LDO with Reverse Current Protection / Soft Start / Discharge Function

■ GENERAL DESCRIPTION

The NJM12888 is a low dropout regulator which achieves high ripple rejection, low noise and high speed response with the bipolar technology.

Adjustable soft-start function is useful for reducing inrush current and controlling power-on sequence. Moreover the discharge function makes effective sequence control with the soft-start function.

In addition, the reverse current protection makes external SBD unnecessary.

■ PACKAGE OUTLINE



NJM12888KG1

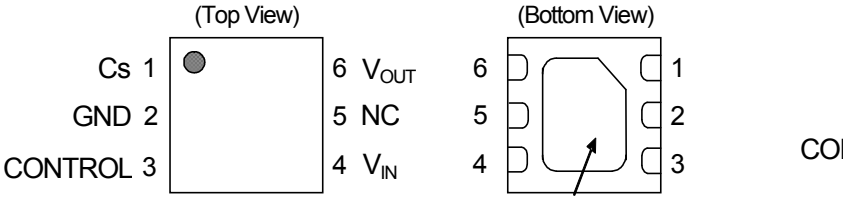


NJM12888F

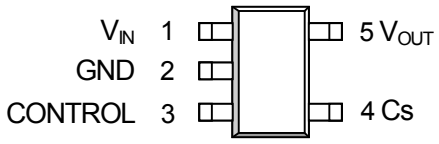
■ FEATURES

- Operating Voltage Range 2.3V to 6.5V
- Output Voltage Accuracy V_O ±1.0%
- Output Current I_O(min.)=300mA
- Reverse Current Protection
- Adjustable soft-start Function
- Discharge Function
- ON/OFF Control
- Correspond to Low ESR capacitor (MLCC)
- Thermal Shutdown Circuit
- Over Current Protection Circuit
- Package Outline DFN6-G1(ESON6-G1), SOT-23-5

■ PIN CONFIGRATION

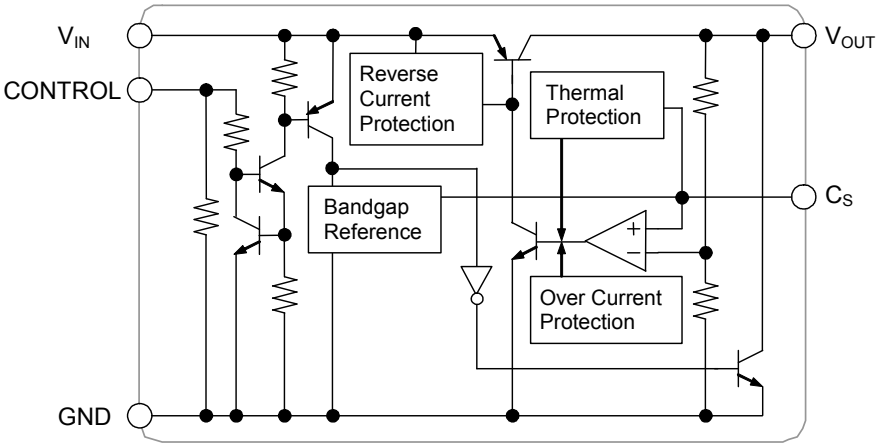


NJM12888KG1



NJM12888F

■ BLOCK DIAGRAM



■ OUTPUT VOLTAGE RANK LIST

DFN6-G1(ESON6-G1), SOT-23-5

Device Name	Output Voltage	Device Name	Output Voltage
NJM12888KG1-15	1.5V	NJM12888F15	1.5V
NJM12888KG1-18	1.8V	NJM12888F18	1.8V
NJM12888KG1-25	2.5V	NJM12888F25	2.5V
NJM12888KG1-33	3.3V	NJM12888F33	3.3V
NJM12888KG1-05	5.0V	NJM12888F05	5.0V

■ ABSOLUTE MAXIMUM RATINGS (Ta=25°C)

PARAMETER	SYMBOL	MAXIMUM RATING		UNIT
Input Voltage	V_{IN}	-0.3 ~ +7		V
Control Pin Voltage	V_{CONT}	-0.3 ~ +7		V
Output Voltage	V_{OUT}	Vo≤1.8V	-0.3 ~ +5.5	V
		Vo>1.8V	-0.3 ~ +7	V
Soft start Pin Voltage	V_{CS}	-0.3 ~ +4		V
Power Dissipation	P_D	DFN6-G1 (ESON6-G1)	420(*1)	mW
			1200(*2)	
		SOT-23-5	480(*3)	
			650(*4)	
Junction Temperature Range	Tj	-40 ~ +150		°C
Operating Temperature Range	Topr	-40 ~ +125		°C
Storage Temperature Range	Tstg	-50 ~ +150		°C

(*1): Mounted on glass epoxy board. (101.5×114.5×1.6mm: based on EIA/JEDEC standard, 2Layers FR-4, with Exposed Pad)

(*2): Mounted on glass epoxy board. (101.5×114.5×1.6mm: based on EIA/JEDEC standard, 4Layers FR-4, with Exposed Pad)
(For 4Layers: Applying 99.5×99.5mm inner Cu area and a thermal via hole to a board based on JEDEC standard JESD51-5)

(*3): Mounted on glass epoxy board. (76.2 × 114.3 × 1.6mm:based on EIA/JDEC standard, 2Layers)

(*4): Mounted on glass epoxy board. (76.2 × 114.3 × 1.6mm:based on EIA/JDEC standard, 4Layers), internal Cu area: 74.2x74.2mm

■ Operating Voltage Range : V_{IN}=2.3V ~ 6.5V

■ ELECTRICAL CHARACTERISTICS

Unless other noted, $V_{IN} = V_O + 1V$, $C_{IN} = 0.1\mu F$, $C_O = 0.47\mu F$(Co=1.0μF :1.8V<Vo≤2.6V, Co=2.2μF :Vo≤1.8V), Cs=0.01μF, Ta = 25°C

PARAMETER	SYMBOL	TEST CONDITION		MIN.	TYP.	MAX.	UNIT
Output Voltage	V_O	I_O=30mA		-1.0%	-	+1.0%	V
Quiescent Current	I_Q	I_O = 0mA, except I_{CONT}		-	150	200	μA
Quiescent Current at OFF-state	$I_{Q(OFF)}$	V_{CONT} = 0V		-	-	10	μA
Output Current	I_O	$V_O \times 0.9$		300	-	-	mA
Line Regulation	$\Delta V_O/\Delta V_{IN}$	$V_{IN} = V_O + 1V \sim 6.5V$, Io=30mA		-	-	0.10	%/V
Load Regulation	$\Delta V_O/\Delta I_O$	I_O = 0 ~ 300mA		-	-	0.006	%/mA
Dropout Voltage (*5)	ΔV_{IO}	I_O=100mA		-	0.10	0.18	V
Average Temperature Coefficient of Output Voltage	$\Delta V_O/\Delta Ta$	Ta= -40 ~ +125°C, I_O=30mA		-	± 50	-	ppm/°C
Ripple Rejection	RR	ein=200mVrms, f=1kHz, Io=10mA	Vo=1.5V	-	71	-	dB
			Vo=1.8V	-	70	-	
			Vo=2.5V	-	69	-	
			Vo=3.3V	-	66	-	
			Vo=5.0V	-	63	-	
Output Noise Voltage	V_{NO}	f=10Hz ~ 80kHz, Io=10mA	Vo=1.5V	-	19	-	μVrms
			Vo=1.8V	-	23	-	
			Vo=2.5V	-	28	-	
			Vo=3.3V	-	32	-	
			Vo=5.0V	-	42	-	
Control Current	I_{CONT}	V_{CONT} =1.6V		-	3	12	μA
Control Voltage at ON-state	$V_{CONT(ON)}$			1.6	-	-	V
Control Voltage at OFF-state	$V_{CONT(OFF)}$			-	-	0.6	V
Soft Start Time	$t_{S(ON)}$	V_{CONT}=L→H, Io=30mA, Cs=0.022μF		-	1.2	-	msec
Discharge Current at OFF-state	I_{DIS}	V_{IN}=2.3V, V_{CONT}=0V, V_O =0.5V		2	9	-	mA
		V_{IN}=6.5V, V_{CONT}=0V, V_O =0.5V		15	25	-	

(*5): Except Output Voltage Rank less than 2.1V

The above specification is a common specification for all output voltages.

