TOSHIBA CMOS Linear Integrated Circuit Silicon Monolithic

TCR5RG series

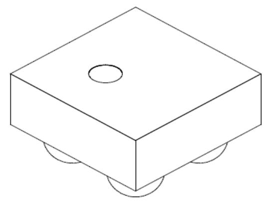
Ultra high Ripple rejection ratio, 500 mA CMOS Low Dropout Regulator in ultra small package

1. Description

The TCR5RG 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 TCR5RG series is offered in the ultra small plastic mold package WCSP4F (0.645 mm x 0.645 mm (Typ.); t 0.33 mm (max)) and has a high ripple rejection ratio of 100 dB (f = 1 kHz, 2.8 V output). As small ceramic input and output capacitors 1.0 μF can be used with the TCR5RG series, these devices are ideal for portable applications that require high-density board assembly such as cellular phones.



WCSP4F

2. Applications

Power IC developed for portable applications

3. Features

- Ultra small package WCSP4F (0.645 mm x 0.645 mm (Typ.); t 0.33 mm (max)).
- 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 67 dB (Typ.) @100 kHz (V_{OUT} = 2.8 V)
- High Ripple rejection ratio 59 dB (Typ.) @1 MHz at (V_{OUT} = 2.8 V)
- Low output noise voltage (V_{NO} = 5 μV_{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} = 150 mV (Typ.), V_{OUT} = 2.8 V, I_{OUT} = 500 mA
- Wide range output voltage line up (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
2020-12

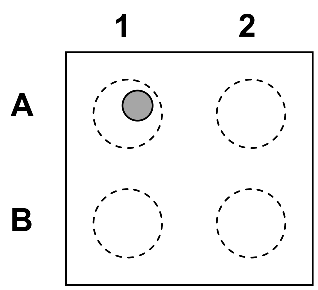
4. Absolute Maximum Ratings (Ta = 25°C)

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}	500	mA
Power dissipation	P_D	800 (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)



	1	2
A	VIN	VOUT
B	CONTROL	GND

6. Operating Ranges

Characteristics	Symbol	Rating		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 5.0		V
Output current	I_{OUT}	DC	500	mA
Operating Temperature	T_{opr}	-40 to 85		°C
Output Capacitance	C_{OUT}	≥ 1.0 μF		—
Input Capacitance	C_{IN}	≥ 1.0 μF		—

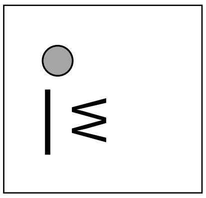
Note 2: Please refer to Dropout Voltage table (Page 6) and use it within Absolute Maximum Ratings Junction temperature and Operating Temperature Ranges.

7. List of Products Number, Output voltage and Marking

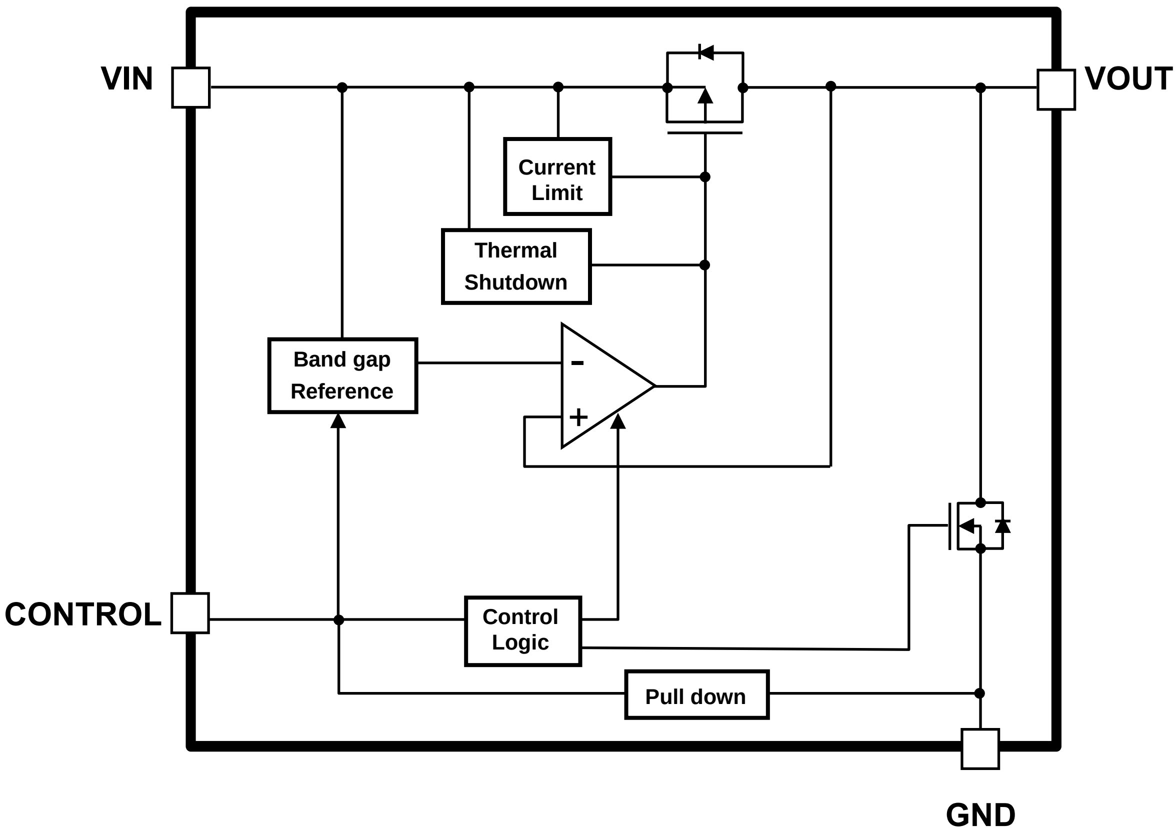
Product No.	Output voltage(V)	Marking
TCR5RG09A	0.9	A
TCR5RG095A	0.95	B
TCR5RG10A	1.0	C
TCR5RG105A	1.05	D
TCR5RG11A	1.1	E
TCR5RG115A	1.15	F
TCR5RG12A	1.2	|N
TCR5RG1225A	1.225	|A
TCR5RG125A	1.25	|B
TCR5RG13A	1.3	H
TCR5RG135A	1.35	J
TCR5RG14A	1.4	|C
TCR5RG15A	1.5	K
TCR5RG16A	1.6	|D
TCR5RG17A	1.7	L
TCR5RG175A	1.75	M
TCR5RG18A	1.8	N
TCR5RG1825A	1.825	|P
TCR5RG185A	1.85	P
TCR5RG19A	1.9	R
TCR5RG20A	2.0	S
TCR5RG25A	2.5	T
TCR5RG255A	2.55	|L
TCR5RG27A	2.7	V
TCR5RG28A	2.8	W
TCR5RG285A	2.85	X
TCR5RG29A	2.9	Y
TCR5RG2925A	2.925	|M
TCR5RG295A	2.95	|R
TCR5RG30A	3.0	0
TCR5RG31A	3.1	1
TCR5RG32A	3.2	2
TCR5RG33A	3.3	3
TCR5RG34A	3.4	|E
TCR5RG35A	3.5	4
TCR5RG36A	3.6	5
TCR5RG40A	4.0	|F
TCR5RG41A	4.1	|S
TCR5RG42A	4.2	6
TCR5RG43A	4.3	|H
TCR5RG45A	4.5	7
TCR5RG46A	4.6	8
TCR5RG47A	4.7	|J
TCR5RG48A	4.8	|K
TCR5RG50A	5.0	9

Top Marking (top view)

Example: TCR5RG28A (2.8 V output)



