RICOH

R1293K Series

Multi Power Supply IC with Amplifier for LCD

NO.EA-301-160107

OUTLINE

The R1293K is a multi power supply IC dedicated for mid-size TFT LCD panels. The R1293K consists of a PWM control step-up DC/DC converter, an LDO regulator, a VCOM amplifier and six GAMMA amplifiers. The output noise can be reduced by SEL pin. (SEL pin "H": normal mode, SEL pin "L": low noise mode.) The MOSFET for step-up DC/DC converter is built-in and, low power operation is realized by standby mode. The package is 4mm square QFN(PLP)0404-32.

FEATURES

Step-up DC/DC converter part

- Input Voltage Range ······························ 2.2V to 5.5V (V_{IN_DC} pin)
- Adjustable Output Voltage Range with external resistors ······ up to 16V
- Feedback Voltage ······························ 1.0V
- Feedback Voltage Accuracy ······························ ±1.5%
- Adjustable Oscillator Frequency with external resistors for RT pin ······· 300kHz to 1MHz
- Adjustable Phase compensation with external components
- Internal Soft Start Time ······························TYP. 10ms
- Adjustable Soft Start Time with external capacitors for DTC pin
- Oscillator Maximum Duty Cycle ······························Set with external resistors for DTC pin (Limit TYP. 90%)
- UVLO detector threshold······························TYP. 1.9V
- Internal 2A /16V capability Nch MOSFET Driver ······························TYP. 0.2Ω
- Built-in Peak Current Limit Circuit
- Short Protection with timer latch function (Adjustable delay time with external capacitors for D_{ELAY} pin)

LDO part

- Input Voltage Range ······························2.2V to 5.5V (V_{IN_LDO} pin)
- Output Voltage Range ······························1.8V to 2.5V (Selectable / 0.1V Step)
- Output Voltage Accuracy······························±1.0%
- Maximum Output Current······························Min. 350mA guaranteed
- Ripple Rejection······························TYP. 65db (Frequency = 1kHz)
- Built-in Fold-back Protection Circuit ······························TYP. 70mA (Current at short mode)

Buffer Amplifier part

- Input Voltage Range for Amplifiers ······························5V to 16V (V_{BUFF} pin)
- Output Current Range for VCOM Amplifier······························-100mA to 100mA
- Output Current Range for GAMMA Amplifier······························-10mA to 10mA

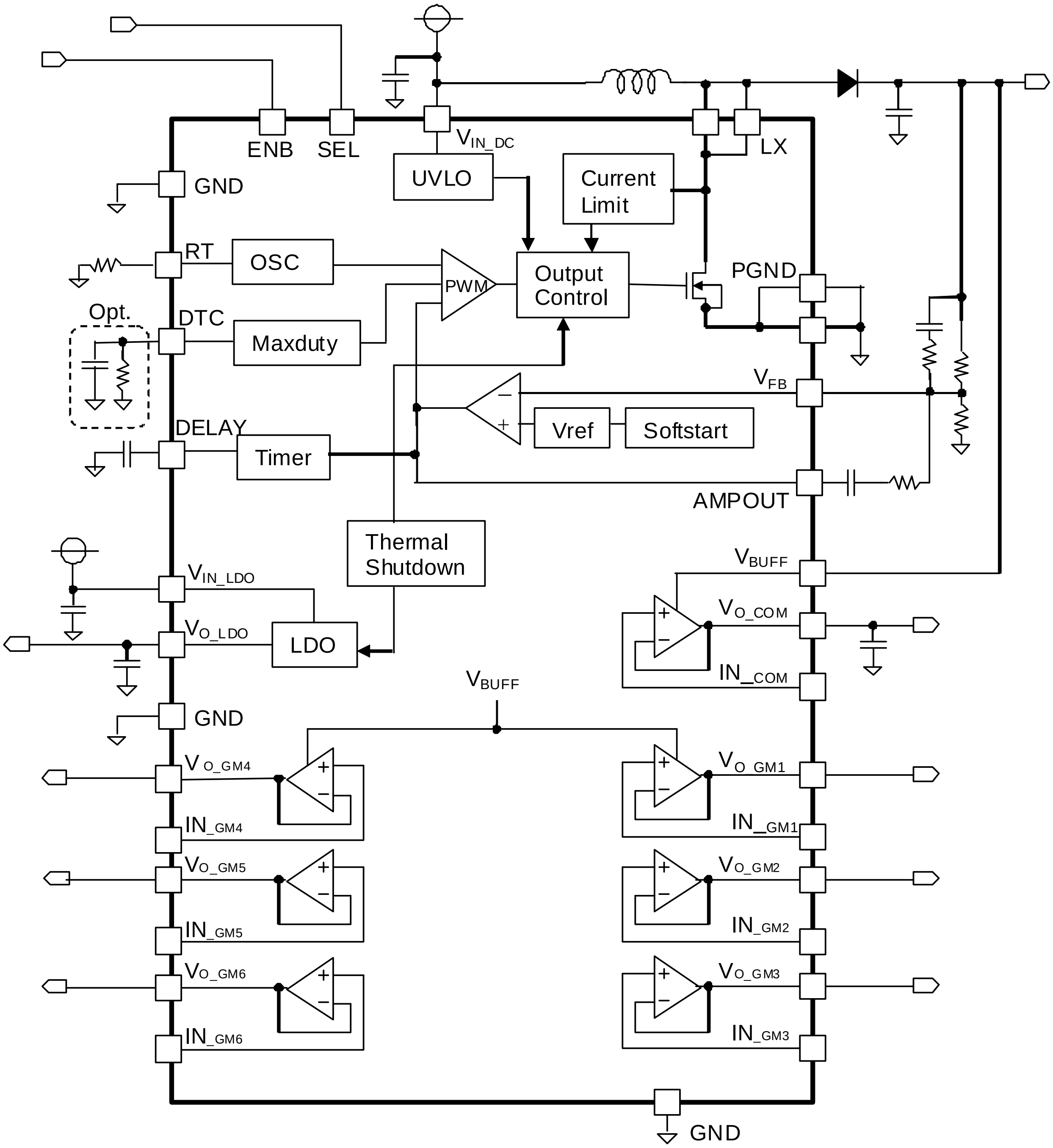
Others

- Built-in Thermal Shutdown Circuit
- Stand-by function by ENB pin
- Package······························QFN(PLP)0404-32

APPLICATIONS

- Power sources of the medium and small sized TFT LCD panels

BLOCK DIAGRAM



R1293K Block Diagram

SELECTION GUIDE

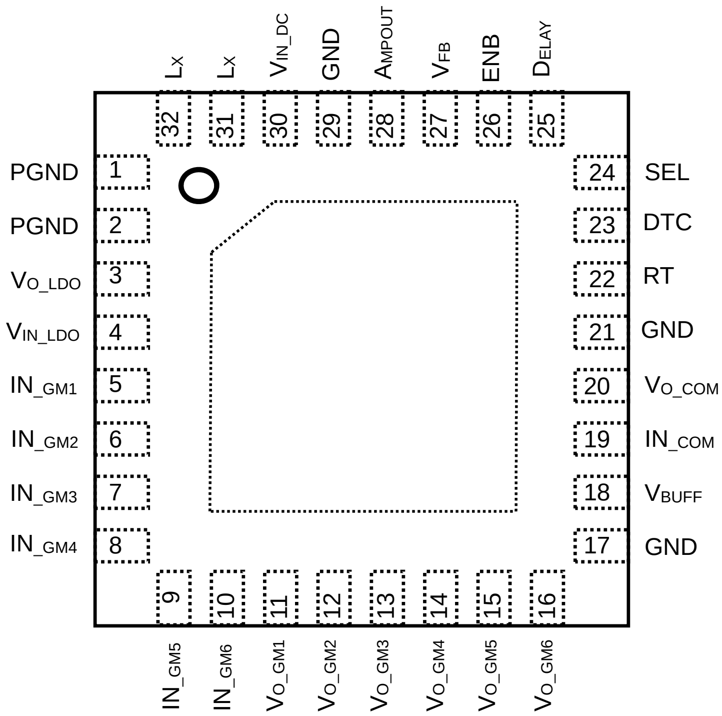
The output voltage (V_{OUT}) for the ICs is a user-selectabe option.

Selection Guide

Product Name	Package	Quantity per Reel	Pb Free	Halogen Free
R1293Kxx1A-E2	QFN(PLP)0404-32	2,000 pcs	Yes	Yes

xx: Designation of the LDO output voltage (V_{OUT})
V_{OUT} can be set within the range of 1.8 V to 2.5 V in 0.1 V steps.

PIN CONFIGURATION



QFN(PLP)0404-32 Pin Configuration

RICOH

PIN DESCRIPTIONS

R1293K Pin Description

Pin No	Symbol	Description	Notes
1	PGND	Power GND Pin	Make the PGND pin a short-circuit with the GND pin.
2	PGND	Power GND Pin	Make the PGND pin a short-circuit with the GND pin.
3	V_{O_LDO}	LDO Output Pin	
4	V_{IN_LDO}	LDO Power Input Pin	Input 2.2V to 5.5V to V_{IN_LDO}. Make V_{IN_LDO} a short-circuit with the V_{IN_DC} pin.
5	$IN_{\_GM1}$[*1]	GAMMA1 Input Pin	
6	$IN_{\_GM2}$[*1]	GAMMA2 Input Pin	
7	$IN_{\_GM3}$[*1]	GAMMA3 Input Pin	
8	$IN_{\_GM4}$[*1]	GAMMA4 Input Pin	
9	$IN_{\_GM5}$[*1]	GAMMA5 Input Pin	
10	$IN_{\_GM6}$[*1]	GAMMA6 Input Pin	
11	V_{O_GM1}	GAMMA1 Output Pin	
12	V_{O_GM2}	GAMMA2 Output Pin	
13	V_{O_GM3}	GAMMA3 Output Pin	
14	V_{O_GM4}	GAMMA4 Output Pin	
15	V_{O_GM5}	GAMMA5 Output Pin	
16	V_{O_GM6}	GAMMA6 Output Pin	
17	GND	GND Pin	
18	V_{BUFF}	Buffer Amplifier Power Source Pin	Connect the V_{BUFF} pin to Boost Output.
19	$IN_{\_COM}$[*1]	VCOM Input Pin	
20	V_{O_COM}	VCOM Output Pin	
21	GND	GND Pin	
22	RT	Oscillator Frequency Setting Pin	Connect a resistor to the RT pin to set the operation frequency.
23	DTC	Maxduty/ Soft-start Time Setting Pin	By adding a resistor, the Maxduty limit can be set; otherwise the Maxduty limit will be the preset value set inside the ICs. By adding a capacitor, Maxduty can start from 0 which means startup-time can be set longer.
24	SEL[*1]	Noise Reduction Level Selection Pin	“L” Input: Low Noise Mode “H” Input: Normal Mode

Pin No	Symbol	Description	Notes
25	DELAY	Short-circuit Protection Delay Time Setting Pin	By adding a capacitor, the DELAY pin can set a protection delay time.
26	ENB[*1]	Chip Enable Pin (DC/DC or Buffer Amplifier)	“L” Input: Active
27	V_{FB}	DC/ DC Feedback Pin	
28	AMPOUT	DC/ DC Phase Compensation Pin	
29	GND	GND Pin	
30	V_{IN_DC}	DC/ DC Power Source Pin	Input voltage should be 2.2V to 5.5V. Make the V_{IN_DC} pin a short-circuit with the V_{IN_LDO} pin.
31	L_X	DC/ DC Switching Pin	
32	L_X	DC/ DC Switching Pin	

The exposed tab on the bottom of the package enhances thermal performance and is electrically connected to GND(substrate level). It is recommended that the exposed tab be connected to the ground plane on the board otherwise be left open.

[*1] Do not leave the IN_{GM1} to IN_{GM6}, IN_{COM}, SEL and ENB pins open.

ABSOLUTE MAXIMAM RATINGS

Absolute Maximum Ratings (GND = PGND = 0 V)

Symbol	Item	Rating	Unit
V_{IN_DC}	V_{IN_DC} Pin Voltage	-0.3 to 6.5	V
V_{IN_LDO}	V_{IN_LDO} Pin Voltage	-0.3 to 6.5	V
V_{BUFF}	V_{BUFF} Pin Voltage	-0.3 to 24	V
V_{RT}	RT Pin Voltage	-0.3 to 4.0	V
V_{DTC}	DTC Pin Voltage	-0.3 to 4.0	V
V_{FB}	V_{FB} Pin Voltage	-0.3 to 4.0	V
V_{AMP}	AMPOUT Pin Voltage	-0.3 to 4.0	V
V_{DELAY}	DELAY Pin Voltage	-0.3 to 4.0	V
V_{SEL}	SEL Pin Voltage	-0.3 to 6.5	V
V_{ENB}	ENB Pin Voltage	-0.3 to 6.5	V
V_{LX}	L_X Pin Voltage	-0.3 to 24	V
V_{O_LDO}	V_{O_LDO} Pin Output Voltage	-0.3 to V_{IN_LDO}+0.3	V
I_{O_LDO}	V_{O_LDO} Pin Output Current	450	mA
V_{IN_BUFF}	Buffer Amplifier Input Voltage	-0.3 to V_{BUFF}+0.3	V
V_{O_BUFF}	Buffer Amplifier Output Voltage	-0.3 to V_{BUFF}+0.3	V
P_D	Power Dissipation (Standard Land Pattern)*1	1500	mW
Ta	Operating Temperature Range	-40 to +85	°C
Tstg	Storage Temperature Range	-55 to +125	°C
Tj	Junction Temperature	-40 to +125	°C

*1 For more information about the Power Dissipation, please refer to PACKAGE INFORMATION.

