Rail-to-Rail Operational Amplifier

General Description

The RT9133A/B consist low cost, high slew rates, single-supply rail-to-rail input and output operation amplifiers. The RT9133A contains a single amplifier and RT9133B contains two amplifiers. The RT9133A/B have high slew rates (12V/us), 35mA continuous output current, 120mA peak output current and offset voltage below 10mV. The RT9133A/B are ideal for Thin Film Transistor Liquid Crystal Displays (TFT-LCD).

The RT9133A is available in SOT-23-5 and WDFN-6L 2x2 packages. The RT9133B is available in MSOP-8 package. The RT9133A/B are specified for operation over the full –40°C to +85°C temperature range.

Ordering Information

RT9133A/B□□

- Package Type
  - QW : WDFN-6L 2x2 (Single only)
  - B : SOT-23-5 (Single only)
  - F : MSOP-8 (Dual only)
- Lead Plating System
  - P : Pb Free
  - G : Green (Halogen Free and Pb Free)
- A : Single Amplifier
- B : Dual Amplifier

Note :

Richtek products are :

- RoHS compliant and compatible with the current requirements of IPC/JEDEC J-STD-020.
- Suitable for use in SnPb or Pb-free soldering processes.

Marking Information

For marking information, contact our sales representative directly or through a Richtek distributor located in your area.

Features

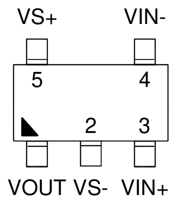
- **Rail-to-Rail Output Swing**
- **Supply Voltage : 4.5V to 15V**
- **Continuous Output Current : 35mA**
- **Peak Output Current : 120mA**
- **High Slew Rate : 12V/us**
- **Offset Voltage : 10mV**
- **RoHS Compliant and 100% Lead (Pb)-Free**

Applications

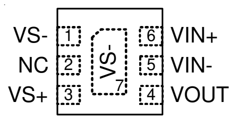
- TFT-LCD Gamma / V_{COM} Buffer
- Portable Electronic Product
- Communications Product

Pin Configurations

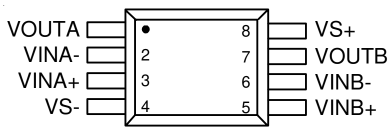
(TOP VIEW)



SOT-23-5

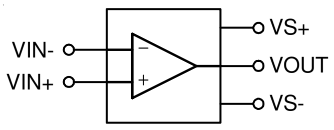


WDFN-6L 2x2

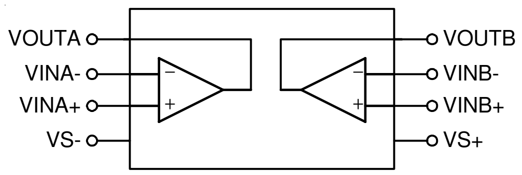


MSOP-8

Function Block Diagram



RT9133A



RT9133B

Functional Pin Description

Single

Pin No.		Pin Name	Pin Function
SOT-23-5	WDFN-6L 2x2		
1	4	VOUT	Amplifier Output.
--	2	NC	No Internal Connection.
2	1, 7 (Exposed Pad)	VS-	Negative Power Supply.
3	6	VIN+	Amplifier Non-Inverting Input.
4	5	VIN-	Amplifier Inverting Input.
5	3	VS+	Positive Power Supply.

Dual

Pin No.	Pin Name	Pin Function
1	VOUTA	Amplifier A Output.
2	VINA-	Amplifier A Inverting Input.
3	VINA+	Amplifier A Non-Inverting Input.
4	VS-	Negative Power Supply.
5	VINB+	Amplifier B Non-Inverting Input.
6	VINB-	Amplifier B Inverting Input.
7	VOUTB	Amplifier B Output.
8	VS+	Positive Power Supply.

Absolute Maximum Ratings (Note 1)

- Supply Voltage ---------- 17V
- Power Dissipation, P_D @ T_A = 25°C
  SOT-23-5 ---------- 500mW
  WDFN-6L 2x2 ---------- 758mW
  MSOP-8 ---------- 781mW
- Package Thermal Resistance (Note 2)
  SOT-23-5, θ_{JA} ---------- 250°C/W
  WDFN-6L 2x2, θ_{JA} ---------- 165°C/W
  MSOP-8, θ_{JA} ---------- 160°C/W
- Differential Input Voltage ---------- V_S
- Lead Temperature (Soldering, 10 sec.) ---------- 260°C
- Storage Temperature Range ---------- −65°C to +150°C
- ESD Susceptibility (Note 3)
  HBM (Human Body Mode) ---------- 2kV
  MM (Machine Mode) ---------- 200V

Recommended Operating Conditions (Note 4)

- Input Voltage ---------- −0.5V to Vs+0.5V
- Junction Temperature Range ---------- −65°C to +150°C
- Ambient Temperature Range ---------- −40°C to +85°C

Note 1. Stresses listed as the above "Absolute Maximum Ratings" may cause permanent damage to the device. These are for stress ratings. Functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may remain possibility to affect device reliability.

