

## 13 $\mu$ A/ch, Rail-to-Rail Output Quad CMOS Operational Amplifier

### ■ GENERAL DESCRIPTION

The **NJU7028** is a low power, quad CMOS operational amplifier. It is tolerant to RF noise. The NJU7028 can operate from a single-supply voltage of +1.8V to +5.5V. In addition, this amplifier features Rail-to-Rail output and low input bias current (1pA). Because of these features, the NJU7028 is ideal for low-side current sense amplifier. The very low supply current of the NJU7028 (13 $\mu$ A/ch) makes it suitable for battery-operated application.

### ■ PACKAGE OUTLINE



**NJU7028V  
(SSOP14)**

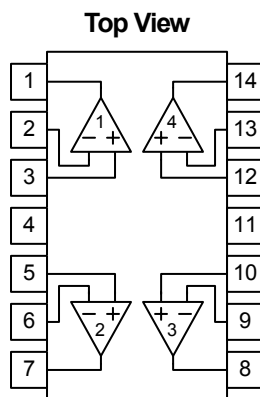
### ■ FEATURES

- Low Supply Current  $I_{DD}=13\mu A/ch$  typ.
- Low Operating Voltage  $V_{opr}= 1.8V$  to  $5.5V$
- Rail-to-Rail Output  $V_{OH}=4.9V$  min./  $V_{OL}=0.1V$  max. (at  $V_{DD}= 5V$ ,  $R_L=100k\Omega$ )  
 $V_{OH}=4.8V$  min./  $V_{OL}=0.2V$  max. (at  $V_{DD}= 5V$ ,  $I_O=1mA$ )
- Enhanced RF Noise Immunity
- CMOS Process
- Package SSOP14

### ■ APPLICATION

- Battery-operated application
- Battery monitor
- Current sensor
- Photodiode amplification

### ■ PIN CONFIGURATION



#### Pin Function

- |             |              |
|-------------|--------------|
| 1. OUTPUT 1 | 8. OUTPUT 3  |
| 2. -INPUT 1 | 9. -INPUT 3  |
| 3. +INPUT 1 | 10. +INPUT 3 |
| 4. $V_{DD}$ | 11. $V_{SS}$ |
| 5. +INPUT 2 | 12. +INPUT 4 |
| 6. -INPUT 2 | 13. -INPUT 4 |
| 7. OUTPUT 2 | 14. OUTPUT 4 |

■ **ABSOLUTE MAXIMUM RATINGS** (Ta=25°C, unless otherwise noted.)

PARAMETER	SYMBOL	RATINGS	UNIT
Supply Voltage	V <sub>DD</sub>	+7	V
Input Common Mode Voltage	V <sub>ICM</sub>	V <sub>SS</sub> -0.3 to V <sub>DD</sub> +0.3	V
Differential Input Voltage	V <sub>ID</sub>	±7 (Note1)	V
Power Dissipation	P <sub>D</sub>	400 (Note2)	mW
Operating Temperature Range	T <sub>opr</sub>	-40 to +85	°C
Storage Temperature Range	T <sub>stg</sub>	-55 to +125	°C

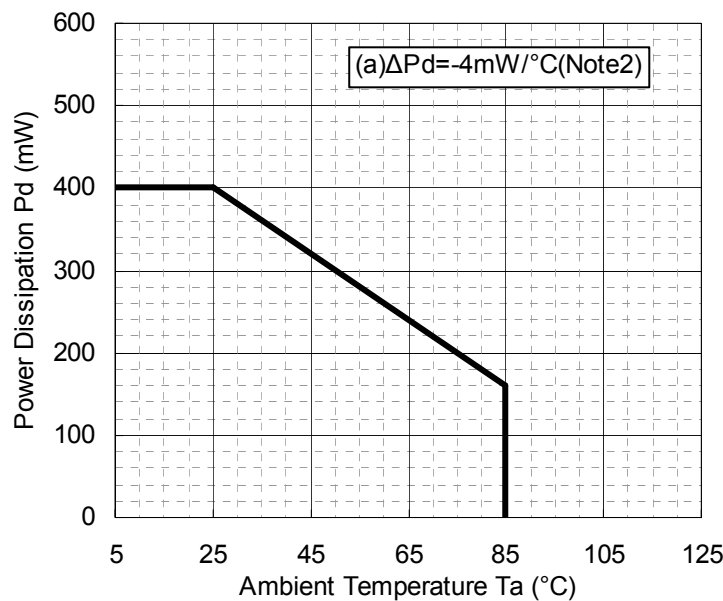
(Note1) For supply voltage less than +7V, the absolute maximum rating is equal to the supply voltage.

(Note2) EIA/JEDEC STANDARD Test board (114.3 x 76.2 x 1.6mm, 2layers, FR-4) mounting.

(Note3) Do not exceed "Power dissipation: P<sub>D</sub>" in which power dissipation in IC is shown by the absolute maximum rating.  
See Figure "Power Dissipation Curve" when ambient temperature is over 25°C.