Block Diagram



8. Electrical Characteristics

(Unless otherwise specified, V_{IN} = 2.0 V or V_{OUT} + 0.5 V (whichever is greater), C_{IN} = C_{OUT} = 1.0 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 mA to 500 mA (Note 3)	V_{OUT} < 1.8 V	—	—	—	-36	+36	mV
			1.8 V ≤ V_{OUT} ≤ 2.8 V	—	—	—	-1.5	+1.5	%
			2.8 V < V_{OUT}	—	—	—	-1.8	+1.8	%
Line regulation	Reg·line	I_{OUT} = 1 mA (Note 3)		—	0.5	—	—	—	mV
Load regulation	Reg·load	1 mA ≤ I_{OUT} ≤ 500 mA		—	3	—	—	—	mV
Quiescent current	$I_{B(ON)}$	I_{OUT} = 0 mA (Note 5)		—	7	—	—	13	μA
Stand-by current	$I_{B\ (OFF)}$	V_{CT} = 0 V		—	0.08	—	—	0.2	μA
Control pull down current	I_{CT}	—		—	0.08	—	—	0.2	μA
Dropout voltage (Note 7)	V_{DO}	I_{OUT} = 500 mA	V_{OUT} = 1.8 V	—	235	—	—	290	mV
			V_{OUT} = 2.8 V	—	150	—	—	210	mV
Output noise voltage	V_{NO}	I_{OUT} = 10 mA 10 Hz ≤ f ≤ 100 kHz (Note 4)		—	5	—	—	15	μV_{rms}
		I_{OUT} = 250 mA 10 Hz ≤ f ≤ 100 kHz (Note 4)		—	5	—	—	15	μV_{rms}
Ripple rejection ratio	R.R.	I_{OUT} = 10 mA, V_{IN} = V_{OUT} + 1 V V_{Ripple} = 200 mV_{p-p}, (Note 4)	f = 1 kHz	—	100	—	—	—	dB
			f = 10 kHz	—	93	—	—	—	dB
			f = 100 kHz	—	67	—	—	—	dB
			f = 1 MHz	—	59	—	—	—	dB
Load transient response	⊿V_{OUT}	I_{OUT} = 1 mA to 500 mA		—	-40	—	—	—	mV
		I_{OUT} = 500 mA to 1 mA		—	+40	—	—	—	mV
Output voltage slew rate	V_{OUTSR}	—		—	30	—	—	—	mV/μs
Output current limit	I_{CL}	—		—	700	—	600	850	mA
Thermal shutdown threshold	T_{SDH}	T_J rising		—	160	—	—	—	°C
	T_{SDL}	T_J falling		—	140	—	—	—	°C
Control voltage (ON)	$V_{CT\ (ON)}$	—		—	—	—	0.9	V_{IN}	V
Control voltage (OFF)	$V_{CT\ (OFF)}$	—		—	—	—	0	0.5	V
Discharge on resistance	R_{SD}	(Note4)		—	30	—	—	—	Ω

Note 3: stable state with fixed I_{OUT} condition

((${V_{OUT}}$ + 0.5 V) or 2 V whichever is greater) ≤ V_{IN} ≤ 5.5 V

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} x 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.

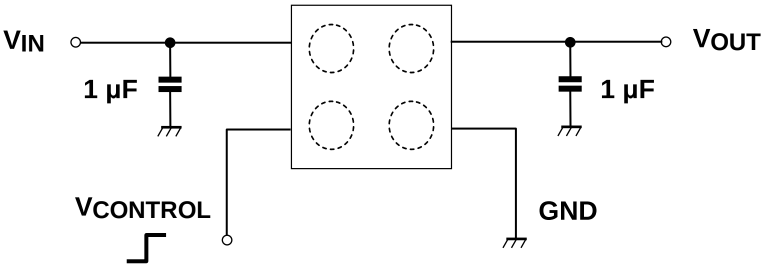
Dropout voltage table
(C_{IN} = 1.0 μF, C_{OUT} = 1.0 μF)

Output voltages	I_{OUT} = 500 mA			Unit
	Min	Typ.	Max (Note 8)	
0.9 V ≤ V_{OUT} ≤ 1.35 V	—	(Note 9)	(Note 9)	mV
1.4 V	—	320 (Note 9)	460 (Note 9)	mV
1.5 V	—	310	400	mV
1.6 V	—	260	350	mV
1.7 V	—	250	320	mV
1.75 V	—	240	300	mV
1.8 V	—	235	290	mV
1.825 V	—	235	285	mV
1.85 V	—	230	280	mV
1.9 V	—	225	270	mV
2.0 V	—	215	255	mV
2.5 V, 2.55 V	—	170	230	mV
2.7 V	—	160	215	mV
2.8 V, 2.85 V	—	150	210	mV
2.9 V, 2.925 V, 2.95 V	—	150	205	mV
3.0 V, 3.1 V	—	145	205	mV
3.2 V	—	140	195	mV
3.3 V, 3.4 V	—	135	190	mV
3.5 V, 3.6 V	—	130	185	mV
4.0 V, 4.1 V	—	115	175	mV
4.2 V, 4.3 V	—	115	170	mV
4.5 V	—	115	165	mV
4.6 V, 4.7 V, 4.8 V	—	110	165	mV
5.0 V	—	108	160	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.

9. Application Note

9.1. Recommended Application Circuit

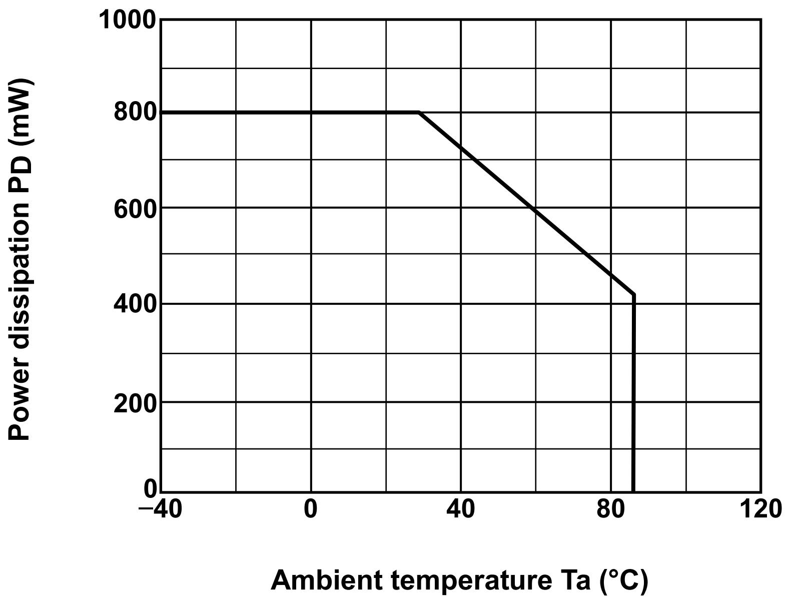


The figure above shows the recommended configuration for using a Low Dropout regulator. Insert a capacitor at VOUT and VIN pins for stable input/output operation. (Ceramic capacitors can be used.)

9.2. Power Dissipation

Board-mounted power dissipation ratings 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%



9.3. 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 0.6 μF or more by considering application condition for selecting capacitors.

- Bias current characteristics
  TCR5RG series has Bias current; $I_{B(ON)}$ characteristic that controlled depending on I_{OUT}.
  When the output current required is very low, TCR5RG series operates with low $I_{B(ON)}$. In this state, Ripple rejection ratio characteristic and load transient response characteristic are inferior than normal characteristics.
  Regarding output current that switches $I_{B(ON)}$ state, TCR5RG series has hysteresis to control. When output current is increased, good Ripple rejection ratio characteristics and good load transient response characteristics are provided with $I_{B(ON)}$ becoming high. In the case of decreasing the I_{OUT}, TCR5RG 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 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%.

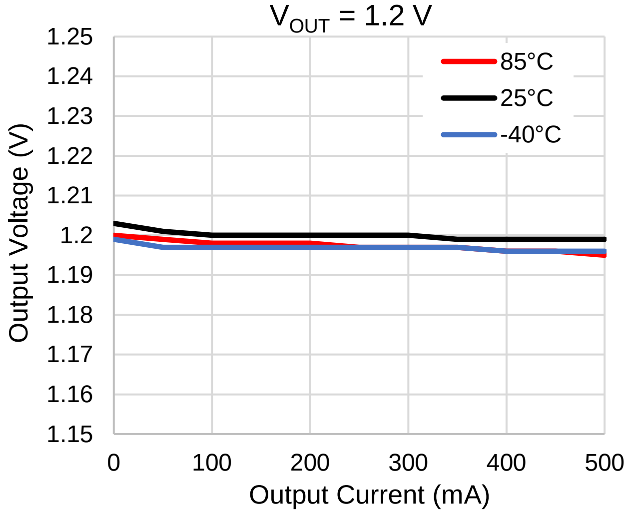
- Over current Protection and Thermal shutdown function
  Over current protection and Thermal shutdown function are designed in these products, but these are not designed to constantly ensure the suppression of the device within operation limits. Depending on the condition during actual usage, it could 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.