Note 2. θ_{JA} is measured in the natural convection at T_A = 25°C on a low effective thermal conductivity test board (single layer, 1S) of JEDEC 51-3 thermal measurement standard.

Note 3. Devices are ESD sensitive. Handling precaution is recommended.

Note 4. The device is not guaranteed to function outside its operating conditions.

Electrical Characteristics

(V_{S+}=+5V, V_{S-} = -5V, R_L = 10kΩ and C_L = 10pF to 0V, T_A =25°C, unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Input Characteristics						
Input Offset Voltage	V_{OS}	V_{CM} = 0	--	2	15	mV
Average Offset Voltage Drift	$\Delta V_{OS}/\Delta T$	$-40°C \leqq T_A \leqq 85°C$	--	5	--	uV/°C
Input Bias Current	I_B	V_{CM} = 0	--	2	50	nA
Input Impedance	R_{IN}		--	1	--	GΩ
Input Capacitance	C_{IN}		--	1.35	--	pF
Common-Mode Input Range	CMIR		-5.5	--	+5.5	V
Common-Mode Rejection Ratio	CMRR	For V_{IN} from –5.5V to +5.5V	50	80	--	dB
Open-Loop Gain	A_{VOL}	$-4.5V \leqq V_{OUT} \leqq +4.5V$	75	95	--	dB
Output Characteristics						
Output swing Low	V_{OL}	I_L = -5mA	--	-4.92	-4.85	V
Output swing High	V_{OH}	I_L = +5mA	4.85	4.92	--	V
Continuous V_{COM} Buffer Output current	I_{OC}		--	±35	--	mA
Peak V_{COM} Buffer Output current	I_{PC}		--	±120	--	mA
Power Supply						
Supply Voltage	V_S		4.5	--	15	V
Power Supply Rejection Ratio	PSRR	V_S is moved from ±2.25V to ±7.75V	60	70	--	dB
Supply Current/Amplifier	I_{SY}	No Load	--	500	750	uA
Dynamic Performance						
Slew Rate(Note)	SR	$-4.0V \leqq V_{OUT} \leqq +4.0V$, 20% to 80%	--	12	--	V/us
Setting to ±0.1% (A_V=+1)	t_S	(A_V = +1), V_{OUT} = 2V step	--	500	--	ns
-3dB Bandwidth	BW	R_L = 10kΩ, C_L =10 pF	--	12	--	MHz
Gain-Bandwidth Product	GBWP	R_L = 10kΩ, C_L =10 pF	--	5	--	MHz
Phase Margin	PM	R_L = 10kΩ, C_L =10 pF	--	50	--	°
Channel Separation	CS	f = 5MHz	--	75	--	dB

Note: Slew rate is measured on rising and falling edges.

