

LMV712

Low Power, Low Noise, High Output, RRIO Dual Operational Amplifier with Independent Shutdown

General Description

The LMV712 duals are high performance BiCMOS operational amplifiers intended for applications requiring Rail-to-Rail inputs combined with speed and low noise. They offer a bandwidth of 5MHz and a slew rate of 5V/μs and can handle capacitive loads of up to 200pF without oscillation.

The LMV712 offers two independent shutdown pins. This feature allows disabling of each device separately and reduces the supply current to less than 1μA typical. The output voltage rapidly ramps up smoothly with no glitch as the amplifier comes out of the shutdown mode.

The LMV712 with the shutdown feature is offered in space saving 10-Bump micro SMD and 10 pin Leadless Leadframe Package (LLP) packages. It is also offered in 10 lead MSOP package. These packages are designed to meet the demands of small size, low power, and low cost required by cellular phones and similar battery operated portable electronics.

Features

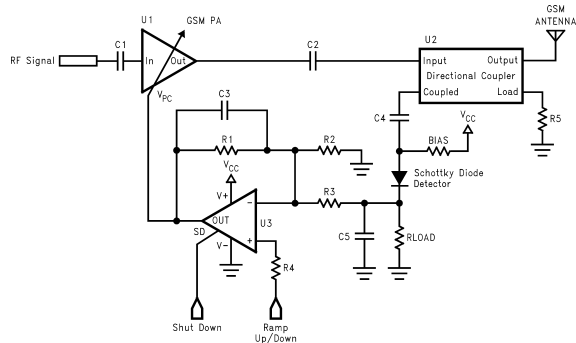
(Typical Unless Otherwise Noted)

- 5 MHz GBP
- Slew rate 5 V/μs
- Low noise 20nV/√Hz
- Supply current 1.22mA/channel
- $V_{OS} < 3\text{mV max.}$
- Low supply voltage 2.7V to 5V.
- Rail-to-Rail inputs and outputs.
- Unity gain stable.
- Small package: 10-Pin LLP, 10-Pin MSOP and 10-Bump micro SMD
- 1.5μA shutdown I_{CC}
- 2.2μs turn on

Applications

- Power amplifier control loop
- Cellular phones
- Portable equipment
- Wireless LAN
- Radio systems
- Cordless phones

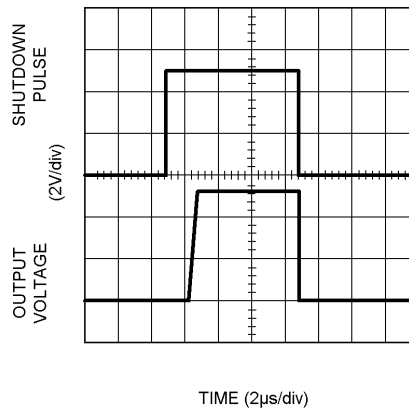
Typical Application Circuit



P.A. Control Loop

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Output Waveform vs. Shutdown Pulse



10137030

Absolute Maximum Ratings (Note 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

ESD Tolerance (Note 2)	
Machine Model	150V
Human Body Model	1.5kV
Differential Input Voltage	\pm Supply Voltage
Voltage at Input/Output Pin	(V ⁺) +0.4V to (V ⁻) -0.4V
Supply Voltage (V ⁺ - V ⁻)	5.5V
Output Short Circuit V ⁺	(Note 3)
Output Short Circuit V ⁻	(Note 3)
Current at Input Pin	\pm 10mA
Current at Output Pin	\pm 50mA
Storage Temp Range	-65°C to 150°C

Mounting Temperature

Infrared or Convection (20 sec) 235°C

Junction Temperature T_{JMAX} (Note 4) 150°C**Recommended Operating Conditions** (Note 1)

Supply Voltage	2.7V to 5V
Temperature Range	-40°C ≤ T _J ≤ 85°C
Thermal Resistance	
10-Pin MSOP	235°C/W
10-Pin LLP	53.4°C/W
10-Bump micro SMD	196°C/W

2.7V Electrical Characteristics

Unless otherwise specified, all limits guaranteed for V⁺ = 2.7V, V⁻ = 0V, V_{CM} = 1.35V and T_A = 25°C and R_L > 1MΩ. **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Condition	Min (Note 6)	Typ (Note 5)	Max (Note 6)	Units	
V _{OS}	Input Offset Voltage	V _{CM} = 0.85V and V _{CM} = 1.85V		0.4	3 3.2	mV	
I _B	Input Bias Current			5.5	115 130	pA	
CMRR	Common Mode Rejection Ratio	0V ≤ V _{CM} ≤ 2.7V	50 45	75		dB	
PSRR	Power Supply Rejection Ratio	2.7V ≤ V ⁺ ≤ 5V, V _{CM} = 0.85V	70 68	90		dB	
		2.7V ≤ V ⁺ ≤ 5V, V _{CM} = 1.85V	70 68	90		dB	
CMVR	Common Mode Voltage Range	For CMRR ≥ 50dB		-0.3	-0.2	V	
				2.9	3	V	
I _{SC}	Output Short Circuit Current	Sourcing V _O = 0V	15 12	25		mA	
		Sinking V _O = 2.7V	25 22	50		mA	
V _O	Output Swing	R _L = 10kΩ to 1.35V	2.62 2.60	2.68		V	
					0.01	0.12 0.15	V
		R _L = 600Ω to 1.35V	2.52 2.50	2.55			V
					0.05	0.23 0.30	V
V _{O(SD)}	Output Voltage in Shutdown			10	200	mV	
I _S	Supply Current per Channel	On Mode		1.22	1.7 1.9	mA	
		Shutdown Mode		0.12	1.5 2.0	uA	

2.7V Electrical Characteristics

Unless otherwise specified, all limits guaranteed for $V^+ = 2.7V$, $V^- = 0V$, $V_{CM} = 1.35V$ and $T_A = 25^\circ C$ and $R_L > 1M\Omega$. **Boldface** limits apply at the temperature extremes. (Continued)

Symbol	Parameter	Condition	Min (Note 6)	Typ (Note 5)	Max (Note 6)	Units
A_{VOL}	Large Signal Voltage Gain	Sourcing $R_L = 10k\Omega$ $V_O = 1.35V$ to $2.3V$	80 76	115		dB
		Sinking $R_L = 10k\Omega$ $V_O = 0.4V$ to $1.35V$	80 76	113		dB
		Sourcing $R_L = 600\Omega$ $V_O = 1.35V$ to $2.2V$	80 76	97		dB
		Sinking $R_L = 600\Omega$ $V_O = 0.5V$ to $1.35V$	80 76	100		dB
V_{SD}	Shutdown Pin Voltage Range	On Mode	2.4 to 2.7	2.0 to 2.7		V
		Shutdown Mode	0 to 0.8	0 to 1		V
GBWP	Gain-Bandwidth Product			5		MHz
SR	Slew Rate	(Note 7)		5		V/ μs
ϕ_m	Phase Margin			60		Deg
e_n	Input Referred Voltage Noise	$f = 1kHz$		20		nV/ \sqrt{Hz}
T_{ON}	Turn-On Time from Shutdown			2.2	4 4.6	μs
	Turn-On Time from Shutdown (micro SMD)		6 8			μs