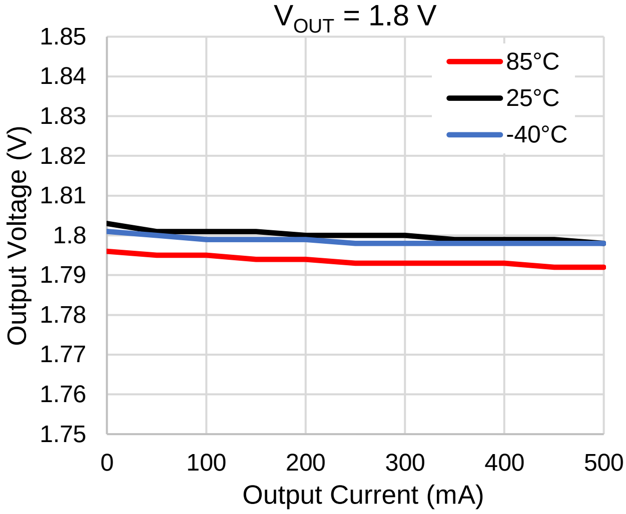
- High ripple rejection ratio and low output noise voltage characteristics
  TCR5RG series has low-pass filter which contributes high ripple rejection ratio and low output noise voltage.
  This low-pass filter turns on after V_{OUT} becomes near the nominal V_{OUT}.
  Therefore, before and when the low-pass filter is turned on, please be careful about the increase and decrease of V_{OUT} such as CONTROL voltage from low to high and road transient response.

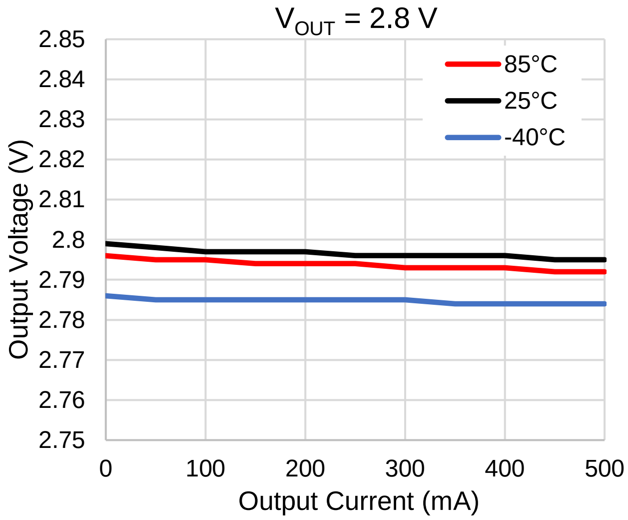
10. Representative Typical Characteristics

10.1. Output Voltage vs. Output Current

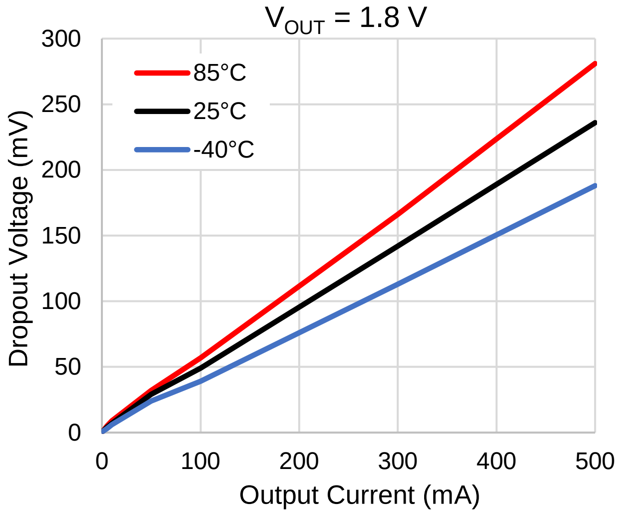
(V_{IN} = 2.0 V or V_{OUT} + 0.5 V (whichever is greater))

