

# LMV422

## Dual Rail-to-Rail Output Operational Amplifier with Power Select

### General Description

The LMV422 dual rail-to-rail output amplifier offers a power select pin (PS) that allows the user to select one of two power modes depending on the level of performance desired. This is ideal for AC coupled circuits where the circuit needs to be kept active to maintain a quiescent charge on the coupling capacitors with minimum power consumption.

For portable applications, the LMV422 operates in low power mode consuming only 2  $\mu\text{A}$  of supply current per channel at a bandwidth of 27 kHz. This allows the user to reduce the power consumption of an amplifier while maintaining an active circuit. For additional bandwidth and output current drive the amplifier can dynamically switch to full power mode with 8MHz bandwidth consuming only 400  $\mu\text{A}$  per channel.

The LMV422 features a rail-to-rail output voltage swing in addition to an input common mode range that includes ground. The LMV422 is designed for closed loop gains of plus two (or minus one) or greater. The LMV422 is offered in MSOP-10 miniature package to ease the adoption in applications where board area is at a premium.

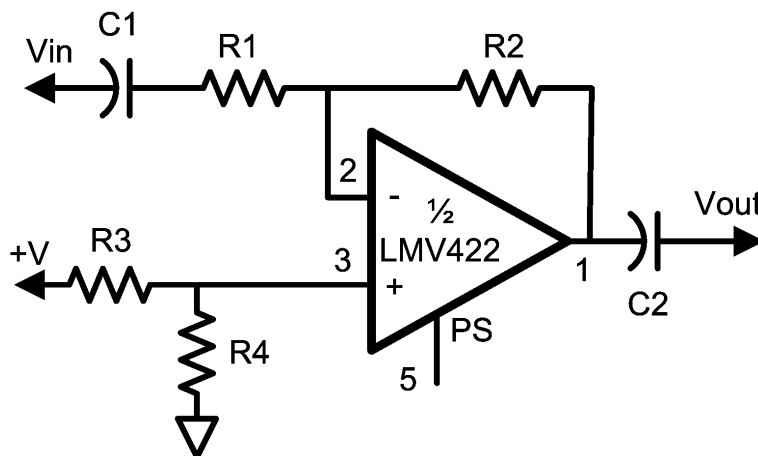
### Features

- Supply Voltage 2.7V to 5.5V
- Supply Current Per Channel
  - Low Power Mode 2  $\mu\text{A}$
  - Full Power Mode 400  $\mu\text{A}$
- Input Common Mode Voltage Range -0.3V to 3.8V
- CMRR 85 dB
- Output Voltage Swing Rail to Rail
- Input Offset Voltage 1 mV
- Bandwidth
  - Low Power Mode 27 kHz
  - Full Power Mode 8 MHz
- Stable for  $A_v \geq +2$  or  $A_v \leq -1$

### Applications

- AC Coupled Circuits
- Portable Instrumentation
- Smoke Detectors

### Typical Application



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**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)

Human Body	2000V
Machine Model	200V
$V_{IN}$ Differential	$\pm 2V$
Supply Voltage ( $V^+ - V^-$ )	2.5V to 5.5V
Storage Temperature Range	$-65^\circ\text{C}$ to $+150^\circ\text{C}$
Junction Temperature (Note 4)	$+150^\circ\text{C}$

## Soldering Information

Infrared or Convection (20 sec)	$235^\circ\text{C}$
Wave Soldering Lead Temp. (10 sec)	$260^\circ\text{C}$

**Operating Ratings** (Note 1)

Supply Voltage ( $V^+ - V^-$ )	2.7V to 5.5V
Temperature Range	$-40^\circ\text{C}$ to $+85^\circ\text{C}$
Package Thermal Resistance ( $\theta_{JA}$ )	$210^\circ\text{C/W}$
MSOP-10	