**Figure 1**

Power Dissipation Derating Curve



■ **RECOMMENDED OPERATING CONDITION** (Ta=25°C)

PARAMETER	SYMBOL	RATING	UNIT
Supply Voltage	V <sub>DD</sub>	1.8 to 5.5	V

## ■ ELECTRICAL CHARACTERISTICS

### ●DC CHARACTERISTICS ( $V_{DD}=5V$ , $V_{SS}=0V$ , $T_a=25^\circ C$ , unless otherwise noted.)

PARAMETER	SYMBOL	TEST CONDITION	MIN.	TYP.	MAX.	UNIT
Supply Current	$I_{DD}$	No Signal	-	48	72	$\mu A$
Input Offset Voltage	$V_{IO}$	$V_{IC}=0V$ , $R_S=50\Omega$	-	0.9	4	mV
Input Offset Voltage drift	$\Delta V_{IO}/\Delta T$		-	1.5	-	$\mu V/^\circ C$
Input Bias Current	$I_B$		-	1	-	$\mu A$
Input Offset Current	$I_{IO}$		-	1	-	$\mu A$
Open loop gain	$A_V$	$V_O=0.5V$ to $4.5V$ , $R_L=100k\Omega$ to $2.5V$	70	90	-	dB
Common Mode Rejection Ratio	CMR	$V_{ICM}=0V$ to $4.1V$	65	80	-	dB
Supply Voltage Rejection Ratio	SVR	$V_{DD}=1.8V$ to $5.5V$	70	90	-	dB
Maximum Output Voltage 1	$V_{OH1}$	$R_L=100k\Omega$ to $2.5V$	4.9	4.95	-	V
	$V_{OL1}$	$R_L=100k\Omega$ to $2.5V$	-	0.05	0.1	V
Maximum Output Voltage 2	$V_{OH2}$	$R_L=100k\Omega$ to $0V$	4.9	4.95	-	V
	$V_{OL2}$	$R_L=100k\Omega$ to $0V$	-	0.02	0.05	V
Maximum Output Voltage 3	$V_{OH3}$	$I_{source}=1mA$	4.8	4.85	-	V
	$V_{OL3}$	$I_{sink}=1mA$	-	0.15	0.2	V
Common Mode Input Voltage Range	$V_{ICM}$	CMR $\geq 65dB$	0	-	4.1	V

### ●AC CHARACTERISTICS ( $V_{DD}=5V$ , $V_{SS}=0V$ , $T_a=25^\circ C$ , unless otherwise noted.)

PARAMETER	SYMBOL	TEST CONDITION	MIN.	TYP.	MAX.	UNIT
Gain Bandwidth Product	GBW	$R_L=100k\Omega$ to $2.5V$ , $C_L=20pF$ , $f=10kHz$	-	160	-	kHz
Phase Margin	$\phi_M$	$R_L=100k\Omega$ to $2.5V$ , $C_L=20pF$	-	80	-	deg
Gain Margin	$G_M$	$R_L=100k\Omega$ to $2.5V$ , $C_L=20pF$	-	15	-	dB
Equivalent Input Noise Voltage	$e_n$	$f=1kHz$	-	50	-	$nV/\sqrt{Hz}$
Slew Rate	SR	$G_V=0dB$ , $R_L=100k\Omega$ to $2.5V$ , $C_L=20pF$ , $V_{in}=3V_{pp}$ (1V to 4V) (Note4) (Note5)	-	0.05	-	V/ $\mu s$
Power Bandwidth	PBW	$G_V=6dB$ , $R_F=50k\Omega$ , $R_G=50k\Omega$ , $C_L=20pF$ , $V_{in}=2.5V_{pp}$ (1.25V to 3.75V), $V_o \geq 4.8V_{pp}$ (Note6)	-	5	-	kHz
Total Harmonic Distortion	THD	$G_V=6dB$ , $R_F=50k\Omega$ , $R_G=50k\Omega$ , $C_L=20pF$ , $V_o=4V_{pp}$ , $f=100Hz$ (Note6)	-	0.01	-	%

(Note4) Slew rate is defined by the lower value of the rise or fall.

(Note5) See figure2-1 for test circuit.

(Note6) See figure2-3 for test circuit.