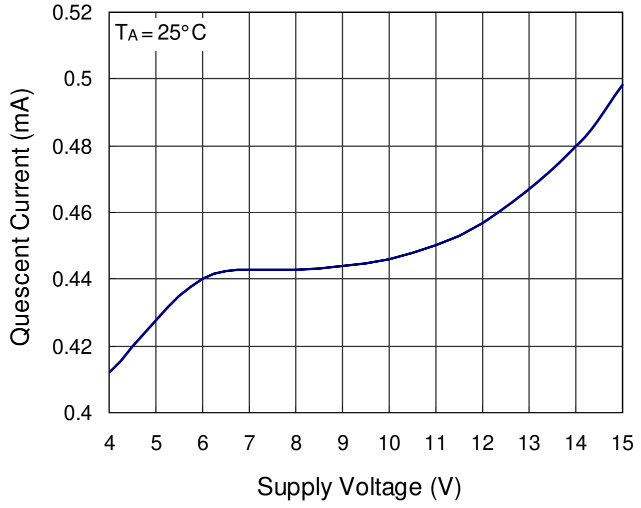
(V_{S+}=+2.5V, V_{S-} = -2.5V, R_L = 10kΩ and C_L = 10pF to 2.5V, T_A =25°C, unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Input Characteristics						
Input Offset Voltage	V_{OS}	V_{CM} = 2.5V	--	2	15	mV
Average Offset Voltage Drift	$\Delta V_{OS}/\Delta T$	−40°C ≦ T_A ≦ 85°C	--	5	--	uV/°C
Input Bias Current	I_B	V_{CM} = 2.5V	--	2	50	nA
Input Impedance	R_{IN}		--	1	--	GΩ
Input Capacitance	C_{IN}		--	1.35	--	pF
Common-Mode Input Range	CMIR		−0.5	--	+5.5	V
Common-Mode Rejection Ratio	CMRR	For V_{IN} from −0.5V to +5.5V	45	65	--	dB
Open-Loop Gain	A_{VOL}	0.5V ≦ V_{OUT} ≦ +4.5V	75	95	--	dB
Output Characteristics						
Output swing Low	V_{OL}	I_L = −5mA	--	−2.42	−2.35	mV
Output swing High	V_{OH}	I_L = +5mA	2.35	2.42	--	V
Continuous V_{COM} Buffer Output current	I_{OC}		--	±35	--	mA
Peak V_{COM} Buffer Output current	I_{PC}		--	±90	--	mA
Power Supply						
Power Supply Rejection Ratio	PSRR	V_S is moved from ±2.25V to ±7.75V	45	70	--	dB
Supply Current/Amplifier	I_{SY}	No Load	--	500	750	uA
Dynamic Performance						
Slew Rate(Note)	SR	−4V ≦ V_{OUT} ≦ +4V, 20% to 80%	--	12	--	V/us
Setting to ±0.1% (A_V = +1)	t_S	(A_V = +1), V_{OUT} = 2V step	--	500	--	ns
-3dB Bandwidth	BW	R_L = 10kΩ, C_L =10 pF	--	12	--	MHz
Gain-Bandwidth Product	GBWP	R_L = 10kΩ, C_L =10 pF	--	5	--	MHz
Phase Margin	PM	R_L = 10kΩ, C_L =10 pF	--	50	--	°
Channel Separation	CS	f = 5MHz	--	75	--	dB

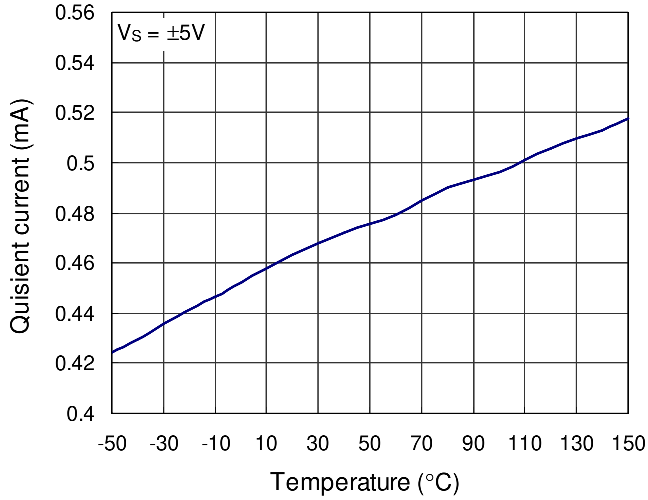
Note: Slew rate is measured on rising and falling edges.