**5V Full Power Mode Electrical Characteristics**

Unless otherwise specified, all limits guaranteed for at  $T_J = 25^\circ\text{C}$ ,  $V^+ = 5V$ ,  $V^- = 0V$ ,  $V_{CM} = V_O = V^+/2$ ,  $PS = V^-$ . **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Conditions	Min (Note 6)	Typ (Note 5)	Max (Note 6)	Units
$V_{OS}$	Input Offset Voltage			1	4 <b>5.5</b>	mV
$\Delta V_{OS}$	Input Offset Voltage Difference	$V_{OS}$ in Full Power Mode – $V_{OS}$ in Low Power Mode		0.1	1	mV
TC $V_{OS}$	Input Offset Average Drift	(Note 9)		2		$\mu\text{V}/\text{C}$
$I_B$	Input Bias Current			5		pA
CMRR	Common Mode Rejection Ratio	$V_{CM}$ Stepped from 0V to 3.5V	68 <b>60</b>	85		dB
PSRR	Power Supply Rejection Ratio	$V^+ = 2.7V$ to 5V	66 <b>60</b>	90		dB
CMVR	Input Common Mode Voltage Range	CMRR $\geq 50$ dB	-0.3		3.8	V
$A_{VOL}$	Large Signal Voltage Gain	$V_O = 0.75V$ to 4.25V $R_L = 1\text{ M}\Omega$	72 <b>70</b>	100		dB
		$V_O = 0.75V$ to 4.25V $R_L = 10\text{ K}\Omega$	75 <b>70</b>	102		
$V_O$	Output Swing High	$R_L = 10\text{ k}\Omega$ to $V^+/2$	4.93 <b>4.88</b>	4.97		V
		$R_L = 1\text{ M}\Omega$ to $V^+/2$	4.94 <b>4.89</b>	4.98		
	Output Swing Low	$R_L = 10\text{ k}\Omega$ to $V^+/2$		33	180 <b>230</b>	mV
		$R_L = 1\text{ M}\Omega$ to $V^+/2$		25	120 <b>170</b>	
$I_{SC}$	Output Short Circuit Current	Sourcing, $V_O = 0V$ $V_{ID} = 100\text{ mV}$	3	5		mA
		Sinking, $V_O = 5V$ $V_{ID} = -100\text{ mV}$	9	16		
$I_S$	Supply Current per channel	$PS \leq 0.5V$		400	650 <b>900</b>	$\mu\text{A}$
SR	Slew Rate	$V_O = 3V$ , $A_V = +2$	1.8	3.8		V/ $\mu\text{s}$
GBW	Gain Bandwidth Product			8		MHz
$e_n$	Input -Referred Voltage Noise	$f = 100\text{ kHz}$		20		$\text{nV}/\sqrt{\text{Hz}}$
		$f = 1\text{ kHz}$		25		

## 5V Full Power Mode Electrical Characteristics (Continued)

Unless otherwise specified, all limits guaranteed for at  $T_J = 25^\circ\text{C}$ ,  $V^+ = 5\text{V}$ ,  $V^- = 0\text{V}$ ,  $V_{\text{CM}} = V_O = V^+/2$ ,  $\text{PS} = V^-$ . **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Conditions	Min (Note 6)	Typ (Note 5)	Max (Note 6)	Units
$i_n$	Input-Referred Current Noise	$f = 1 \text{ kHz}$		0.006		$\text{pA}/\sqrt{\text{Hz}}$
$t_{\text{LF}}$	Time from Low Power Mode to Full Power Mode			210		ns
$\text{TH}_{\text{PS}}$	Full Power Mode Voltage Threshold				0.5	V
$I_{\text{PS}}$	Input Current PS pin (Note 7)			-2		$\mu\text{A}$

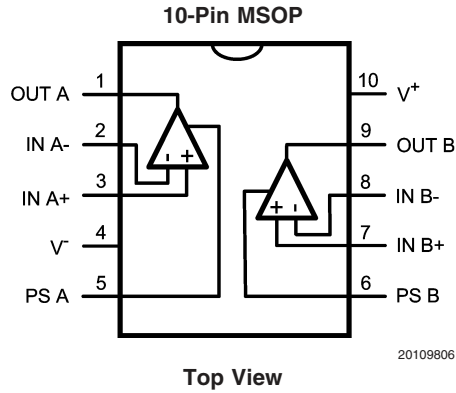
## 5V Low Power Mode Electrical Characteristics

