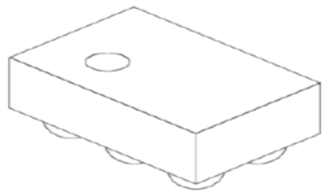
TOSHIBA CMOS Linear Integrated Circuit Silicon Monolithic

TCR13AGADJ

1.3 A CMOS Ultra Low Dropout Regulator

The TCR13AGADJ is CMOS single output voltage regulator with an on/off control input, featuring ultra low dropout voltage, low inrush current and fast load transient response.
This voltage regulator is available in output voltage adjustable type from 0.55 V to 3.6 V and capable of driving up to 1.3 A.
Other features include overcurrent protection, thermal shutdown, inrush current reduction, under voltage lockout and auto-discharge.
The TCR13AGADJ is offered in the ultra small package WCSP6F (0.8 mm x 1.2 mm (typ.), t: 0.33 mm (max))
As small ceramic input and output capacitors can be used with the TCR13AGADJ, this device is ideal for portable applications that require high-density board assembly such as cellular phones.


WCSP6F

Weight : 0.61 mg (typ.)

Features

- Low dropout voltage
  V_{DO} = 92 mV (typ.) at 0.9 V output, V_{BIAS} = 3.3 V, I_{OUT} = 1.0 A
  V_{DO} = 9.2 mV (typ.) at 0.9 V output, V_{BIAS} = 3.3 V, I_{OUT} = 0.1 A
- Wide range output voltage (Adjustable from 0.55 V to 3.6 V)
- Fast load transient response -100 / +115 mV (typ.) at 0.01 A⇔1 A, $C_{OUT} \geq$ 4.7 μF
- Overcurrent protection
- Thermal shutdown
- Inrush current reduction
- Under voltage lockout
- Soft start function
- Auto-discharge
- Pull down connection between CONTROL and GND
- Ultra small package WCSP6F (0.8 mm x 1.2 mm (typ.), t: 0.33 mm (max))
- Stable with over 4.7 μF Input capacitor, 1.0 μF Bias capacitor and 4.7 μF output ceramic capacitor

Notice

This device is sensitive to electrostatic discharge.
Please ensure equipment, operator and tools are adequately earthed when handling.

Start of commercial production
2016-11

Absolute Maximum Ratings (Ta = 25°C)

Characteristics	Symbol	Rating	Unit
Bias voltage	V_{BIAS}	6.0	V
Input voltage	V_{IN}	6.0	V
Control voltage	V_{CT}	-0.3 to 6.0	V
Adjustable voltage	V_{ADJ}	-0.3 to 6.0	V
Output voltage	V_{OUT}	-0.3 to V_{IN} + 0.3 ≤ 6.0	V
Power dissipation	P_D	1.9 (Note 1)	W
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).

Note 1: Rating at mounting on a board
(Glass epoxy board (FR4) dimension: 40 mm x 40 mm (4 layer), t = 1.8 mm
Metal pattern ratio: approximately 70 % each layer)

Operating Ranges

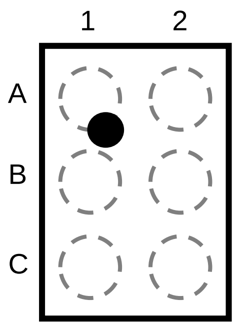
Characteristics	Symbol	Rating		Unit
Bias voltage	V_{BIAS}	V_{OUT} ≦ 1.1 V, I_{OUT} = 1 mA	2.5 to 5.5	V
		V_{OUT} > 1.1 V, I_{OUT} = 1 mA	V_{OUT} + 1.4 V to 5.5	
Input voltage	V_{IN}	V_{OUT} + 0.1 V to V_{BIAS} (Note 2)		V
Control voltage	V_{CT}	-0.3 to V_{BIAS}		V
Output voltage	V_{OUT}	0.55 to 3.6 (Note 3)		V
Output current	I_{OUT}	1.3 (Max) (Note 4)		A
Operation Temperature	T_{opr}	-40 to 85		°C
COUT	C_{OUT}	≥ 4.7μF		—
CIN	C_{IN}	≥ 4.7μF		—
CBIAS	C_{BIAS}	≥ 1.0μF		—

Note 2: I_{OUT} = 1 mA.
Please refer to Dropout voltage vs. Output current(Page 12), and use it within Absolute Maximum Ratings Junction temperature and Operation Temperature Ranges.

Note 3: Output voltage adjustable type. Please refer to Application Note (Page 7).

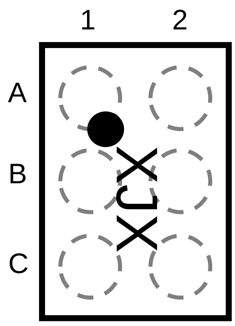
Note 4: Do not operate at or near the maximum ratings of operating ranges for extended periods of time. Exposure to such conditions may adversely impact product reliability and results in failures not covered by warranty.
Maximum output current of operating ranges table is defined as lifetime average junction temperature of +45℃ where maximum output current = lifetime average current to avoid electro migration.

Pin Assignment (top view)

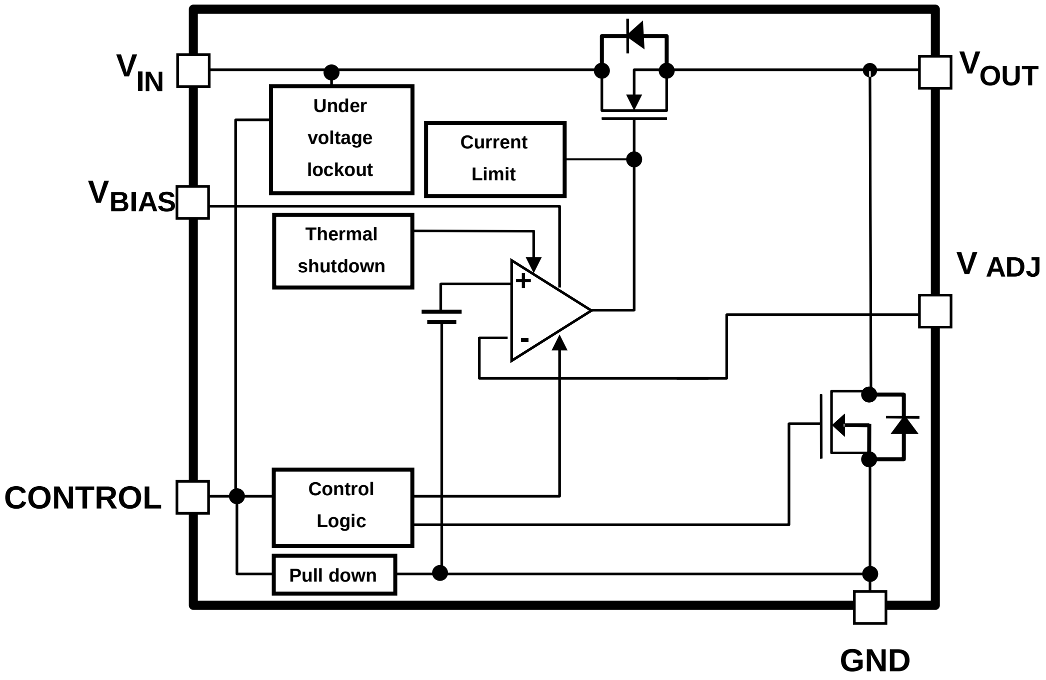


	1	2
A	V_{OUT}	V_{IN}
B	V_{ADJ}	CONTROL
C	GND	V_{BIAS}

Top Marking (top view)