## ■ ELECTRICAL CHARACTERISTICS

### ●DC CHARACTERISTICS ( $V_{DD}=3V$ , $V_{SS}=0V$ , $T_a=25^{\circ}C$ , unless otherwise noted.)

PARAMETER	SYMBOL	TEST CONDITION	MIN.	TYP.	MAX.	UNIT
Supply Current	$I_{DD}$	No Signal	-	45	68	$\mu A$
Input Offset Voltage	$V_{IO}$	$V_{ic}=0V$ , $R_S=50\Omega$	-	0.9	4	mV
Input Offset Voltage drift	$\Delta V_{IO}/\Delta T$		-	1.5	-	$\mu V/^{\circ}C$
Input Bias Current	$I_B$		-	1	-	pA
Input Offset Current	$I_{IO}$		-	1	-	pA
Open loop gain	$A_v$	$V_o=0.5V$ to $2.5V$ , $R_L=100k\Omega$ to $1.5V$	70	90	-	dB
Common Mode Rejection Ratio	CMR	$V_{ICM}=0V$ to $2.1V$	65	80	-	dB
Supply Voltage Rejection Ratio	SVR	$V_{DD}=1.8V$ to $5.5V$	70	90	-	dB
Maximum Output Voltage 1	$V_{OH1}$	$R_L=100k\Omega$ to $1.5V$	2.9	2.95	-	V
	$V_{OL1}$	$R_L=100k\Omega$ to $1.5V$	-	0.05	0.1	V
Maximum Output Voltage 2	$V_{OH2}$	$R_L=100k\Omega$ to $0V$	2.9	2.95	-	V
	$V_{OL2}$	$R_L=100k\Omega$ to $0V$	-	0.02	0.05	V
Maximum Output Voltage 3	$V_{OH3}$	$I_{source}=1mA$	2.8	2.85	-	V
	$V_{OL3}$	$I_{sink}=1mA$	-	0.15	0.2	V
Common Mode Input Voltage Range	$V_{ICM}$	CMR $\geq 65dB$	0	-	2.1	V

### ●AC CHARACTERISTICS ( $V_{DD}=3V$ , $V_{SS}=0V$ , $T_a=25^{\circ}C$ , unless otherwise noted.)

PARAMETER	SYMBOL	TEST CONDITION	MIN.	TYP.	MAX.	UNIT
Gain Bandwidth Product	GBW	$R_L=100k\Omega$ to $1.5V$ , $C_L=20pF$ , $f=10kHz$	-	150	-	kHz
Phase Margin	$\phi_M$	$R_L=100k\Omega$ to $1.5V$ , $C_L=20pF$	-	80	-	deg
Gain Margin	$G_M$	$R_L=100k\Omega$ to $1.5V$ , $C_L=20pF$	-	15	-	dB
Equivalent Input Noise Voltage	$e_n$	$f=1kHz$	-	50	-	$nV/\sqrt{Hz}$
Slew Rate	SR	$G_v=0dB$ , $R_L=100k\Omega$ to $1.5V$ , $C_L=20pF$ , $V_{in}=1V_{pp}$ (1V to 2V) (Note4) (Note5)	-	0.05	-	V/ $\mu s$
Power Bandwidth	PBW	$G_v=6dB$ , $R_F=50k\Omega$ , $R_G=50k\Omega$ , $C_L=20pF$ , $V_{in}=1.5V_{pp}$ (0.75V to 2.25V), $V_o\geq 2.8V_{pp}$ (Note6)	-	8	-	kHz
Total Harmonic Distortion	THD	$G_v=6dB$ , $R_F=50k\Omega$ , $R_G=50k\Omega$ , $C_L=20pF$ , $V_o=2V_{pp}$ , $f=100Hz$ (Note6)	-	0.01	-	%

(Note4) Slew rate is defined by the lower value of the rise or fall.

(Note5) See figure2-1 for test circuit.

(Note6) See figure2-3 for test circuit.

## ■ ELECTRICAL CHARACTERISTICS

●DC CHARACTERISTICS ( $V_{DD}=1.8V$ ,  $V_{SS}=0V$ ,  $T_a=25^\circ C$ , unless otherwise noted.)

PARAMETER	SYMBOL	TEST CONDITION	MIN.	TYP.	MAX.	UNIT
Supply Current	$I_{DD}$	No Signal	-	43	65	$\mu A$
Input Offset Voltage	$V_{IO}$	$V_{ic}=0V$ , $R_S=50\Omega$	-	0.9	4	mV
Input Offset Voltage drift	$\Delta V_{IO}/\Delta T$		-	1.5	-	$\mu V/^\circ C$
Input Bias Current	$I_B$		-	1	-	pA
Input Offset Current	$I_{IO}$		-	1	-	pA
Open loop gain	$A_V$	$V_o=0.5V$ to $2.5V$ , $R_L=100k\Omega$ to $0.9V$	70	90	-	dB
Common Mode Rejection Ratio	CMR	$V_{ICM}=0V$ to $0.9V$	65	80	-	dB
Supply Voltage Rejection Ratio	SVR	$V_{DD}=1.8V$ to $5.5V$	70	90	-	dB
Maximum Output Voltage 1	$V_{OH1}$	$R_L=100k\Omega$ to $0.9V$	1.7	1.75	-	V
	$V_{OL1}$	$R_L=100k\Omega$ to $0.9V$	-	0.05	0.1	V
Maximum Output Voltage 2	$V_{OH2}$	$R_L=100k\Omega$ to $0V$	1.7	1.75	-	V
	$V_{OL2}$	$R_L=100k\Omega$ to $0V$	-	0.02	0.05	V
Maximum Output Voltage 3	$V_{OH3}$	$I_{source}=0.5mA$	1.5	1.55	-	V
	$V_{OL3}$	$I_{sink}=0.5mA$	-	0.25	0.3	V
Common Mode Input Voltage Range	$V_{ICM}$	CMR $\geq$ 65dB	0	-	0.9	V

●AC CHARACTERISTICS ( $V_{DD}=1.8V$ ,  $V_{SS}=0V$ ,  $T_a=25^\circ C$ , unless otherwise noted.)