Typical Operating Characteristics

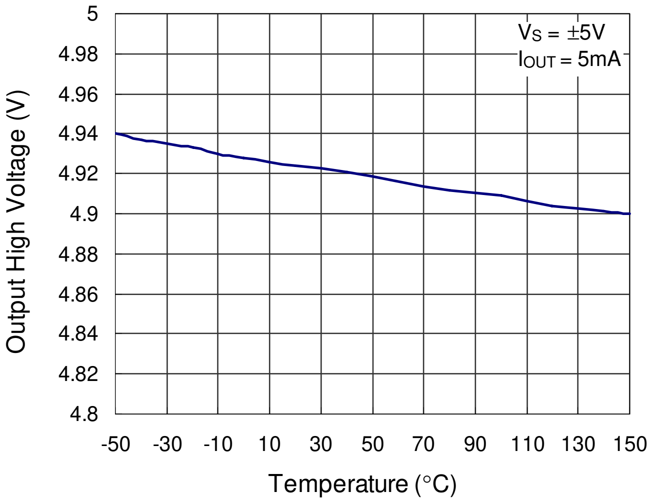
Quescent Current vs. Supply Voltage



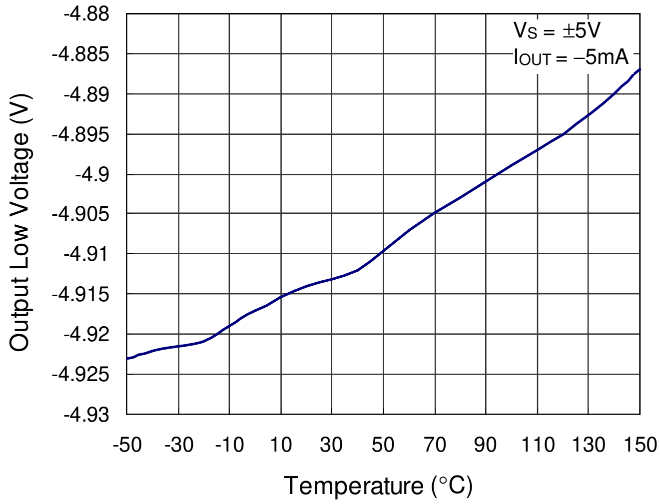
Quisient current vs. Temperature



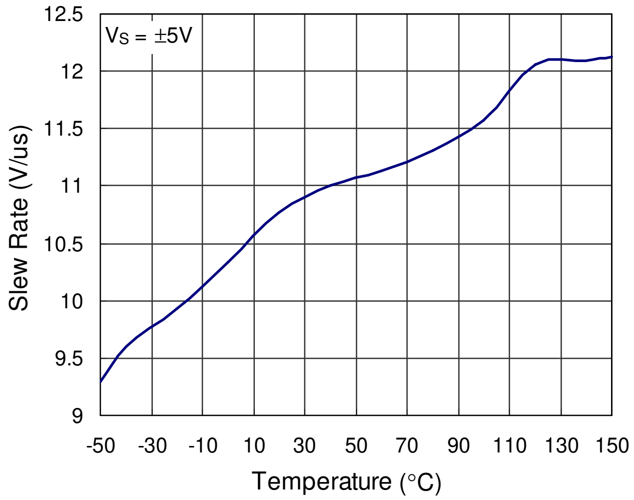
Output High Voltage vs. Temperature



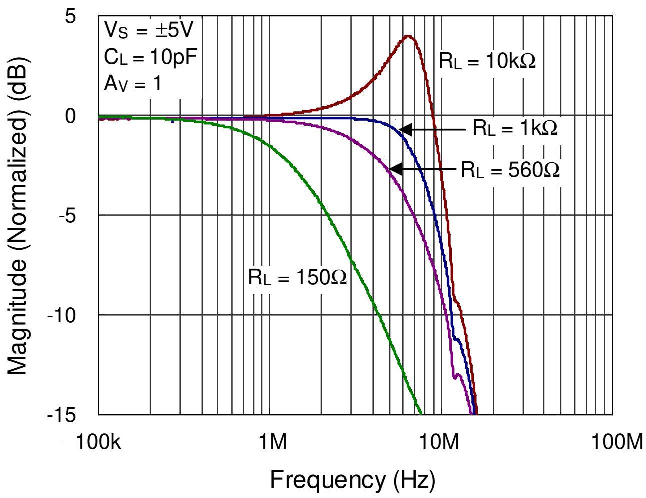
Output Low Voltage vs. Temperature



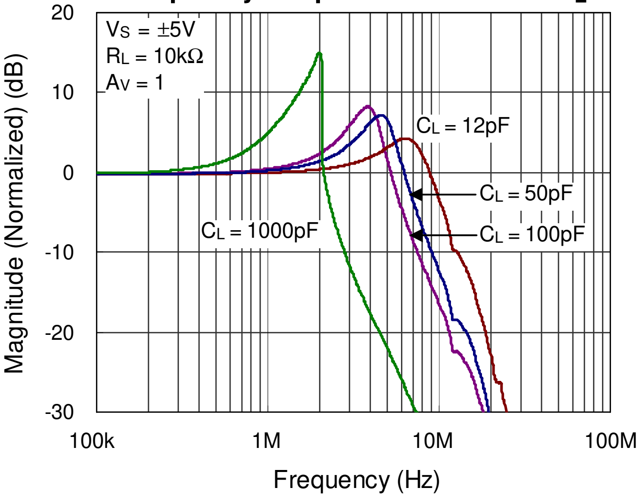
Slew Rate vs. Temperature



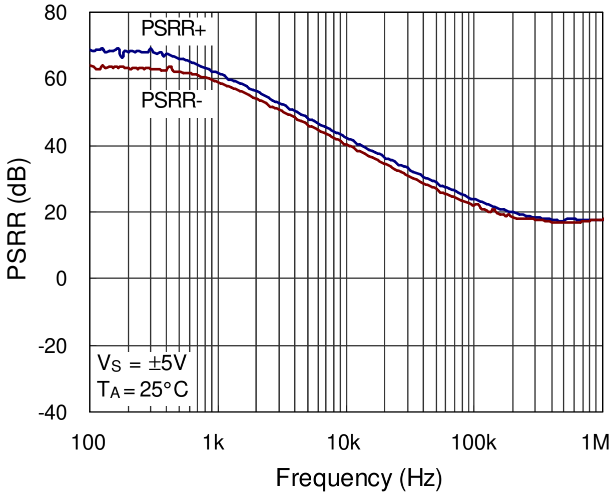
Frequency Response for Various R_L



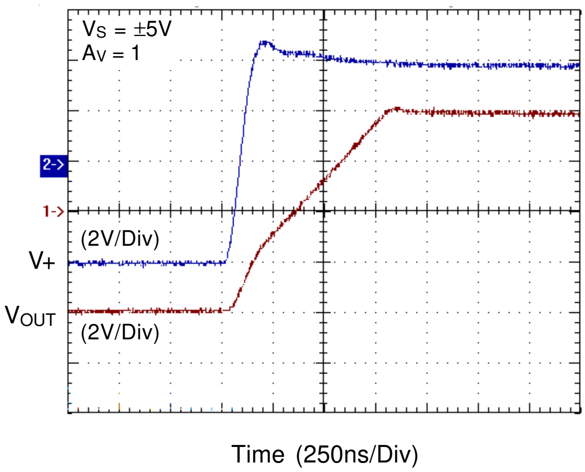
Frequency Response for Various C_L



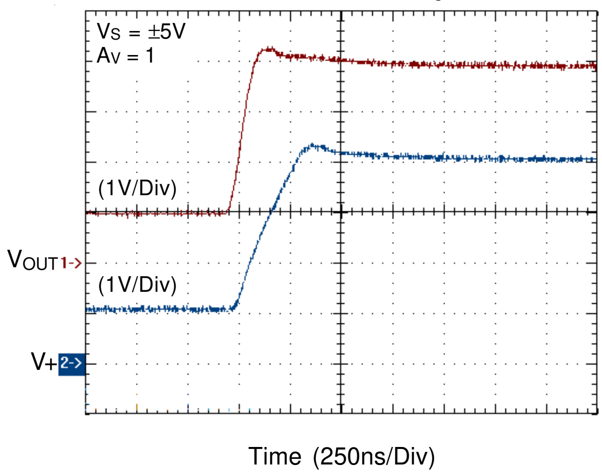
PSRR vs. Frequency



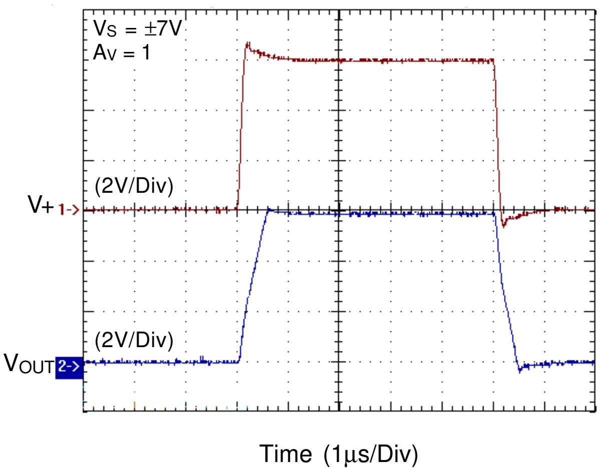
Slew Transient Response



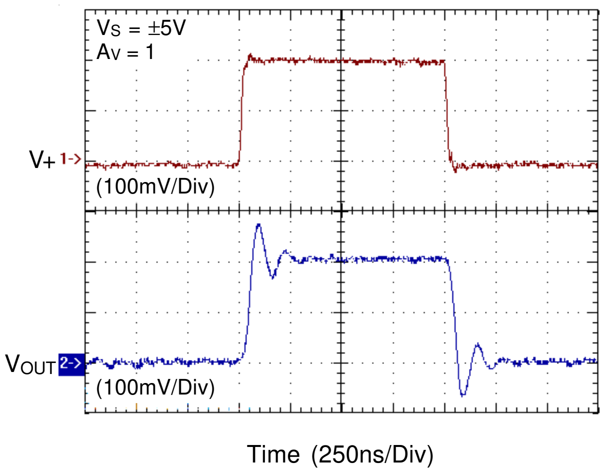
Slew Transient Response

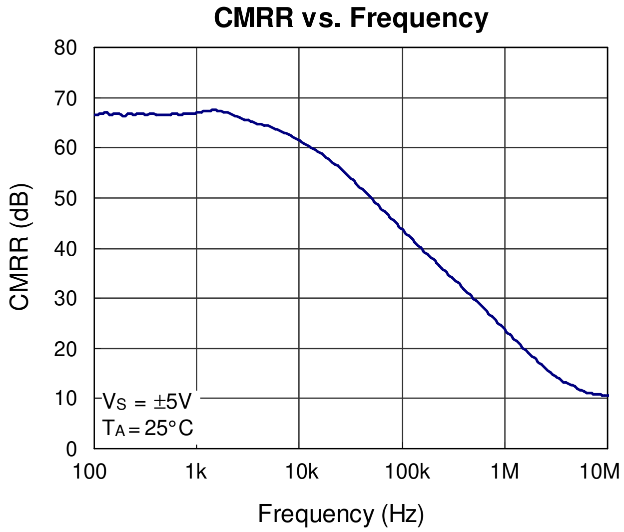


Large Signal Transient Response



Small Signal Transient Response




CMRR vs. Frequency