Block Diagram



Operation Logic table

Control inputs	Output voltage(V)
High	V_{OUT}
Low	0 V (Output discharge)

Electrical Characteristics

(Unless otherwise specified, $V_{IN} = V_{OUT} + 0.5$ V, $I_{OUT} = 50$ mA, $C_{IN} = 4.7$ μF, $C_{BIAS} = 1.0$ μF, $C_{OUT} = 4.7$ μF)

Characteristics	Symbol	Test Condition	$T_j = 25°C$			$T_j = -40$ to 85°C (Note 8)		Unit
			Min	Typ.	Max	Min	Max	
Bias voltage	V_{BIAS}	$V_{OUT} \leq 1.1$ V, $I_{OUT} = 1$ mA	2.5	—	5.5	2.5	5.5	V
		$V_{OUT} > 1.1$ V, $I_{OUT} = 1$ mA	V_{OUT} + 1.4 V	—	5.5	V_{OUT} + 1.4 V	5.5	V
Input voltage	V_{IN}	$I_{OUT} = 1$ mA (Note 5)	V_{OUT} + 0.1 V	—	V_{BIAS}	V_{OUT} + 0.1 V	V_{BIAS}	V
Adjustable voltage	V_{ADJ}	—	0.490	0.500	0.510	—	—	V
Line regulation	Reg·line	$V_{OUT} + 0.5$ V $\leq V_{IN} \leq 5.5$ V, $I_{OUT} = 1$ mA	—	1	15	—	—	mV
Load regulation	Reg·load	0.01 A $\leq I_{OUT} \leq$ 1 A	—	2	—	—	—	mV
Quiescent current	I_B	$I_{OUT} = 0$ mA, $V_{BIAS} = 2.5$ V (Note 6)	—	56	72	—	92	μA
Stand-by current	$I_{BIAS\ (OFF)}$	$V_{CT} = 0$ V	—	0.1	—	—	1	μA
	$I_{IN(OFF)}$	$V_{CT} = 0$ V (Note 6)	—	0.8	—	—	2	μA
Control pull down current	I_{CT}	—	—	0.1	—	—	—	μA
Dropout voltage	V_{DO}	$I_{OUT} = 1$ A, $V_{BIAS} = 3.3$ V (Note 7)(Note 9)	—	92	—	—	163	mV
Under voltage lockout	V_{UVLO}	V_{IN} voltage	—	0.5	—	—	0.65	V
Temperature coefficient	T_{CVO}	-40°C ≦ T_{opr} ≦ 85°C	—	60	—	—	—	ppm/°C
Output noise voltage	V_{NO}	$V_{BIAS} = 5.5$ V, $V_{IN} = V_{OUT} + 1$ V, $I_{OUT} = 10$ mA, 10 Hz ≦ f ≦ 100 kHz, (Note 7)	—	52	—	—	—	μV_{rms}
Ripple rejection ratio	R.R.(V_{IN})	$V_{BIAS} = 5.5$ V, $V_{IN} = V_{OUT} + 1$ V, $I_{OUT} = 10$ mA, f = 1 kHz, $V_{IN\ Ripple} = 200$ mV_{p-p}, (Note 7)	—	90	—	—	—	dB
	R.R.(V_{BIAS})	$V_{BIAS} = 5.5$ V, $V_{IN} = V_{OUT} + 1$ V, $I_{OUT} = 10$ mA, f = 1 kHz, $V_{BIAS\ Ripple} = 200$ mV_{p-p}, (Note 7)	—	50	—	—	—	dB
Load transient response	⊿V_{OUT}	I_{OUT}=0.01 A → 1 A	—	-100	—	—	—	mV
		I_{OUT}=1 A → 0.01 A	—	+115	—	—	—	mV
Control voltage (ON)	$V_{CT\ (ON)}$	—	1.0	—	5.5	1.0	5.5	V
Control voltage (OFF)	$V_{CT\ (OFF)}$	—	0	—	0.4	0	0.4	V
Output discharge on resistance	R_{SD}	—	—	20	—	—	—	Ω

Note 5: Please refer to Dropout voltage vs. Output current (Page 12), and use it within Absolute Maximum Ratings Junction temperature and Operation Temperature Ranges.

Note 6: This parameter is tested at $V_{OUT} = 0.9$ V.
Control pull down current and external resistors current not included in this parameter.

Note 7: This parameter is tested at $V_{OUT} = 0.9$ V.

Note 8: This parameter is warranted by design.

Note 9: $V_{DO} = V_{IN1} - (V_{OUT1} - 100$ mV)
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 100 mV drop of V_{OUT1} after gradually decreasing the input voltage

t_{ON} t_{OFF} Characteristics (Ta = 25°C)

V_{OUT} = 1.0 V

Characteristics	Symbol	Test Condition (Figure 1)	Min	Typ.	Max	Unit
Turn on delay	t_{ON}	V_{IN} = 1.235 V , V_{BIAS} = 3.3 V , I_{OUT} = No Load C_{IN} = 4.7 μF, C_{BIAS} = 1.0 μF, C_{OUT} = 4.7 μF	—	135	—	μs
Turn off delay	t_{OFF}	V_{IN} = 1.235 V , V_{BIAS} = 3.3 V , I_{OUT} = No Load C_{IN} = 4.7 μF, C_{BIAS} = 1.0 μF, C_{OUT} = 4.7 μF	—	230	—	μs

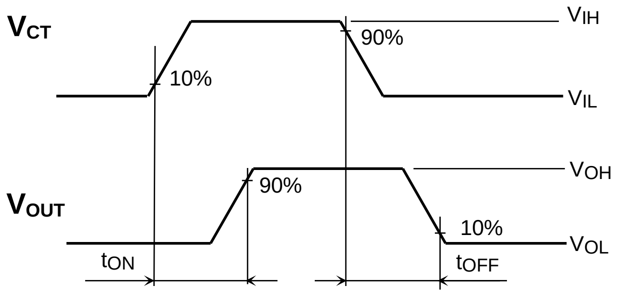
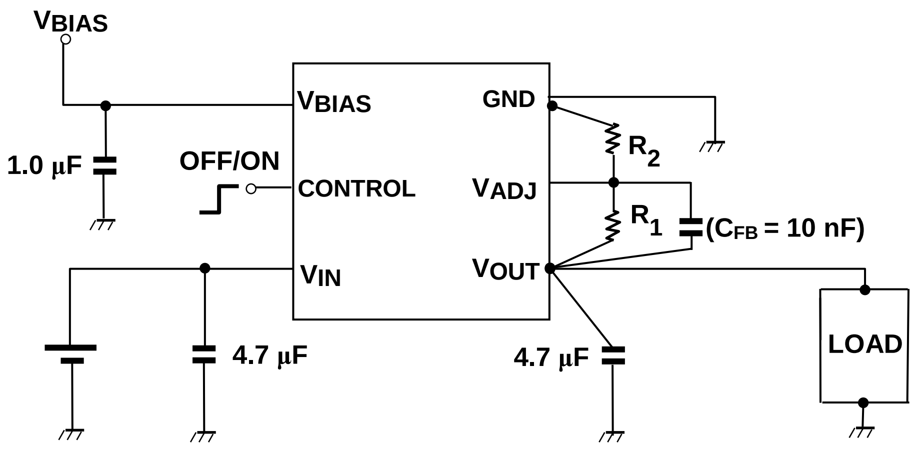