5V Electrical Characteristics

Unless otherwise specified, all limits guaranteed for $V^+ = 5V$, $V^- = 0V$, $V_{CM} = 2.5V$ and $T_A = 25^\circ C$ and $R_L > 1M\Omega$. **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Condition	Min (Note 6)	Typ (Note 5)	Max (Note 6)	Units
V_{OS}	Input Offset Voltage	$V_{CM} = 0.85V$ and $V_{CM} = 1.85V$		0.4	3 3.2	mV
I_B	Input Bias Current			5.5	115 130	μA
CMRR	Common Mode Rejection Ratio	$0V \leq V_{CM} \leq 5V$	50 45	80		dB
PSRR	Power Supply Rejection Ratio	$2.7V \leq V^+ \leq 5V$, $V_{CM} = 0.85V$	70 68	90		dB
		$2.7V \leq V^+ \leq 5V$, $V_{CM} = 1.85V$	70 68	90		dB
CMVR	Common Mode Voltage Range	For CMRR $\geq 50dB$		-0.3	-0.2	V
				5.2	5.3	V
I_{SC}	Output Short Circuit Current	Sourcing $V_O = 0V$	20 18	35		mA
		Sinking $V_O = 5V$	25 21	50		mA

5V Electrical Characteristics (Continued)

Unless otherwise specified, all limits guaranteed for $V^+ = 5V$, $V^- = 0V$, $V_{CM} = 2.5V$ and $T_A = 25^\circ C$ and $R_L > 1M\Omega$. **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Condition	Min (Note 6)	Typ (Note 5)	Max (Note 6)	Units
V_O	Output Swing	$R_L = 10k\Omega$ to 2.5V	4.92	4.98		V
			4.90		0.01	0.12
		$R_L = 600\Omega$ to 2.5V	4.82	4.85		V
			4.80		0.05	0.23
				0.30		
$V_{O(SD)}$	Output Voltage in Shutdown			10	200	mV
I_S	Supply Current per Channel	On Mode		1.17	1.7	mA
		Shutdown Mode		0.12	1.5	2.0
A_{VOL}	Large Signal Voltage Gain	Sourcing $R_L = 10k\Omega$ $V_O = 2.5V$ to 4.6V	80	130		dB
			76			
		Sinking $R_L = 10k\Omega$ $V_O = 0.4V$ to 2.5V	80	130		dB
			76			
A_{VOL}	Large Signal Voltage Gain	Sourcing $R_L = 600\Omega$ $V_O = 2.5V$ to 4.6V	80	110		dB
			76			
A_{VOL}	Large Signal Voltage Gain	Sinking $R_L = 600\Omega$ $V_O = 0.4V$ to 2.5V	80	107		dB
			76			
V_{SD}	Shutdown Pin Voltage Range	On Mode	4.5 to 5	3.5 to 5		V
		Shutdown Mode	0 to 0.8	0 to 1.5		V
GBWP	Gain-Bandwidth Product			5		MHz
SR	Slew Rate	(Note 7)		5		V/ μs
ϕ_m	Phase Margin			60		Deg
e_n	Input Referred Voltage Noise	$f = 1kHz$		20		nV/ \sqrt{Hz}
T_{ON}	Turn-On Time for Shutdown			1.6	4	μs
					4.6	
	Turn-On Time for Shutdown (micro SMD)		6			μs
			8			

Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is intended to be functional, but specific performance is not guaranteed. For guaranteed specifications and the test conditions, see the Electrical Characteristics.

Note 2: Human body model: 1.5k Ω in series with 100pF. Machine model, 0 Ω in series with 100pF.

Note 3: Shorting circuit output to either V^+ or V^- will adversely affect reliability.

Note 4: The maximum power dissipation is a function of $T_{J(MAX)}$, θ_{JA} and T_A . The maximum allowable power dissipation at any ambient temperature is $P_D = (T_{J(MAX)} - T_A) / \theta_{JA}$. All numbers apply for packages soldered directly into a PC board.

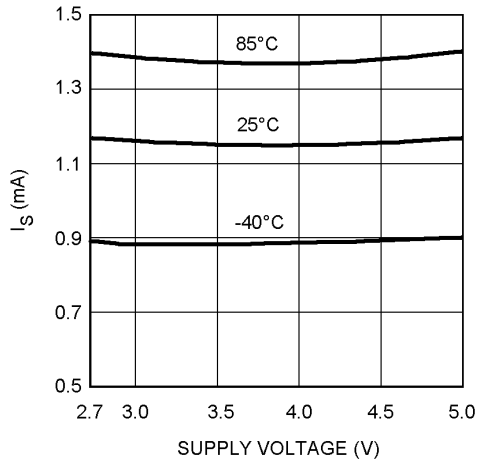
Note 5: Typical values represent the most likely parametric norm.

Note 6: All limits are guaranteed by testing or statistical analysis.

Note 7: Number specified is the slower of the positive and negative slew rates.

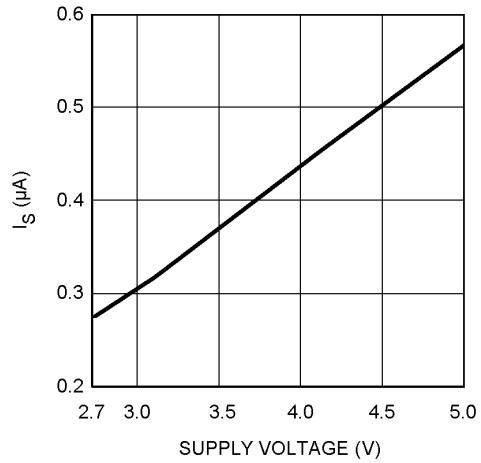
Typical Performance Characteristics Unless otherwise specified, $V_S = +5V$, single supply, $T_A = 25^\circ C$.