ABSOLUTE MAXIMUM RATINGS
Electronic and mechanical stress momentarily exceeded absolute maximum ratings may cause the permanent damages and may degrade the life time and safety for both device and system using the device in the field. The functional operation at or over these absolute maximum ratings is not assured.

RECOMMENDED OPERATING CONDITIONS (ELECTRICAL CHARACTERISTICS)
All of electronic equipment should be designed that the mounted semiconductor devices operate within the recommended operating conditions. The semiconductor devices cannot operate normally over the recommended operating conditions, even if when they are used over such conditions by momentary electronic noise or surge. And the semiconductor devices may receive serious damage when they continue to operate over the recommended operating conditions.

ELECTRICAL CHARACTERISTICS

V_{IN_DC} = 3.6 V, Ta = 25°C unless otherwise noted.

R1293K Electrical Characteristics

Symbol	Item	Conditions	Min.	Typ.	Max.	Unit
V_{IN}	V_{IN} Input Voltage	$V_{IN} = V_{IN\_DC} = V_{IN\_LDO}$	2.2		5.5	V
I_{IN}	V_{IN} Supply Current	V_{IN_DC}=5.5V , V_{FB}=1.1V		300	550	µA
I_{STB}	Standby V_{IN} Current	V_{IN_DC}=5.5V		60	90	µA
V_{UVLO1}	UVLO Detector Threshold	V_{IN_DC}=2.2V→1.7V	1.8	1.9	2.0	V
V_{UVLO2}	UVLO Release Voltage	V_{IN_DC}=1.7V→2.2V		2.05	2.15	V

DC/ DC CONVERTER

Symbol	Item	Conditions	Min.	Typ.	Max.	Unit
V_{FB}	V_{FB} Voltage		0.985	1.000	1.015	V
A_V	Opened-loop Voltage Grain			90		dB
f_T	Single Gain-bandwidth Range	A_V=0dB		1.8		MHz
I_{AMPH}	AMP ”H” Output Current	V_{AMP}=1V, V_{FB}=0.9V	0.3	1.4	3.5	mA
I_{AMPL}	AMP ”L” Output Current	V_{AMP}=1V, V_{FB}=1.1V	50	90	150	µA
f_{OSC}	Oscillator Frequency	V_{DELAY}=V_{FB}=0V, R6=24kΩ	630	700	770	kHz
DTC_duty	DTC Maximum Duty Cycle	R6=24kΩ, R5=100kΩ	62	72	82	%
Maxduty	Oscillator Maximum Duty Cycle	V_{FB}=0V	85	90	95	%
t_{SS}	Soft-start Time		3.5	10	16	ms
I_{DLY}	DELAY Pin Charge Current	V_{DELAY}=0.8V, V_{FB}=0V	2	4	6	µA
V_{DLY}	DELAY Pin Detector Threshold Voltage	V_{FB}=0V	0.95	1.0	1.05	V
R_{ON}	L_X ON Resistance			0.2		Ω
I_{LXLIM}	L_X Limit Current		2.0	3.0	3.7	A
V_{OVP1}	OVP Detector Threshold Voltage	V_{OUT} rising		21	23	V
V_{OVP2}	OVP Release Voltage	V_{OUT} falling	18	V_{OVP1}-1		V
V_{SELL}	SEL ”L” Input Voltage	V_{IN_DC}=2.2V			0.4	V
V_{SELH}	SEL ”H” Input Voltage	V_{IN_DC}=5.5V	1.5			V

LDO

Symbol	Item	Conditions	Min.	Typ.	Max.	Unit
V_{O_LDO}	LDO Output Voltage	V_{IN_DC}= V_{O_LDO} +1.0V, I_{O_LDO}=1mA	x 0.99		x 1.01	V
V_{DIF}	Dropout Voltage	I_{O_LDO}=250mA, V_{SET}[*1]<2.4V		600	700	mV
		I_{O_LDO}=250mA, V_{SET}≥2.4V		400	500	mV
$\Delta V_{O\_LDO}/\Delta V_{IN}$	Line Regulation	I_{O_LDO}=30mA, V_{O_LDO}+0.5V≤V_{IN_LDO}≤5.5V			0.2	%/V
$\Delta V_{O\_LDO}/\Delta I_{OUT}$	Load Regulation	V_{IN_DC}= V_{O_LDO} +1.0V, 1mA≤I_{O_LDO}≤250mA			0.4	mV/mA
RR	Ripple Rejection	f=1kHz, Ripple Rejection 0.2 Vp-p, I_{O_LDO}=30mA		65		dB
I_{LIM_LDO}	LDO Output Current Limit	V_{IN_DC}= V_{O_LDO} +1.0V	350			mA
I_{SC_LDO}	LDO Short Current	V_{IN_DC}= V_{O_LDO} +1.0V		70		mA

V_{IN_DC}=3.6V, Ta = 25°C unless otherwise noted.

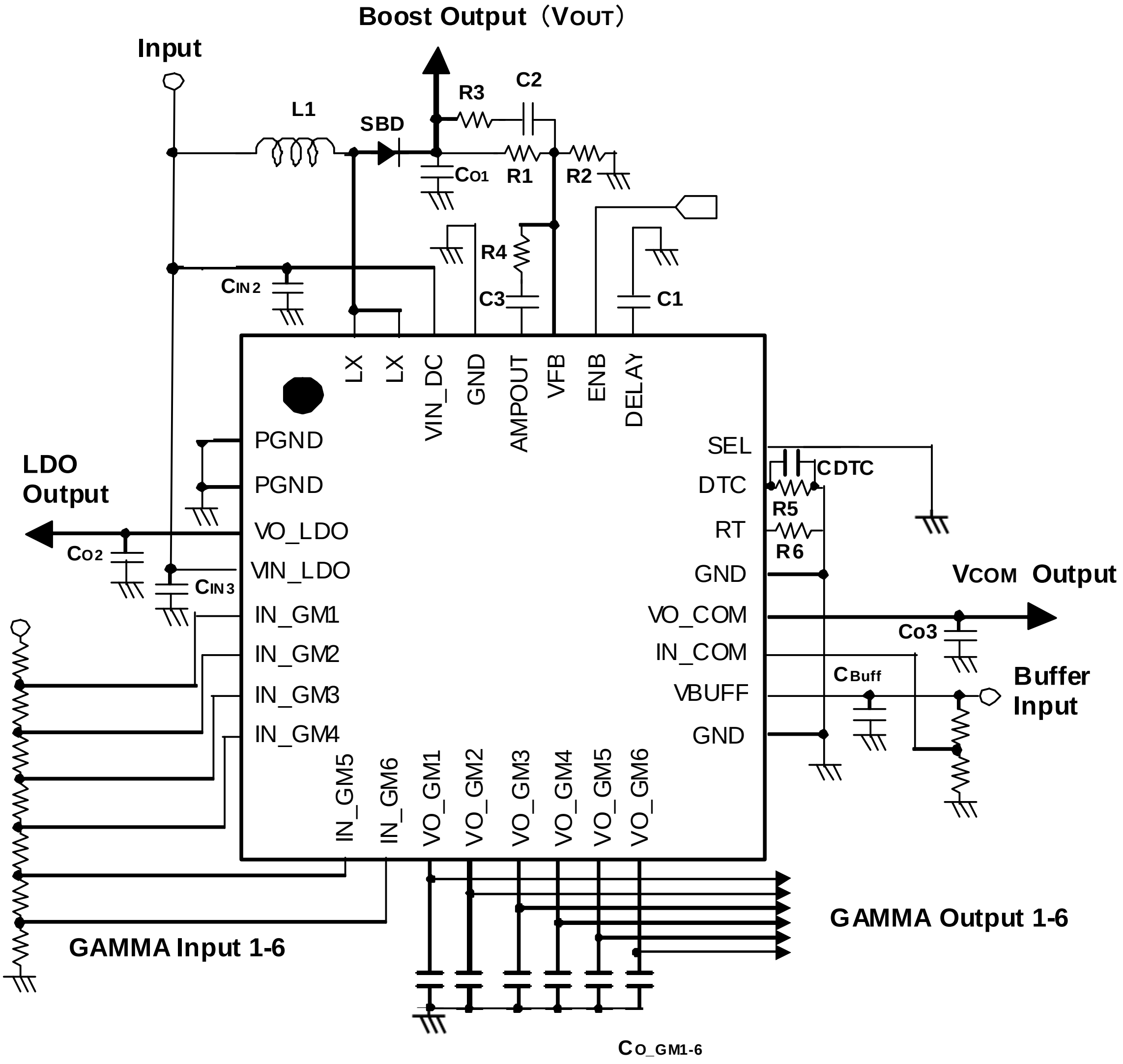
R1293K Electrical Characteristics

Symbol	Item	Conditions	Min.	Typ.	Max.	Unit
BUFFER AMP						
V_{BUFF}	Amplifier Power Source Voltage		5		16	V
I_{DD_BUFF}	Amplifier Supply Current	V_{BUFF}=16V, V_I=8V, VCOM 1ch + GAMMA 1 to 6ch		0.6		mA
V_{OS}	Offset Voltage	V_I=V_{BUFF} / 2		1		mV
V_{CM_COM}	VCOM Common-mode Input Voltage Range	VCOM ch	1.5		V_{BUFF} -1.5	V
V_{CM_GM}	GAMMA Common-mode Input Voltage Range	GAMMA ch	0		V_{BUFF}	V
I_{O_COM}	VCOM Output Current	V_{BUFF}=10V, Vi=5V	-100		100	mA
I_{O_GM}	GAMMA Output Current	V_{BUFF}=10V, Vi=5V	-10		10	mA
ΔV_{O_COM}/ ΔI_{OUT}	VCOM Load Regulation	V_{BUFF}=10V, Vi=5V, -50mA≤I_{OUT}≤+50mA		0.5	1	mV /mA
ΔV_{O_GM}/ ΔI_{OUT}	GAMMA Load Regulation	V_{BUFF}=10V, Vi=5V, -10mA≤I_{OUT}≤+10mA		0.5	1	mV /mA
CMRR	Input Voltage Ripple Rejection	f=0.1kHz, V_{BUFF}=10V, Vi=5V, Ripple Rejection 50mVp-p		75		dB
PSRR	Power Source Ripple Rejection	f=0.1kHz, V_{BUFF}=10V, Vi=5V, Ripple Rejection 0.2Vp-p		70		dB
V_{OL_COM}	VCOM "L" Output Voltage	V_{BUFF}=10V, V_I=1.5V, I_O=+50mA		1.5	1.55	V
V_{OL_GM}	GAMMA "L" Output Voltage	V_{BUFF}=10V, V_I=0V, I_O=+5mA		0.1	0.2	V
		V_{BUFF}=10V, V_I=0.2V, I_O=+10mA		0.2	0.25	V
		V_{BUFF}=10V, V_I=1.5V, I_O=+10mA		1.5	1.55	V
V_{OH_COM}	VCOM "H" Output Voltage	V_{BUFF}=10V, V_I=8.5V, I_O=-50mA	8.45	8.5		V
V_{OH_GM}	GAMMA "H" Output Voltage	V_{BUFF}=10V, V_I=10V, I_O=-5mA	9.8	9.9		V
		V_{BUFF}=10V, V_I=9.8V, I_O=-10mA	9.75	9.8		V
		V_{BUFF}=10V, V_I=8.5V, I_O=-10mA	8.45	8.5		V
CONTROL						
V_{ENBL}	ENB "L" Input Voltage	V_{IN_DC}=2.2V			0.4	V
V_{ENBH}	ENB "H" Input Voltage	V_{IN_DC}=5.5V	1.5			V
T_{TSD}	Thermal Shutdown Temperature	Junction Temperature		150		ºC
T_{TSR}	Thermal Shutdown Released Temperature	Junction Temperature		100		ºC

All test items listed under *Electrical Characteristics* are done under the pulse load condition (Tj≈Ta=25ºC) except Opened-loop Voltage Gain (DC/ DC), Single Gain-bandwidth Range (DC/ DC), Ripple Rejection (LDO), Input Voltage Ripple Rejection (Buffer AMP) and Power Source Ripple Rejection (Buffer AMP).