Figure 1 t_{ON}, t_{OFF} Waveforms

Application Note

1. Example of Application Circuit



The figure above shows the recommended configuration for using a Low-Dropout regulator. Please connect over 4.7µF capacitor at V_{IN} and V_{OUT} pins, and over 1µF capacitor at V_{BIAS} pin, as close as possible to each pins for stable input/output operation. (Ceramic capacitors can be used). But simple usage of large input capacitance is known to form unwanted LC resonance in combination with input wire inductance. So please check parameter with the actual device and circuit.

C_{FB} is optional capacitance that improve Transient response, Output noise, Oscillation resistance, PSRR and Overshoot. However, it does not necessarily need.

V_{ADJ} is the output voltage control pin. Typical V_{ADJ} value is 0.5 V. For best performance R1 and R2 should have similar temperature coefficients, otherwise output voltage accuracy will be compromised.

$$V_{OUT} = V_{ADJ} \times \left(1 + \frac{R1}{R2}\right)$$

Reference resistance table

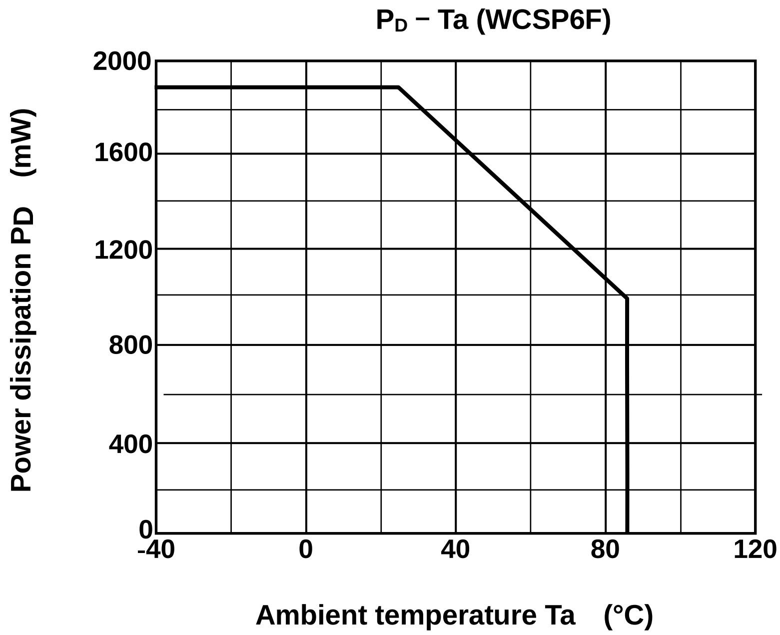
This is reference data. Please check parameter with the actual device and circuit.

Output voltage (typ.)	R1	R2
0.6 V	4 kΩ	20 kΩ
0.7 V	8 kΩ	20 kΩ
0.8 V	12 kΩ	20 kΩ
0.9 V	16 kΩ	20 kΩ
1.0 V	20 kΩ	20 kΩ
1.1 V	24 kΩ	20 kΩ
1.2 V	28 kΩ	20 kΩ
1.3 V	32 kΩ	20 kΩ
1.8 V	52 kΩ	20 kΩ
3.6 V	124 kΩ	20 kΩ

2. Power Dissipation

Board-mounted power dissipation ratings for TCR13AGADJ is 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 (4 layer), t = 1.8 mm
Metal pattern ratio: approximately 70 % each layer,



Please allow sufficient margin when designing a board pattern to fit the expected power dissipation. Also take into consideration the ambient temperature, input voltage, output current etc. and applying the appropriate derating for allowable power dissipation during operation.

Attention in Use

- Capacitors(Output, Input, and Bias Capacitor)
  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. For stable operation, please use over 4.7 μF input capacitor, 1.0 μF bias capacitor and 4.7 μF output ceramic capacitor.

- Mounting
  The long distance between IC and each 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 V_{IN} and GND pattern need to be large and make the wire impedance small as possible.

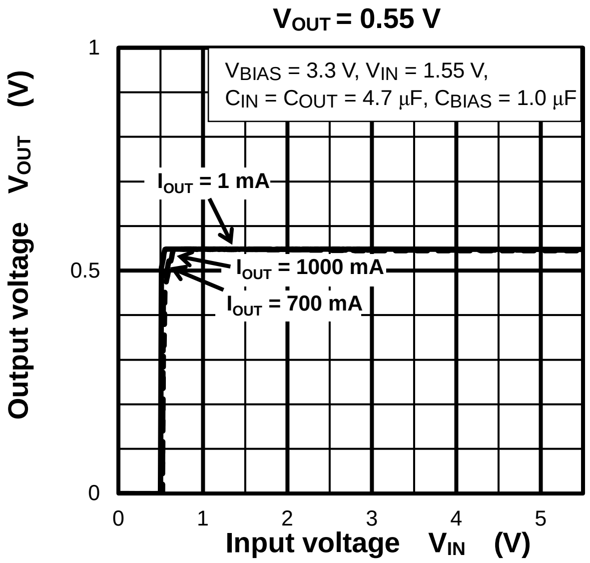
- Permissible Loss
  Please have enough design patterns for expected maximum permissible loss. And under consideration of ambient temperature, input voltage, and output current etc, we recommend proper dissipation ratings for maximum permissible loss; in general maximum dissipation rating is 70 to 80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

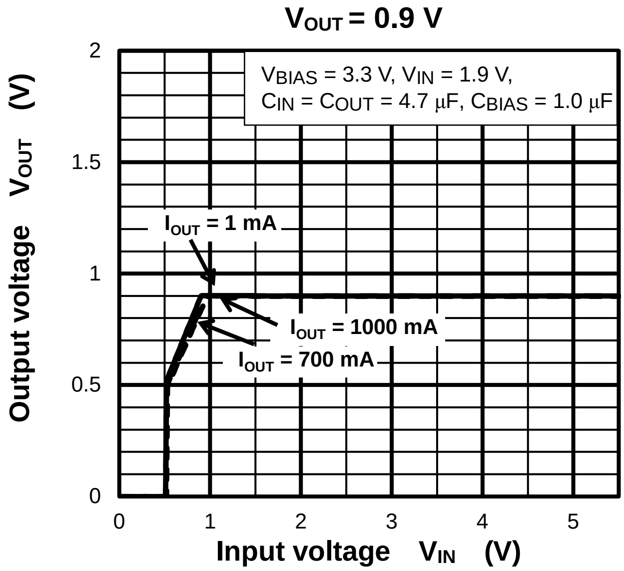
- Overcurrent Protection and Thermal shutdown
  Overcurrent protection and Thermal shutdown are designed in these products, but these are not designed to constantly ensure the suppression of the device within operation limits. Depending on the condition during actual usage, it could affect the electrical characteristic specification and reliability. Also note that if output pins and GND pins are not completely shorted out, these products might 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.