Unless otherwise specified, all limits guaranteed for at  $T_J = 25^\circ\text{C}$ ,  $V^+ = 5\text{V}$ ,  $V^- = 0\text{V}$ ,  $V_{\text{CM}} = V_O = V^+/2$ ,  $\text{PS} = V^+$  or Open. **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Conditions	Min (Note 6)	Typ (Note 5)	Max (Note 6)	Units
$V_{\text{OS}}$	Input Offset Voltage			1	4 <b>5.5</b>	mV
$\Delta V_{\text{OS}}$	Input Offset Voltage Difference	$V_{\text{OS}}$ in Full Power Mode – $V_{\text{OS}}$ in Low Power Mode		0.1	1	mV
$\text{TC } V_{\text{OS}}$	Input Offset Average Drift	(Note 9)		2		$\mu\text{V}/\text{C}$
$I_{\text{B}}$	Input Bias Current			5		$\text{pA}$
CMRR	Common Mode Rejection Ratio	$V_{\text{CM}}$ Stepped from 0V to 3.5V	60 <b>55</b>	82		dB
PSRR	Power Supply Rejection Ratio	$V^+ = 2.7\text{V}$ to 5V	62 <b>60</b>	90		dB
CMVR	Input Common-Mode Voltage Range	CMRR $\geq 50$ dB	0		3.5	V
$A_{\text{VOL}}$	Large Signal Voltage Gain	$R_L = 1 \text{ M}\Omega$ $V_O = 0.75$ to 4V	62 <b>54</b>	72		dB
$V_O$	Output Swing High	$R_L = 1 \text{ M}\Omega$	4.94 <b>4.89</b>	4.98		V
	Output Swing Low	$R_L = 1 \text{ M}\Omega$		150	200 <b>250</b>	mV
$I_{\text{SC}}$	Output Short Circuit Current	Sourcing, $V_O = 0\text{V}$ $V_{\text{ID}} = 200 \text{ mV}$	40	140		$\mu\text{A}$
		Sinking, $V_O = 5\text{V}$ $V_{\text{ID}} = -200 \text{ mV}$	25	130		
$I_{\text{S}}$	Supply Current per channel	$\text{PS} \geq 4.5\text{V}$		2	3.5 <b>4.5</b>	$\mu\text{A}$
SR	Slew Rate	$V_O = 3\text{V}$ , $A_V = +2$	8	14		V/ms
GBW	Gain Bandwidth Product			27		kHz
$e_n$	Input -Referred Voltage Noise	$f = 100 \text{ kHz}$		40		$\text{nV}/\sqrt{\text{Hz}}$
		$f = 1 \text{ kHz}$		60		
$i_n$	Input-Referred Current Noise	$f = 1 \text{ kHz}$		0.06		$\text{pA}/\sqrt{\text{Hz}}$
$t_{\text{FL}}$	Time from Full Power Mode to Low Power Mode			500		ns
$\text{TH}_{\text{PS}}$	Low Power Mode Voltage Threshold		4.5			V
$I_{\text{PS}}$	Input Current PS pin (Note 7)			8		nA

- 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, 1.5 kΩ in series with 100 pF. Machine Model, 0Ω in series with 200 pF.
- Note 3:** Applies to both single-supply and split-supply operation. Continuous short circuit operation at elevated ambient temperature can result in exceeding the maximum allowed junction temperature of 150°C.
- Note 4:** The maximum power dissipation is a function of  $T_{J(MAX)}$ ,  $\theta_{JA}$ , 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 onto 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:** Positive current corresponds to current flowing into the device.
- Note 8:** Slew rate is the average of the rising and falling slew rates.
- Note 9:** Offset voltage average drift determined by dividing the change in  $V_{OS}$  at temperature extremes into the total temperature change.

## Connection Diagram



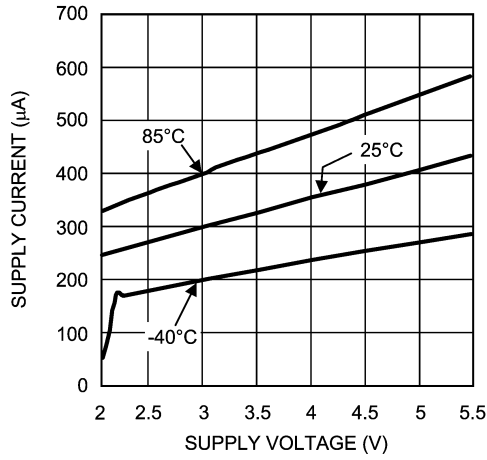
## Ordering Information

Package	Part Number	Package Marking	Transport Media	NSC Drawing
10-Pin MSOP 3 x 5 mm	LMV422MM	AJ1A	1k Units Tape and Reel	MUB10A
	LMV422MMX		3.5k Units Tape and Reel	