[*1] V_{SET}=Set Output Voltage

TYPICAL APPLICATION



R1293K Typical Application

External Parts Example

Vout [V]	Frequency [kHz]	L1	CIN2	CO1	VO_GM [pF]
8～10	300	VLF5014S-4R7M1R7	C1608JB0J106M	GRM21BB31E475KA75B	1000
10～12	300	VLF5014S-4R7M1R7	C1608JB0J106M	GRM21BB31E475KA75B * 2	1000
12～16	300	NR6020T4R7N	C1608JB0J106M	GRM21BB31E475KA75B * 2	1000
8～10	700	NR4018T4R7M	GRM21BB31E475KA75B	GRM21BB31E475KA75B	1000
10～12	700	NR4018T4R7M	GRM21BB31E475KA75B	GRM21BB31E475KA75B * 2	1000
12～16	700	VLF5014S-4R7M1R7	GRM21BB31E475KA75B	GRM21BB31E475KA75B * 2	1000
8～10	1000	NR4018T4R7M	GRM21BB31E475KA75B	GRM21BB31E475KA75B	1000
10～12	1000	NR4018T4R7M	GRM21BB31E475KA75B	GRM21BB31E475KA75B * 2	1000
12～16	1000	VLF5014S-4R7M1R7	GRM21BB31E475KA75B	GRM21BB31E475KA75B * 2	1000

Vout [V]	Frequency [kHz]	CO3	CIN3	CO2
8～10	300	TMK316BJ106MD-TD	CM105B105K10AT	CM105B105K10AT
10～12	300	TMK316BJ106MD-TD	CM105B105K10AT	CM105B105K10AT
12～16	300	TMK316BJ106MD-TD	CM105B105K10AT	CM105B105K10AT
8～10	700	TMK316BJ106MD-TD	CM105B105K10AT	CM105B105K10AT
10～12	700	TMK316BJ106MD-TD	CM105B105K10AT	CM105B105K10AT
12～16	700	TMK316BJ106MD-TD	CM105B105K10AT	CM105B105K10AT
8～10	1000	TMK316BJ106MD-TD	CM105B105K10AT	CM105B105K10AT
10～12	1000	TMK316BJ106MD-TD	CM105B105K10AT	CM105B105K10AT
12～16	1000	TMK316BJ106MD-TD	CM105B105K10AT	CM105B105K10AT

Vout [V]	Frequency [kHz]	R4 [kΩ]	C3 [pF]	R3 [kΩ]	C2 [pF]	R1 [kΩ]	R2 [kΩ]	R6 [kΩ]	R5 [kΩ]	CDTC [uF]	C1 [uF]
8～10	300	3.3	1000	8.2	120	(VOUT-1) * R2	33	62	330	-	0.22
10～12	300	3.3	1000	8.2	120	(VOUT-1) * R2	33	62	330	-	0.22
12～16	300	4.7	1500	10	47	(VOUT-1) * R2	22	62	330	-	0.22
8～10	700	3.3	1000	8.2	120	(VOUT-1) * R2	33	24	130	-	0.22
10～12	700	3.3	1000	8.2	120	(VOUT-1) * R2	33	24	130	-	0.22
12～16	700	4.7	1500	10	47	(VOUT-1) * R2	22	24	130	-	0.22
8～10	1000	3.3	1000	8.2	120	(VOUT-1) * R2	33	16	91	-	0.22
10～12	1000	3.3	1000	8.2	120	(VOUT-1) * R2	33	16	91	-	0.22
12～16	1000	4.7	1500	10	47	(VOUT-1) * R2	22	16	91	-	0.22

TECHNICAL NOTES

Output Voltage Setting (DC/ DC)

V_{OUT} controls the V_{FB} pin voltage to maintain V_{FB}=1.0V. V_{OUT} can be set using R1 and R2 in the following equation. V_{OUT} voltage should be set between 5V to 16V. Also, the sum of R1 and R2 should be equal or less than 500kΩ.

$V_{OUT} = V_{FB} \times (R1 + R2) / R2$

Phase Compensation Setting (DC/ DC)

A 180 degree phase shift may be caused by the inductor (L1) and the capacitor (C_{01}). The phase shift reduces phase margin and stability of the system. Thus, it is necessary to keep a leading phase margin. In the following equation, the pole is made by L1 and C_{01}.

$F_{pole} \sim 1 / \{2 \times \pi \times \sqrt{(L1 \times C_{01})}\}$

The phase compensation and the system gain can be set by using R4, C3 and C2. Please refer to *Typical Application* (P.10,11) for positioning and setting value examples. In the following equation, the zero is made by R4 and C3.

$Fzero \sim 1 / (2 \times \pi \times R4 \times C3)$

When selecting the values for R4 and C3, please consider that the cutoff frequency of zero should be approximately equal to the cutoff frequency of pole.
For example, if L1=10µH and C_{01}=10µF, the cutoff frequency of pole is approximately 16kHz.

The gain can be set by the resistance ratio of R4 and RT which is the combined resistance of R1 and R2 (RT=R1xR2/(R1+R2)). If R4 is larger than RT, the gain becomes high. The high gain improves the response characteristic; however, the extremely high gain decreases stability of the operation. It is important to select an appropriate value for R4. In the following equation, zero is made by R1 and C2.

$Fzero \sim 1 / (2 \times \pi \times R1 \times C2)$

Set the cutoff frequency of zero lower than the cutoff frequency of pole.

Reduction of Feedback Voltage Noise (DC/ DC)

If the system noise is large, it may wrap around the V_{FB} pin and causes unstable operation. In this case, set R1 and R2 resistance values lower to reduce the noise entering the V_{FB} pin. Or, place R3 with 1kΩ to 5kΩ to reduce the noise entering the V_{FB} pin as shown in *Typical Application* (P.10,11).

Input Voltage Setting (DC/ DC and LDO)

The input voltage ranges of the V_{IN_DC} and V_{IN_LDO} pins are from 2.2V to 5.5V. Place a bypass capacitor between V_{IN} and GND. Use Boost Output as the input voltage for the V_{BUFF} pin.

Oscillator Frequency Setting (DC/ DC)

By connecting R6 to the the RT pin, f_{OSC} can be set in the range of 300kHz to 1MHz. R6 can be calculated by inserting a desired oscillator frequency value into f_{OSC} in the following equation.

R6 = 19.128 x 10 ^ 9/ Fosc - 3443

Example: Oscillator Frequency 700kHz

R6 = 19.128 x 10 ^ 9 / (700 x 10 ^ 3) - 3443 = 23883 ≈ 24kΩ

Maxduty and Maxduty Soft-start Adjustment (DC/ DC)

Maxduty is preset to 90% (Typ.); however, it can be set lower by adding R5 to the DTC pin. Maxduty is determined by R6 and R5 as shown in the equation below. The preset Maxduty is compared with the Maxduty set by the DTC pin, and the lower Maxduty will be selected.

$$\text{Maxduty (DC)} = \frac{0.3267 \times R5 - 0.6285 \times R6 + 2367}{R6 + 3550}$$

Example: R6=24kΩ, R5=110kΩ

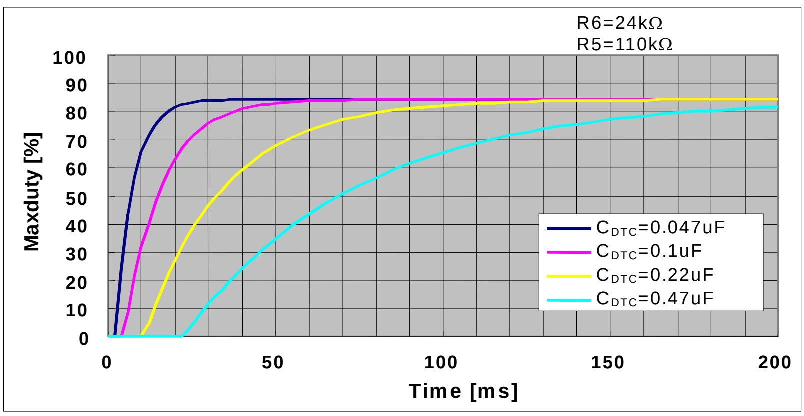
Maxduty = (0.3267 x 110000 - 0.6285 x 24000 + 2367) / 24000 + 3550)

≈ 0.843 ➔ 84.3%

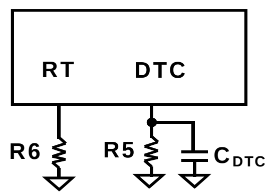
By adding C_{DTC} to the DTC pin, Maxduty can increase gradually and the inrush current can be controlled. (Maxduty Soft-start). After start-up, Maxduty after t-time (Maxduty (t)) can be calculated by the follwoing equation.

$$\text{Maxduty}(t) = \frac{0.3267 \times R5 \times [1 - EXP(-t / C_{DTC} \times R5)] - 0.6285 \times R6 + 2367}{R6 + 3550}$$

Example: R6=24kΩ, R5=110kΩ, C_{DTC}=0.047μF to 0.47μF



Typical Application with RT Pin/ DTC Pin



When using Maxduty soft-start, it is recommended that latch protection delay time (t_{DLY}) be set t_{DLY} > 6 x (R5 x C_{DTC}). t_{DLY} should be longer than the soft-start time.

Overcurrent Protection (DC/ DC)

The overcurrent protection circuit monitors the Nch-swich current and immediately turns off if the Nch-switch current reaches the current limit. Nch-switch turns on every internal refernce clock cycle and turns off if the Nch-switch current reaches the current limit again.

Short Current Protection/ Protection Delay Time Setting (DC/ DC)

If Boost Output drops and causes the VFB voltage drop to 85% of the preset value, the IC recognizes a short-circuit and starts to charge C1. If the short-circuit condition persists for a certain period of time and the DELAY pin voltage rechaes V_{DLY}, the latch-type protection circuit shuts down Boost Output. t_{DLY} can be set by C1 shown in the following equations.

$t_{DLY} = C \times V_{DLY} / I_{DLY}$

To release latch state, make V_{IN_DC} voltage below the UVLO detector threshold and then restart, or set ENB "H" once and then set it back to "L".

Undervoltage Lock Out (DC/ DC)

If the V_{IN_DC} pin voltage becomes equal or lower than UVLO detector threshold, the UVLO circuit immediately disables the switching output.

Thermal Shutdown (LDO and Buffer AMP)

Thermal shutdown circuit detects overheating of the IC and turns off VCOM Output, GAMMA Output, and LDO Outputs to reset the IC if the junction temperature becomes more than the detector threshold. If the causes of overheating are removed and the junction temperature decreases to the release temperature, the IC restarts.

Standby Mode (DC/ DC and Buffer AMP)

By setting the ENB pin “H”, DC/ DC and Buffer AMP go into Standby mode and the output shuts down. LDO is always-on and outputs voltage.

SEL Pin Mode Switching (DC/ DC)

By setting the SEL pin voltage “L”, the switching speed of a built-in MOSFET shifts to moderate mode to reduce the influences of noise to external parts. The SEL pin voltage operates in normal mode when “H”.

Diode, Inductor and Capacitor Selections (DC/ DC, LDO and Buffer AMP)

Efficiency and stability of system can be affected by the following conditions. Spike voltage may be generated by the influence of an inductor when Nch MOSFET turns off. Therefore, diodes, inductors and capacitors should not exceed the voltage tolerance of the capacitor connected to V_{OUT} or their respected rated values (voltage, current and power). Please refer to *Operation of DC/ DC Converter and Output Current* (P.15). Choose the diode with low forward voltage (schottky diode), small reverse current and fast switching speed.

Operation of DC/ DC Converter and Output Current

Figure 1. Basic Circuit

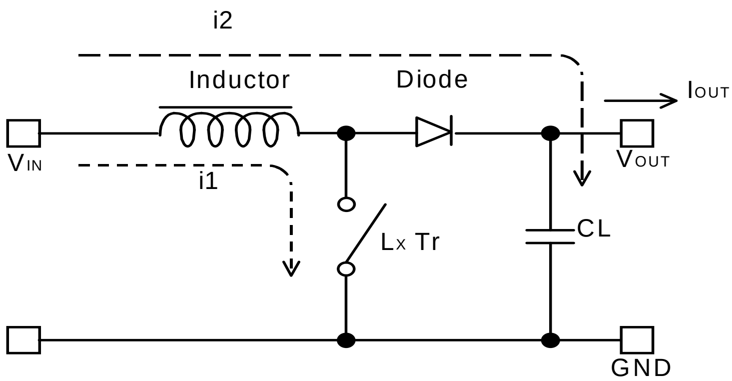
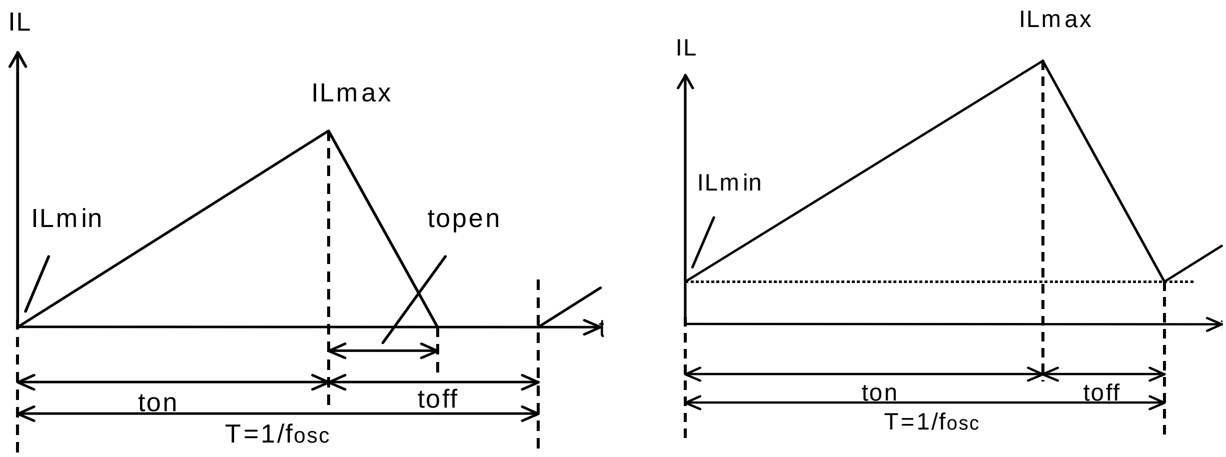


Figure 2. The inductor current (IL) flowing through the inductor (L)



Discontinuous Mode **Continuous Mode**

There are two operation modes in the PWM step-up DC/ DC converter: continuous mode and discontinuous mode. When a transistor is in the On-state, the voltage to be applied to L is described as V_{IN}. An increase in the inductor current (i1) can be written as follows:

$\Delta i1 = V_{IN} \times t_{on} / L$ ········· Formula 1

In the step-up circuit, the energy accumulated during the On-state is transferred into the capacitor even in the Off-state. A decrease in the inductor current (i2) can be written as follows:

$\Delta i2 = (V_{OUT} - V_{IN}) \times t_{open} / L$ ········· Formula 2

In the PWM switching control, i1 and i2 become continuous when topen=toff, which is called continuous mode.