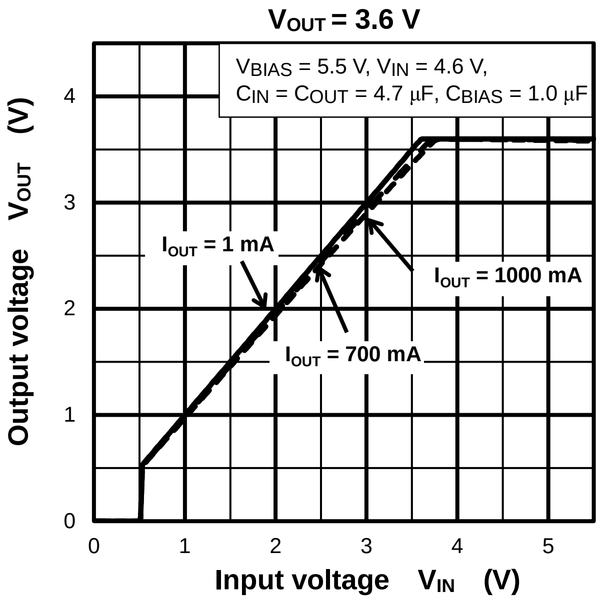
- Adjustable output voltage type
  TCR13AGADJ is adjustable output voltage type. V_{ADJ} is the output voltage control pin, please refer to example of application circuit and reference resistance table. Please select the tolerance of the resistance value in accordance by the system. In addition, please assemble R1 and R2 to minimize common impedance. For V_{ADJ} assembly,
  please design PCB pattern as short as possible to avoid noise effect.

Representative Typical Characteristics

Output voltage vs. Input voltage



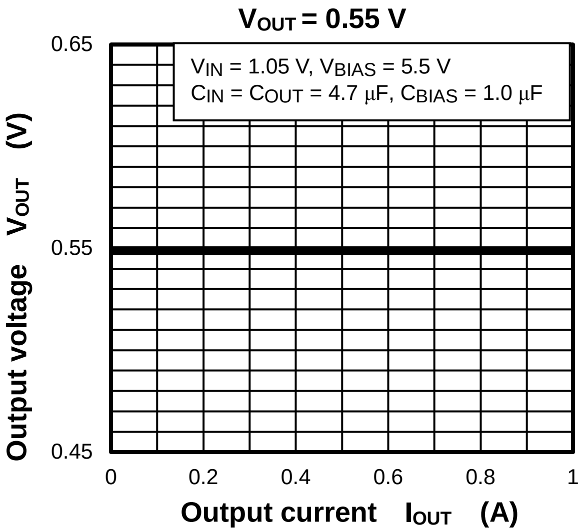


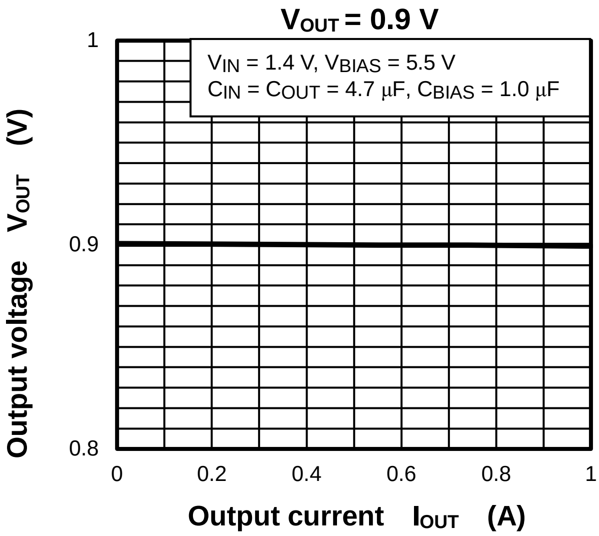


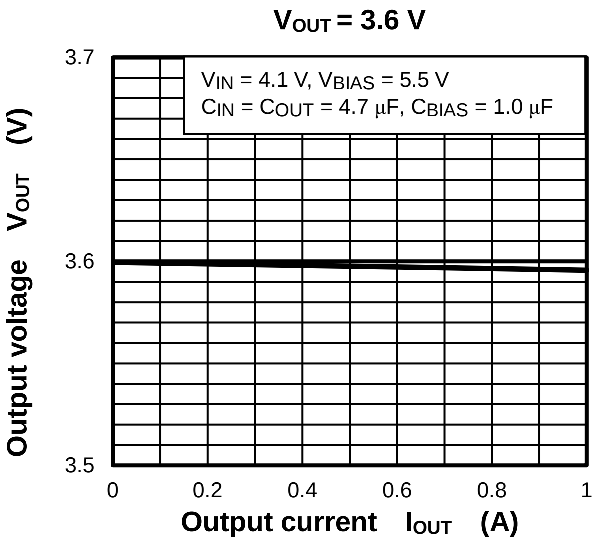
Note: The above characteristics curves are presented for reference only and not guaranteed by production test, unless otherwise noted.