# Typical Performance Characteristics

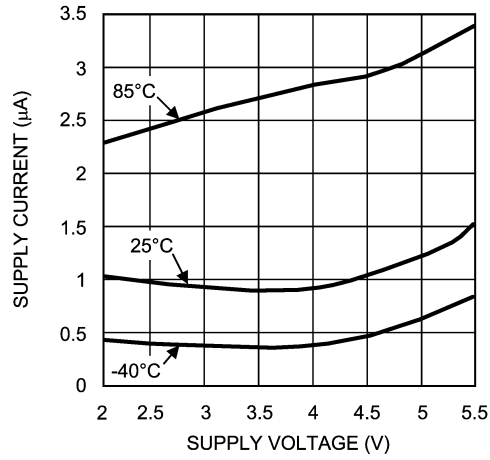
Unless otherwise specified,  $V^+ = 5V$ ,  $T_A = 25^\circ C$ ,  $PS = V^+$  for Full Power Mode,  $PS = V^-$  for Low Power Mode.

**Supply Current vs. Supply Voltage per Channel (Full Power Mode)**



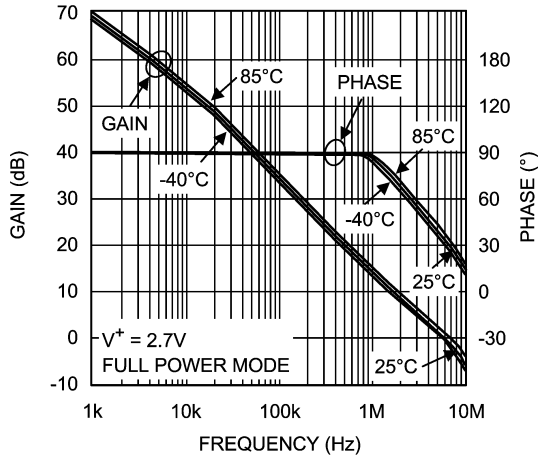
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**Supply Current vs. Supply Voltage per Channel (Low Power Mode)**



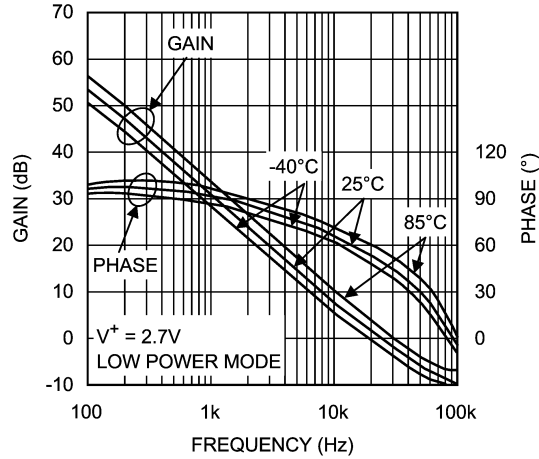
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**Gain and Phase vs. Frequency**



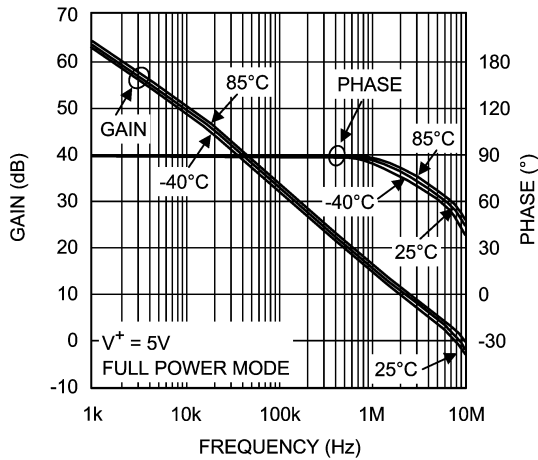
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**Gain and Phase vs. Frequency**



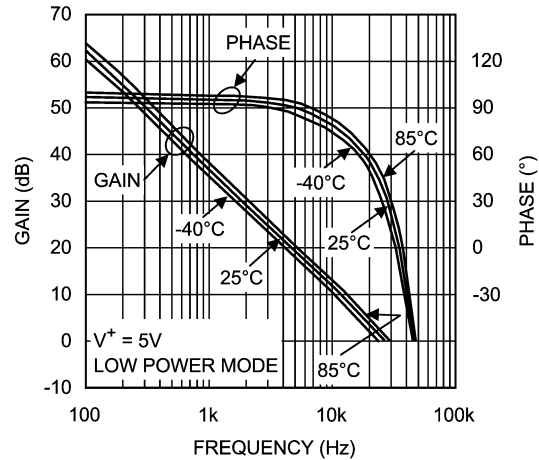
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**Gain and Phase vs. Frequency**