PARAMETER	SYMBOL	TEST CONDITION	MIN.	TYP.	MAX.	UNIT
Gain Bandwidth Product	GBW	$R_L=100k\Omega$ to $0.9V$ , $C_L=20pF$ , $f=10kHz$	-	140	-	kHz
Phase Margin	$\square_M$	$R_L=100k\Omega$ to $0.9V$ , $C_L=20pF$	-	80	-	deg
Gain Margin	$G_M$	$R_L=100k\Omega$ to $0.9V$ , $C_L=20pF$	-	15	-	dB
Equivalent Input Noise Voltage	$e_n$	$f=1kHz$	-	50	-	$nV/\sqrt{Hz}$
Slew Rate	SR	$G_V=0dB$ , $R_L=100k\Omega$ to $1.5V$ , $C_L=20pF$ , $V_{in}=0.5V_{pp}$ ( $0.3V$ to $0.8V$ ) (Note4) (Note7)	-	0.05	-	V/us
Power Bandwidth	PBW	$G_V=6dB$ , $R_F=50k\Omega$ , $R_G=50k\Omega$ , $C_L=20pF$ , $V_{in}=0.9V_{pp}$ ( $0V$ to $0.9V$ ), $V_o\geq 1.6V_{pp}$ (Note8)	-	14	-	kHz
Total Harmonic Distortion	THD	$G_V=6dB$ , $R_F=50k\Omega$ , $R_G=50k\Omega$ , $C_L=20pF$ , $V_o=1V_{pp}$ , $f=100Hz$ (Note8)	-	0.01	-	%

(Note4) Slew rate is defined by the lower value of the rise or fall.

(Note7) See figure2-2 for test circuit.

(Note8) See figure2-4 for test circuit..