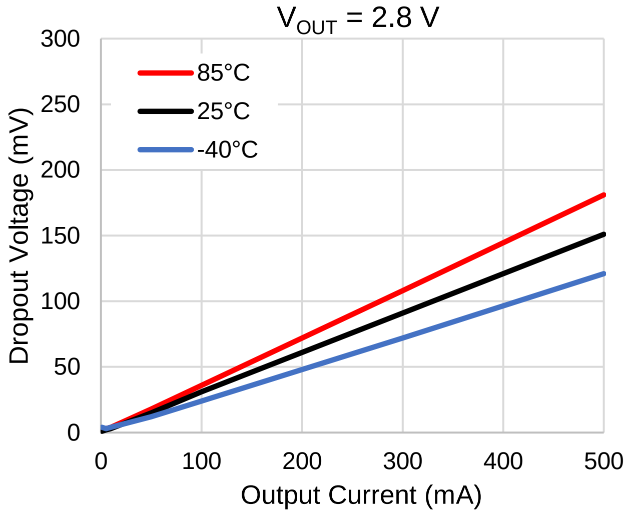


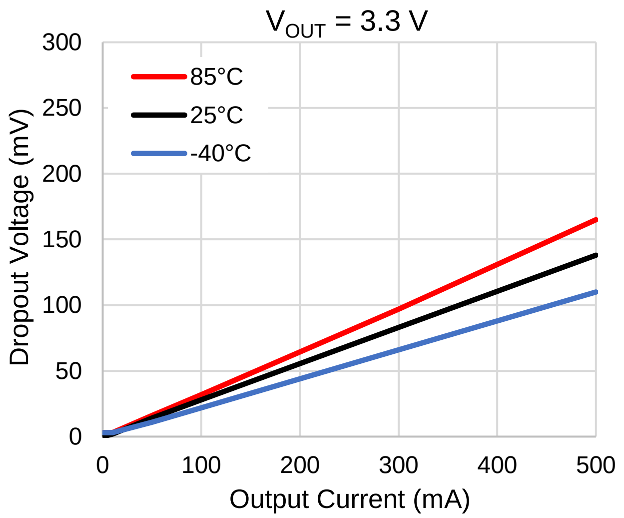


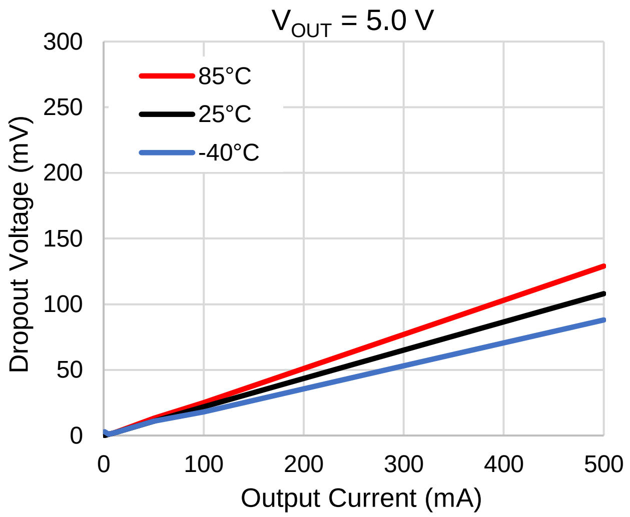


10.2. Dropout Voltage vs. Output Current

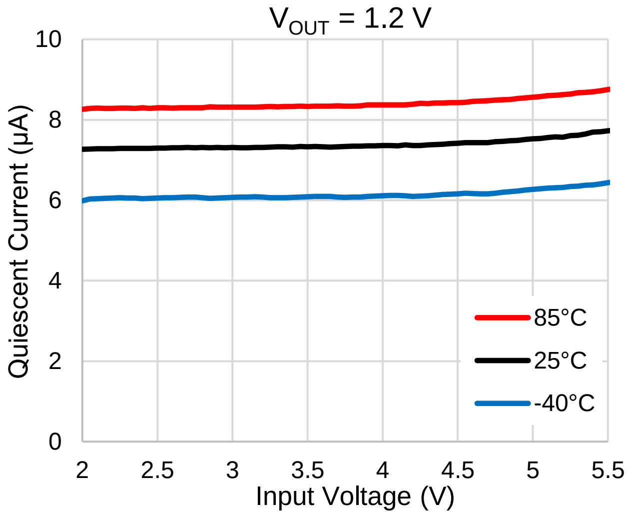


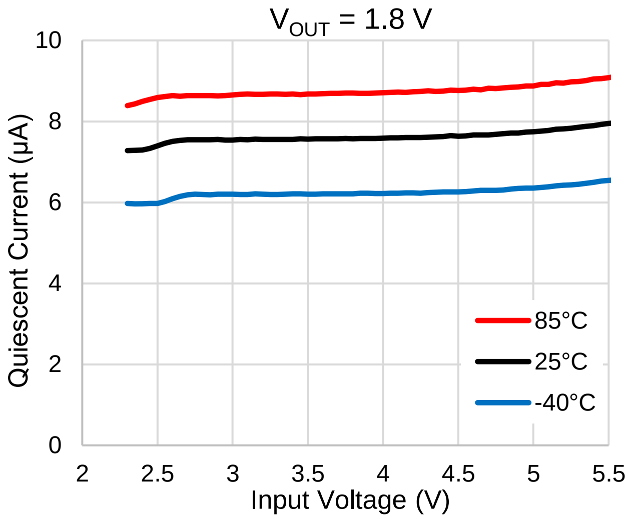


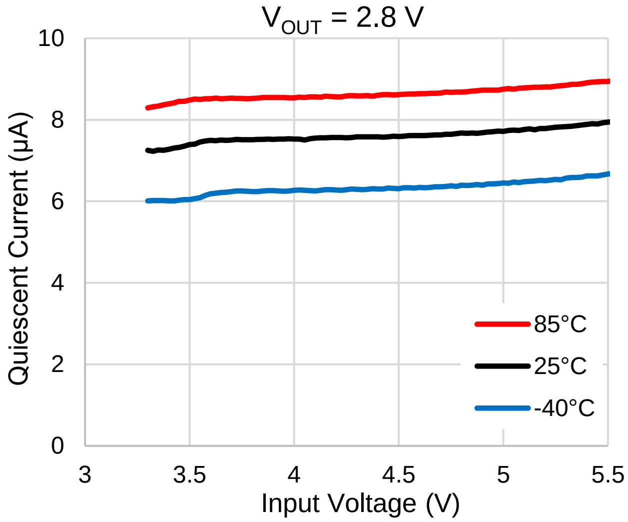




10.3. Quiescent Current vs. Input Voltage (I_{OUT} = 0 mA)

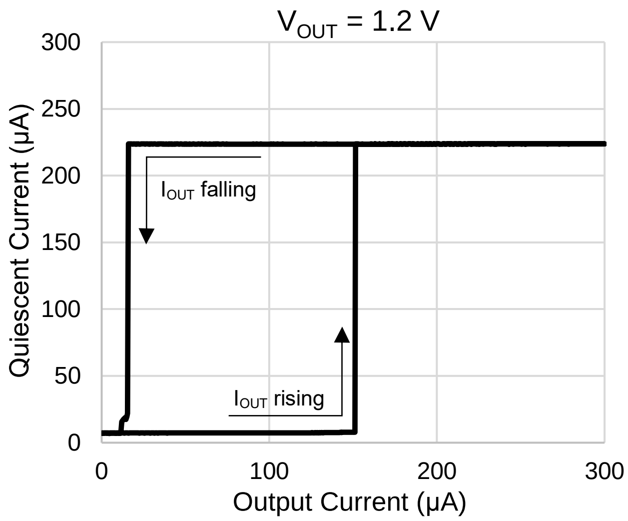


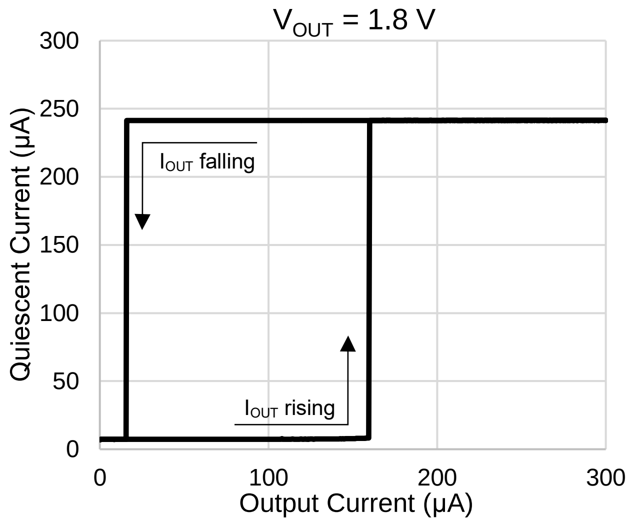


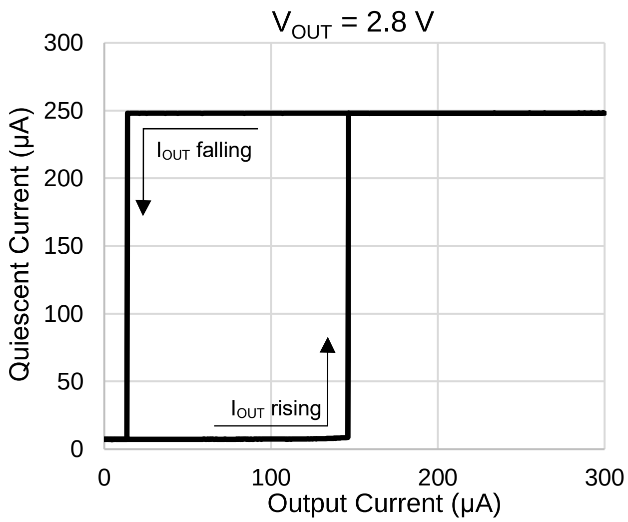


10.4. Quiescent Current vs. Output Current

(V_{IN} = 2.0 V or V_{OUT} + 0.5 V (whichever is greater), I_{OUT} = 0 A↔300 μA, T_a = 25°C)