CMRR (dB)
80
70
60
50
40
30
20
10
0
100
1k
10k
100k
1M
10M
Frequency (Hz)
VS = ±5V
TA = 25°C

Applications Information

The RT9133A/B has high performance to drive large load for different application. High slew rates, rail-to-rail input and output capability and low power consumption are the features to make the RT9133A/B ideal for LCD applications. The RT9133A/B also has wide bandwidth and phase margin to drive a load of 10kΩ and 10pF.

Operating Voltage

The RT9133A/B is specified with single supply voltage from 5V to 15V. According to the electrical characteristics, the total supply voltage range is guaranteed from 4.5V to 15V. To refer the typical operational curves can get stable specifications in wide range of temperature and operating voltage.

The output swing of the RT9133A/B typically extends to within 80mV of positive/negative supply rails with 5mA load current source/sink. Decreasing the load current will get output swing even closer to the supply rails. Figure 1 shows the rail-to-rail input and output waveforms in the unit gain configuration without load current. The supply rails are +/-5V. Applying an input 10Vp_p sinusoidal waveform results in a 9.8Vp_p output voltage as shown in Figure 1.

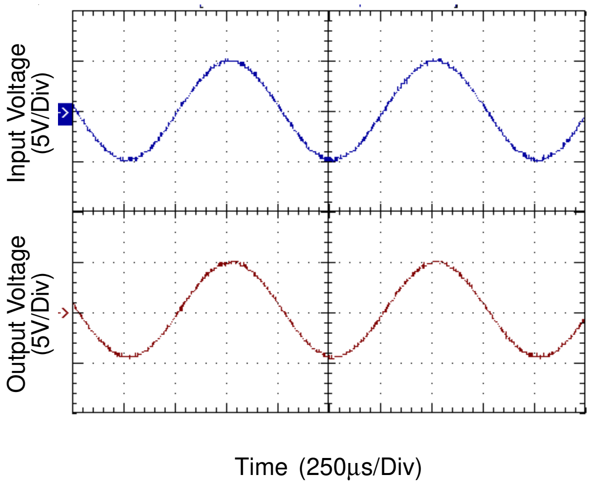


Figure 1. Operation with Rail-to-Rail Input and Output

Power Dissipation

The maximum power dissipation depends on the thermal resistance of IC package, PCB layout, the rate of surroundings airflow and temperature difference between junction to ambient. The maximum power dissipation can be calculated by following formula:

$P_{D(MAX)} = (T_{J(MAX)} - T_A) / \theta_{JA}$

Where

$T_{J(MAX)}$: The maximum operation junction temperature 150°C

T_A : The ambient temperature.

θ_{JA} : The junction to ambient thermal resistance.