Therefore, it may be different from the individual specification for a specific output voltage.

■ THERMAL CHARACTERISTICS

PARAMETER	SYMBOL	VALUE		UNIT
Junction-to-ambient thermal resistance	θja	DFN6-G1 (ESON6-G1)	298 (*6) 104 (*7)	°C/W
		SOT-23-5	260 (*8) 192 (*9)	
Junction-to-Top of package characterization parameter	ψjt	DFN6-G1 (ESON6-G1)	52 (*6) 26 (*7)	°C/W
		SOT-23-5	70 (*8) 60 (*9)	

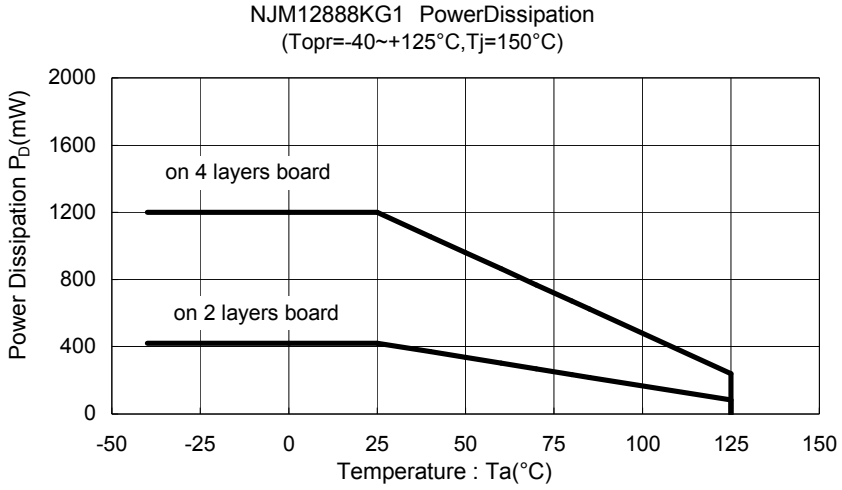
(*6): Mounted on glass epoxy board. (101.5×114.5×1.6mm: based on EIA/JEDEC standard, 2Layers FR-4, with Exposed Pad)

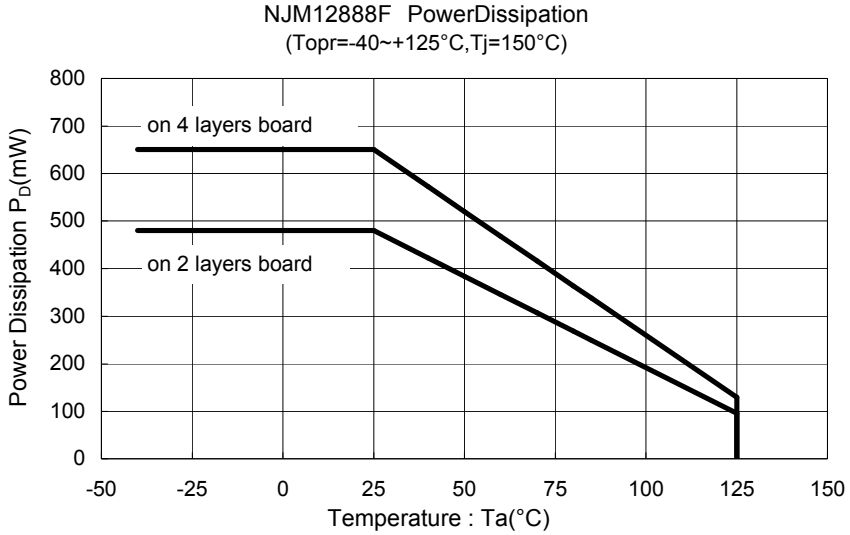
(*7): Mounted on glass epoxy board. (101.5×114.5×1.6mm: based on EIA/JEDEC standard, 4Layers FR-4, with Exposed Pad)
(For 4Layers: Applying 99.5×99.5mm inner Cu area and a thermal via hole to a board based on JEDEC standard JESD51-5)

(*8): Mounted on glass epoxy board. (76.2 × 114.3 × 1.6mm:based on EIA/JDEC standard, 2Layers)

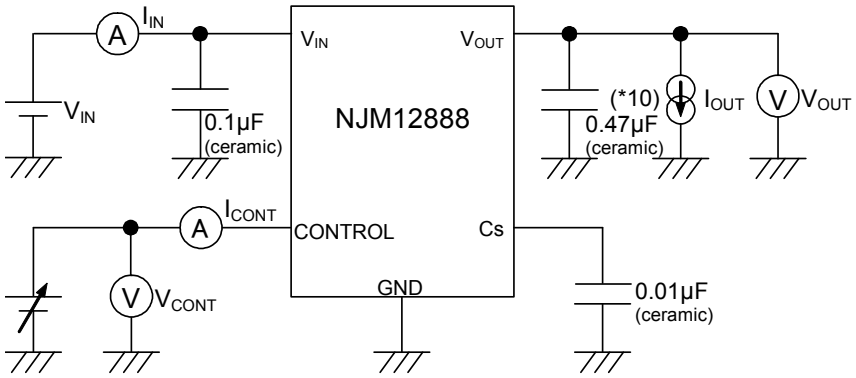
(*9): Mounted on glass epoxy board. (76.2 × 114.3 × 1.6mm:based on EIA/JDEC standard, 4Layers), internal Cu area: 74.2x74.2mm

■ POWER DISSIPATION vs. AMBIENT TEMPERATURE





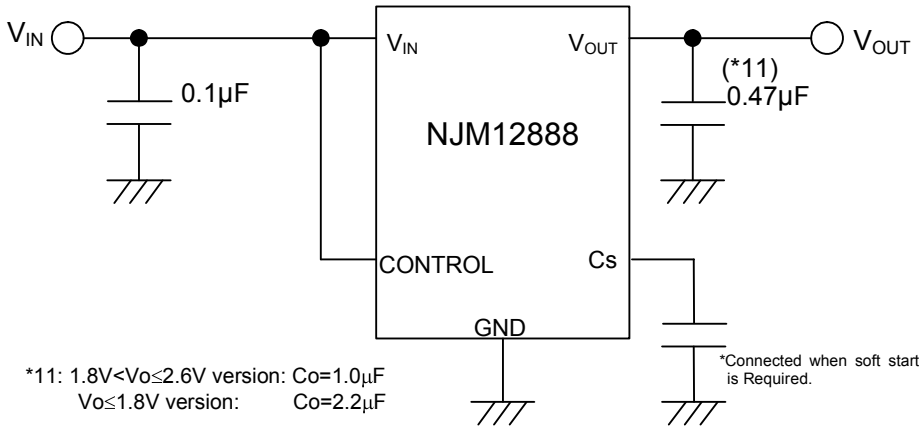
■ TEST CIRCUIT



*10: 1.8V<Vo≤2.6V version: Co=1.0μF(Ceramic)
Vo≤1.8V version: Co=2.2μF(Ceramic)