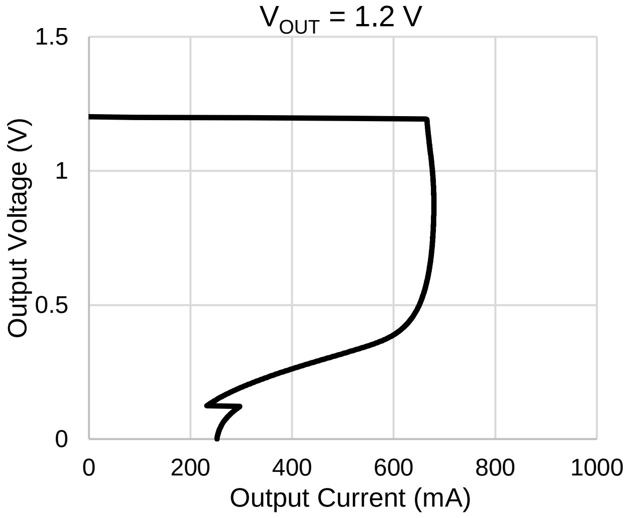


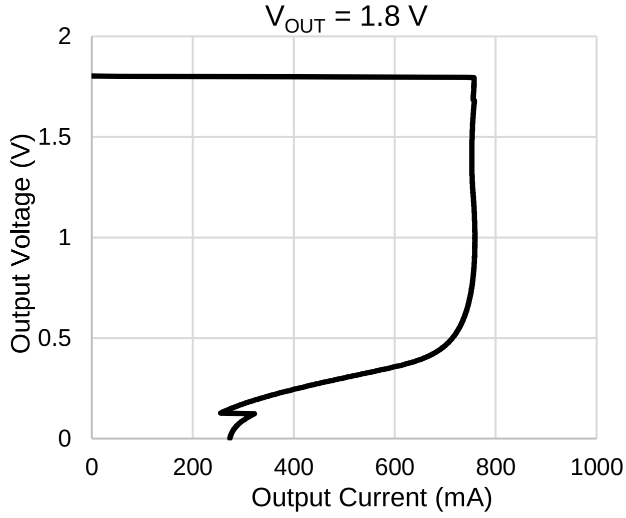


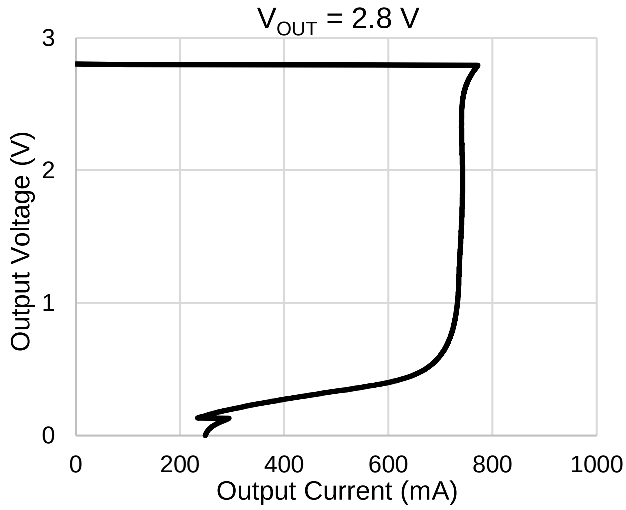


10.5. Output Current Limit

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

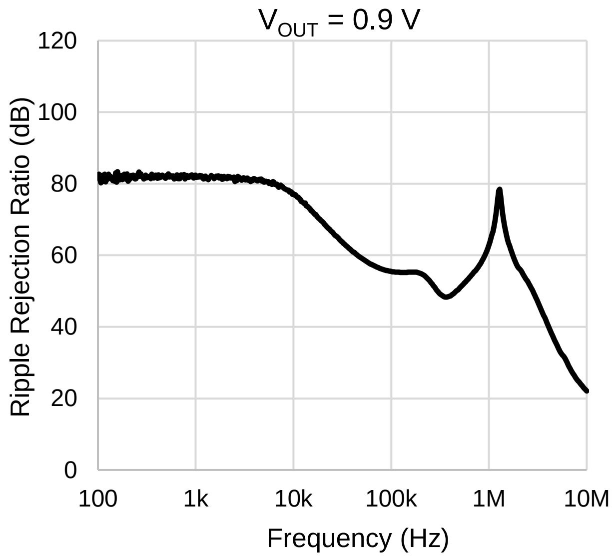


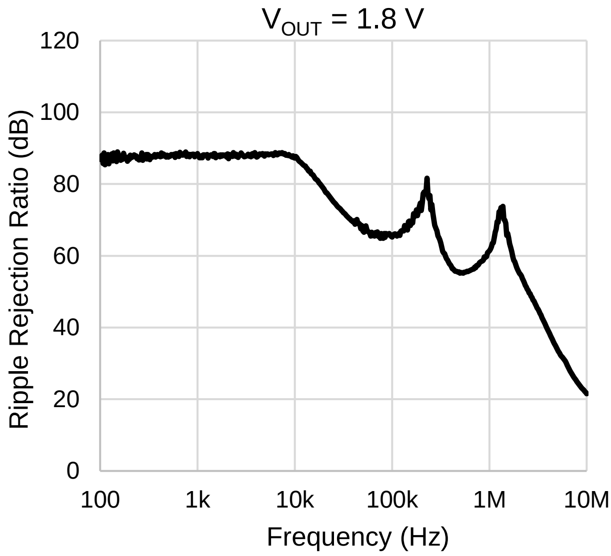


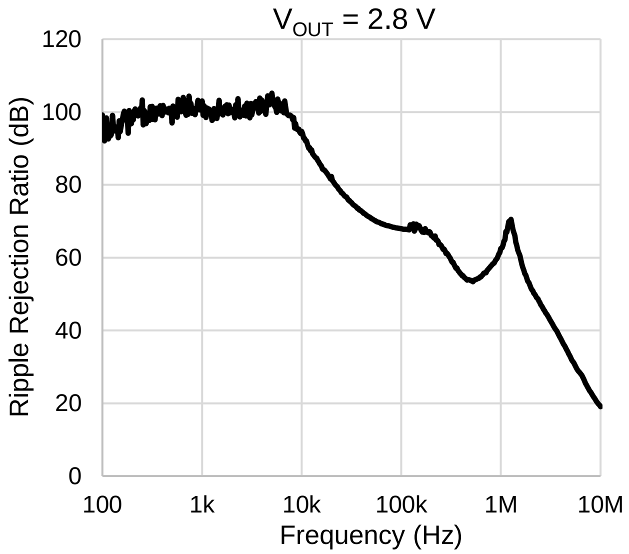


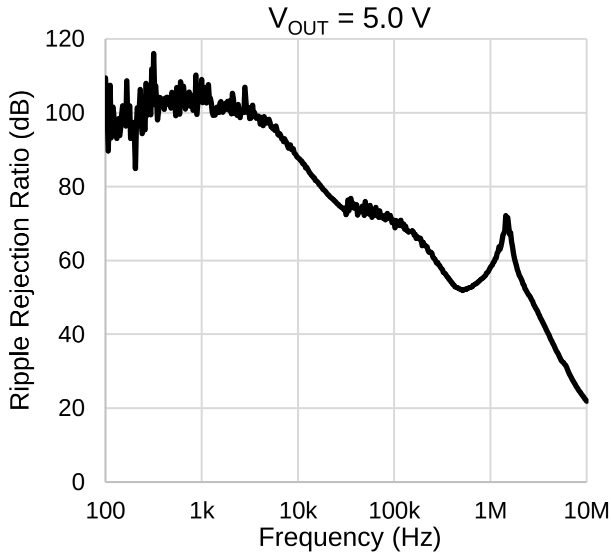
10.6. Ripple rejection Ratio vs. Frequency

(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)



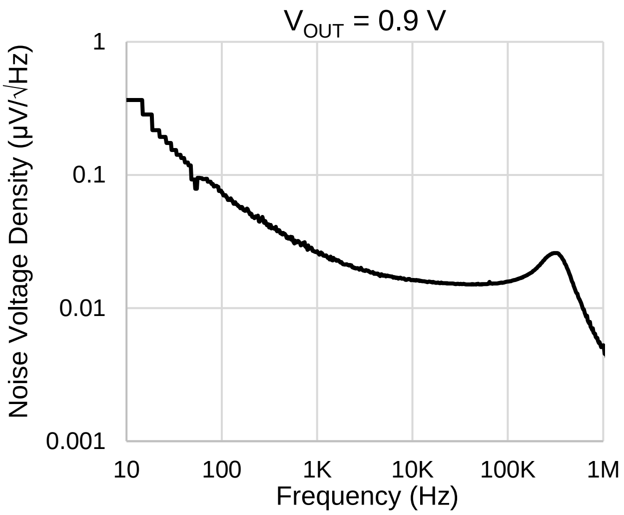


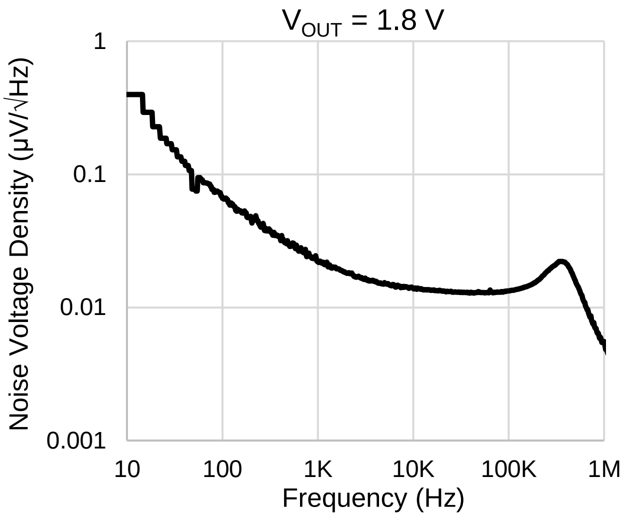


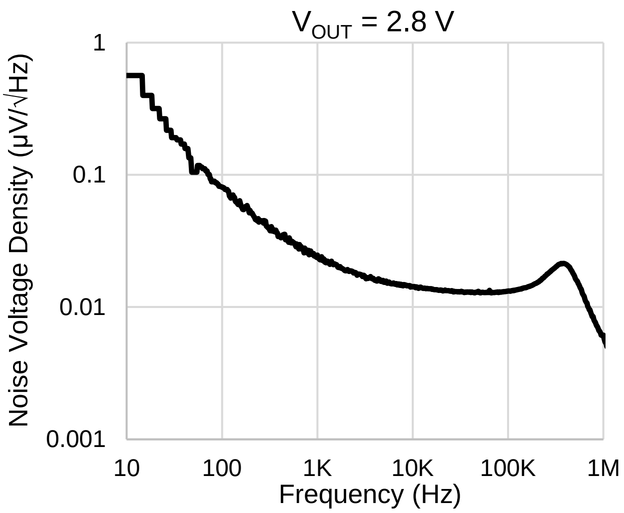


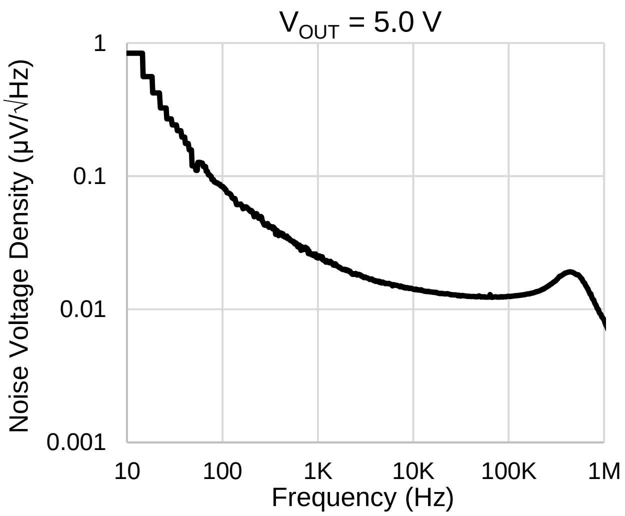
10.7. Output noise Voltage

(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)