Representative Typical Characteristics

Output voltage vs. Output current







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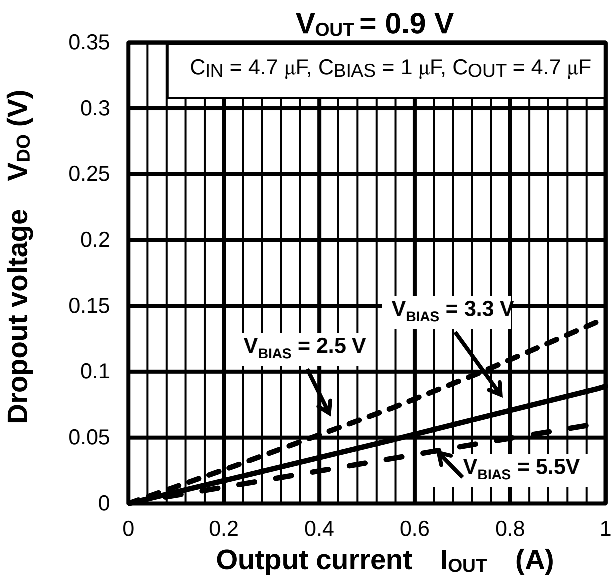
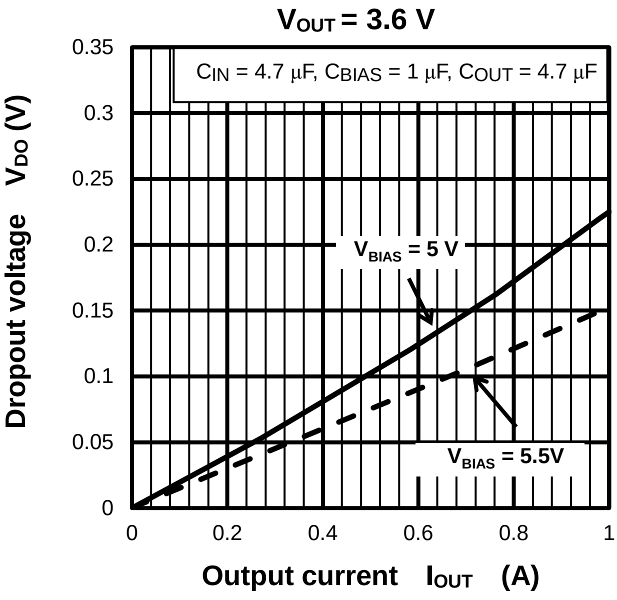
Representative Typical Characteristics

Dropout voltage vs. Output current

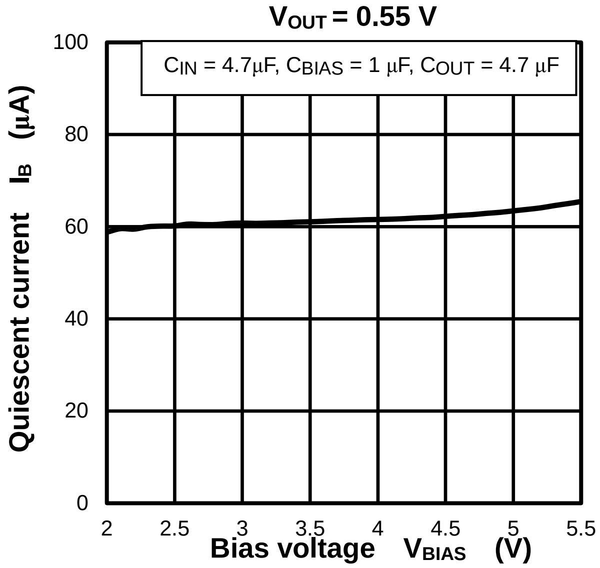


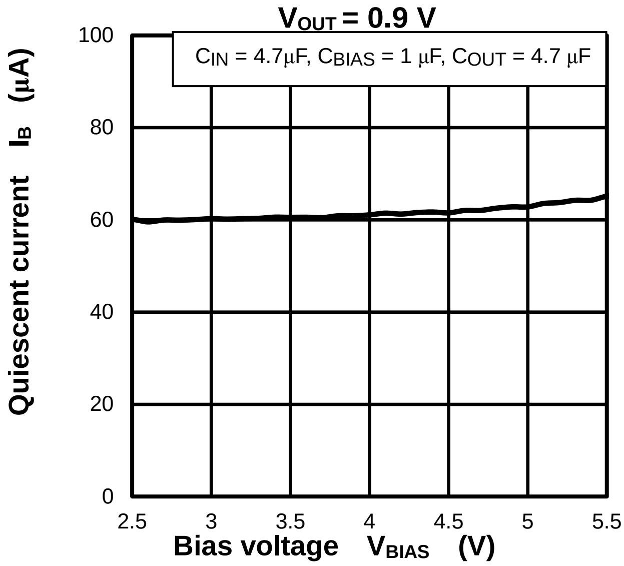


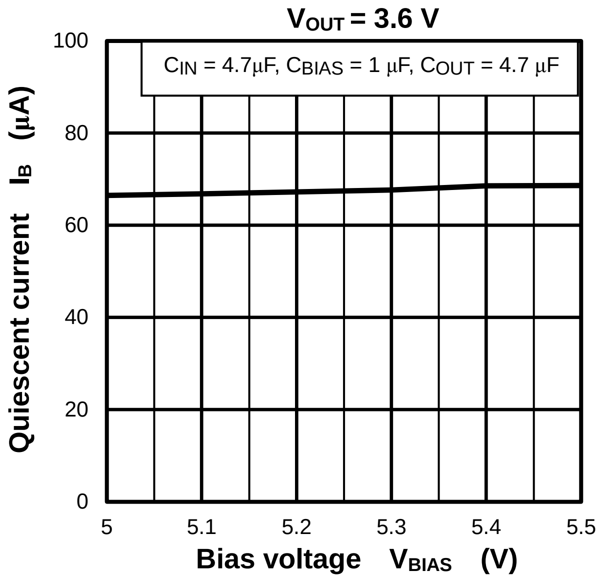
Note: The above characteristics curves are presented for reference only and not guaranteed by production test, unless otherwise noted.

Representative Typical Characteristics

Quiescent current vs. Input voltage







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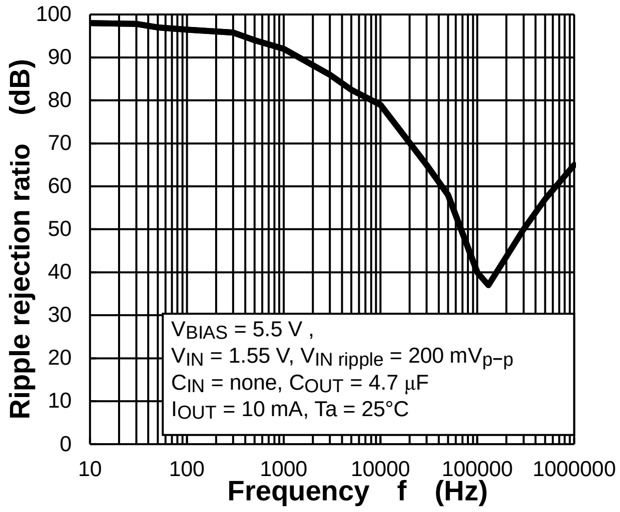
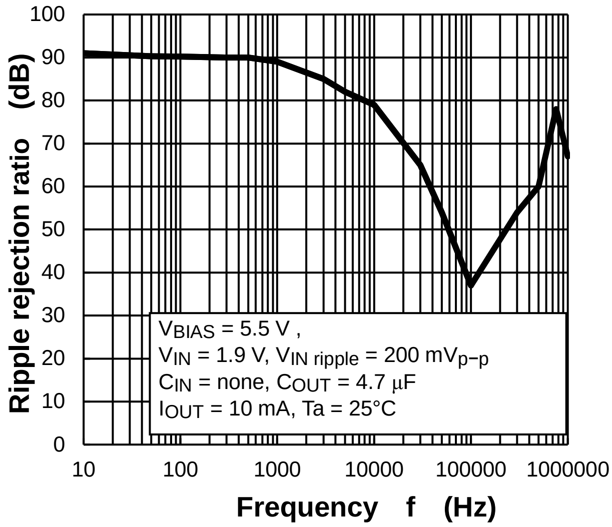
Representative Typical Characteristics