Supply Current Per Channel vs. Supply Voltage



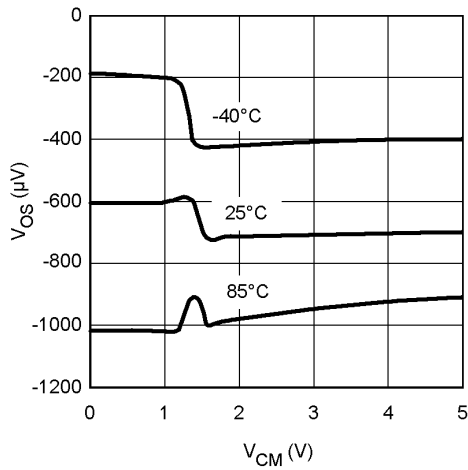
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Supply Current vs. Supply Voltage (Shutdown)



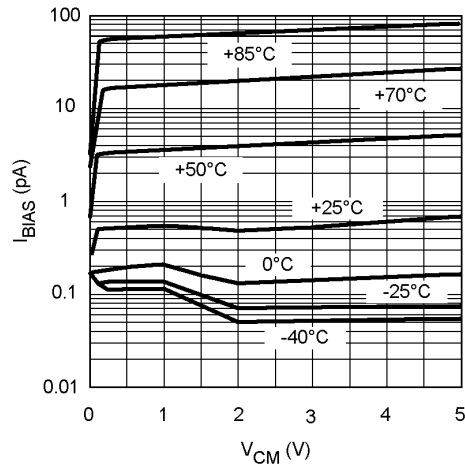
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V_{OS} vs. V_{CM}



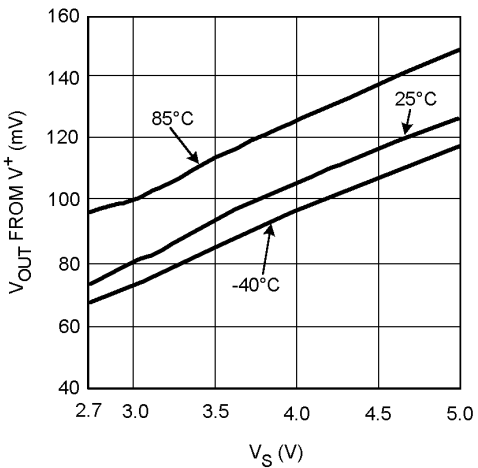
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I_B vs. V_{CM} Over Temp



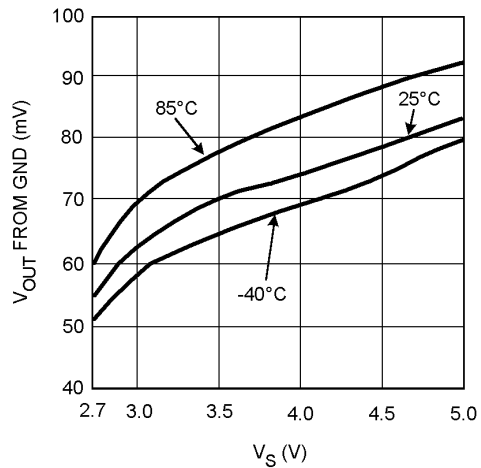
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Output Positive Swing vs. Supply Voltage, $R_L = 600\Omega$



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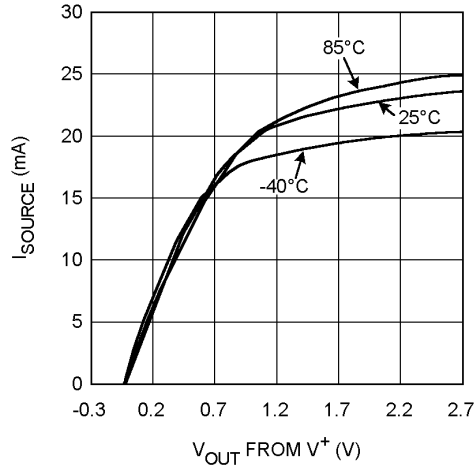
Output Negative Swing vs. Supply Voltage, $R_L = 600\Omega$



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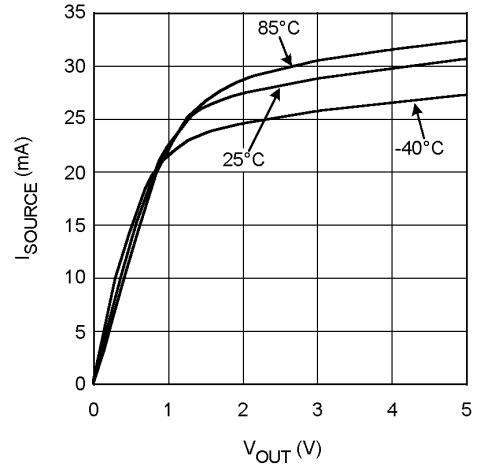
Typical Performance Characteristics Unless otherwise specified, $V_S = +5V$, single supply, $T_A = 25^\circ C$. (Continued)

Sourcing Current vs. Output Voltage, $V_S = 2.7V$



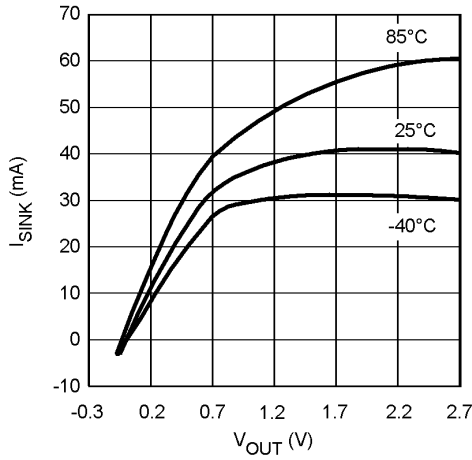
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Sourcing Current vs. Output Voltage, $V_S = 5V$



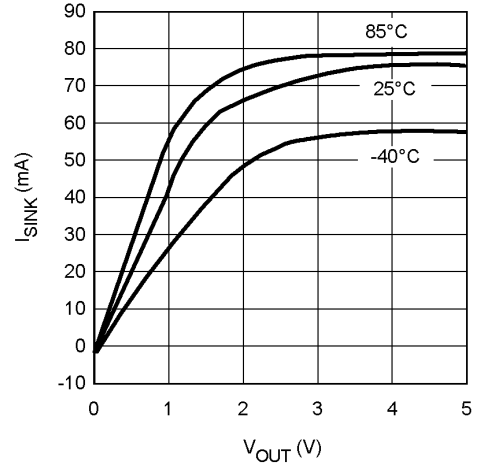
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Sinking Current vs. Output Voltage, $V_S = 2.7V$