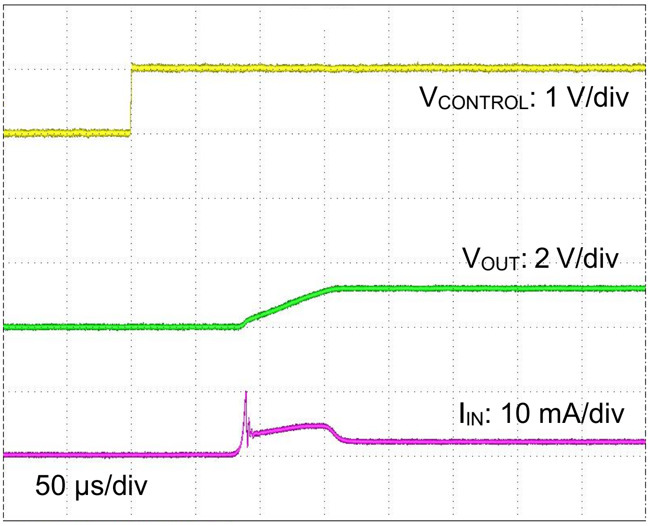


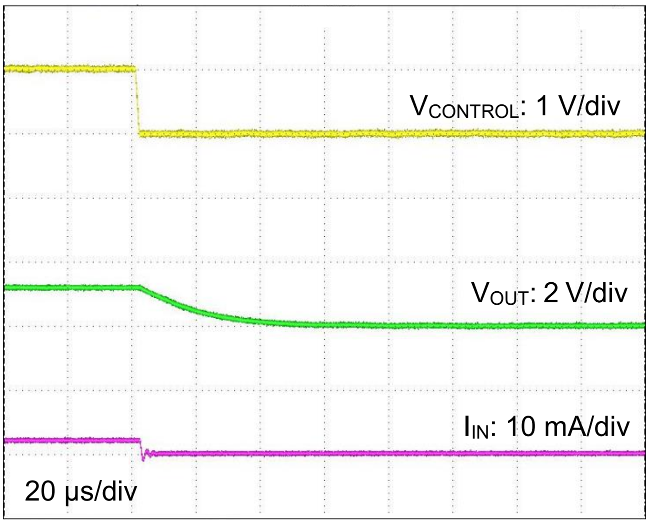
10.8. t_{ON} / t_{OFF} Response

(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)