The recommended operating condition of RT9133A/B is below the maximum junction temperature 150°C of the die. The junction to ambient thermal resistance for SOT-23-5 package is 250°C/W, WDFN-6L 2x2 package is 165°C/W and MSOP-8 package is 160°C/W on the standard JEDEC 51-3 single layer thermal test board. The maximum power dissipation at T_A = 25°C can be calculated by following formula:

$P_{D(MAX)}$ = (150°C–25°C) / 250 = 500mW (SOT-23-5)

$P_{D(MAX)}$ = (150°C–25°C) / 165 = 758mW (WDFN-6L 2x2)

$P_{D(MAX)}$ = (150°C - 25°C) / 160 = 781mW (MSOP-8)

For continuous operation, do not exceed absolute maximum operation junction temperature 150°C. The power dissipation definition for the RT9133A/B is as following:

$P_D = (V_S - V_{OUT}) \times I_{Load}$

V_S : the supply voltage

V_{OUT} : the output voltage

I_{Load} : the output load current

The maximum power dissipation depends on operating ambient temperature for fixed $T_{J(MAX)}$ and thermal resistance θ_{JA}. Figure 2 shows the power dissipation derating curves of the RT9133A/B with different packages. As the ambient temperature increases, the maximum power dissipation decreases linearly to keep the junction temperature below 150°C.

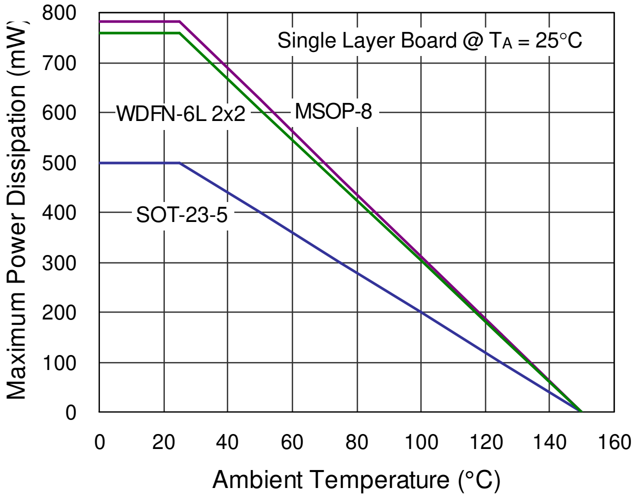


Figure 2. Derating Curves for the RT9133A/B Package

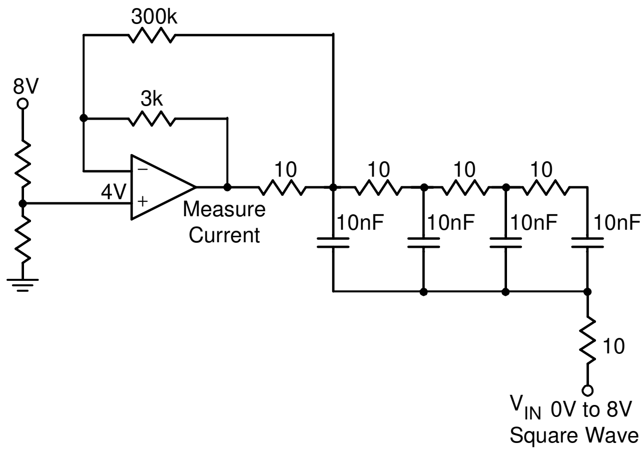


Figure 3. V-com Test Circuit

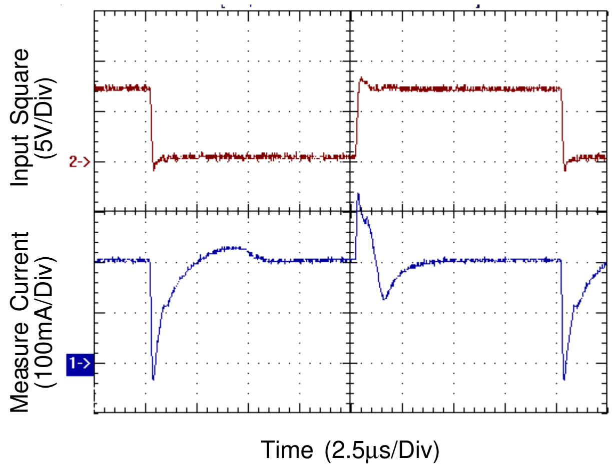


Figure 4. Scope Photo of the V-com Peak Current

Short Circuit Condition

An internal short-circuit protection circuit is implemented to protect the device from output short circuit. The RT9133A/B limits the short circuit current to ±120mA if the output is directly shorted to positive/negative supply rails. For maximum reliability, the maximum continuous output current more than ±35mA is not recommended.