When the IC is in the continuous mode and operates in steady-state conditions, the variations of i1 and i2 are same:

$V_{IN} \times t_{on} / L = (V_{OUT} - V_{IN}) \times t_{off} / L$ ········· Formula 3

Therefore, the duty cycle in the continuous mode is:

$Duty = t_{on} / (t_{on} + t_{off}) = (V_{OUT} - V_{IN}) / V_{OUT}$ ········· Formula 4

When topen=toff, the average of IL is:

$IL\ (Ave.) = V_{IN} \times t_{on} / (2 \times L)$ ········· Formula 5

If the input voltage (V_{IN}) is equal to V_{OUT}, the output current (I_{OUT}) is:

$I_{OUT} = V_{IN}^2 \times t_{on} / (2 \times L \times V_{OUT})$ ········· Formula 6

If I_{OUT} is larger than Formula 6, the IC switches to the continuous mode.

ILmax flowing through L is:

$IL_{max} = I_{OUT} \times V_{OUT} / V_{IN} + V_{IN} \times t_{on} / (2 \times L)$ ········· Formula 7

$IL_{max} = I_{OUT} \times V_{OUT} / V_{IN} + V_{IN} \times T \text{ x } (V_{OUT} - V_{IN}) / (2 \times L \times V_{OUT})$ ········· Formula 8

As a result, ILmax becomes larger compared to I_{OUT}.

When considering the input and output conditions or selecting the external parts, please pay attention to ILmax.

The above calculations are based on the ideal operation of the ICs in the continuous mode. They do not include the losses caused by the external parts or L_X switch. The actual maximum output current will be 50% to 80% of the above calculation results. Especially, if IL is large or V_{IN} is low, it may cause the switching losses. As for V_{OUT}, please consider V_F of the diode (approximately 0.8V).

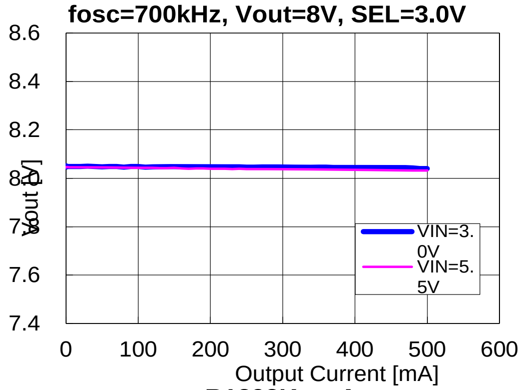
TYPICAL CHARACTERISTICS

V_{IN} = V_{IN_DC} = V_{IN_LDO}, unless otherwise noted.

1) Output Voltage vs. Output Current (DCDC)

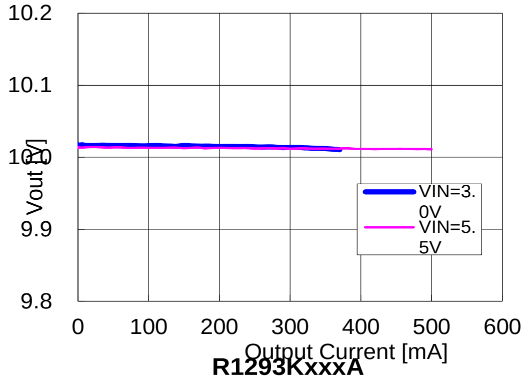
R1293KxxxA

fosc=700kHz, Vout=8V, SEL=3.0V



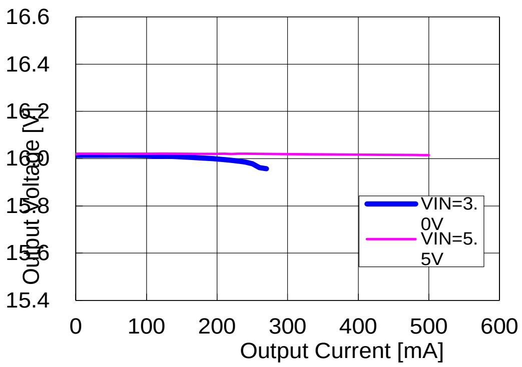
R1293KxxxA

fosc=700kHz, Vout=10V, SEL=3.0V



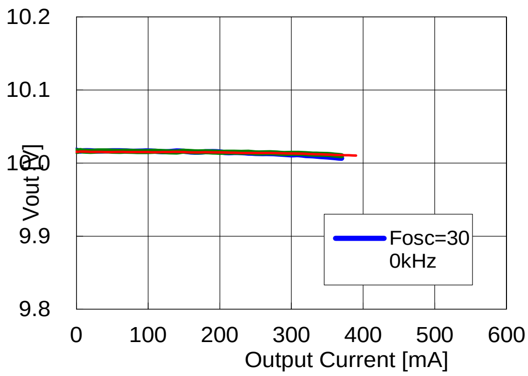
R1293KxxxA

fosc=700kHz, Vout=16V, SEL=3.0V



R1293KxxxA

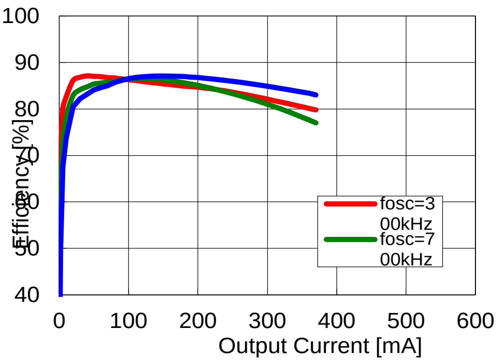
fosc=700kHz, VIN=3.0V, Vout=10V, SEL=3.0V, Ta=25℃



2) Efficiency vs. Output Current (DCDC)

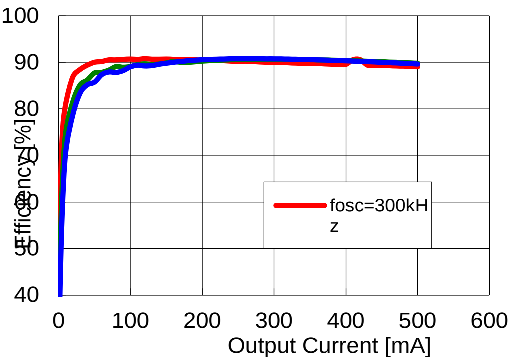
R1293KxxxA

VIN=3.0V, Vout=10V, SEL=3.0V

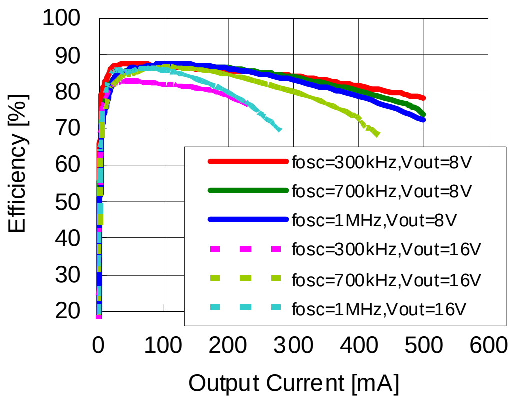


R1293KxxxA

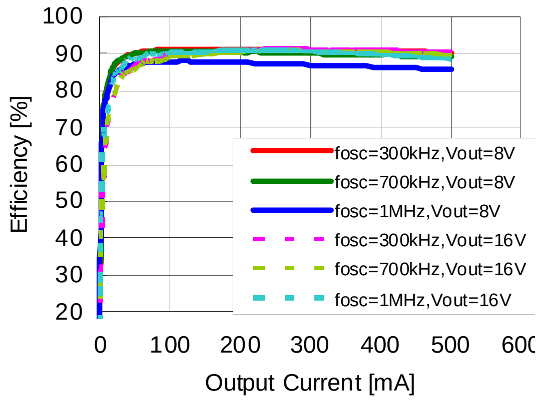
VIN=5.5V, Vout=10V, SEL=5.5V



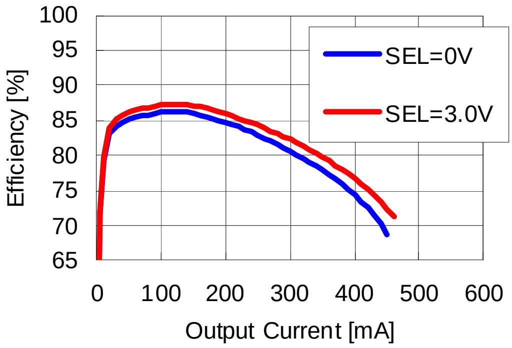
R1293KxxxA
VIN=3.0V, SEL=3.0V, Ta=25℃



R1293KxxxA
VIN=5.5V, SEL=5.5V, Ta=25℃

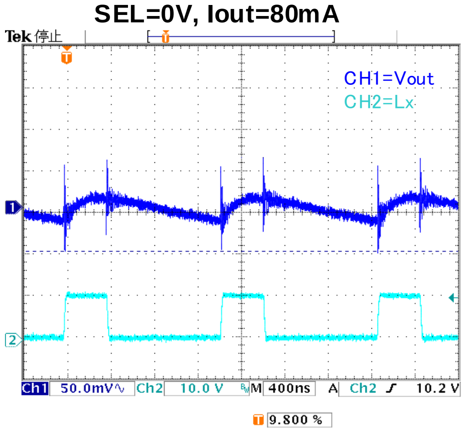


R1293KxxxA
fosc=700kHz,VIN=3.0V, Vout=10V, Ta=25℃

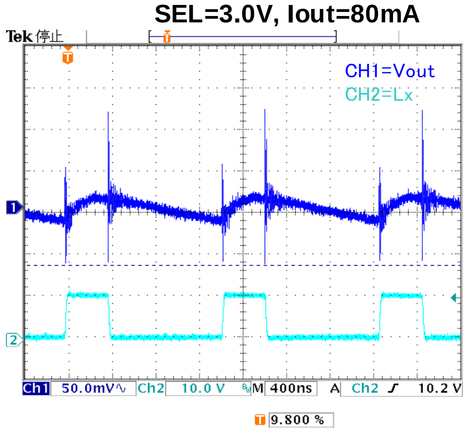


3) Output Voltage Waveform (DCDC)

R1293KxxxA
fosc=700kHz, VIN=3.0V, Vout=10V, Ta=25℃
SEL=0V, Iout=80mA

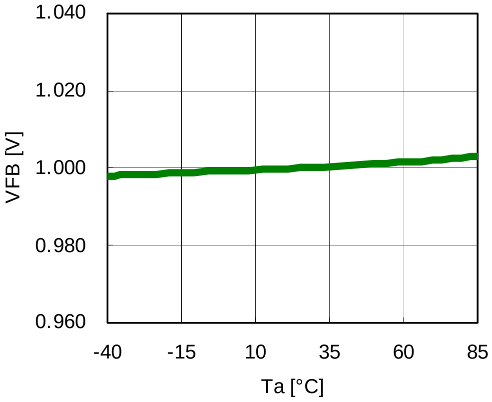


R1293KxxxA
fosc=700kHz, VIN=3.0V, Vout=10V, Ta=25℃
SEL=3.0V, Iout=80mA



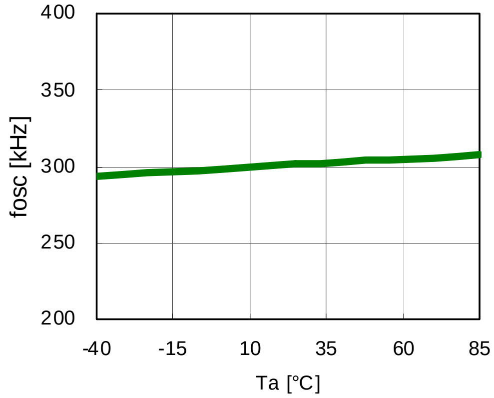
4) VFB Voltage vs. Temperature

R1293KxxxA
VIN=3.6V

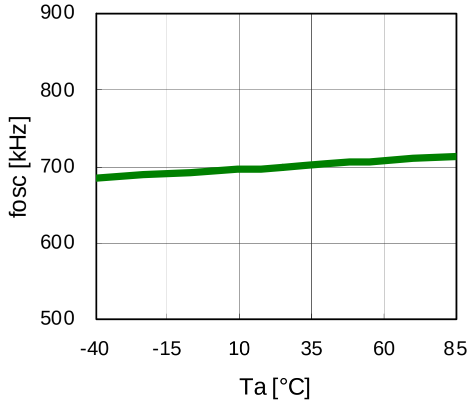


5) Oscillator Frequency vs. Temperature

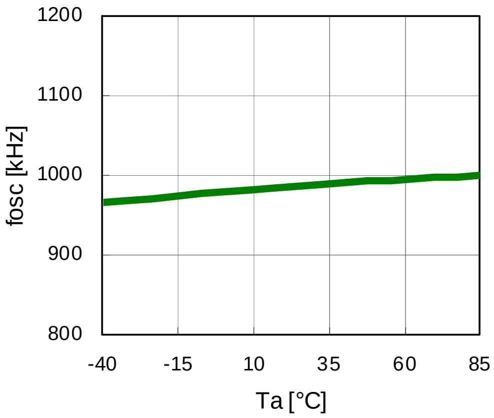
R1293KxxxA
fosc=300kHz, VIN=3.6V, VDELAY=VFB=0V