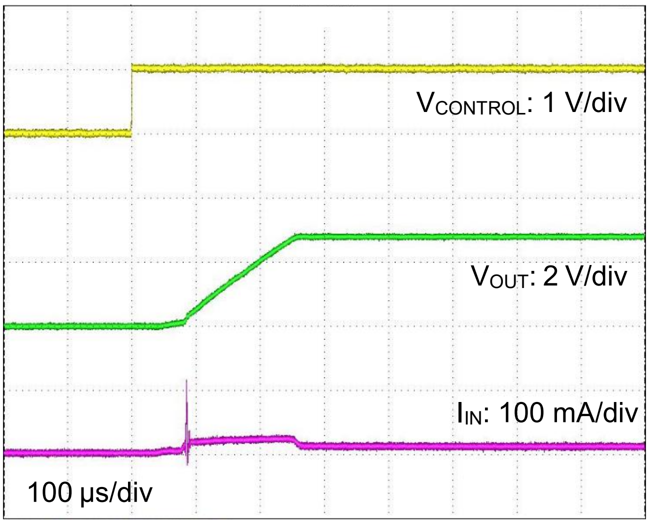
- **C_{OUT} = 1.0 μF, I_{OUT} = 10 mA**

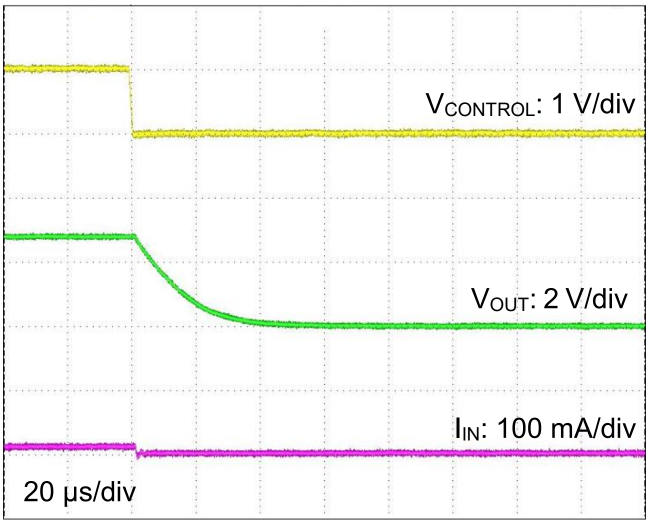
V_{OUT} = 1.2 V





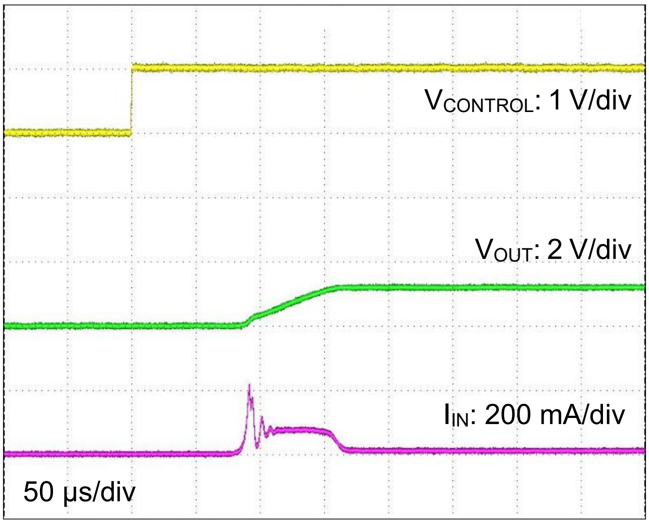
V_{OUT} = 2.8 V

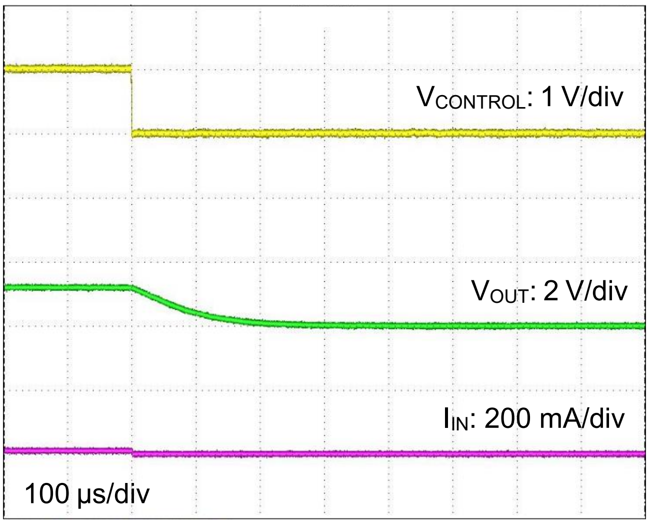




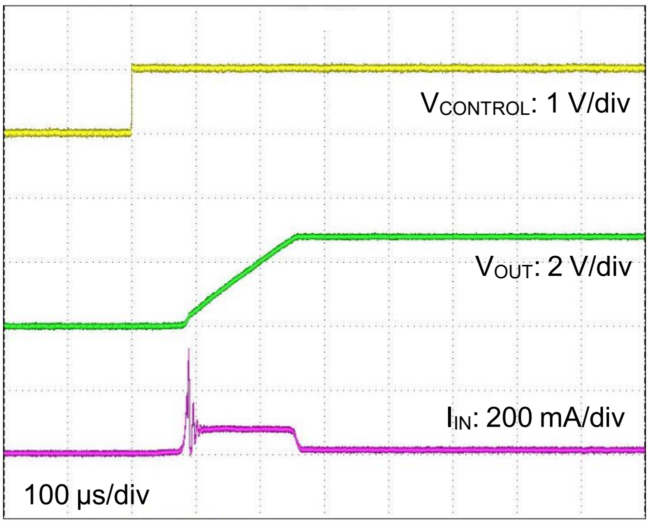
- **C_{OUT} = 4.7 μF, I_{OUT} = 10 mA**

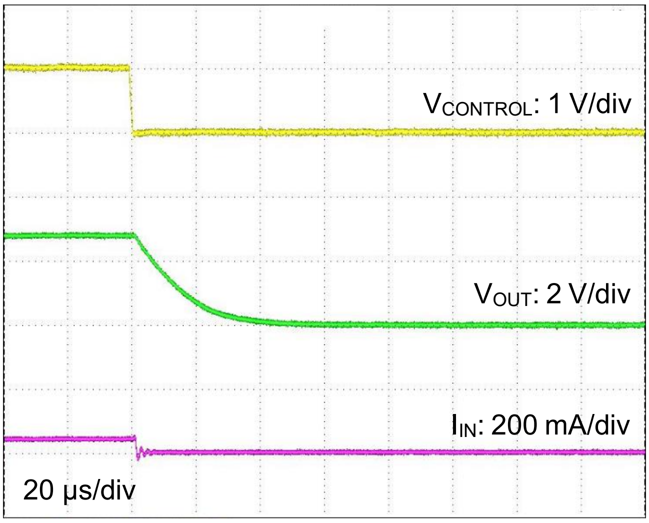
V_{OUT} = 1.2 V





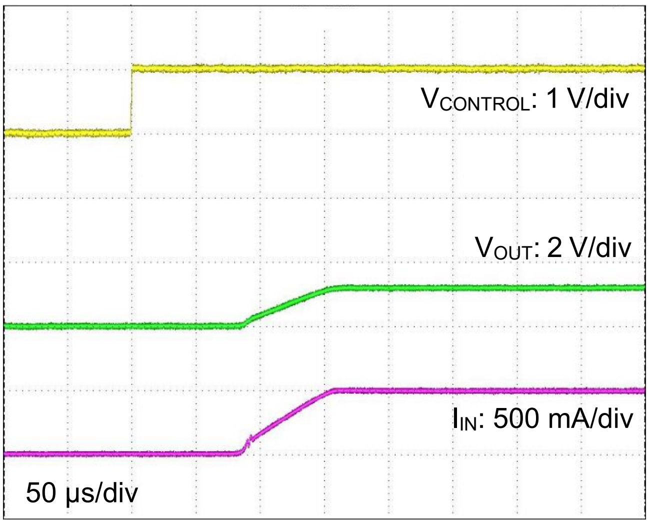
V_{OUT} = 2.8 V

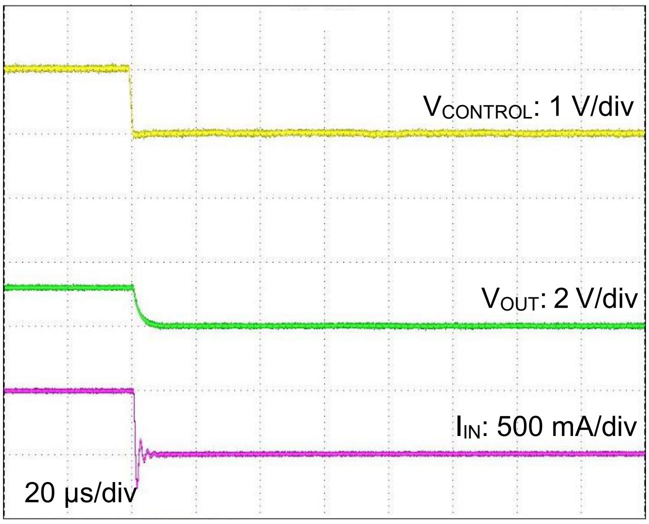




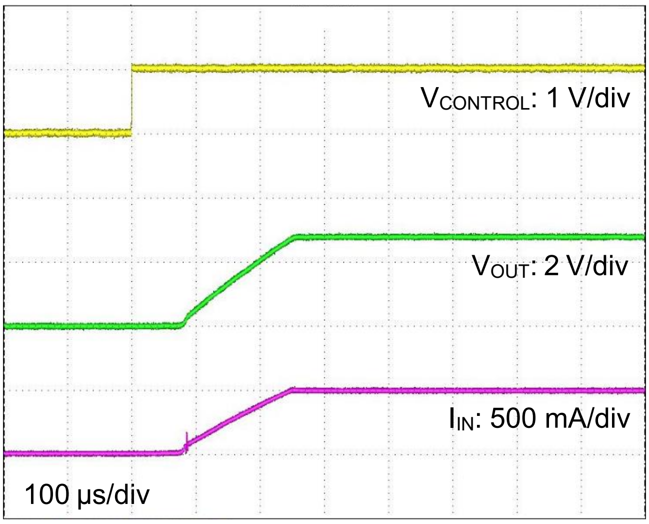
- **C_{OUT} = 1.0 μF, I_{OUT} = 500 mA**

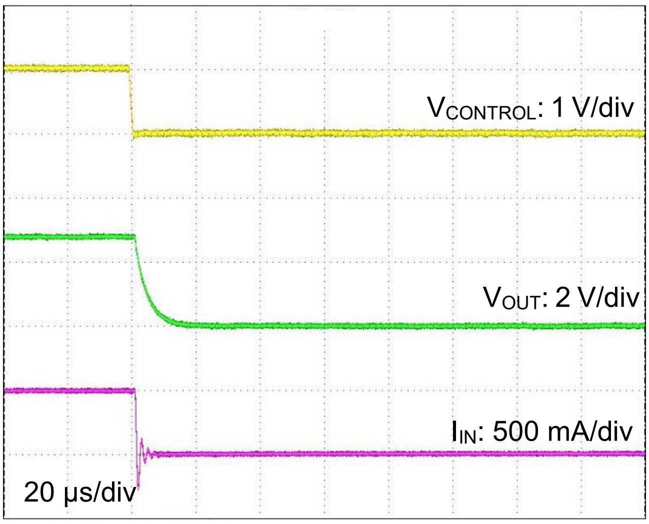
V_{OUT} = 1.2 V





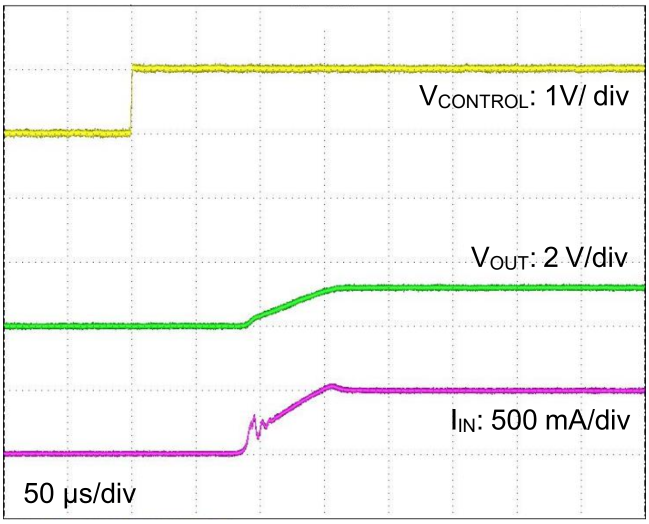
V_{OUT} = 2.8 V

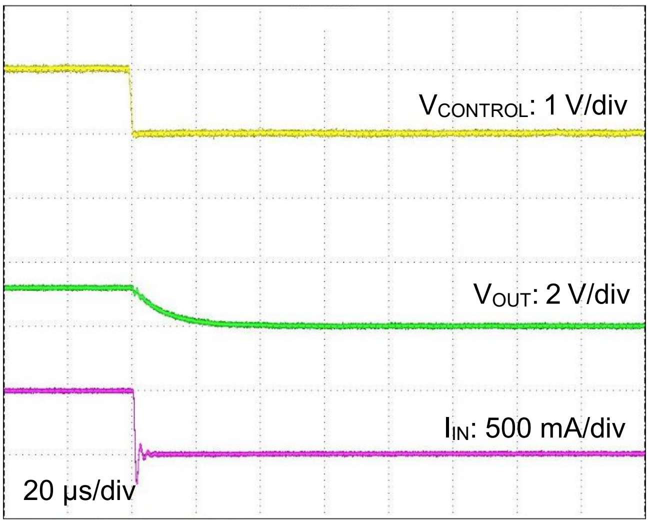




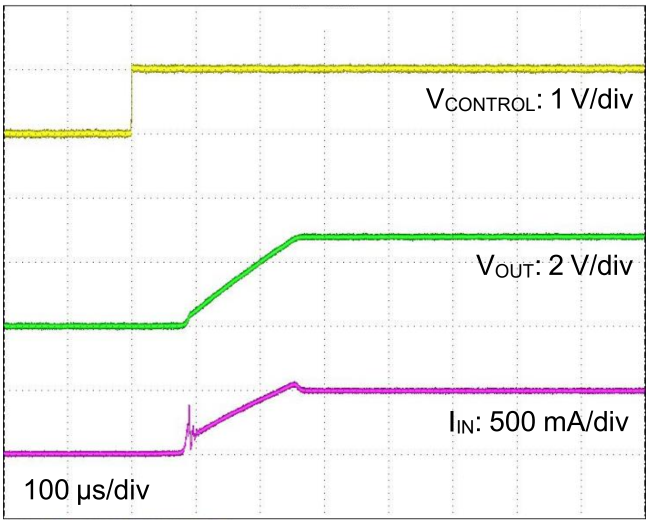
- **C_{OUT} = 4.7 µF, I_{OUT} = 500 mA**