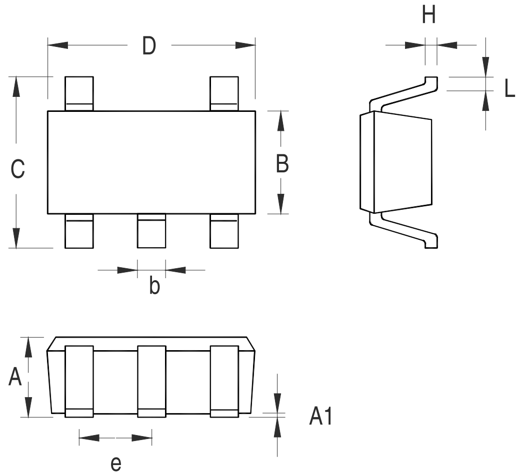
Unused Amplifier

It is recommended to connect the unused amplifier as a unit gain circuit. The negative input is directly connected to the output and the positive input should be connected to the ground.

LCD Panel Applications

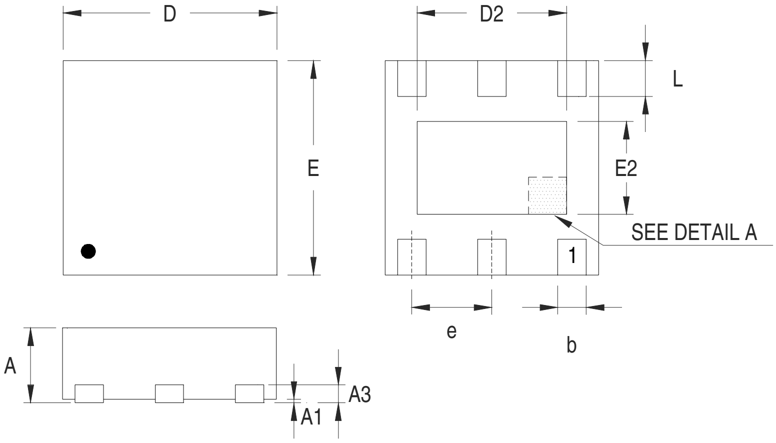
The RT9133A/B is mainly designed for LCD gamma and V-com buffer. OP Amplifier has 120mA instantaneous source/sink peak current. To test the performance of the RT9133A/B for LCD driving capability, the test circuit is to simulate the V-com driver as shown Figure 3. Series capacitors and resistors connected to the output of the OP simulate the load of LCD panel. The 300Ω and 3kΩ feedback resistors are used to improve the settling time. This circuit is the worst case for a V-com buffer. Figure 4 shows the waveforms of the output peak current capability.

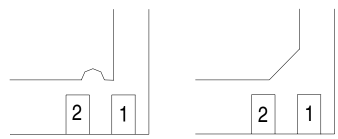
Outline Dimension



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	0.889	1.295	0.035	0.051
A1	0.000	0.152	0.000	0.006
B	1.397	1.803	0.055	0.071
b	0.356	0.559	0.014	0.022
C	2.591	2.997	0.102	0.118
D	2.692	3.099	0.106	0.122
e	0.838	1.041	0.033	0.041
H	0.080	0.254	0.003	0.010
L	0.300	0.610	0.012	0.024

SOT-23-5 Surface Mount Package





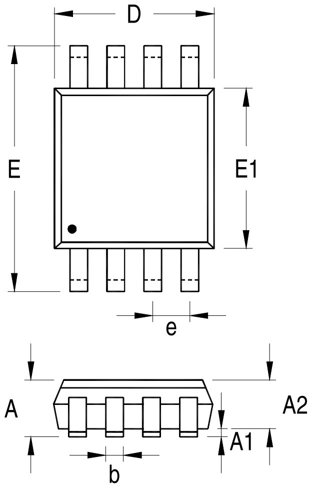
DETAIL A

Pin #1 ID and Tie Bar Mark Options

Note : The configuration of the Pin #1 identifier is optional, but must be located within the zone indicated.

Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	0.700	0.800	0.028	0.031
A1	0.000	0.050	0.000	0.002
A3	0.175	0.250	0.007	0.010
b	0.200	0.350	0.008	0.014
D	1.950	2.050	0.077	0.081
D2	1.000	1.450	0.039	0.057
E	1.950	2.050	0.077	0.081
E2	0.500	0.850	0.020	0.033
e	0.650		0.026	
L	0.300	0.400	0.012	0.016

W-Type 6L DFN 2x2 Package



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	0.810	1.100	0.032	0.043
A1	0.000	0.150	0.000	0.006
A2	0.750	0.950	0.030	0.037
b	0.220	0.380	0.009	0.015
D	2.900	3.100	0.114	0.122
e	0.650		0.026	
E	4.800	5.000	0.189	0.197
E1	2.900	3.100	0.114	0.122
L	0.400	0.800	0.016	0.031

8-Lead MSOP Plastic Package

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