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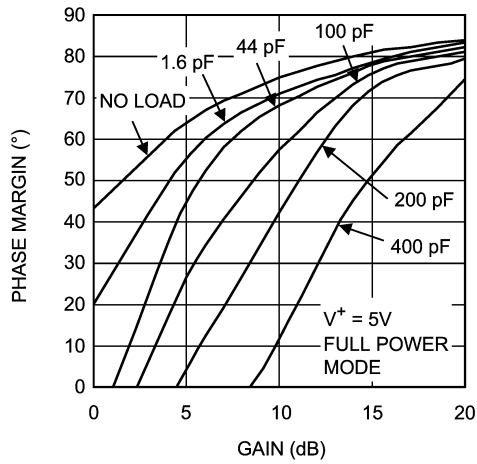
**Gain and Phase vs. Frequency**



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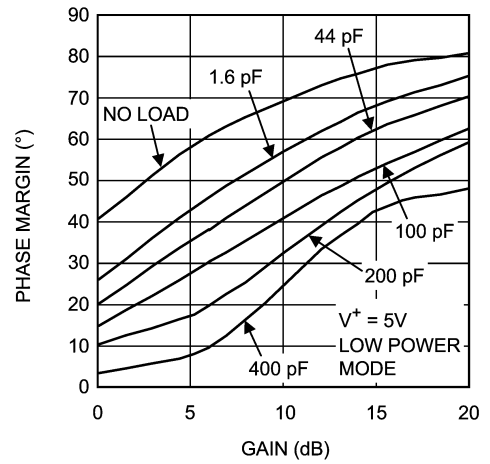
**Typical Performance Characteristics** Unless otherwise specified,  $V^+ = 5V$ ,  $T_A = 25^\circ C$ ,  $PS = V^+$  for Full Power Mode,  $PS = V^-$  for Low Power Mode. (Continued)

**Phase Margin vs. Gain for Various Capacitive Load**



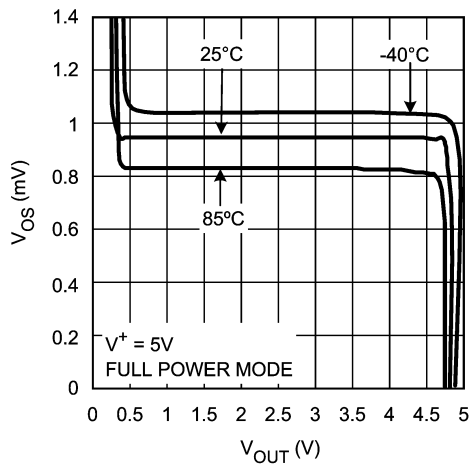
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**Phase Margin vs. Gain for Various Capacitive Load**



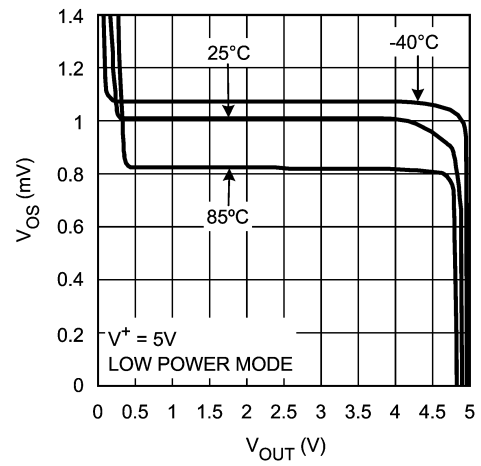
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**Input Offset Voltage vs. Output Voltage**



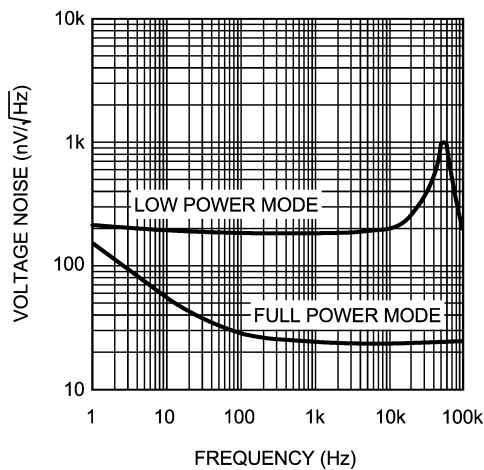
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**Input Offset Voltage vs. Output Voltage**