■ TYPICAL APPLICATION

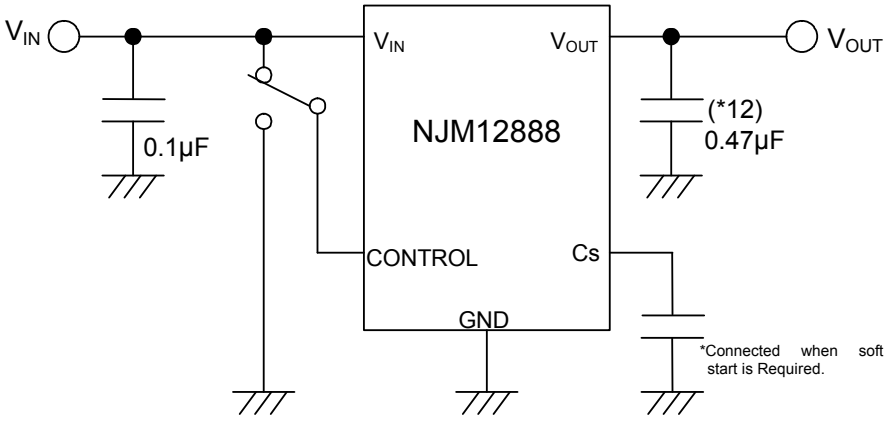
1. In the case where ON/OFF Control is not required



*11: 1.8V<Vo≤2.6V version: Co=1.0μF
Vo≤1.8V version: Co=2.2μF

Connect CONTROL Pin to V_{IN} Pin

2. In use of ON/OFF CONTROL



*12: 1.8V<Vo≤2.6V version:Co=1.0μF
Vo≤1.8V version: Co=2.2μF

State of CONTROL Pin:
"H" → output is enabled.
"L" or "open" → output is disabled

*Reverse Current Protection

The NJM12888 has built-in Reverse Current Protection circuit.

This circuit prevents the large reverse current when output voltage is higher than input voltage. Therefore external schottky-barrier diode(SBD) is not required

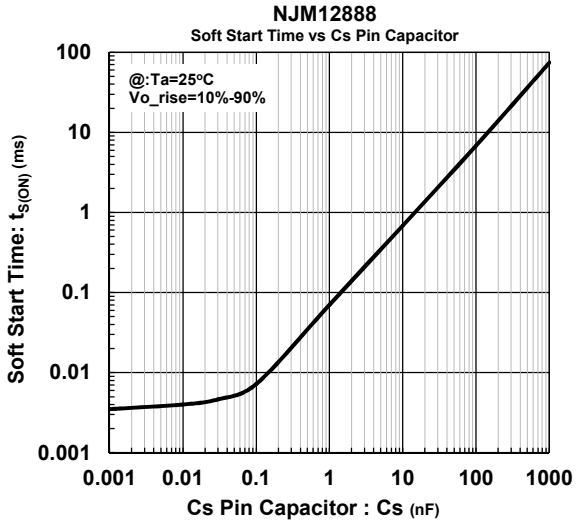
*Soft Start capacitor Cs

The Soft Start function can control the rise time of Output Voltage and reduce the inrush current by connecting the Cs capacitor.

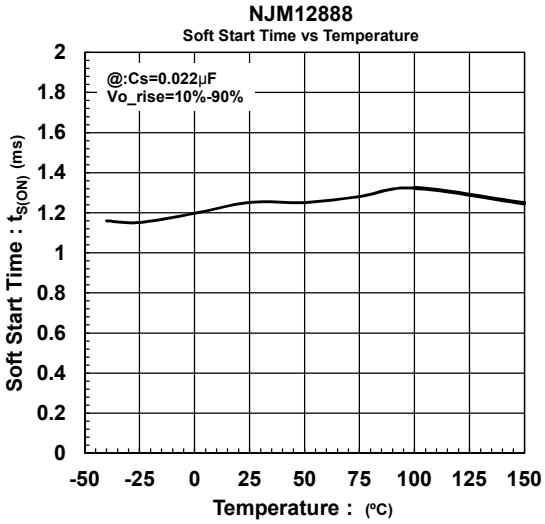
The Soft Start time is defined as 10% to 90% of the Output Voltage.

The Cs capacitor is not essential, but it used for noise bypass of bandgap reference either. Therefore Output Noise Voltage increases when the capacitor isn't connected.

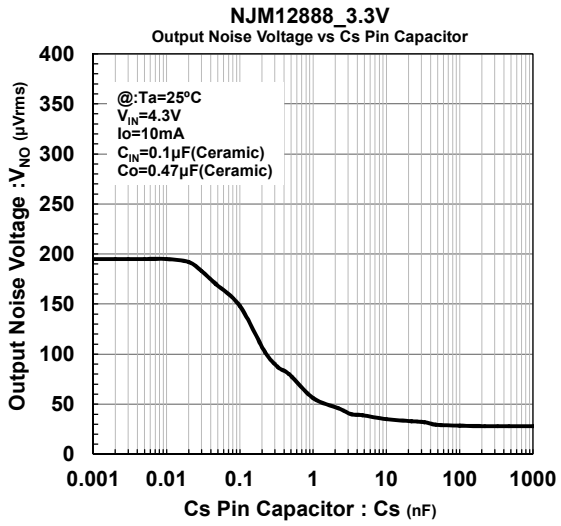
If the Cs capacitor is not used, the Cs Pin should be OPEN.



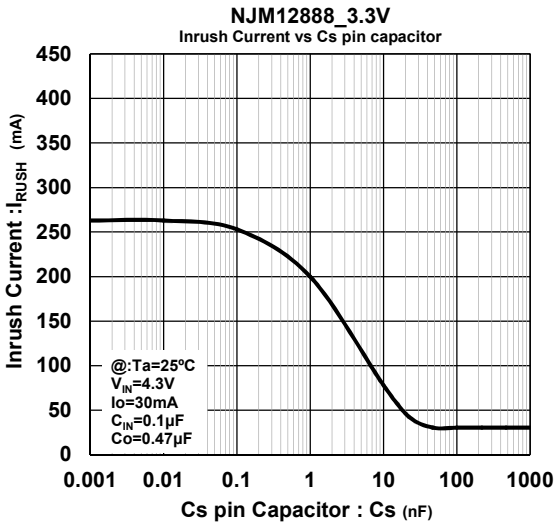
Soft-Start Time vs. Cs Pin Capacitor



Soft-Start Time (0.022µF) vs. Temperature



Output Noise Voltage vs. Cs Pin Capacitor

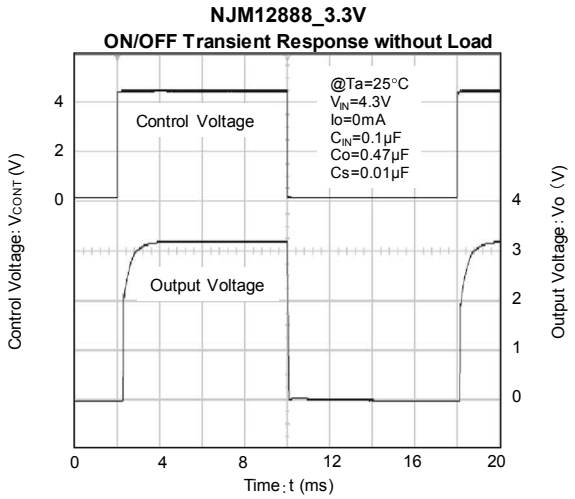


Inrush Current vs. Cs Pin Capacitor

*Discharge Function

The NJM12888 has a built-in discharge circuit to discharge the charged output capacitors.