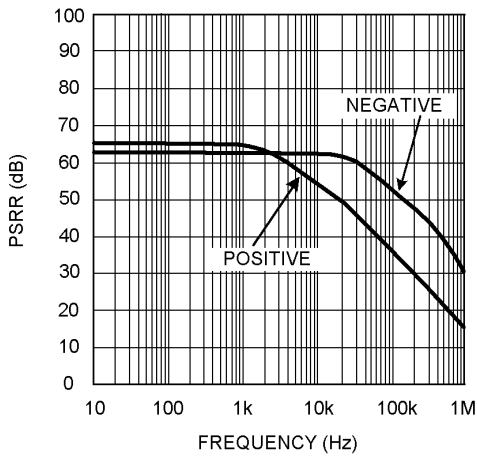
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Sinking Current vs. Output Voltage, $V_S = 5V$



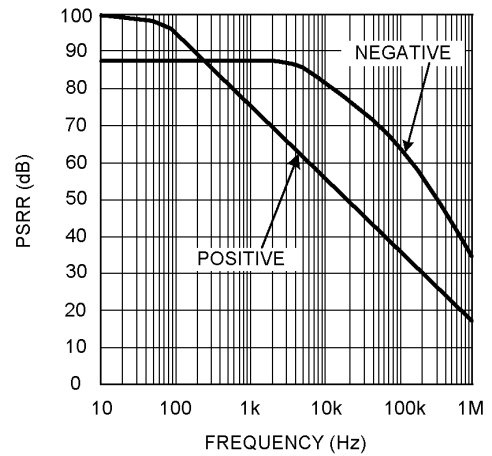
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PSRR vs. Frequency $V_S = 2.7V$



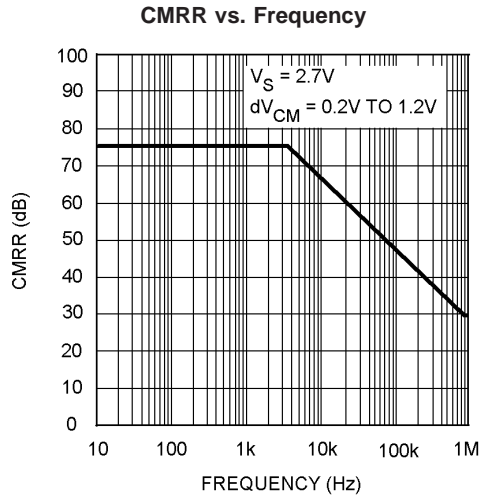
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PSRR vs. Frequency $V_S = 5V$

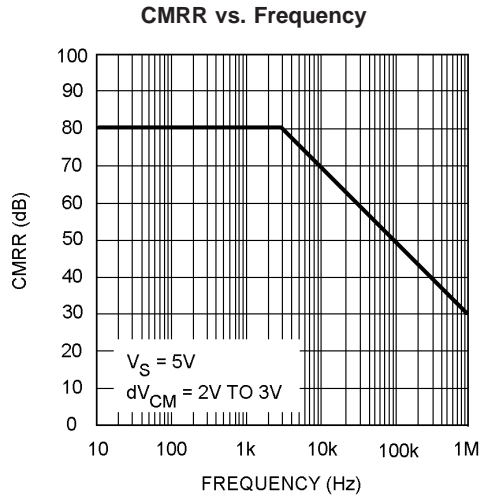


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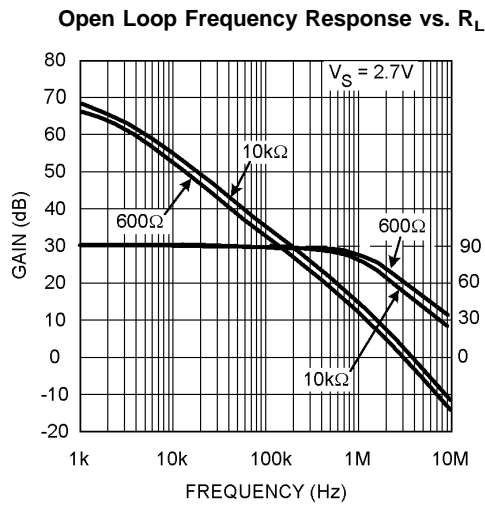
Typical Performance Characteristics Unless otherwise specified, $V_S = +5V$, single supply, $T_A = 25^\circ C$. (Continued)



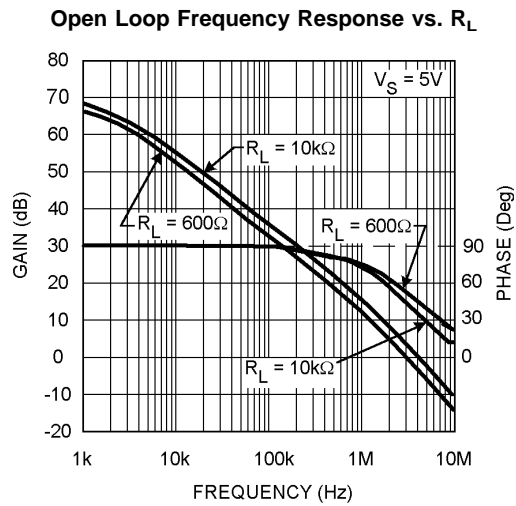
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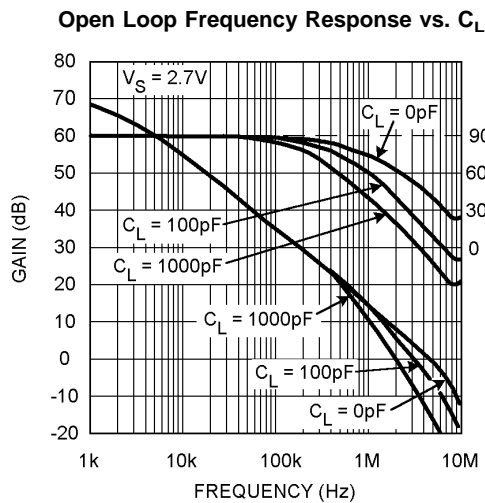
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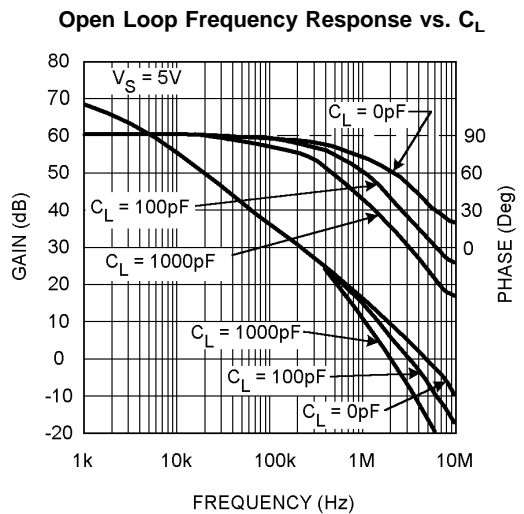
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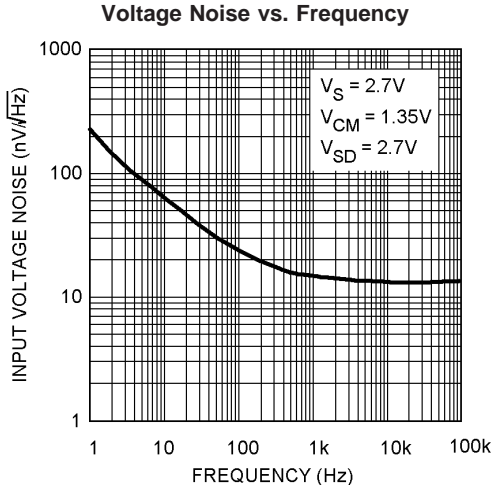


