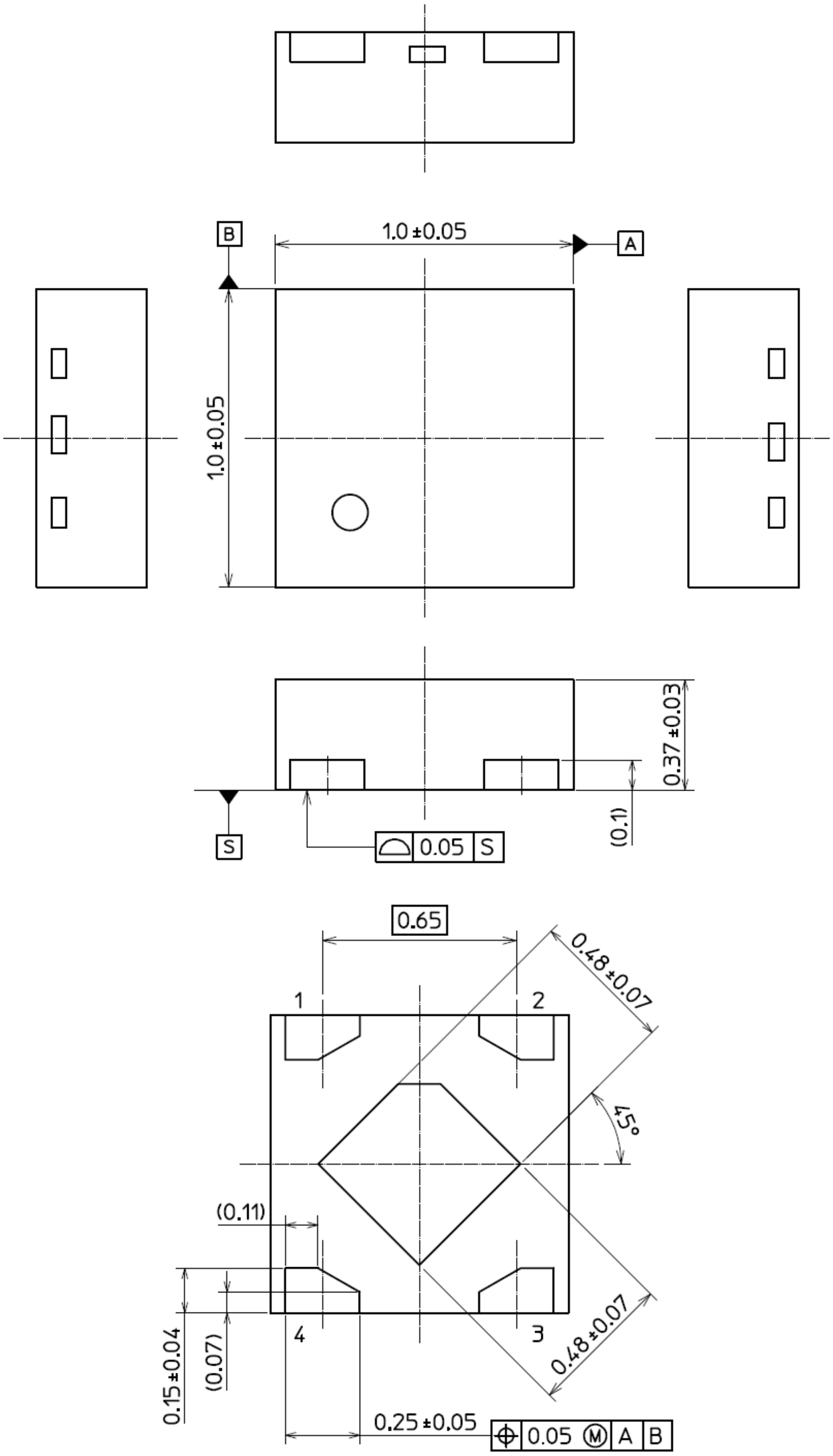
13. Package Information

DFN4D

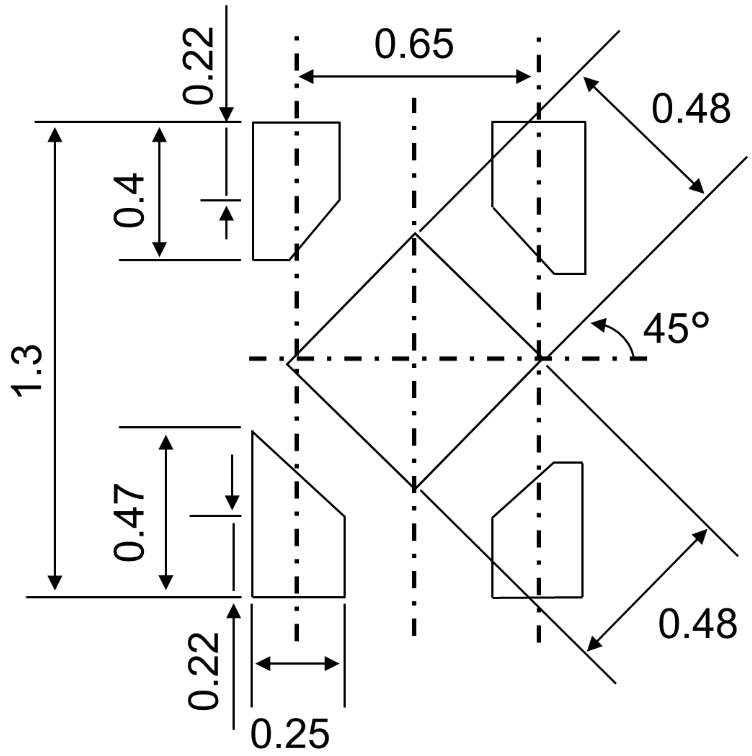
Unit: mm



Weight: 1.1 mg (typ.)

14. Land pattern Dimensions (for reference only)

Unit: mm



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