Discharge circuit operates when the CONTROL Pin is set in LOW level. The circuit discharges the charged output capacitors rapidly.



Output Voltage sweep down characteristics by Discharge function

*Transient response characteristic of Output Voltage

In general, overshoot or undershoot of output voltage may occur due to the transient response characteristic of an internal error amplifier.

Especially, low current consumption regulator may have overshoot or undershoot due to slow feedback caused by current saving design.

Therefore, design validation is important in the following cases:

1. Input voltage or output current change sharply
2. Output capacitors is small
3. Output load is light
4. A regulator starts up with very low dropout voltage operation.

Increasing the value of input and/or output capacitor is a common countermeasure for improving a transient response characteristic.

A transient response characteristic may vary with operating conditions and external components value.

Please check it with the actual environment.

*Input Capacitor C_{IN}

The input capacitor C_{IN} is required to prevent oscillation and reduce power supply ripple for applications when high power supply impedance or a long power supply line.

Therefore, use the recommended C_{IN} value (refer to conditions of ELECTRIC CHARACTERISTIC) or larger and should connect between GND and V_{IN} as shortest path as possible to avoid the problem.

*Output Capacitor C_O

The output capacitor C_O will be required for a phase compensation of the internal error amplifier.

The capacitance and the equivalent series resistance (ESR) influence to stable operation of the regulator.

Use of a smaller C_O may cause excess an output noise or an oscillation of the regulator due to lack of the phase compensation.

On the other hand, use of a larger C_O reduces an output noise and a ripple output, and also improves an output transient response when a load rapidly changes.

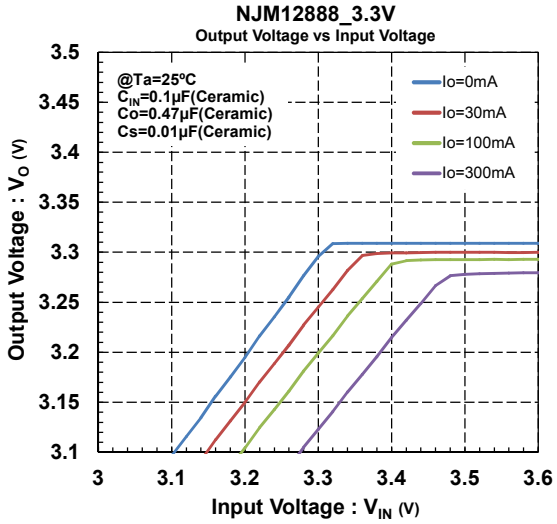
Therefore, use the recommended C_O value (refer to conditions of ELECTRIC CHARACTERISTIC) or larger and should connect between GND and V_{OUT} as shortest path as possible for stable operation

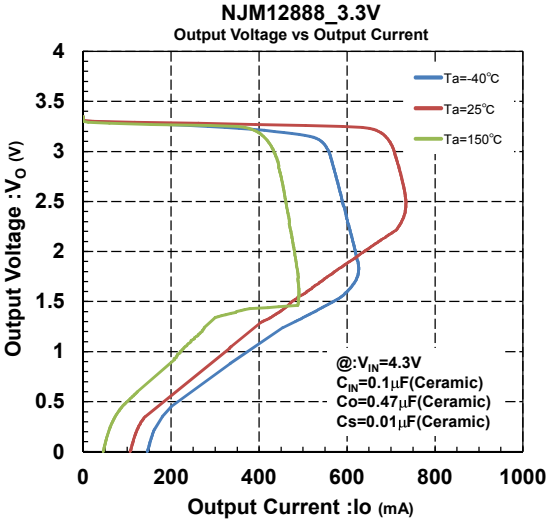
The recommended capacitance depends on the output voltage rank. Especially, a low voltage regulator requires larger C_O value.

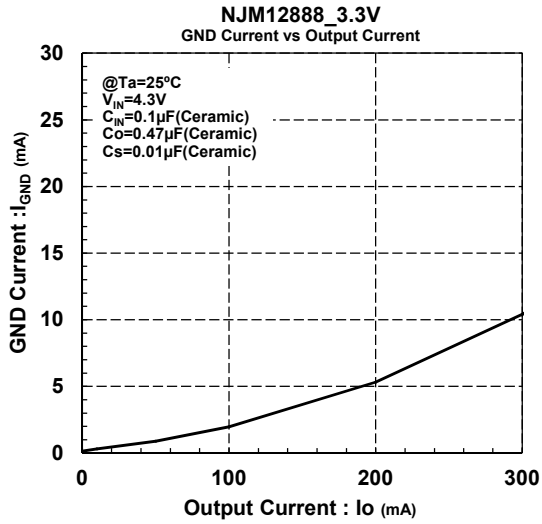
In addition, you should consider varied characteristics of capacitor (a frequency characteristic, a temperature characteristic, a DC bias characteristic and so on) and unevenness peculiar to a capacitor supplier enough.

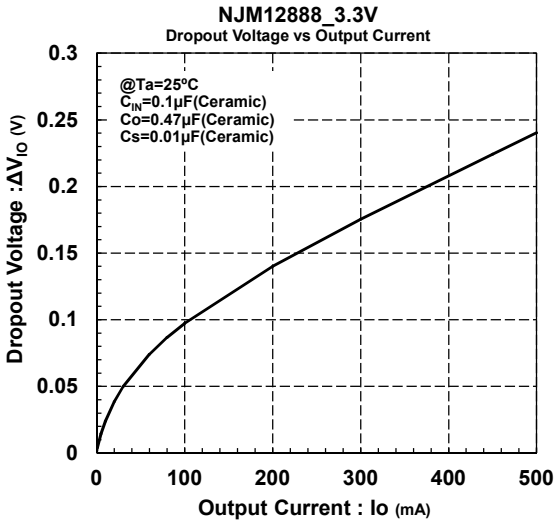
When selecting C_O, recommend that have withstand voltage margin against an output voltage and superior temperature characteristics though this product is designed stability works with wide range ESR of capacitor including low ESR products.