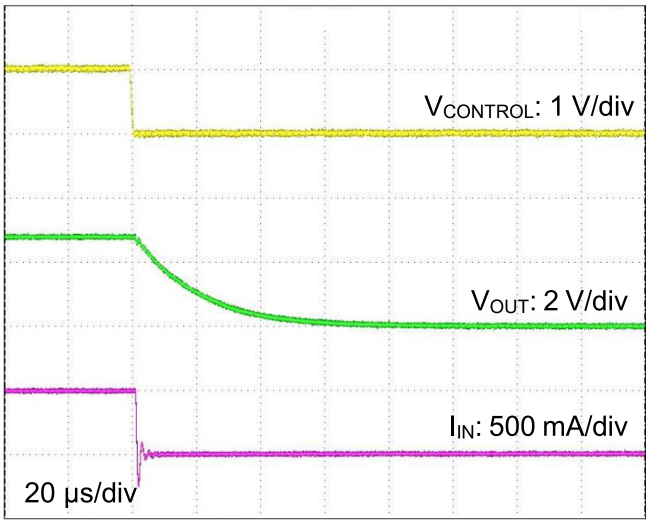
V_{OUT} = 1.2 V





V_{OUT} = 2.8 V

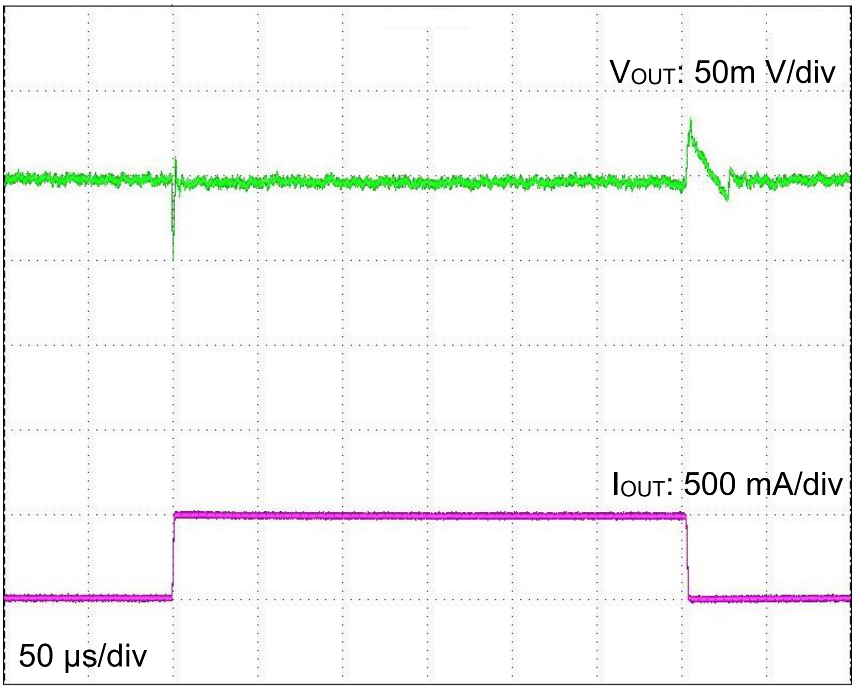




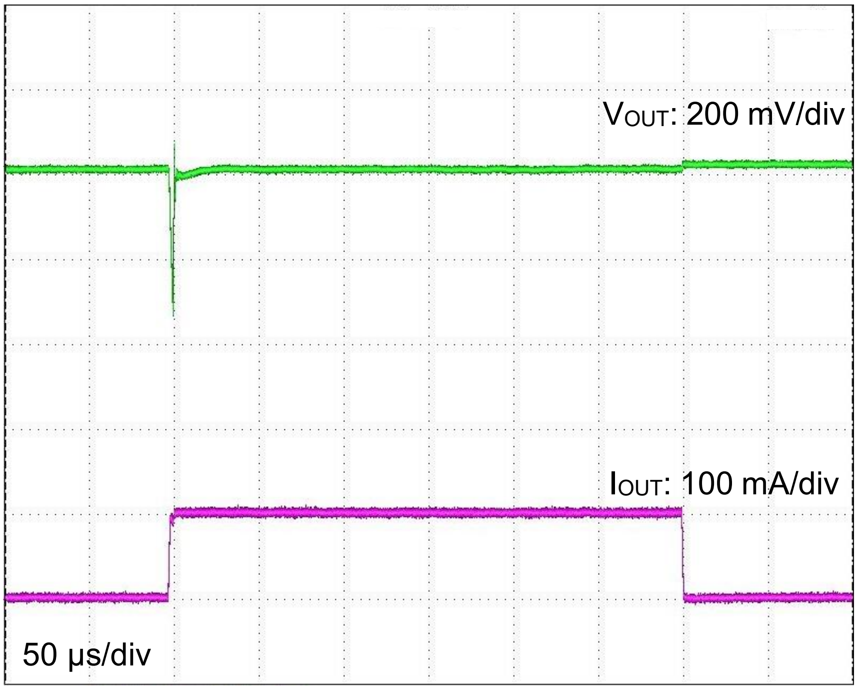
10.9. Load Transient Response

(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

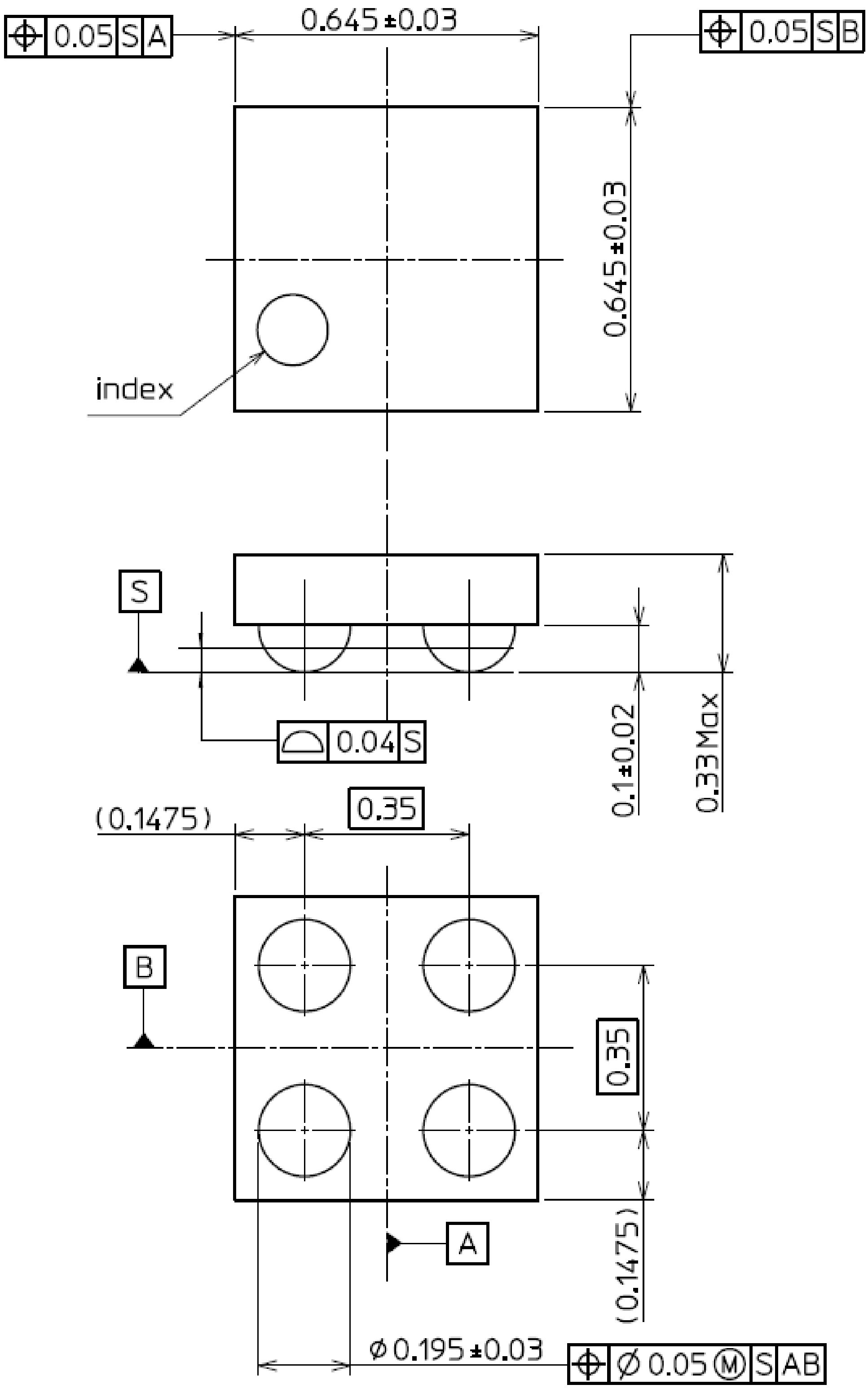


Note: The above characteristics curves are presented for reference only and not guaranteed by production test, unless otherwise noted.

11. Package Information

WCSP4F

Unit: mm



Weight: 0.26 mg (Typ.)

Figure 11.1 Package Dimensions

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