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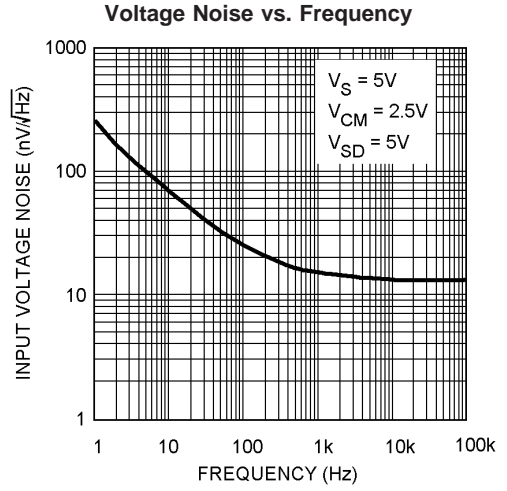


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Typical Performance Characteristics Unless otherwise specified, $V_S = +5V$, single supply, $T_A = 25^\circ C$. (Continued)

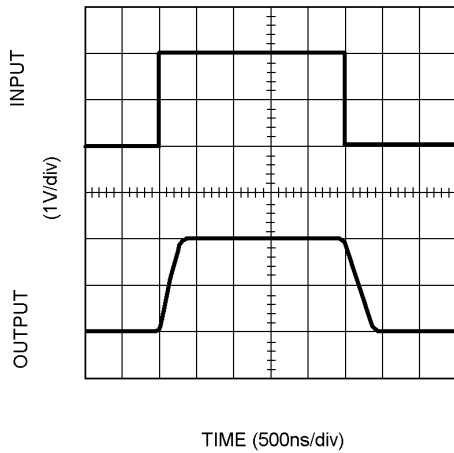


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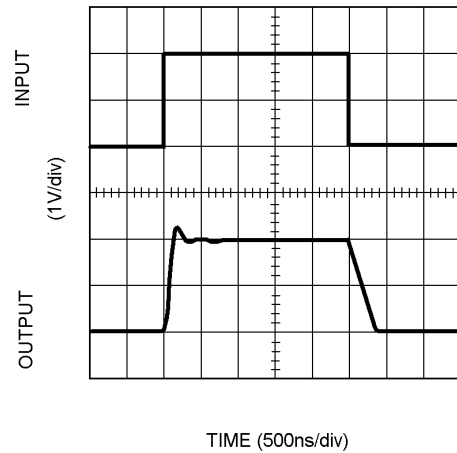
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Non-Inverting Large Signal Pulse Response, $V_S = 2.7V$



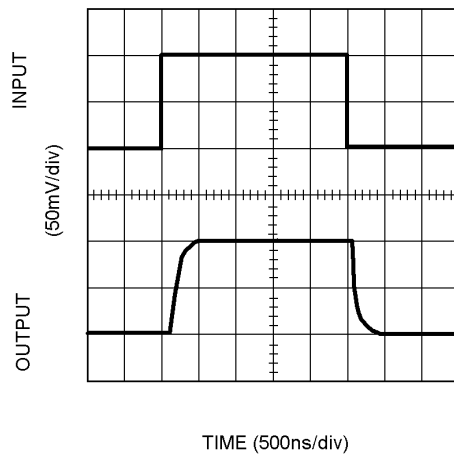
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Non-Inverting Large Signal Pulse Response, $V_S = 5V$



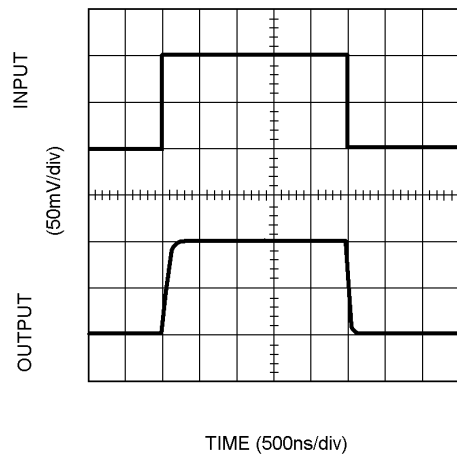
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Non-Inverting Small Signal Pulse Response, $V_S = 2.7V$



10137023

Non-Inverting Small Signal Pulse Response, $V_S = 5V$

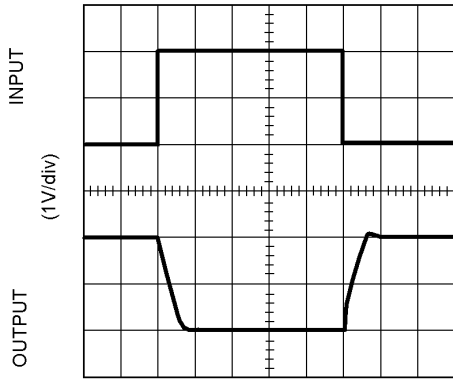


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Typical Performance Characteristics

Unless otherwise specified, $V_S = +5V$, single supply, $T_A = 25^\circ C$. (Continued)

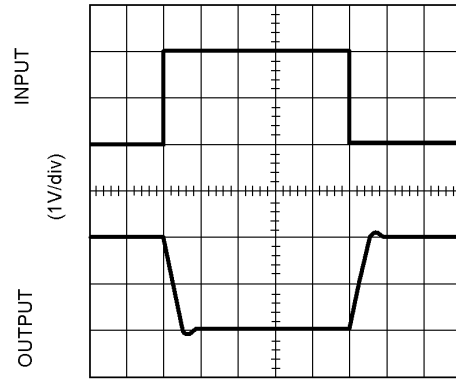
Inverting Large Signal Pulse Response, $V_S = 2.7V$



TIME (500ns/div)