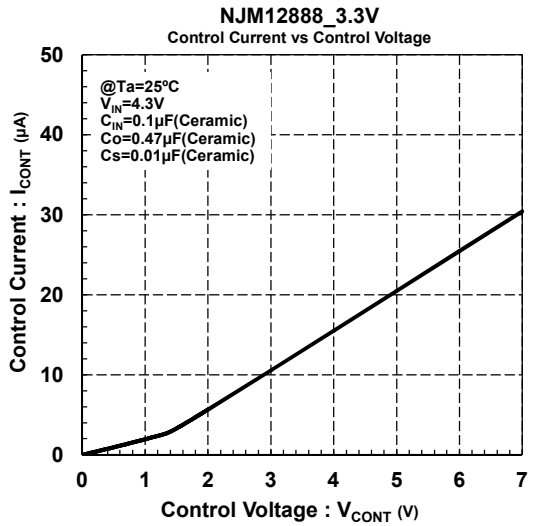
■ TYPICAL CHARACTERISTICS

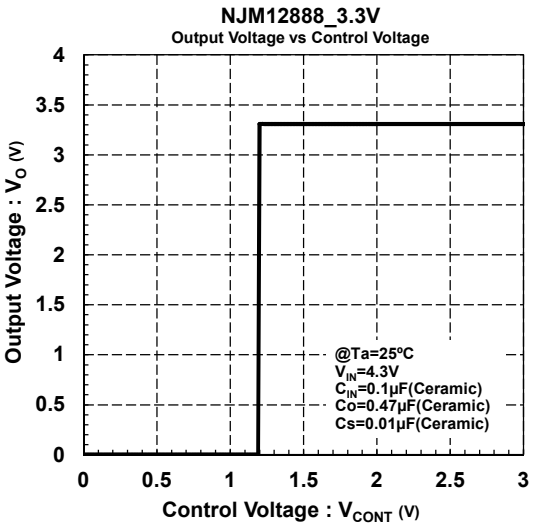


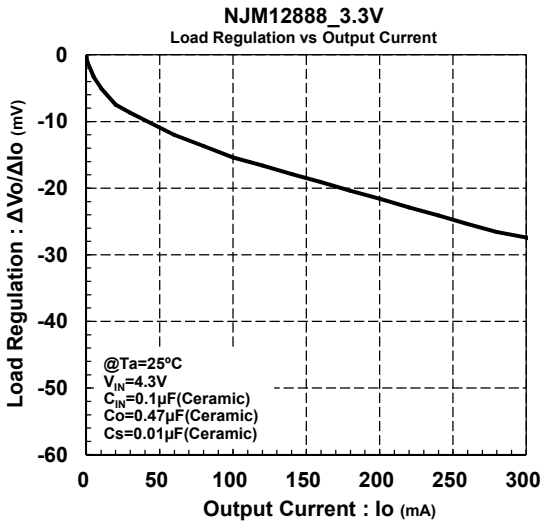


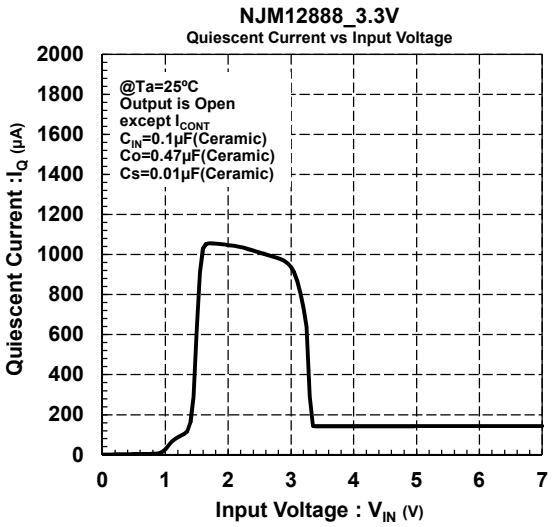


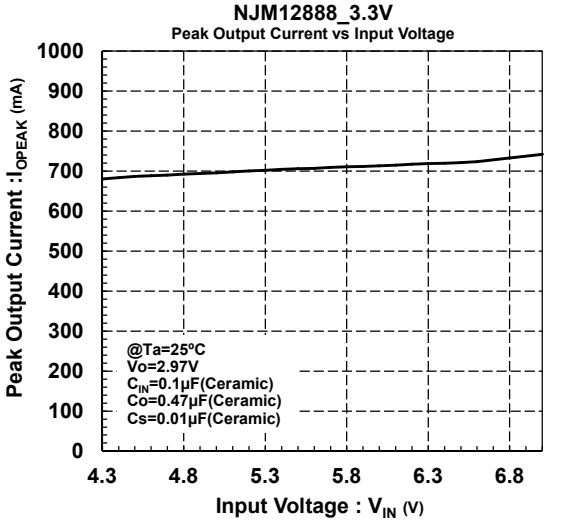


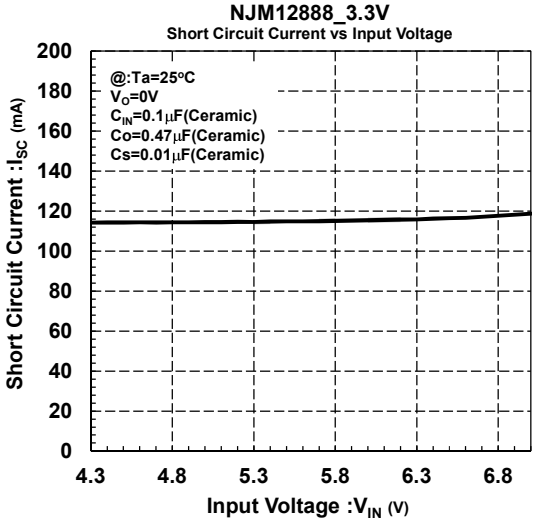


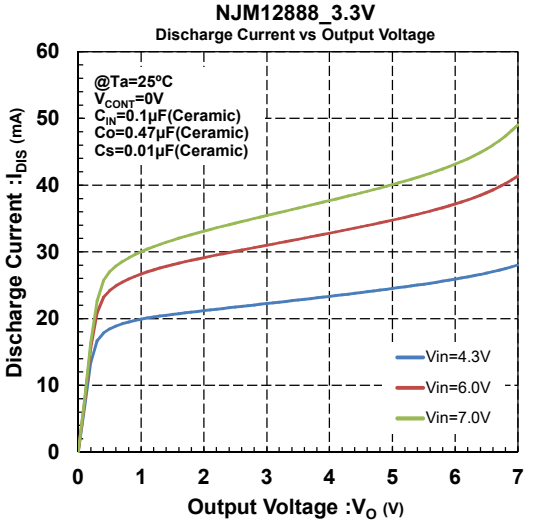


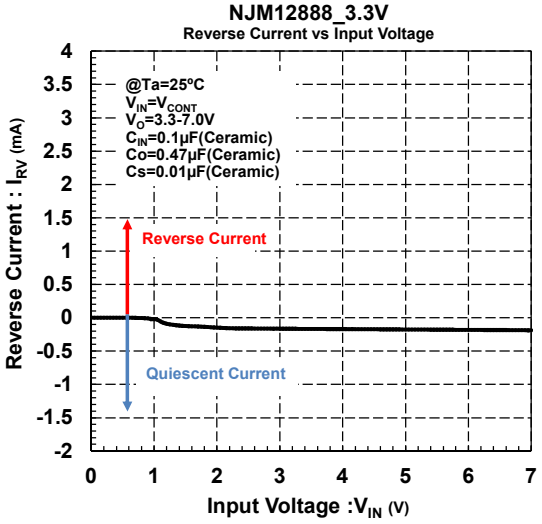

NJM12888_3.3V
Load Regulation vs Output Current
Load Regulation : ΔVo/ΔIo (mV)
Output Current : Io (mA)
@Ta=25°C
V_IN=4.3V
C_IN=0.1μF(Ceramic)
Co=0.47μF(Ceramic)
Cs=0.01μF(Ceramic)


NJM12888_3.3V
Quiescent Current vs Input Voltage
Quiescent Current :I_Q (μA)
Input Voltage : V_IN (V)
@Ta=25°C
Output is Open
except I_CONT
C_IN=0.1μF(Ceramic)
Co=0.47μF(Ceramic)
Cs=0.01μF(Ceramic)

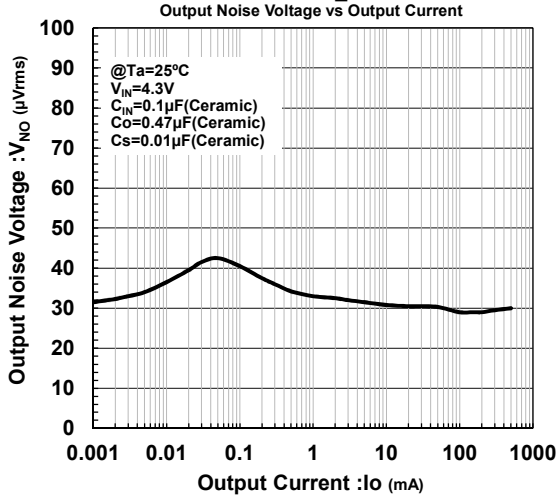

NJM12888_3.3V
Peak Output Current vs Input Voltage
Peak Output Current :I_OPEAK (mA)
Input Voltage : V_IN (V)
@Ta=25°C
Vo=2.97V
C_IN=0.1μF(Ceramic)
Co=0.47μF(Ceramic)
Cs=0.01μF(Ceramic)