Ripple rejection ratio vs. Frequency

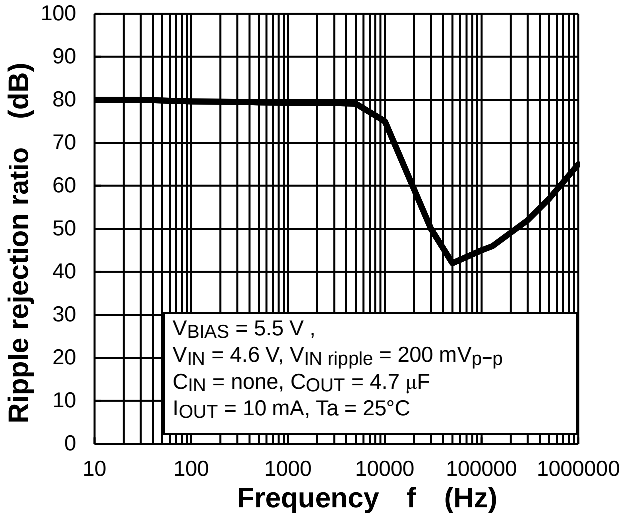
V_{OUT} = 0.55 V



V_{OUT} = 0.9 V

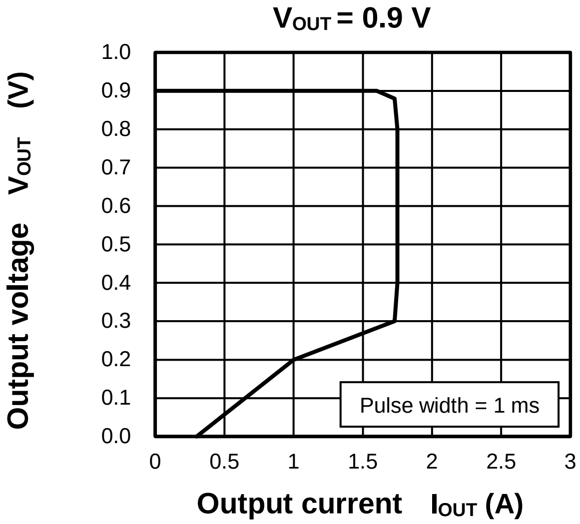


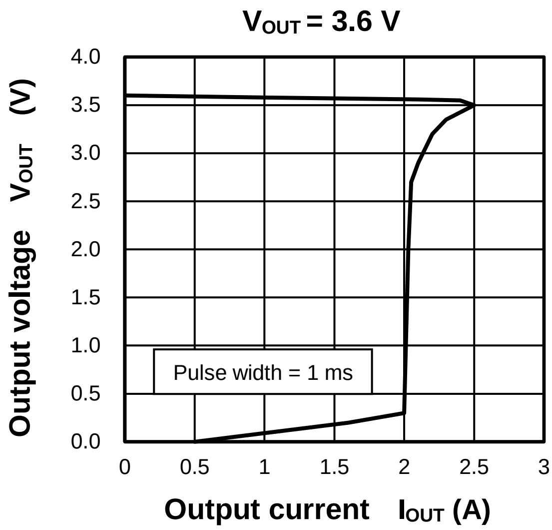
V_{OUT} = 3.6 V



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

Output voltage vs. Output current (Simulation data)

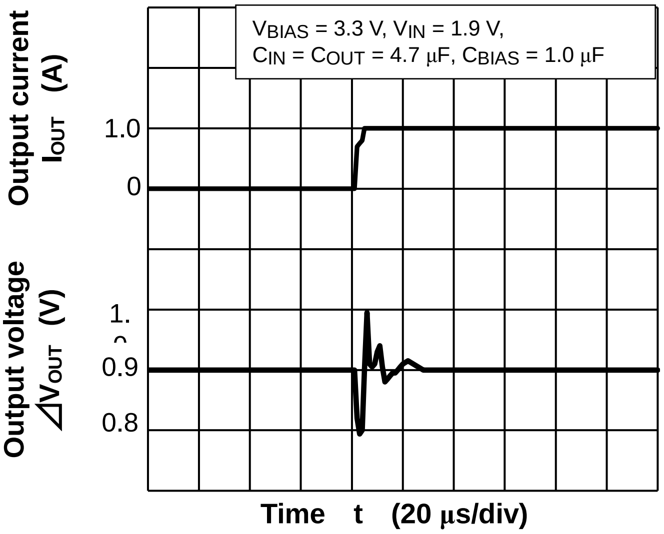




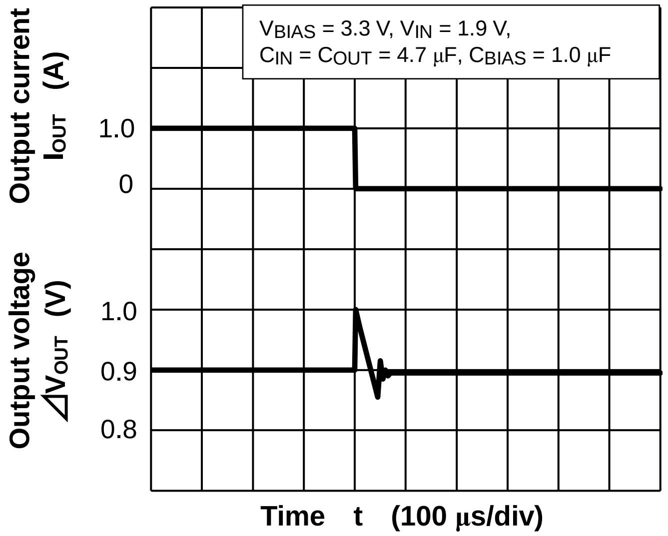
Note: The above characteristics curves are presented for reference only and not guaranteed by production test, unless otherwise noted.

Load transient response

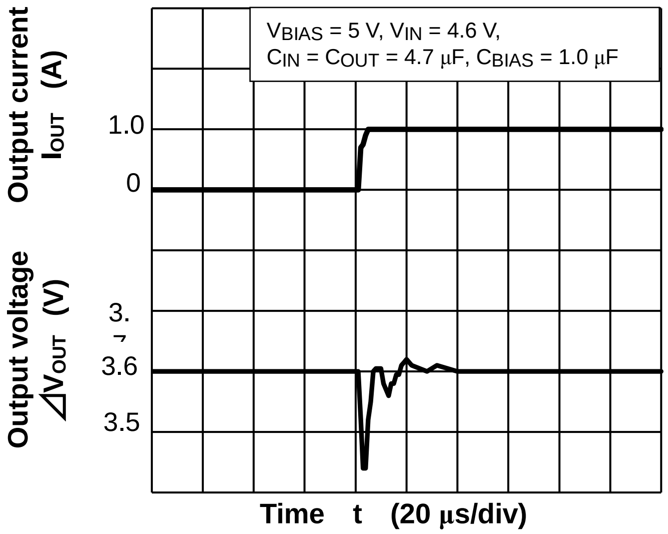
V_{OUT} = 0.9 V
(I_{OUT} = 1 mA ⇔ 1 A)