10137026

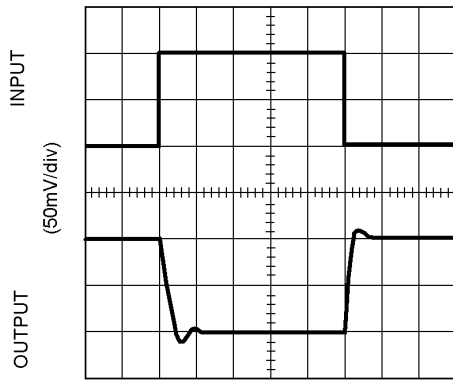
Inverting Large Signal Pulse Response, $V_S = 5V$



TIME (500ns/div)

10137028

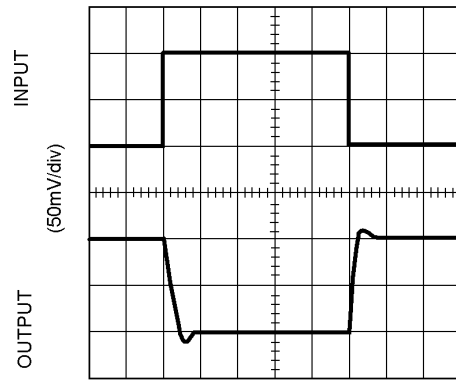
Inverting Small Signal Pulse Response, $V_S = 2.7V$



TIME (500ns/div)

10137027

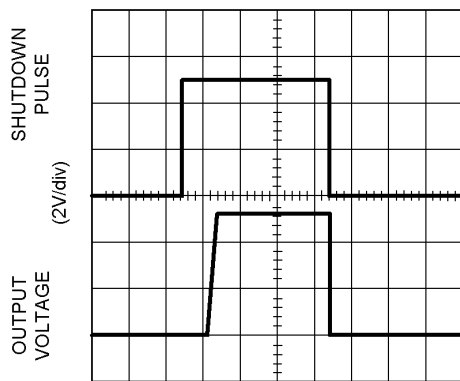
Inverting Small Signal Pulse Response $V_S = 5V$



TIME (500ns/div)

10137029

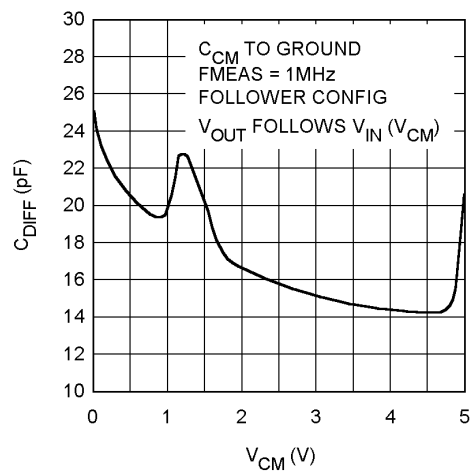
Turn on Time Response $V_S = 5V$



TIME (2µs/div)

10137030

Input Common Mode Capacitance vs. V_{CM} $V_S = 5V$

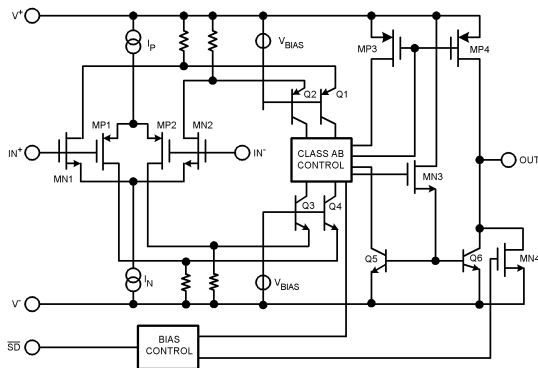


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Application Information

Theory of Operation

The LMV712 dual op amp is derived from the LMV711 single op amp. *Figure 1* contains a simplified schematic of one channel of the LMV712.



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FIGURE 1.

Rail-to-Rail input is achieved by using in parallel, one NMOS differential pair (MN1 and MN2) and one PMOS differential pair (MP1 and MP2). When the common mode input voltage (V_{CM}) is near V^+ , the NMOS pair is on and the PMOS pair is off. When V_{CM} is near V^- , the NMOS pair is off and the PMOS pair is on. When V_{CM} is between V^+ and V^- , internal logic decides how much current each differential pair will get. This special logic ensures stable and low distortion amplifier operation within the entire common mode voltage range.

Because both input stages have their own offset voltage (V_{OS}) characteristic, the offset voltage of the LMV712 becomes a function of V_{CM} . V_{OS} has a crossover point at 1.4V above V^- . Refer to the ' V_{OS} vs. V_{CM} ' curve in the Typical Performance Characteristics section. Caution should be taken in situations where input signal amplitude is comparable to V_{OS} value and/or the design requires high accuracy. In these situations, it is necessary for the input signal to avoid the crossover point.

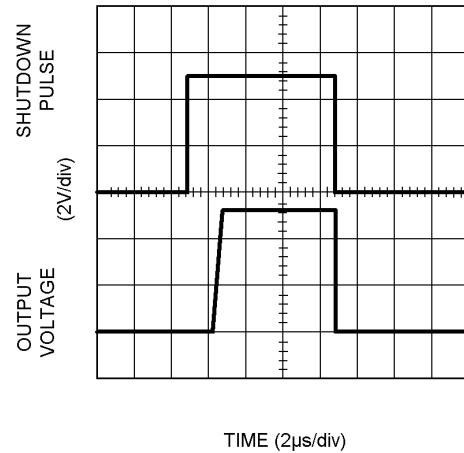
The current coming out of the input differential pairs gets mirrored through two folded cascode stages (Q1, Q2, Q3, Q4) into the 'class AB control' block. This circuitry generates voltage gain, defines the op amp's dominant pole and limits the maximum current flowing at the output stage. MN3 introduces a voltage level shift and acts as a high impedance to low impedance buffer.

The output stage is composed of a PMOS and a NPN transistor in a common source/emitter configuration, delivering a rail-to-rail output excursion.

The MN4 transistor ensures that the LMV712 output remains near V^- when the amplifier is in shutdown mode.

Shutdown Pin

The LMV712 offers independent shutdown pins for the dual amplifiers. When the shutdown pin is tied low, the respective amplifier shuts down and the supply current is reduced to less than 1 μ A. In shutdown mode, the amplifier's output level stays at V^- . In a 2.7V operation, when a voltage between 1.5V to 2.7V is applied to the shutdown pin, the amplifier is enabled. As the amplifier is coming out of the shutdown mode, the output waveform ramps up without any glitch. This is demonstrated in *Figure 2*.



10137030

FIGURE 2.

A glitch-free output waveform is highly desirable in many applications, one of which is power amplifier control loops. In this application, the LMV712 is used to drive the power amplifier's power control. If the LMV712 did not have a smooth output ramp during turn on, it would directly cause the power amplifier to produce a glitch at its output. This adversely affects the performance of the system.