NJM12888_3.3V
Short Circuit Current vs Input Voltage
Short Circuit Current :I_SC (mA)
Input Voltage :V_IN (V)
@:Ta=25°C
V_O=0V
C_IN=0.1μF(Ceramic)
Co=0.47μF(Ceramic)
Cs=0.01μF(Ceramic)

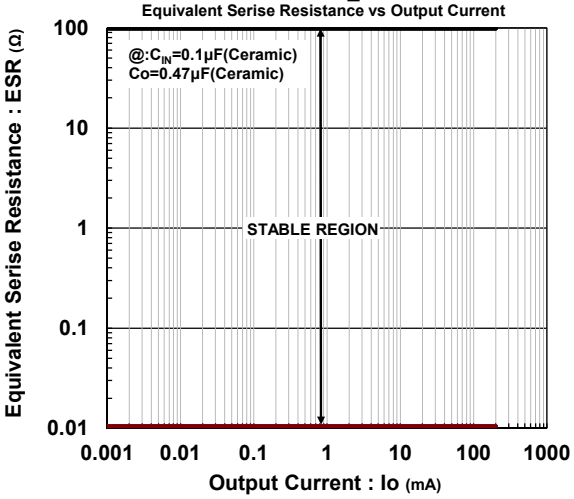

NJM12888_3.3V
Discharge Current vs Output Voltage
Discharge Current :I_DIS (mA)
Output Voltage :V_O (V)
@Ta=25°C
V_CONT=0V
C_IN=0.1μF(Ceramic)
Co=0.47μF(Ceramic)
Cs=0.01μF(Ceramic)
Vin=4.3V
Vin=6.0V
Vin=7.0V


NJM12888_3.3V
Reverse Current vs Input Voltage
Reverse Current : I_RV (mA)
Input Voltage :V_IN (V)
@Ta=25°C
V_IN=V_CONT
V_O=3.3-7.0V
C_IN=0.1μF(Ceramic)
Co=0.47μF(Ceramic)
Cs=0.01μF(Ceramic)
Reverse Current
Quiescent Current

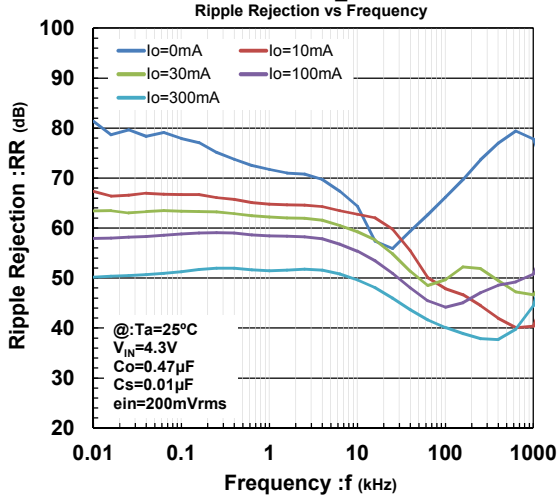
NJM12888_3.3V
Output Noise Voltage vs Output Current



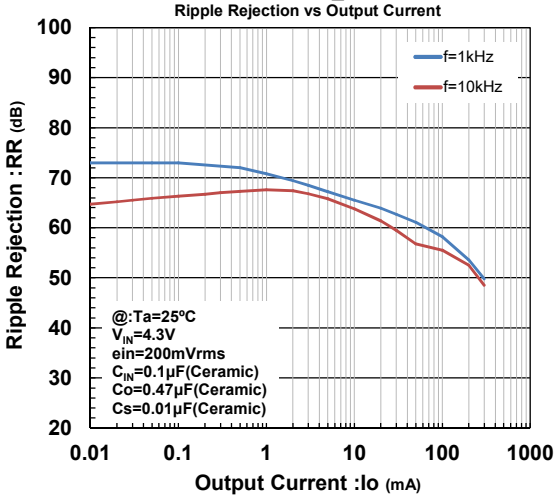
NJM12888_3.3V
Equivalent Serise Resistance vs Output Current



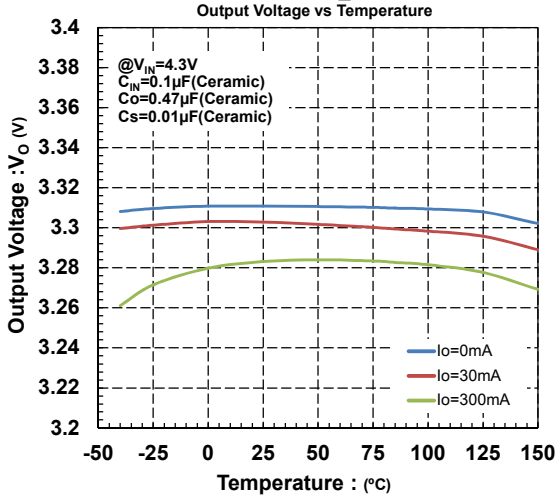
NJM12888_3.3V
Ripple Rejection vs Frequency



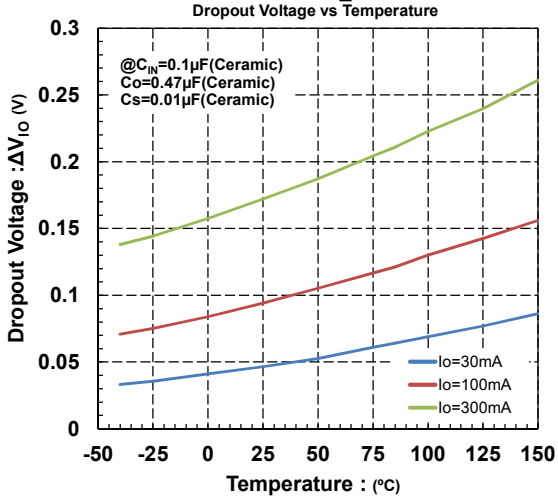
NJM12888_3.3V
Ripple Rejection vs Output Current



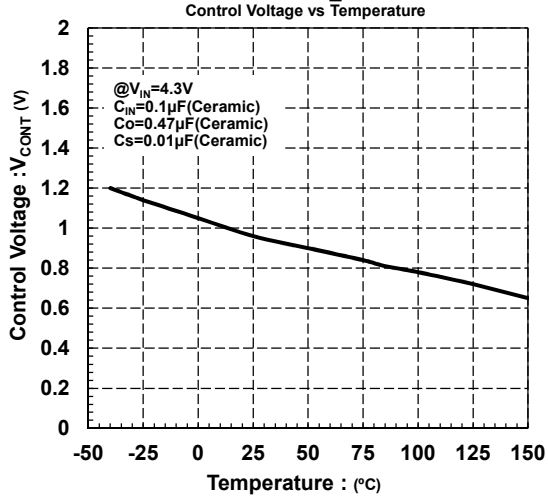
NJM12888_3.3V
Output Voltage vs Temperature