R1293KxxxA
fosc=700kHz, VIN=3.6V, VDELAY=VFB=0V



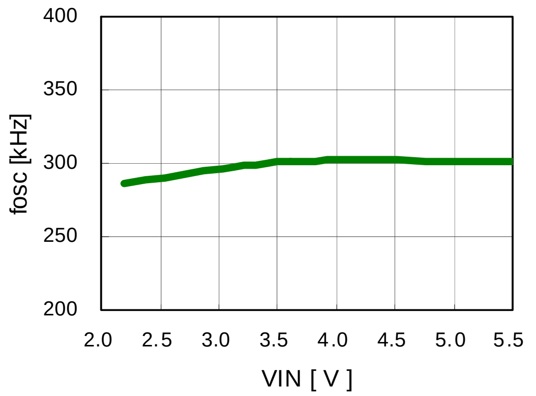
R1293KxxxA
fosc=1MHz, VIN=3.6V, VDELAY=VFB=0V



6) Oscillator Frequency vs. VIN Voltage

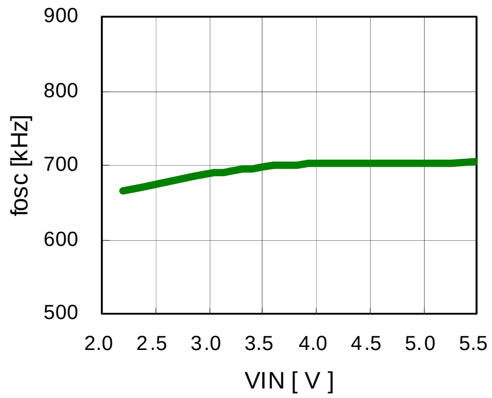
R1293KxxxA

fosc=300kHz, V_{IN}=3.6V, V_{DELAY}=V_{FB}=0V , Ta=25℃



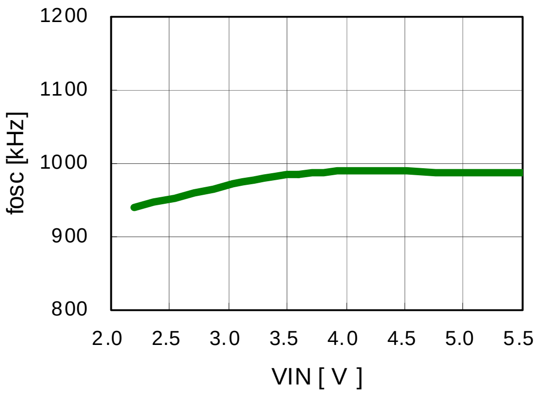
R1293KxxxA

fosc=700kHz, V_{IN}=3.6V, V_{DELAY}=V_{FB}=0V , Ta=25℃



R1293KxxxA

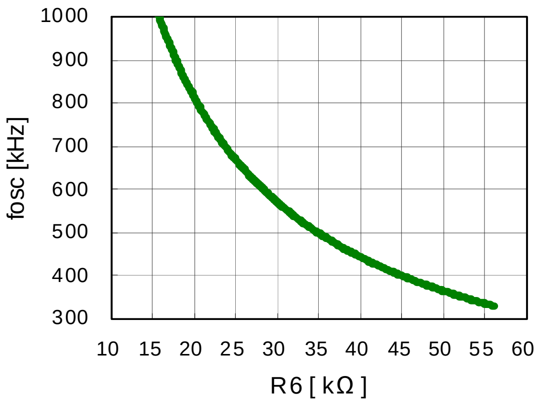
fosc=1MHz, V_{IN}=3.6V, V_{DELAY}=V_{FB}=0V , Ta=25℃



7) Oscillator Frequency vs. R6 Resistance

R1293KxxxA

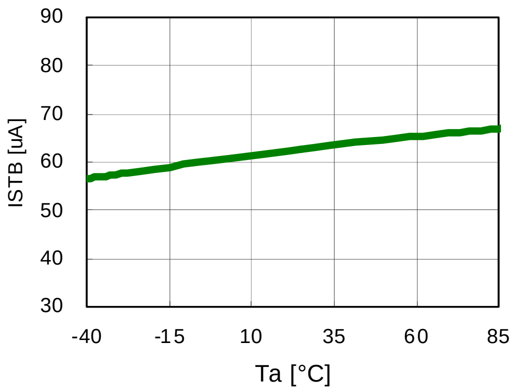
VIN=3.6V, V_{DELAY}=V_{FB}=0V , Ta=25℃



8) Standby VIN Current vs. Temperature

R1293KxxxA

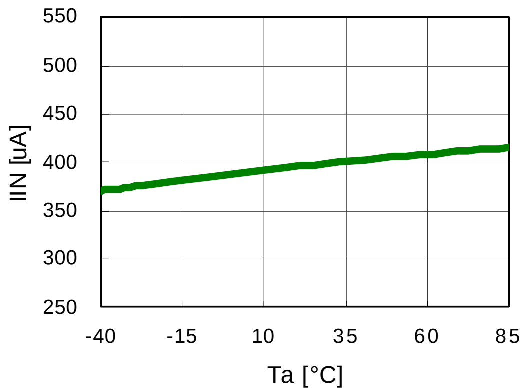
V_{IN}=ENB=5.5V



9) Supply VIN Current vs. Temperature

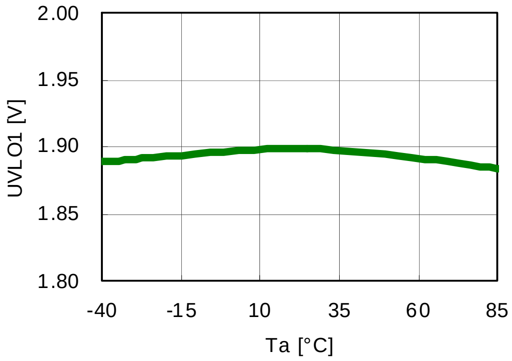
R1293KxxxA

V_{IN}=5.5V, ENB=0V, SEL=0V, VFB=1.1V



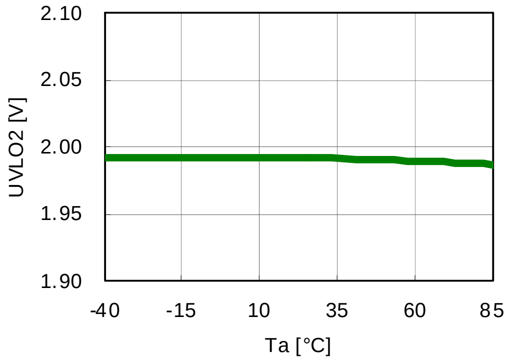
10) UVLO Detector Threshold vs. Temperature

R1293KxxxA
VIN=2.2V → 1.7V



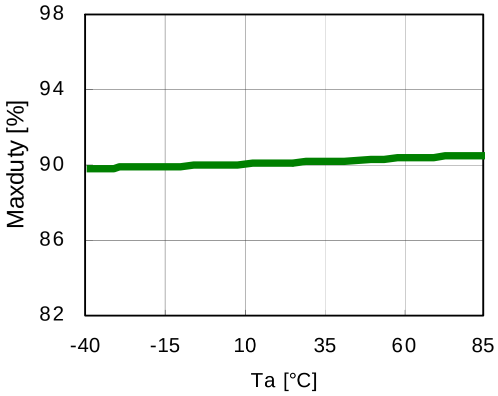
11) UVLO Released Voltage vs. Temperature

R1293KxxxA
VIN=1.7V → 2.2V



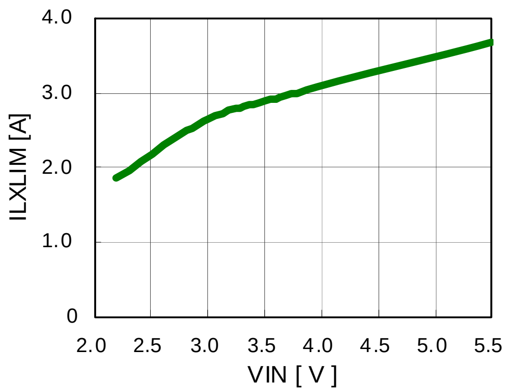
12) Oscillator Maximum Duty Cycle vs. Temperature

R1293KxxxA
VIN=3.6V, VFB=0V

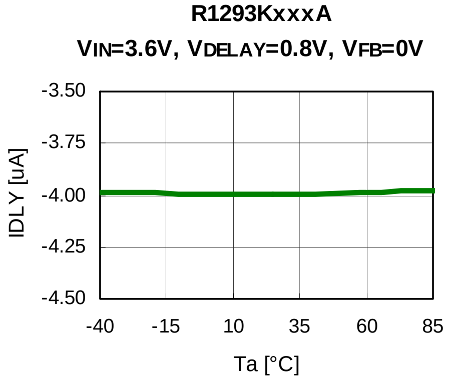


13) LX Limit Current vs. VIN Voltage

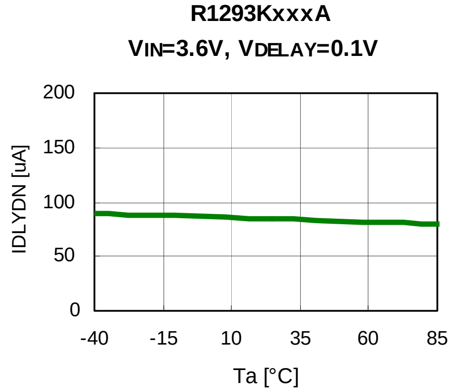
R1293KxxxA
Ta=25℃



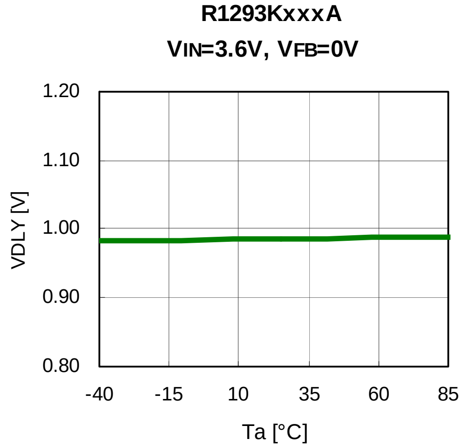
14) DELAY Pin Charge Current vs. Temperature



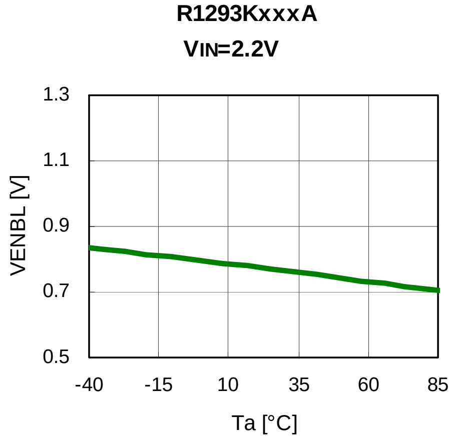
15) DELAY Pin Discharge Current vs. Temperature



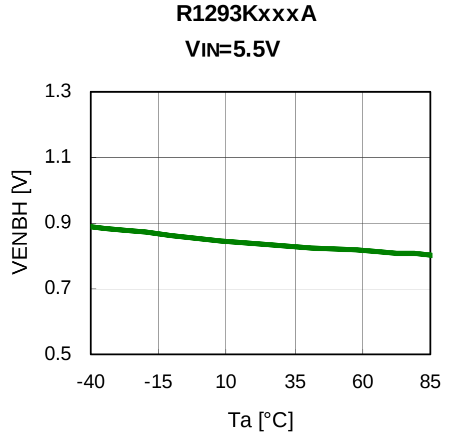
16) DELAY Pin Detector Threshold Voltage vs. Temperature