To enable the amplifier, the shutdown pin must be pulled high. It should not be left floating in the event that any leakage current may inadvertently turn off the amplifier.

Printed Circuit Board Consideration

To properly bypass the power supply, several locations on a printed circuit board need to be considered. A 6.8 μ F or greater tantalum capacitor should be placed at the point where the power supply for the amplifier is introduced onto the board. Another 0.1 μ F ceramic capacitor should be placed as close as possible to the power supply pin of the amplifier. If the amplifier is operated in a single power supply, only the V^+ pin needs to be bypassed with a 0.1 μ F capacitor. If the amplifier is operated in a dual power supply, both V^+ and V^- pins need to be bypassed.

It is good practice to use a ground plane on a printed circuit board to provide all components with a low inductive ground connection.

Surface mount components in 0805 size or smaller are recommended in the LMV712 application circuits. Designers can take advantage of the micro SMD, MSOP and LLP miniature sizes to condense board layout in order to save space and reduce stray capacitance.

Capacitive Load Tolerance

The LMV712 can directly drive 200pF in unity-gain without oscillation. The unity-gain follower is the most sensitive configuration to capacitive loading. Direct capacitive loading reduces the phase margin of amplifiers. The combination of the amplifier's output impedance and the capacitive load induces phase lag. This results in either an under-damped pulse response or oscillation. To drive a heavier capacitive load, *Figure 3* can be used.

Application Information (Continued)

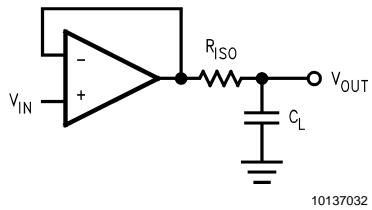


FIGURE 3.

In *Figure 3*, the isolation resistor R_{ISO} and the load capacitor C_L form a pole to increase stability by adding more phase margin to the overall system. The desired performance depends on the value of R_{ISO} . The bigger the R_{ISO} resistor value, the more stable V_{OUT} will be. But the DC accuracy is degraded when the R_{ISO} gets bigger. If there were a load resistor in *Figure 3*, the output voltage would be divided by R_{ISO} and the load resistor.

The circuit in *Figure 4* is an improvement to the one in *Figure 3* because it provides DC accuracy as well as AC stability. In this circuit, R_F provides the DC accuracy by using feed-forward techniques to connect V_{IN} to R_L . C_F and R_{ISO} serve to counteract the loss of phase margin by feeding the high frequency component of the output signal back to the amplifier's inverting input, thereby preserving phase margin

in the overall feedback loop. Increased capacitive drive is possible by increasing the value of C_F . This in turn will slow down the pulse response.

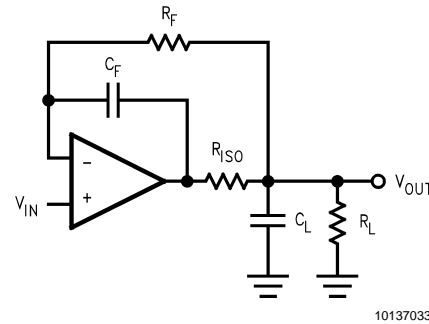
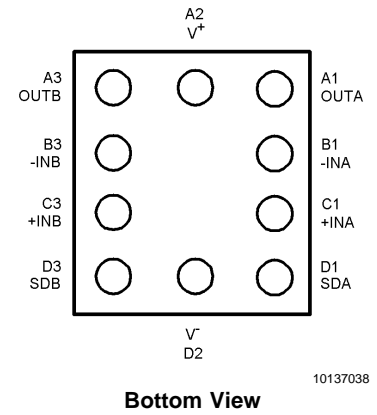
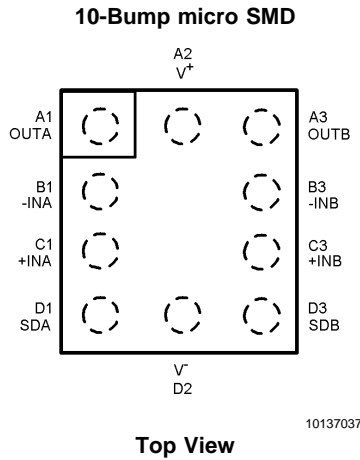
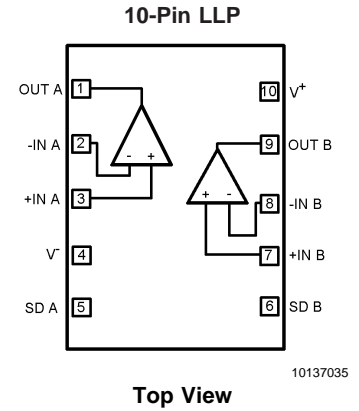
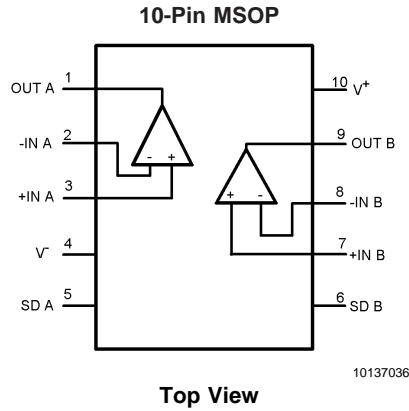


FIGURE 4.

Latchup

CMOS devices tend to be susceptible to latchup due to their internal parasitic SCR (silicon controlled rectifier) effects. The input and output pins look similar to the gate of the SCR. There is a minimum current required to trigger the SCR gate lead. The LMV712 is designed to withstand 150mA surge current on all the pins. Some resistive method should be used to isolate any capacitance from supplying excess current to the pins. In addition, like an SCR, there is a minimum holding current for any latchup mode. Limiting current to the supply pins will also inhibit latchup susceptibility.