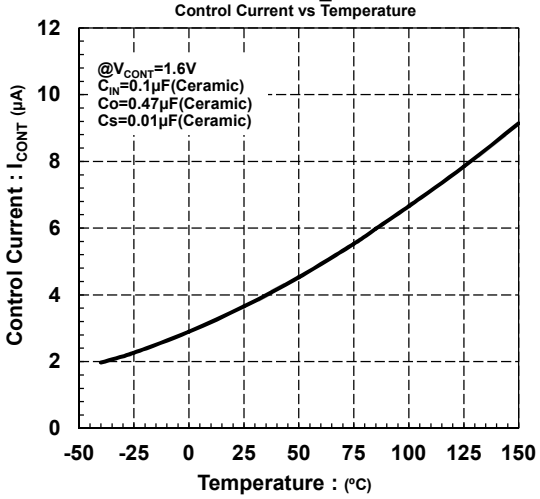
NJM12888_3.3V
Dropout Voltage vs Temperature



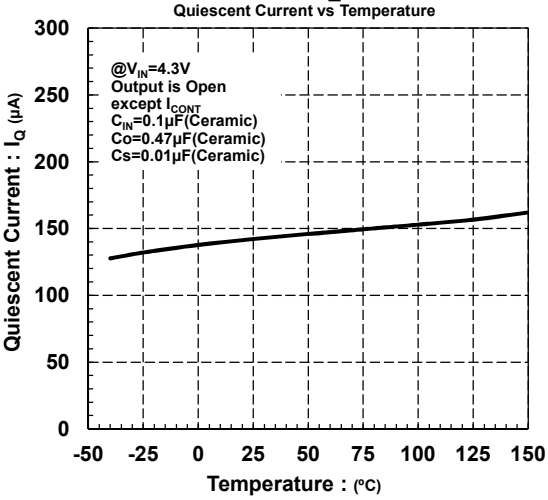
NJM12888_3.3V
Control Voltage vs Temperature



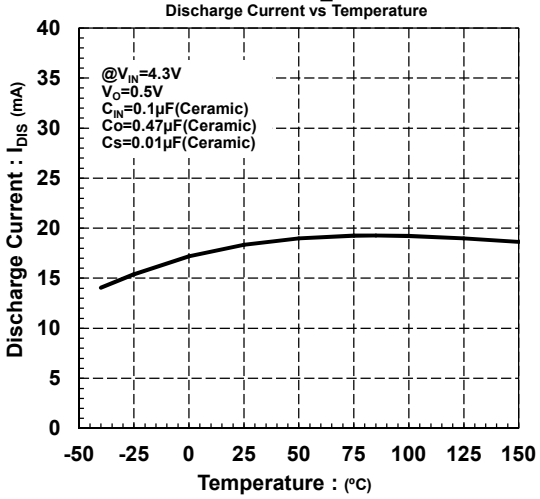
NJM12888_3.3V
Control Current vs Temperature



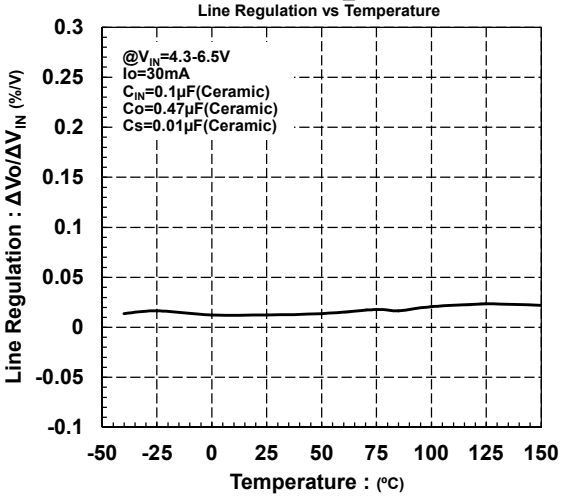
NJM12888_3.3V
Quiescent Current vs Temperature



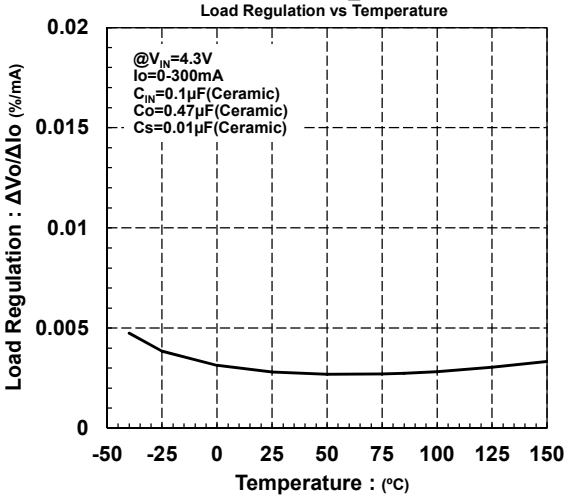
NJM12888_3.3V
Discharge Current vs Temperature

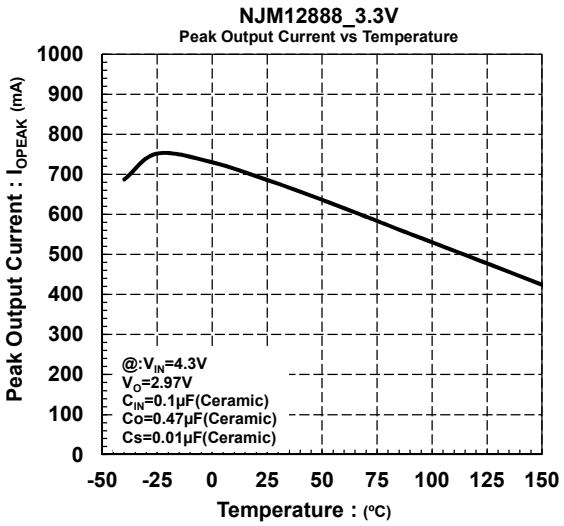


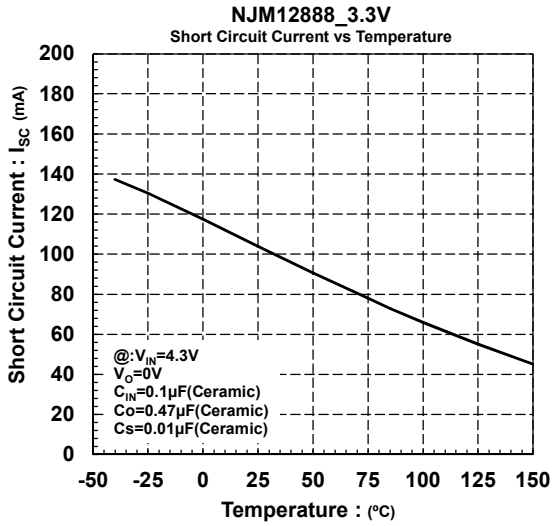
NJM12888_3.3V
Line Regulation vs Temperature