17) ENB "L" Input Voltage vs. Temperature

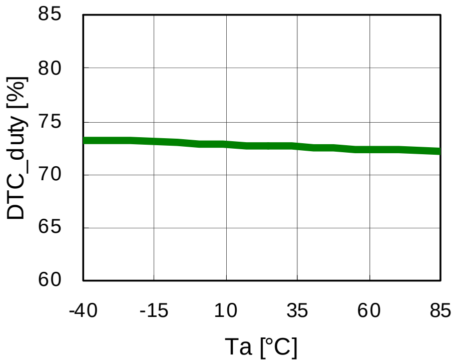


18) ENB "H" Input Voltage vs. Temperature



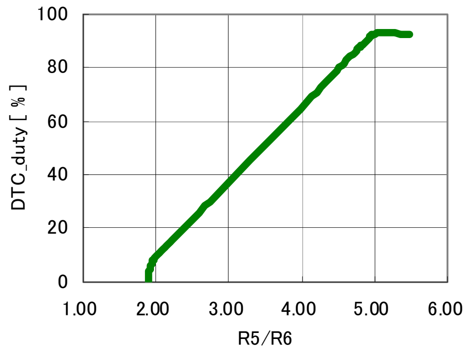
19) DTC Maximum Duty Cycle vs. Temperature

R1293KxxxA
R6=24kΩ, R5=100kΩ



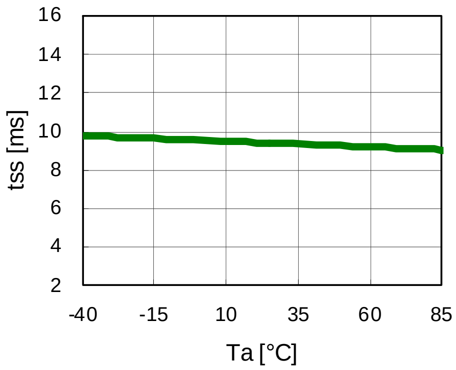
20) DTC Maximum Duty Cycle vs. R_5/R_6

R1293KxxxA
V_{IN}=3.6V, R_6=24kΩ, Ta=25℃



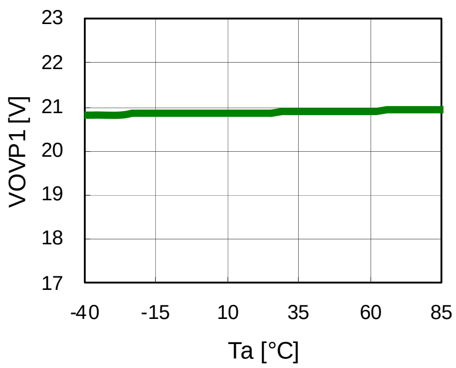
21) Soft Start Time vs. Temperature

R1293KxxxA
V_{IN}=3.6V



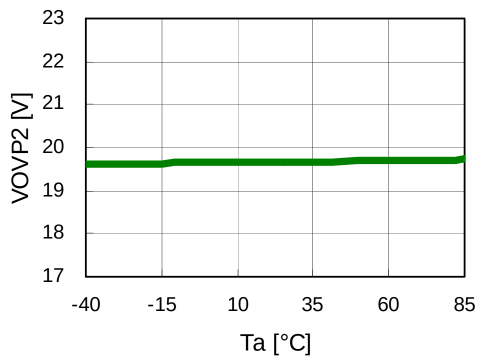
22) OVP Detector Threshold Voltage vs Temperature

R1293KxxxA
V_{IN}=3.6V



23) OVP Release Voltage vs Temperature

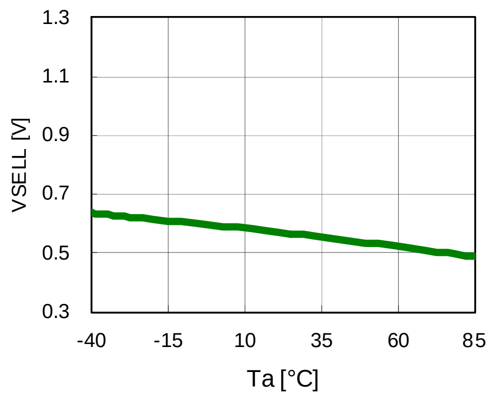
R1293KxxxA
V_{IN}=3.6V



RICOH

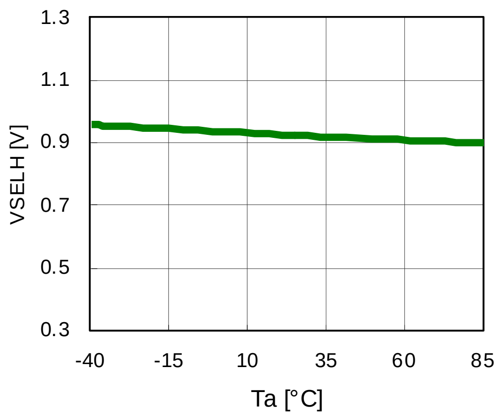
24) SEL "L" Input Voltage vs. Temperature

R1293K181A
VIN=2.2V



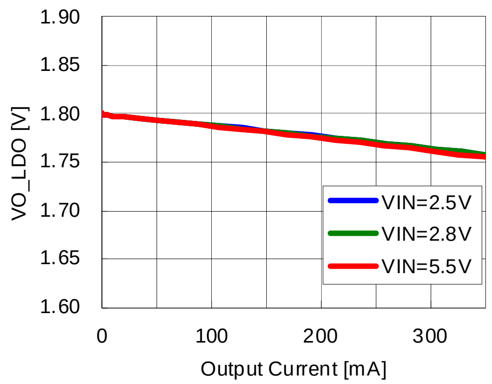
25) SEL "H" Input Voltage vs. Temperature

R1293K251A
VIN=5.5V

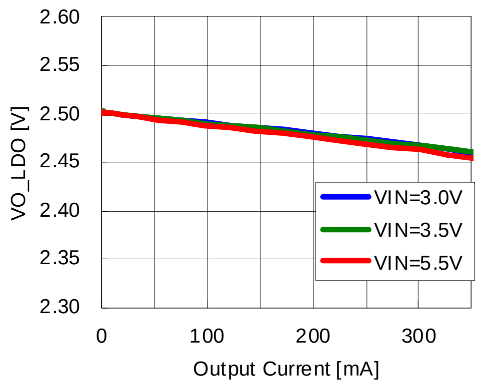


26) Output Voltage vs Output Current (LDO)

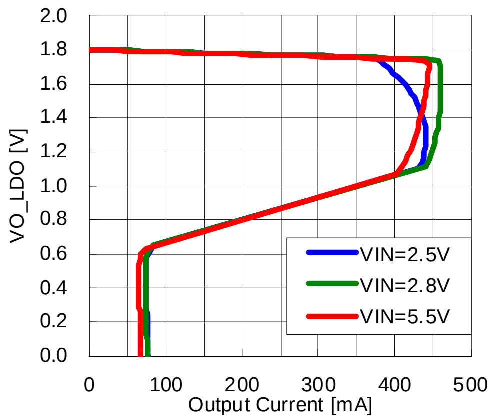
R1293K181A
Ta=25℃



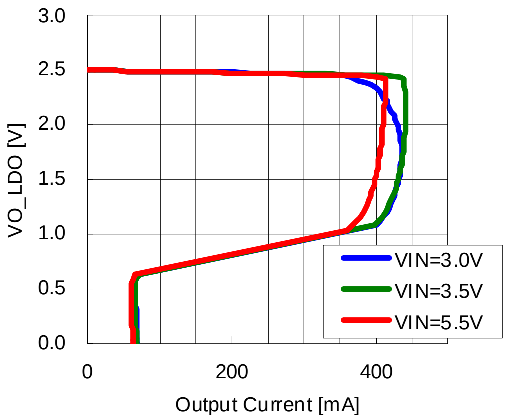
R1293K251A
Ta=25℃



R1293K181A
Ta=25℃

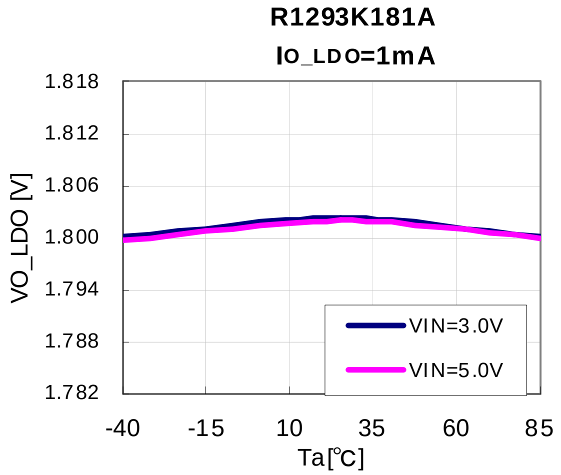


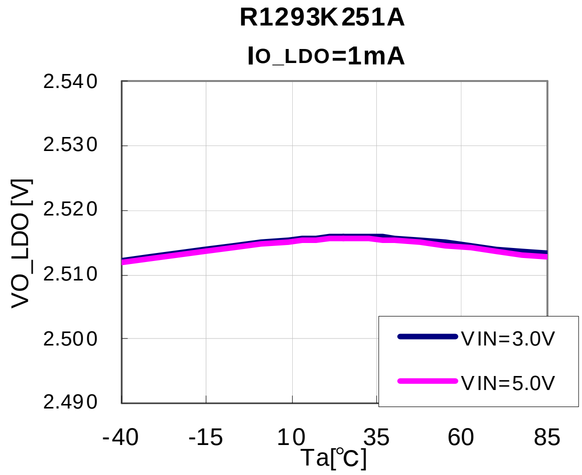
R1293K251A
Ta=25℃



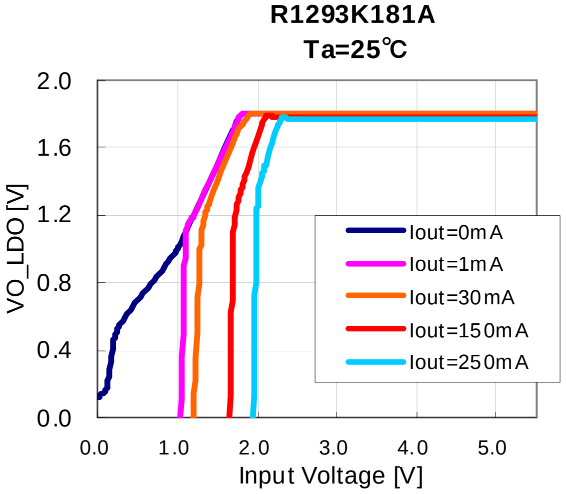
RICOH

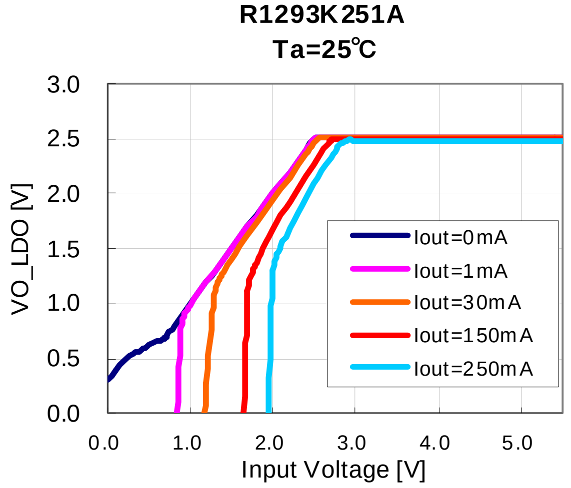
27) Output Voltage vs. Temperature (LDO)



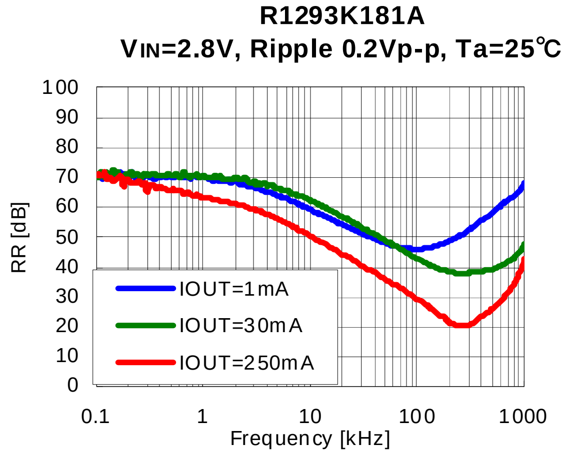


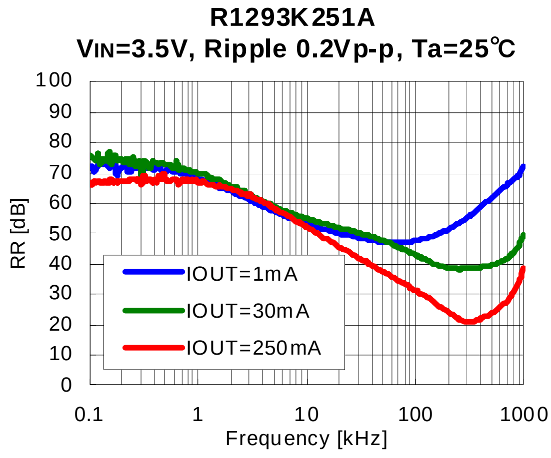
28) Output Voltage vs. VIN Voltage (LDO)