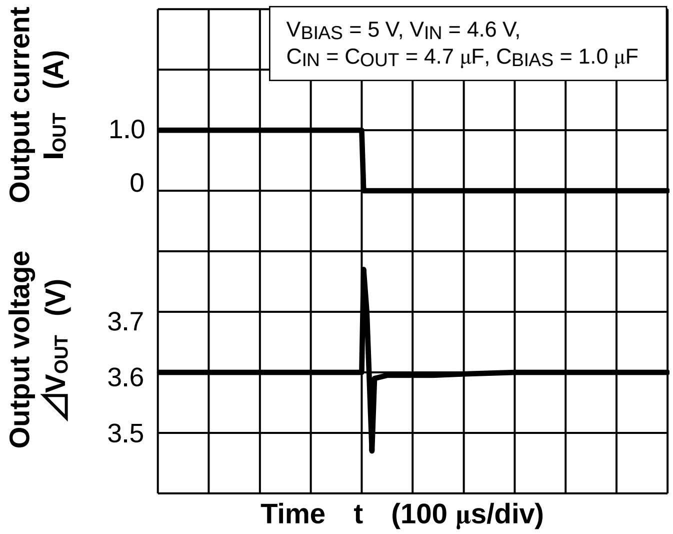
V_{OUT} = 0.9 V
(I_{OUT} = 1 mA ⇔ 1A)



V_{OUT} = 3.6 V
(I_{OUT} = 1 mA ⇔ 1 A)



V_{OUT} = 3.6 V
(I_{OUT} = 1 mA ⇔ 1 A)



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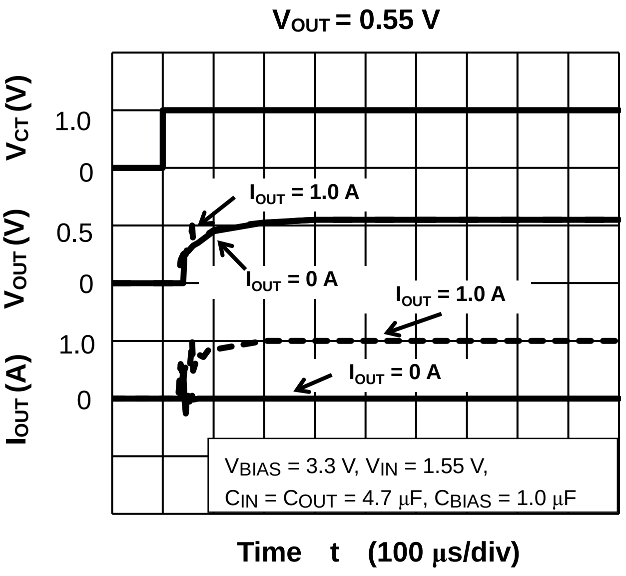
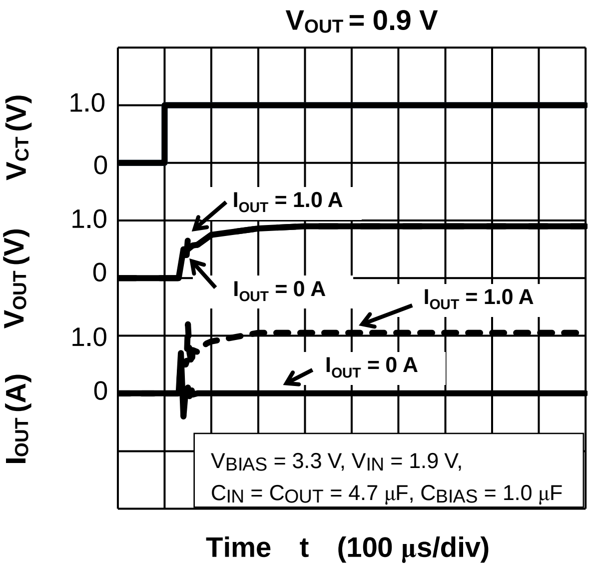
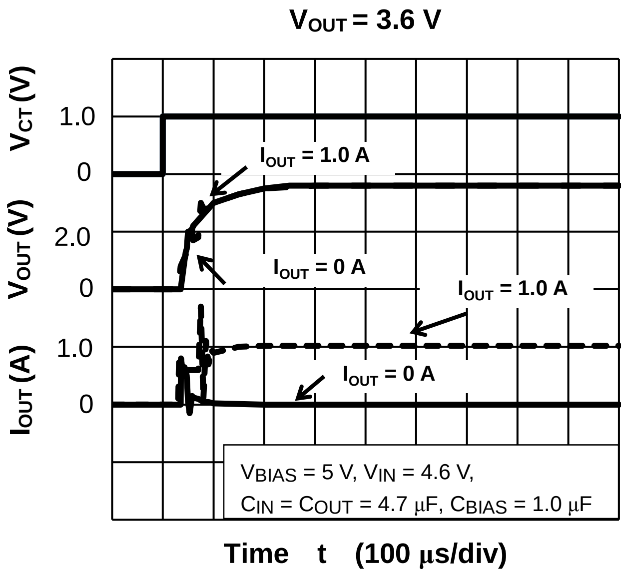
t_{ON} Response