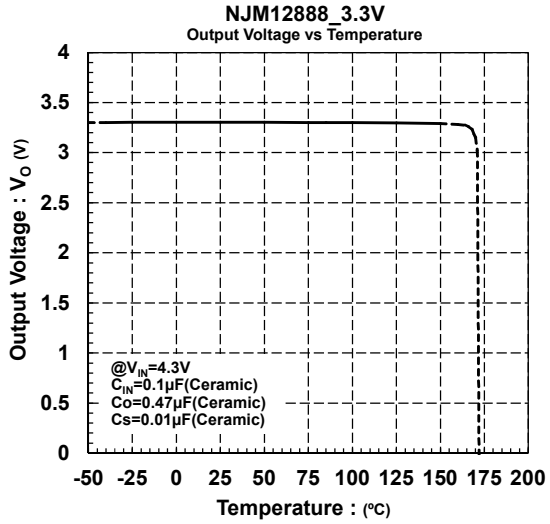


NJM12888_3.3V
Load Regulation vs Temperature

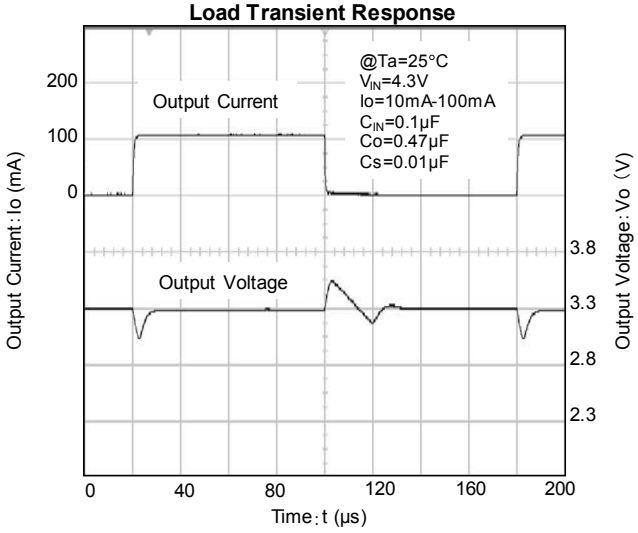



NJM12888_3.3V
Peak Output Current vs Temperature
Peak Output Current : I_{OPEAK} (mA)
1000
900
800
700
600
500
400
300
200
100
0
-50 -25 0 25 50 75 100 125 150
Temperature : (°C)
@:V_{IN}=4.3V
V_O=2.97V
C_{IN}=0.1µF(Ceramic)
Co=0.47µF(Ceramic)
Cs=0.01µF(Ceramic)

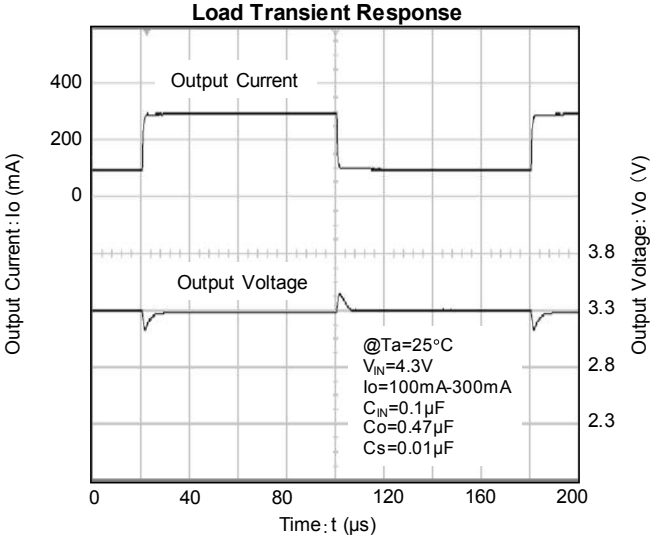

NJM12888_3.3V
Short Circuit Current vs Temperature
Short Circuit Current : I_{SC} (mA)
200
180
160
140
120
100
80
60
40
20
0
-50 -25 0 25 50 75 100 125 150
Temperature : (°C)
@:V_{IN}=4.3V
V_O=0V
C_{IN}=0.1µF(Ceramic)
Co=0.47µF(Ceramic)
Cs=0.01µF(Ceramic)


NJM12888_3.3V
Output Voltage vs Temperature
Output Voltage : V_O (V)
4
3.5
3
2.5
2
1.5
1
0.5
0
-50 -25 0 25 50 75 100 125 150 175 200
Temperature : (°C)
@V_{IN}=4.3V
C_{IN}=0.1µF(Ceramic)
Co=0.47µF(Ceramic)
Cs=0.01µF(Ceramic)

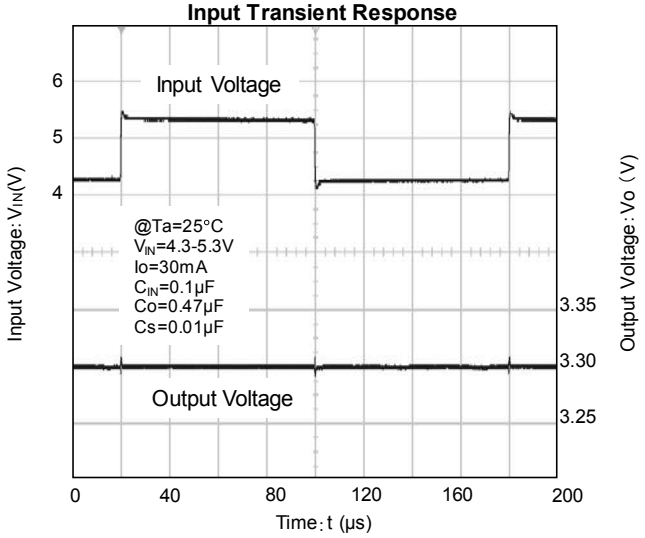
NJM12888_3.3V
Load Transient Response



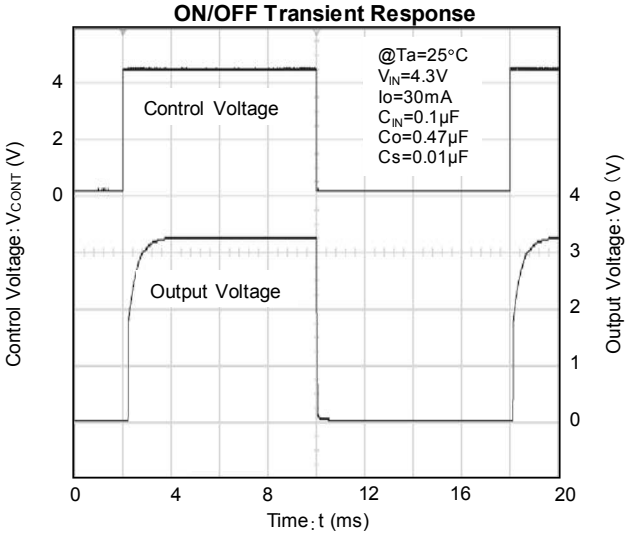
NJM12888_3.3V
Load Transient Response



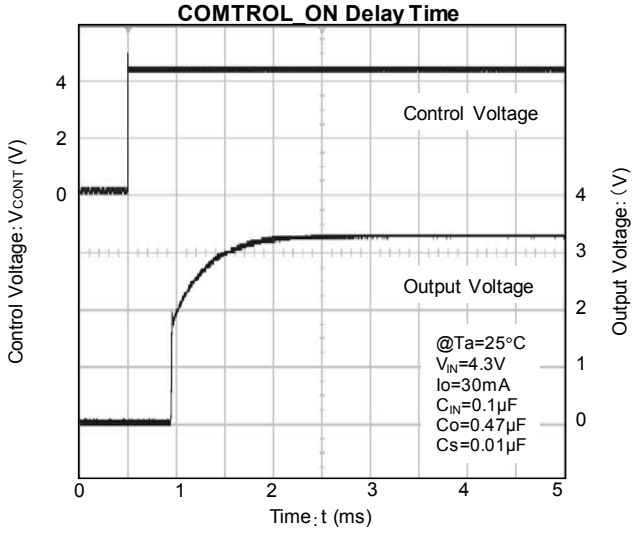
NJM12888_3.3V
Input Transient Response



NJM12888_3.3V
ON/OFF Transient Response



NJM12888_3.3V
COMTROL_ON Delay Time



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