29) LDO Ripple Rejection vs. Frequency

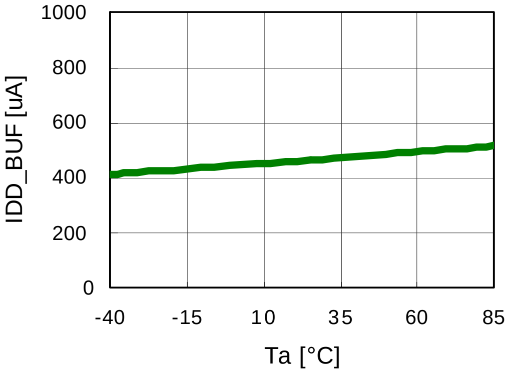




30) Amplifier Supply Current vs. Temperature (BUFFER AMP)

R1293KxxxA

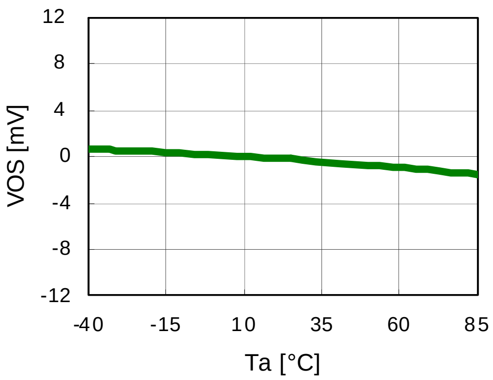
VIN=3.6V, VBUFF=16V, IN_COM=8V, IN_GM*=8V



31) VCOM Offset Voltage vs. Temperature

R1293KxxxA

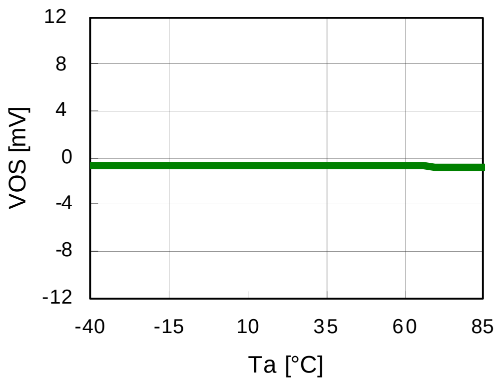
VIN=3.6V, VBUFF=7V, IN_COM=3.5V, IO_COM=0mA



32) GAMMA Offset Voltage vs. Temperature

R1293KxxxA

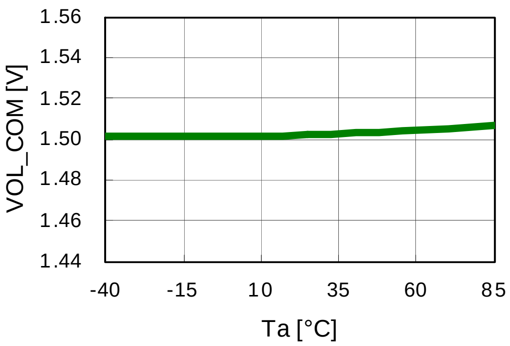
VIN=3.6V, VBUFF=7V, IN_GM*=3.5V, IO_GM*=0mA



33) VCOM Output Voltage vs. Temperature

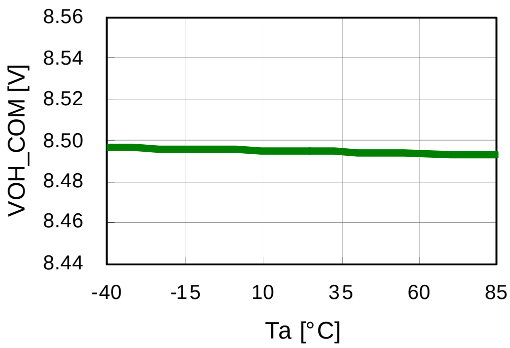
R1293KxxxA

VIN=3.6V, VBUFF=10V, IN_COM=1.5V, IO_COM=+50mA



R1293KxxxA

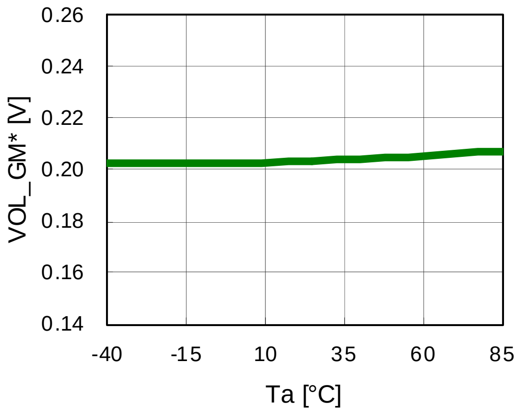
VIN=3.6V, VBUFF=10V, IN_COM=8.5V, IO_COM=-50mA



34) GAMMA Output Voltage vs. Temperature

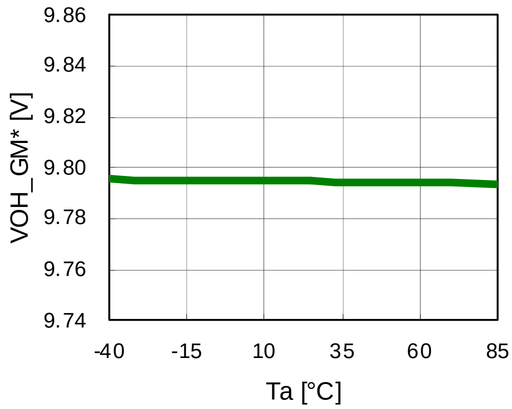
R1293KxxxA

VIN=3.6V, VBUFF=10V, IN_GM*=1.5V, IO_GM*=+10mA



R1293KxxxA

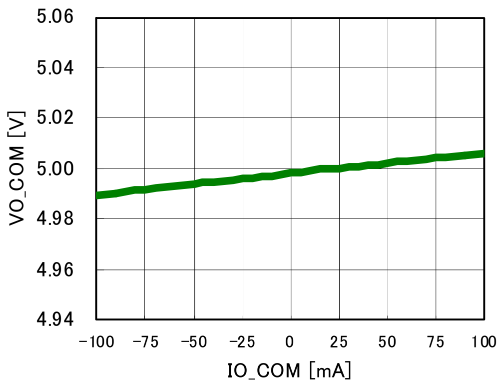
VIN=3.6V, VBUFF=10V, IN_GM*=8.5V, IO_GM*=-10mA



35) VCOM Output Voltage vs. Output Current

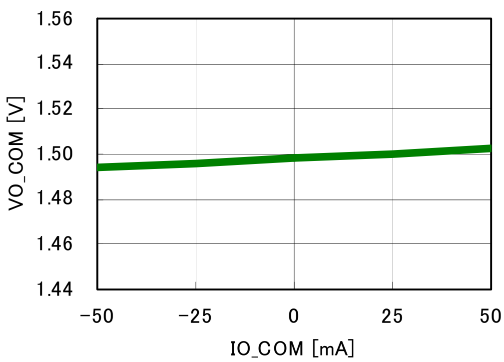
R1293KxxxA

VIN=3.6V, VBUFF=10V, IN_COM=5V, Ta=25℃



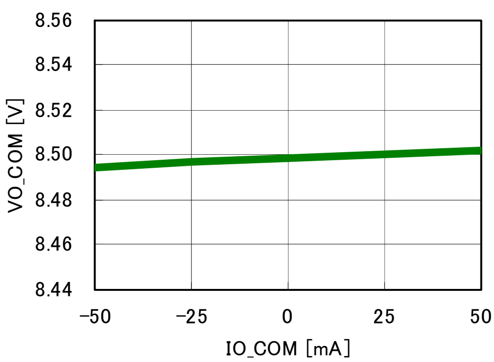
R1293KxxxA

VIN=3.6V, VBUFF=10V, IN_COM=1.5V, Ta=25℃



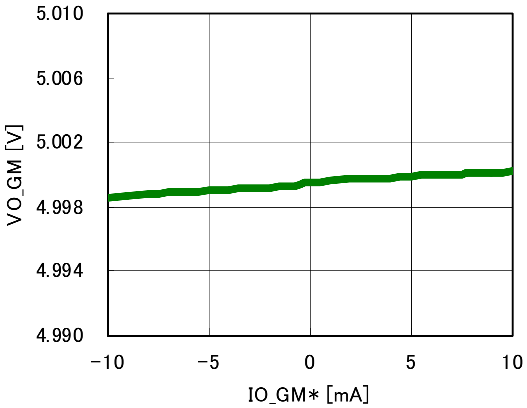
R1293KxxxA

VIN_DC=3.6V, VBUFF=10V, IN_COM=8.5V, Ta=25℃

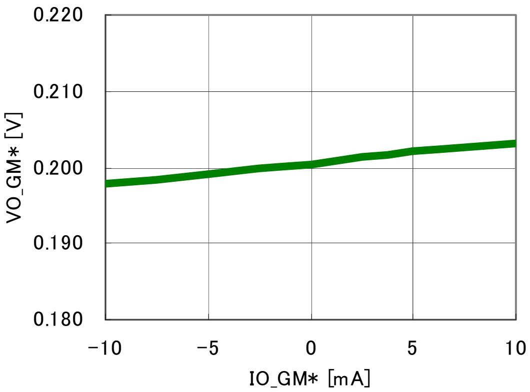


36) GAMMA Output Voltage vs. Output Current

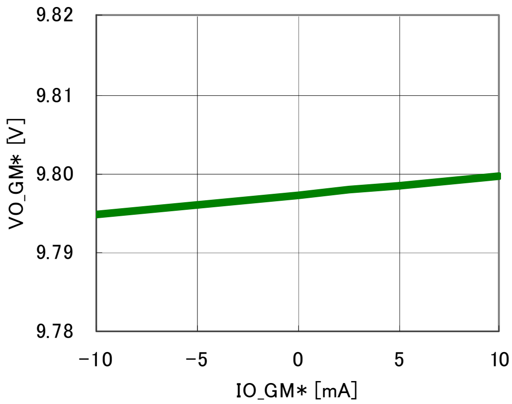
R1293KxxxA
V_{IN}=3.6V, V_{BUFF}=10V, IN_GM*=5V, Ta=25°C



R1293KxxxA
V_{IN}=3.6V, V_{BUFF}=10V, IN_GM*=0.2V, Ta=25°C

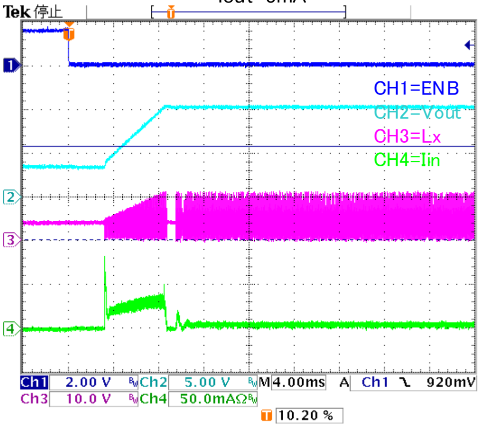


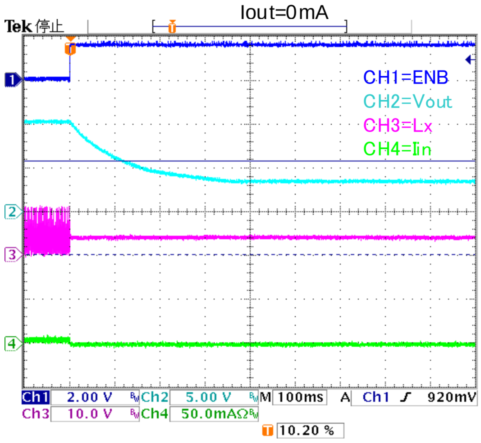
R1293KxxxA
V_{IN}=3.6V, V_{BUFF}=10V, IN_GM*=9.8V, Ta=25°C



37) DCDC Turn-on/Turn-off WaveForm by ENB

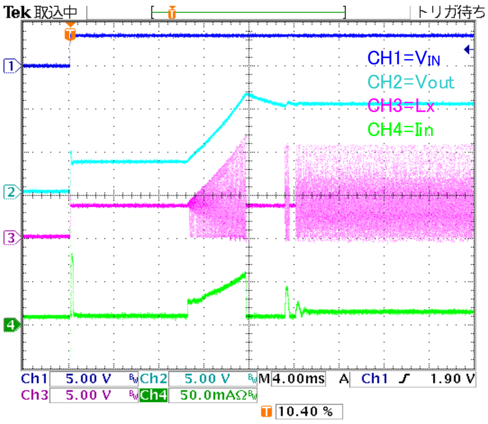
R1293KxxxA	R1293KxxxA
V_{IN}=3.6V, Vout=V_{BUFF}=10V,fosc=700kHz, SEL=0V, Ta=25℃	V_{IN}=3.6V, Vout=V_{BUFF}=10V,fosc=700kHz, SEL=0V, Ta=25℃
Iout=0mA	Iout=0mA