## MEASUREMENT CIRCUITS

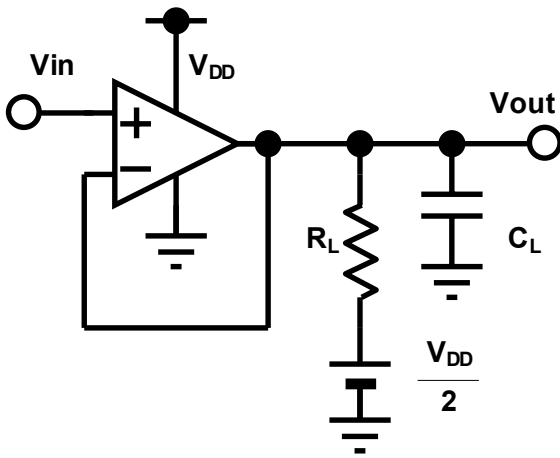


Figure 2-1: Measurement circuit 1

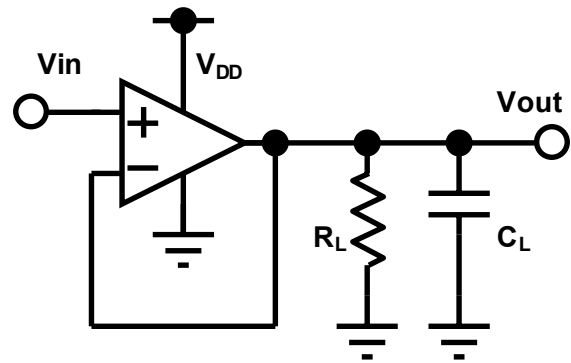


Figure 2-2: Measurement circuit 2

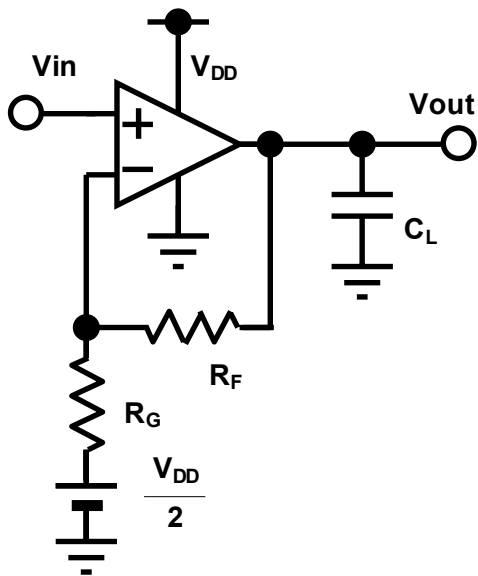


Figure 2-3: Measurement circuit 3

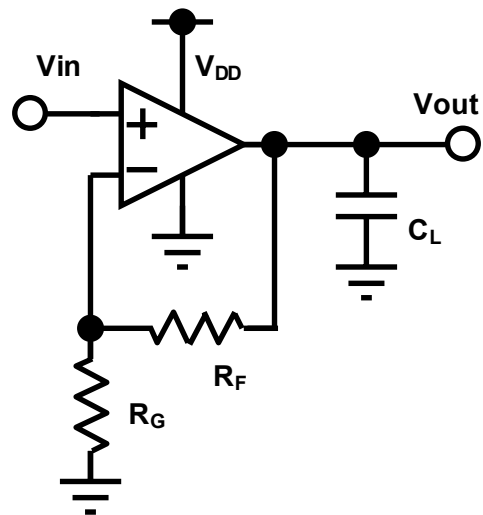
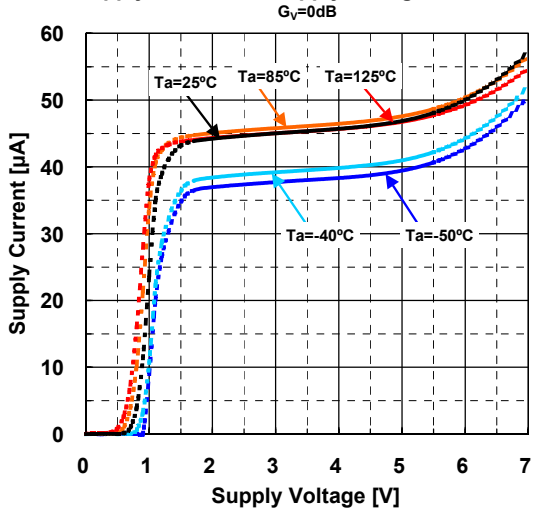


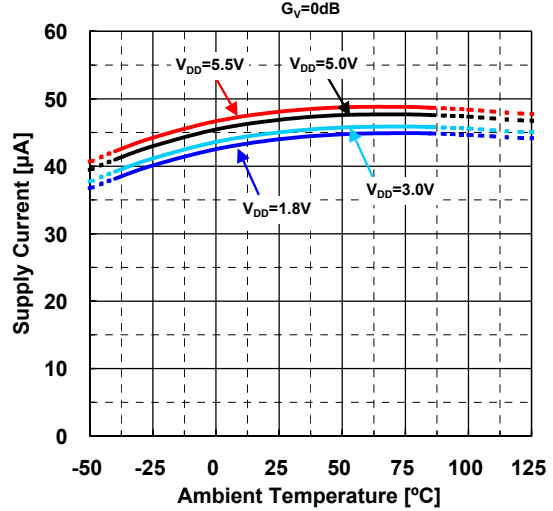
Figure 2-4: Measurement circuit 4

## ■ TYPICAL CHARACTERISTICS

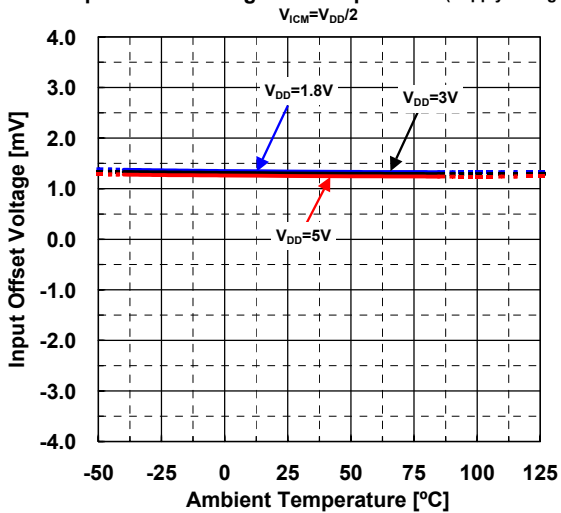
Supply Current vs. Supply Voltage (Temperature)



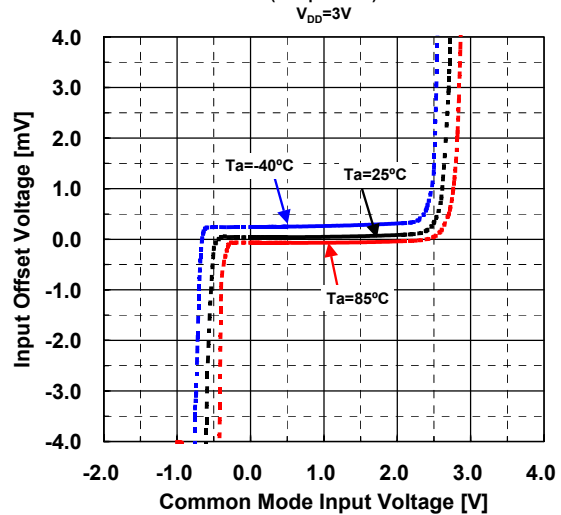
Supply Current vs. Temperature (Supply Voltage)