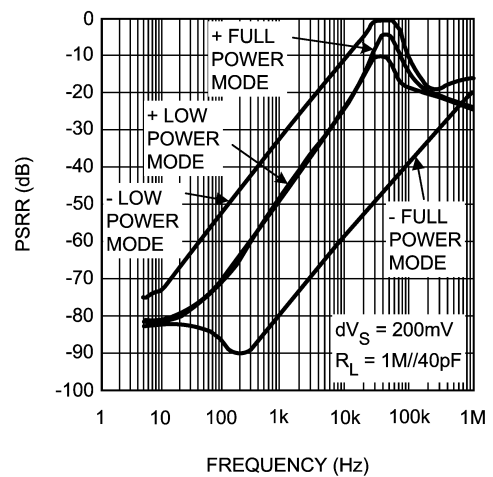
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**Noise vs. Frequency**



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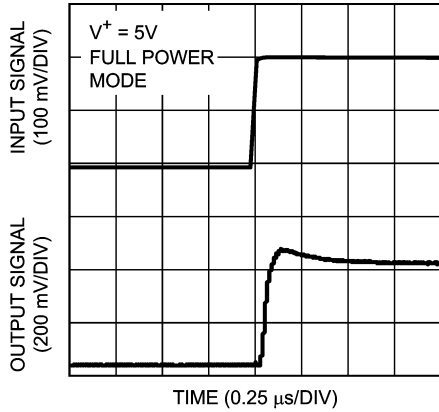
**PSRR vs. Frequency**



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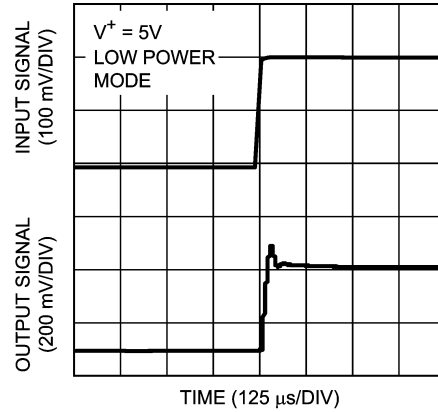
**Typical Performance Characteristics** Unless otherwise specified,  $V^+ = 5V$ ,  $T_A = 25^\circ C$ ,  $PS = V^+$  for Full Power Mode,  $PS = V^-$  for Low Power Mode. (Continued)

**Small Signal Non-Inverting Response**



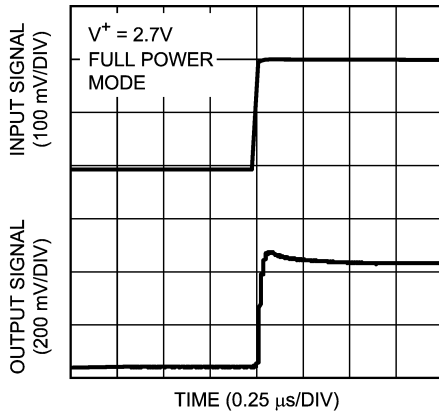
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**Small Signal Non-Inverting Response**



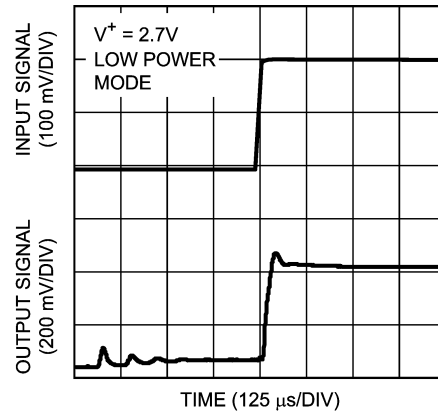
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**Small Signal Non-Inverting Response**



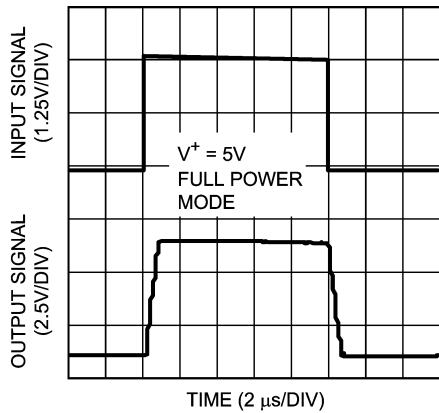
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**Small Signal Non-Inverting Response**