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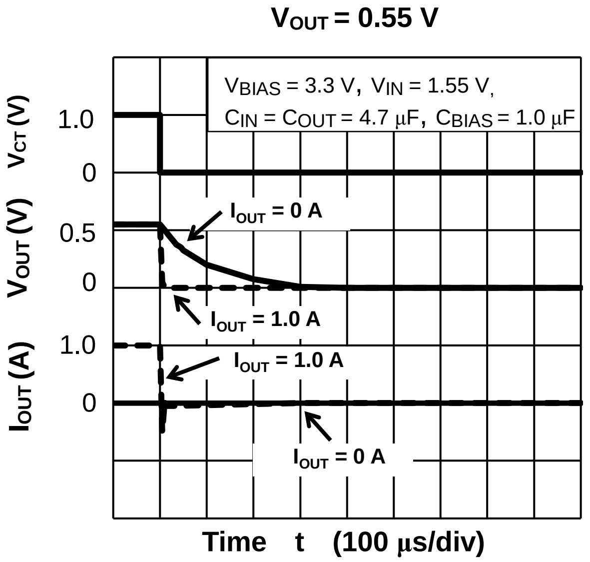
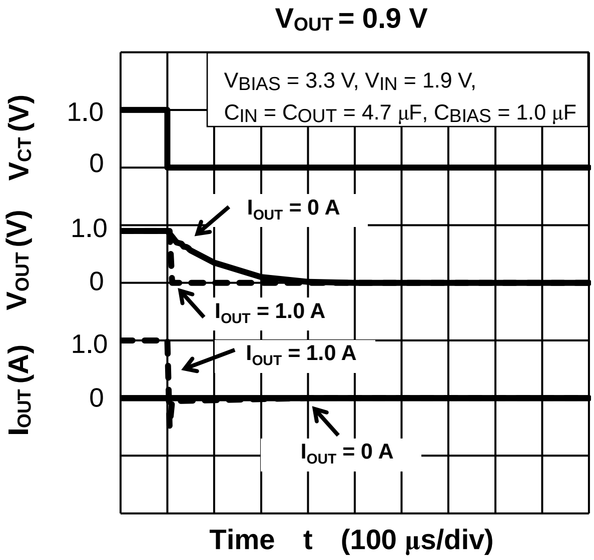
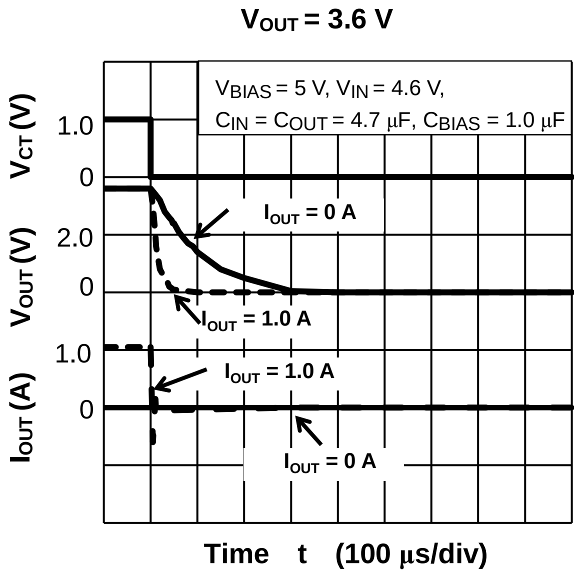
t_{OFF} Response





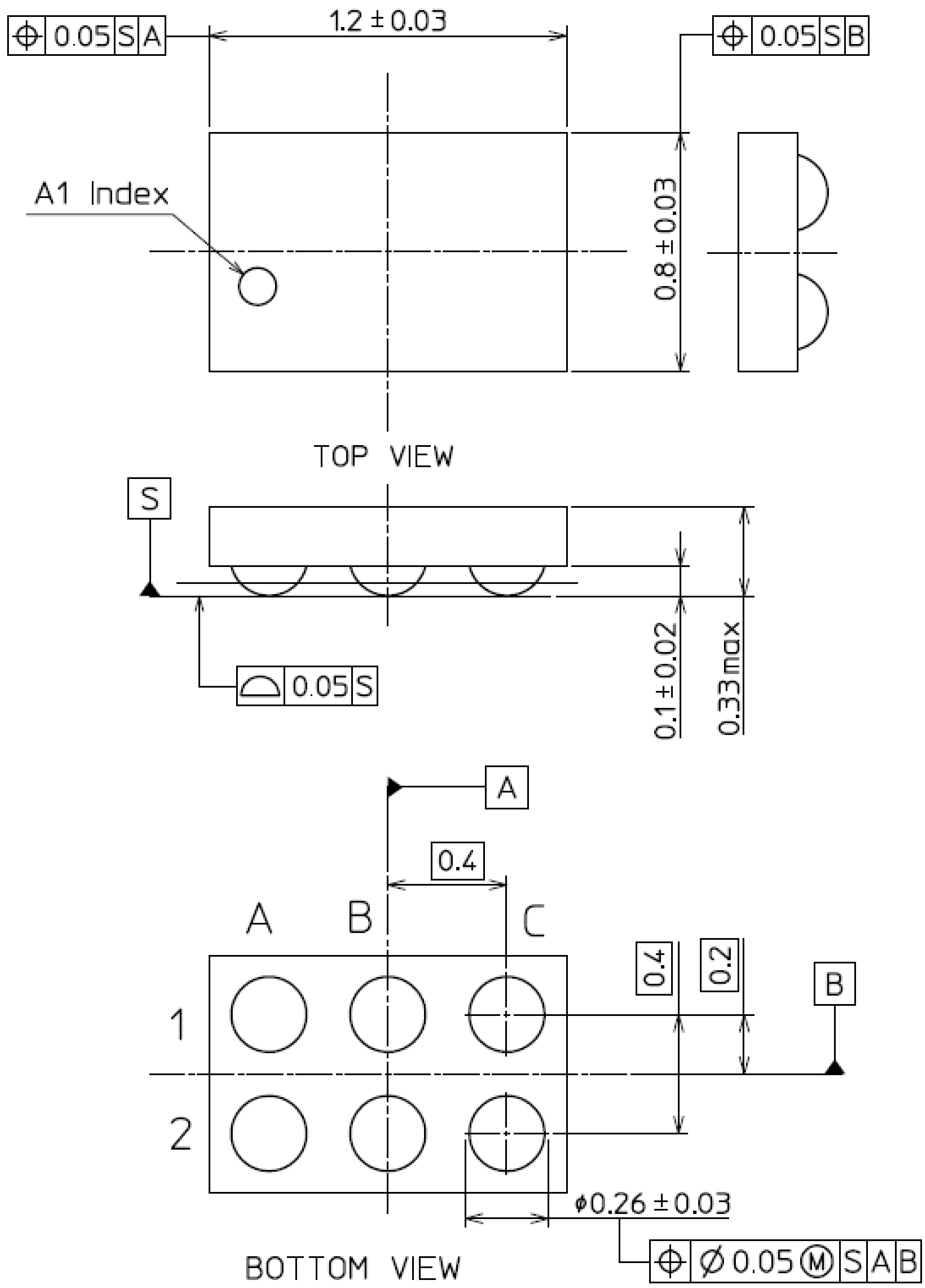


Note: The above characteristics curves are presented for reference only and not guaranteed by production test, unless otherwise noted.

Package Dimensions

WCSP6F

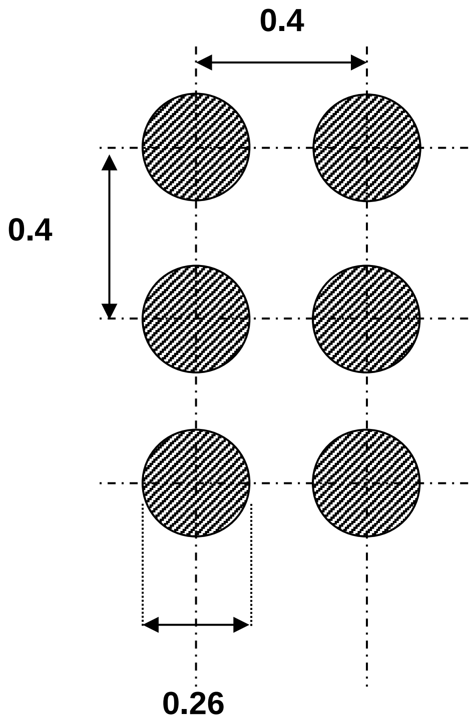
Unit: mm



Weight : 0.61 mg (typ.)

Land pattern dimensions for reference only

WCSP6F



Unit: mm

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