Connection Diagrams

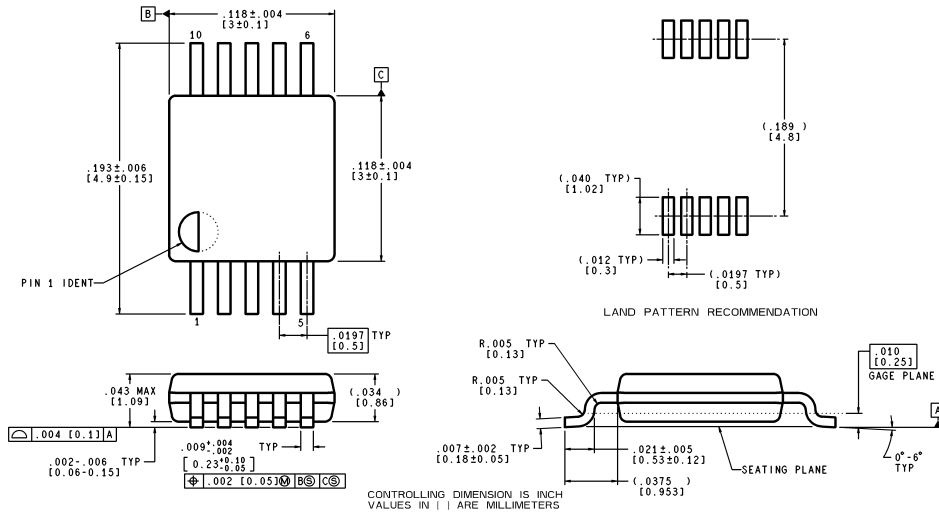


Ordering Information

Package	Part Number	Package Marking	Transport Media	NSC Drawing
10-Pin MSOP	LMV712MM	A61	1k Units Tape and Reel	MUB10A
	LMV712MMX		3.5k Units Tape and Reel	
10-Pin LLP	LMV712LD	A62	1k Units Tape and Reel	LDA10A
	LMV712LDX		3.5k Units Tape and Reel	
10-Bump micro SMD	LMV712BL	A76A	250 Units Tape and Reel	BLP10AAB
	LMV712BLX		3k Units Tape and Reel	

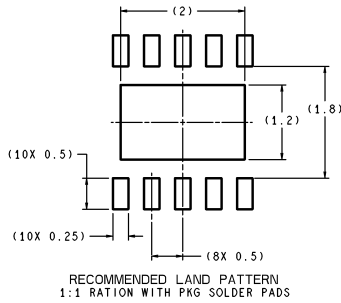
Physical Dimensions inches (millimeters)

unless otherwise noted

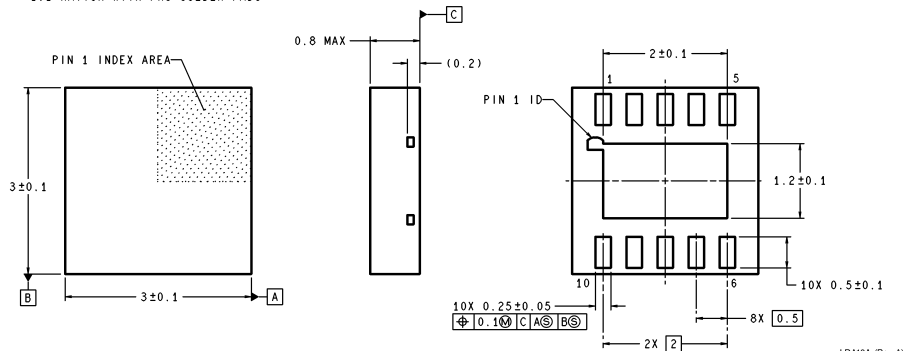


MUB10A (Rev A)

10-Pin MSOP NS Package Number MUB10A



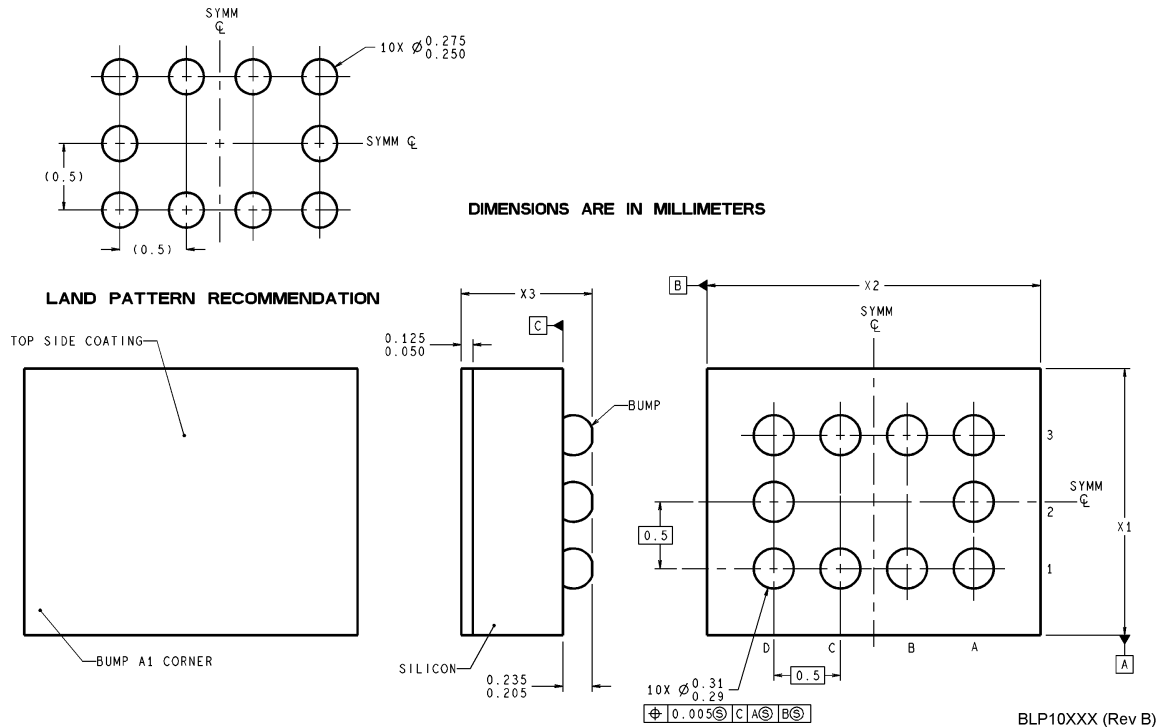
DIMENSIONS ARE IN MILLIMETERS



LDA10A (Rev A)

10-Pin LLP NS Package Number LDA10A

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)



**10-Bump micro SMD
NS Package Number BLP10AAB**

X1 = 1.514 ± 0.030mm X2 = 1.996 ± 0.030mm X3 = 0.945 ± 0.100mm

NOTES: UNLESS OTHERWISE SPECIFIED

1. EPOXY COATING
2. Sn/37Pb EUTECTIC BUMP
3. RECOMMEND NON-SOLDER MASK DEFINED LANDING PAD.
4. PIN A1 IS ESTABLISHED BY LOWER LEFT CORNER WITH RESPECT TO TEXT ORIENTATION. REMAINING PINS ARE NUMBERED COUNTER CLOCKWISE.
5. XXX IN DRAWING NUMBER REPRESENTS PACKAGE SIZE VARIATION WHERE X1 IS PACKAGE WIDTH, X2 IS PACKAGE LENGTH AND X3 IS PACKAGE HEIGHT.
6. REFERENCE JEDEC REGISTRATION MO-211, VARIATION BC.

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2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

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