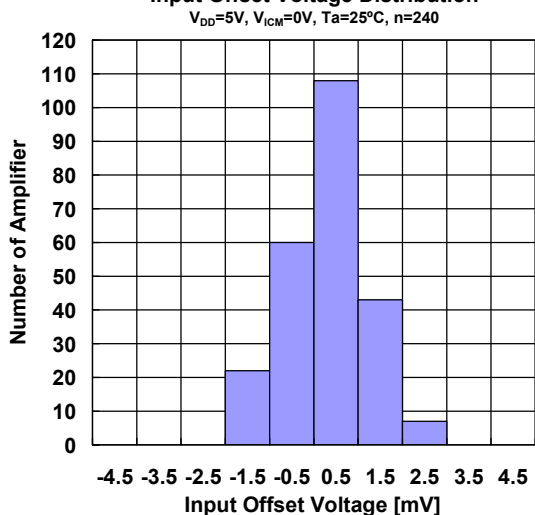
Input Offset Voltage vs. Temperature (Supply Voltage)



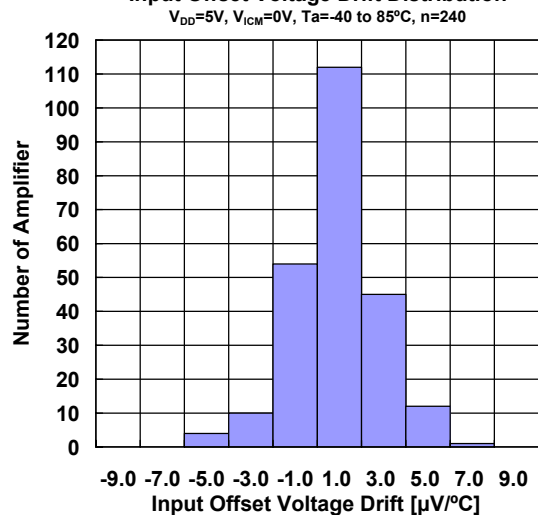
Input Offset Voltage vs. Common Mode Input Voltage (Temperature)



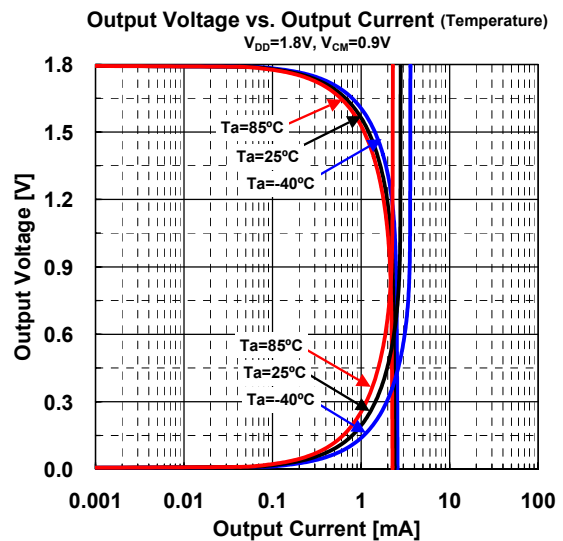