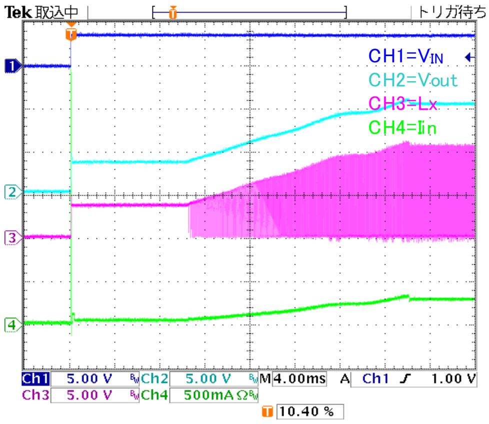




38) DCDC Turn-on/Turn-off WaveForm (DTC Soft Start) by VIN

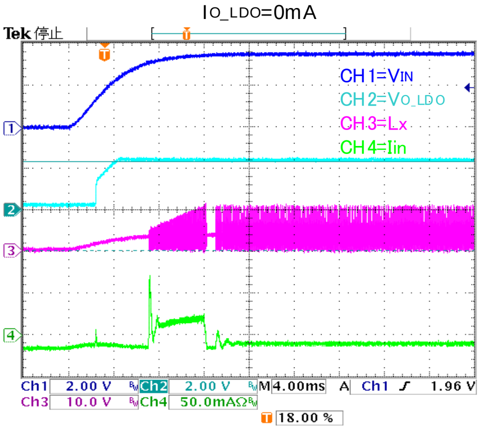
R1293KxxxA	R1293KxxxA
V_{IN}=3.6V, Vout=V_{BUFF}=10V,fosc=700kHz, SEL=0V, Ta=25℃	V_{IN}=3.6V, Vout=V_{BUFF}=10V,fosc=700kHz, SEL=0V, Ta=25℃
R_5=130kΩ, C_{DTC}=0.22uF, Iout=0mA	R_5=130kΩ, C_{DTC}=0.22uF, I_{OUT}=80mA

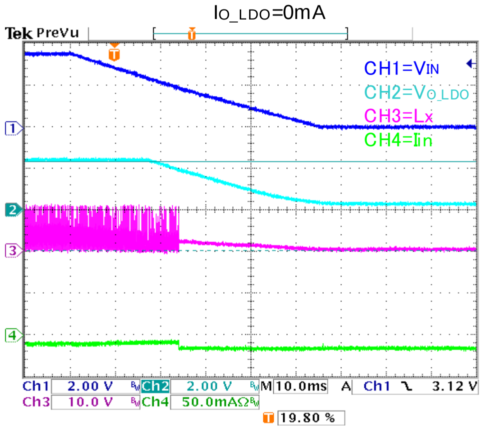




39) LDO Turn-on/Turn-off WaveForm by VIN

V_{IN}=3.6V,V_{O_LDO}=2.4V,Ta=25℃	V_{IN}=3.6V,V_{O_LDO}=2.4V,Ta=25℃
I_{O_LDO}=0mA	I_{O_LDO}=0mA



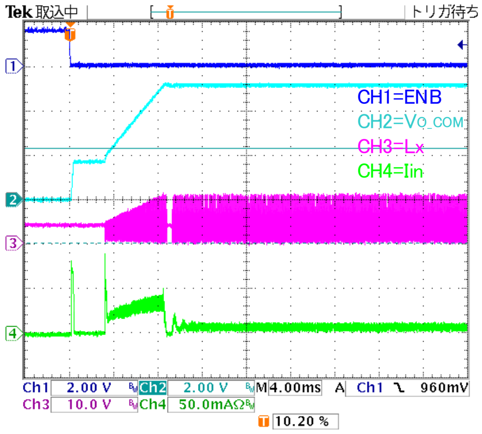


40) VCOM Turn-on/Turn-off WaveForm by ENB

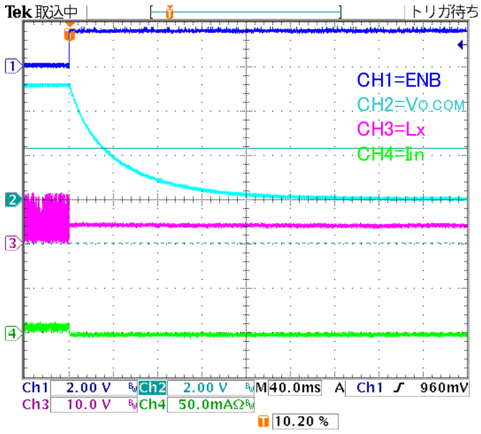
V_{IN}=3.6V, Vout=V_{BUFF}=10V, IN_COM=V_{BUFF}/2 V, SEL=0V, Ta=25℃

V_{IN}=3.6V, Vout=V_{BUFF}=10V, IN_COM=V_{BUFF}/2 V, , SEL=0V, Ta=25℃

Iout=1mA



Iout=1mA

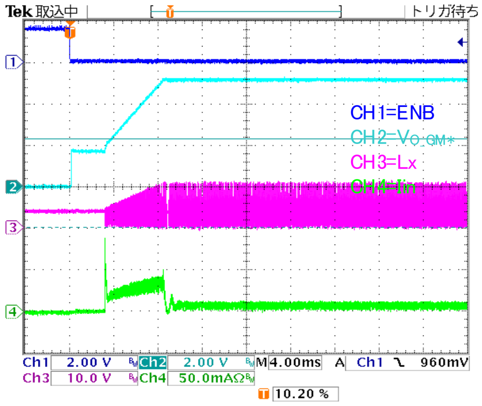


41) GAMMA Turn-on/Turn-off WaveForm by ENB

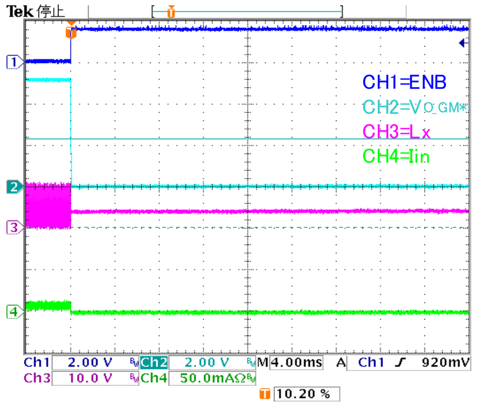
V_{IN}=3.6V, Vout=V_{BUFF}=10V, IN_GM=V_{BUFF}/2 V, SEL=0V, Ta=25℃

V_{IN}=3.6V, Vout=V_{BUFF}=10V, IN_GM=V_{BUFF}/2 V, SEL=0V, Ta=25℃

Iout=1mA

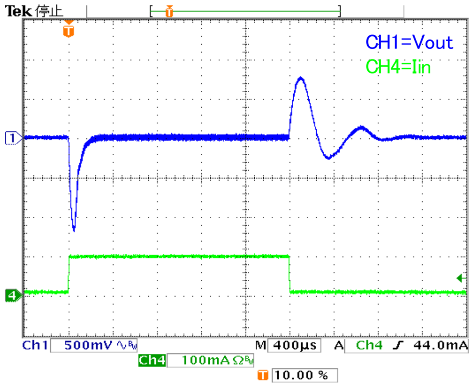


Iout=1mA

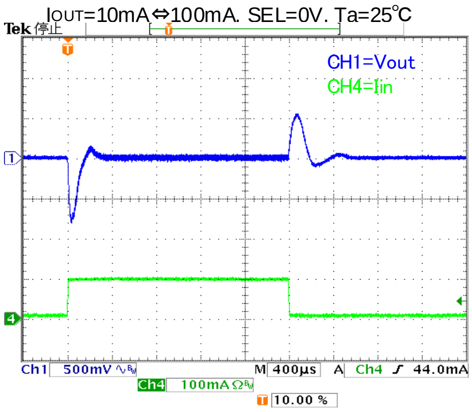


42) DCDC Load Tranjent Response

V_{IN}=3.3V, Vout=V_{BUFF}=10V, f_{osc}=700kHz,
I_{OUT}=10mA⇔100mA, SEL=0V, Ta=25℃



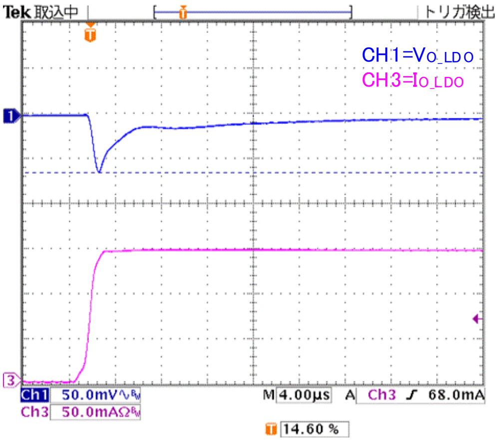
V_{IN}=5.0V, Vout=V_{BUFF}=10V, f_{osc}=700kHz,
I_{OUT}=10mA⇔100mA. SEL=0V. Ta=25℃



43) LDO Load Tranjent Response

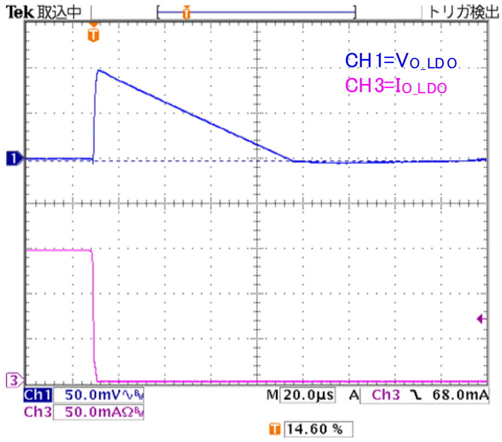
V_{IN}=2.9V, V_{O_LDO}=2.4V

I_{O_LDO}=1mA→150mA, Ta=25℃



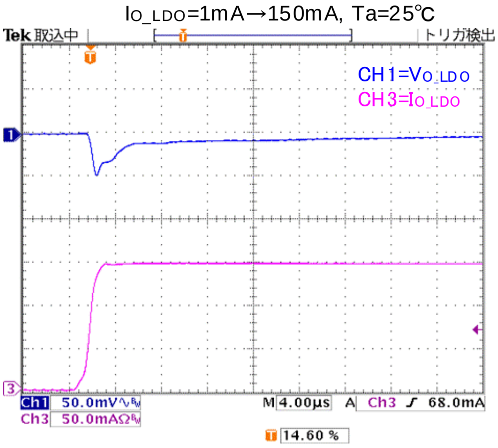
V_{IN}=2.9V, V_{O_LDO}=2.4V

I_{O_LDO}=150mA→1mA, Ta=25℃



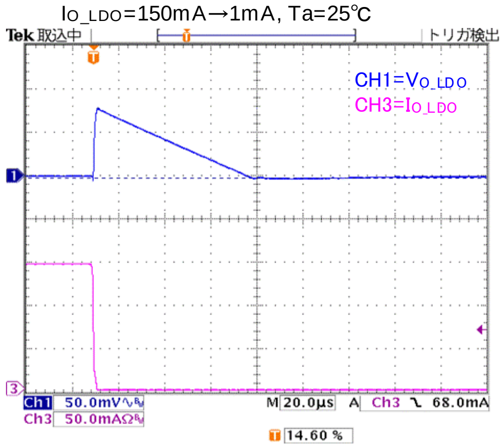
V_{IN}=5.5V, V_{O_LDO}=2.4V

I_{O_LDO}=1mA→150mA, Ta=25℃



V_{IN}=5.5V, V_{O_LDO}=2.4V

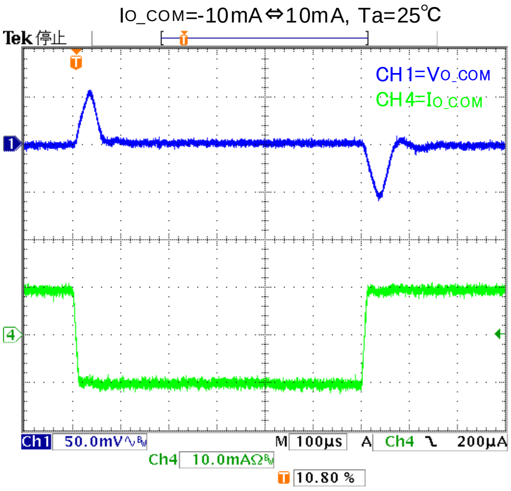
I_{O_LDO}=150mA→1mA, Ta=25℃



44) VCOM Load Tranjent Response

V_{IN}=3.6V, V_{BUFF}=10V, IN_COM=V_{BUFF}/2 V,

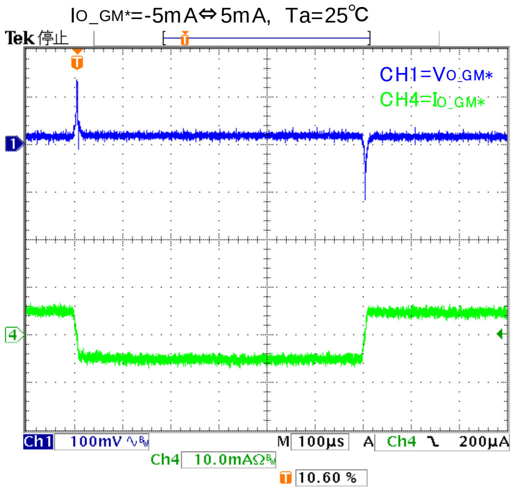
I_{O_COM}=-10mA⇔10mA, Ta=25℃



45) GAMMA Load Tranjent Response

V_{IN}=3.6V, V_{BUFF}=10V, IN_GM*=V_{BUFF}/2 V,

I_{O_GM*}=-5mA⇔5mA, Ta=25℃



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