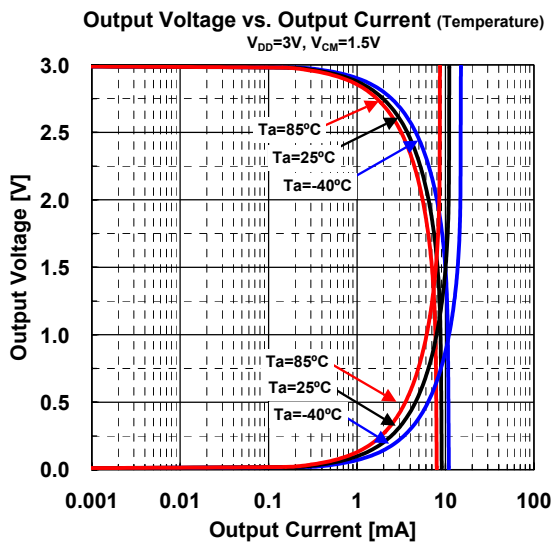
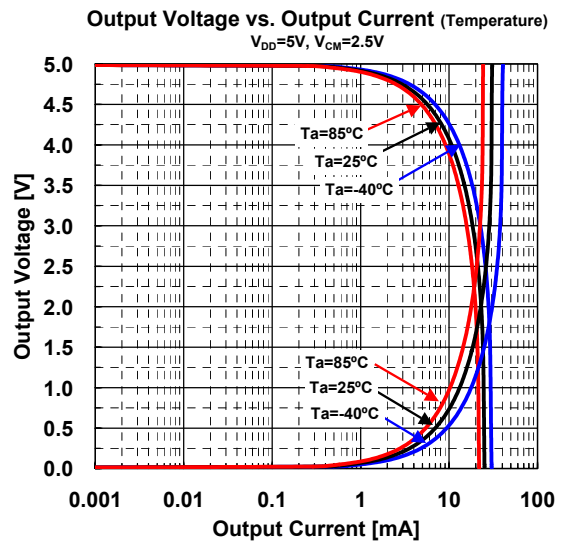
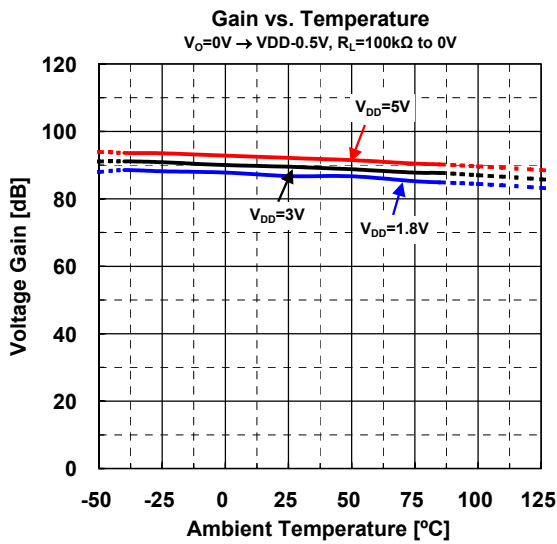
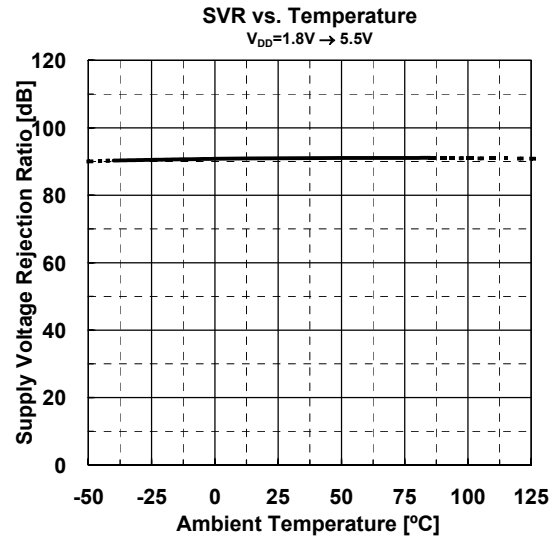
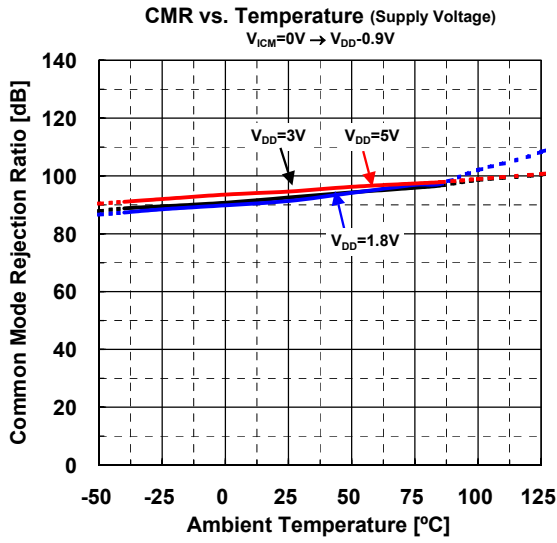
Input Offset Voltage Distribution



Input Offset Voltage Drift Distribution

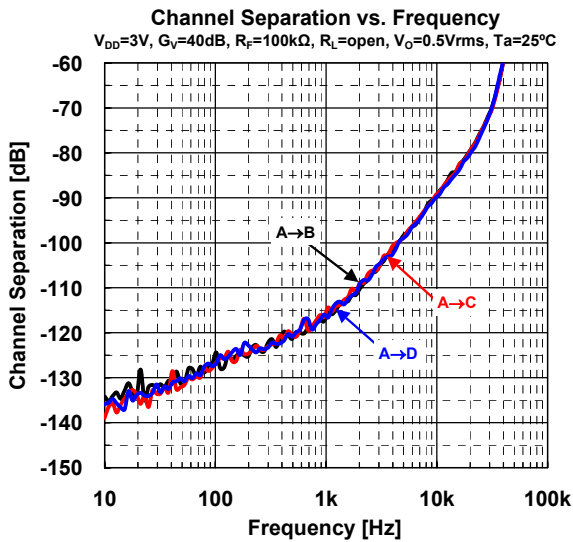
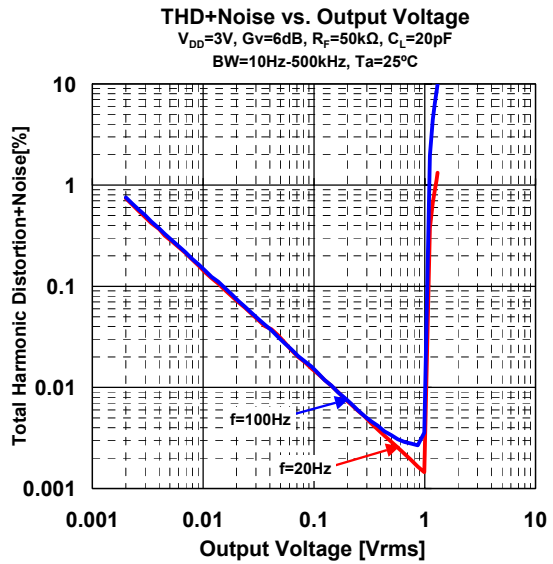
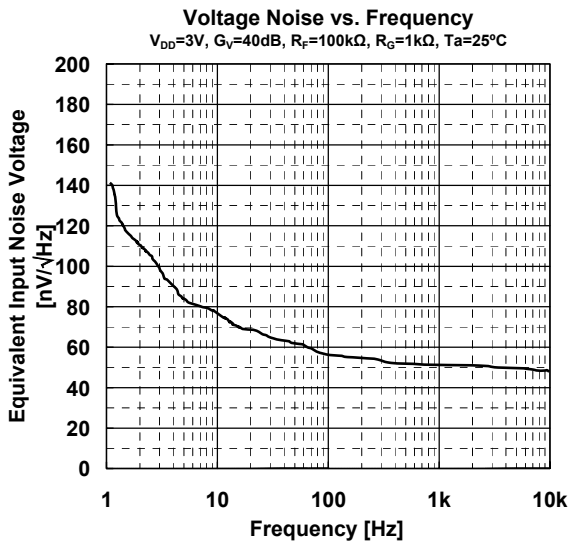
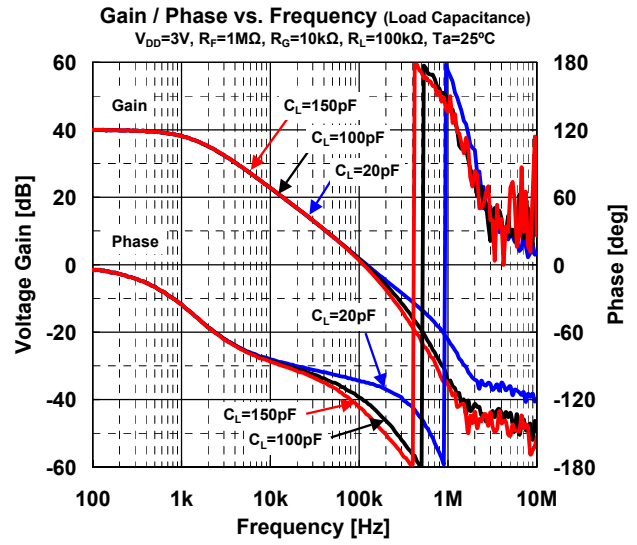
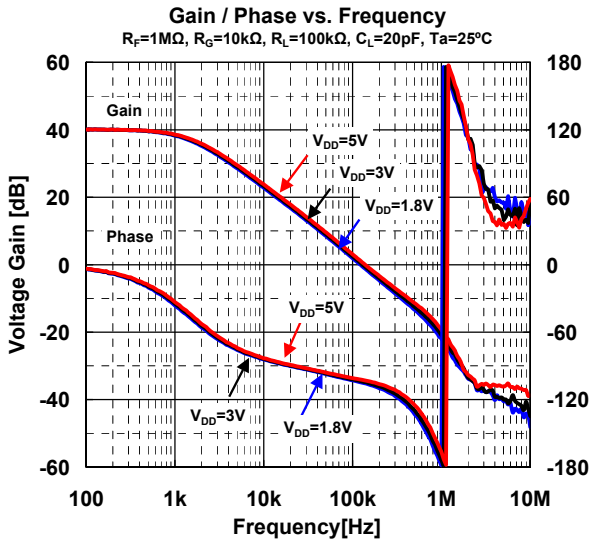


## ■ TYPICAL CHARACTERISTICS

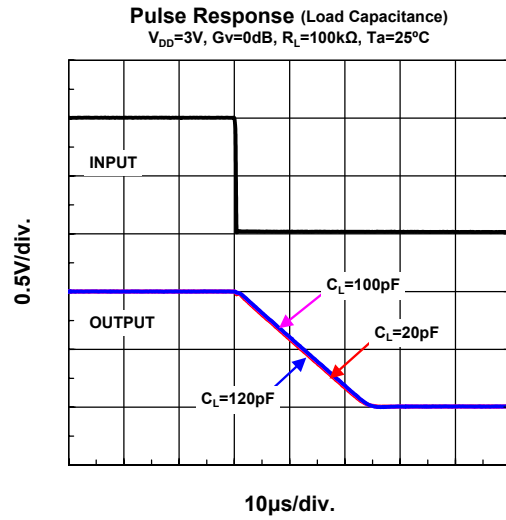
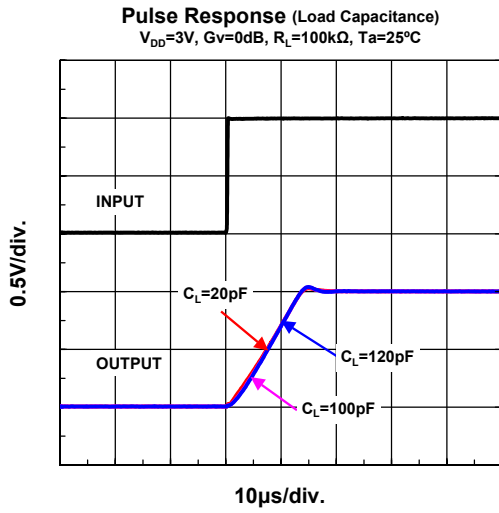




■ TYPICAL CHARACTERISTICS



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**[CAUTION]**

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