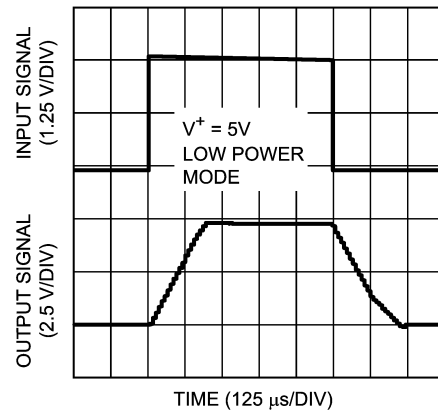
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**Large Signal Non-Inverting Response**



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**Large Signal Non-Inverting Response**



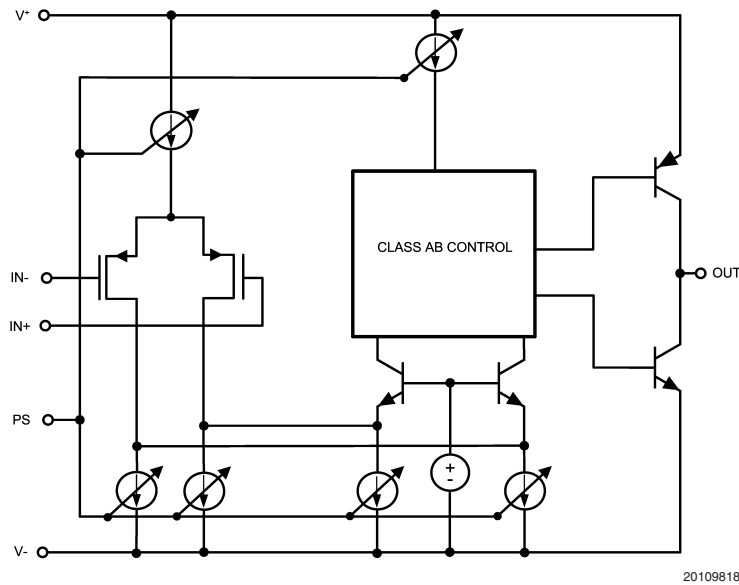
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## Application Information

The LMV422 is a dual rail-to-rail output amplifier that can dynamically switch between two active power modes. When the PS pin is set to greater than 4.5V or left open, the LMV422 is in Low Power Mode operating at a bandwidth of 27 kHz and consuming only 2uA of supply current per channel. Setting the PS pin to less than 0.5V, switches the LMV422 to Full Power Mode with a bandwidth of 8MHz and supply current of 400 uA per channel. The PS pin should not exceed the supply voltages. The two amplifiers are independently controlled.

The two power modes makes the LMV422 ideal for AC coupled circuit where the circuit needs to be kept active to maintain a quiescent charge on the coupling capacitors with minimum power consumption.

### SIMPLIFIED SCHEMATIC



### POWER SAVING MODE

The LMV422 offers a power select pin (PS) that provides a method to optimize the power consumption, bandwidth and short circuit current. To conserve battery life in portable applications, the LMV422 can be dynamically switched to

low power mode with minimum supply current and low bandwidth by leaving the PS pin unconnected or connecting the PS pin to  $V^+$  as shown in Fig1A. For maximum supply current and higher bandwidth connect PS to ground as shown in Figure 1B.

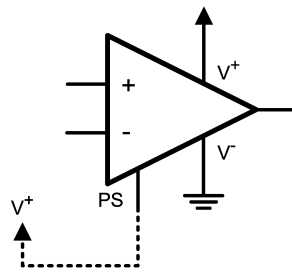


Figure 1A Low Power Mode

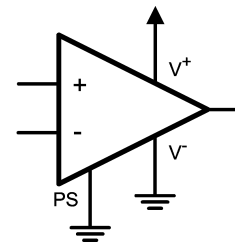


Figure 1B Full Power Mode

### FIGURE 1.

The LMV422 PS pin has an internal pull up and a logic level control gate that makes it easy for the PS pin to be controlled dynamically by the output of a logic gate or the output pin of

a microcontroller. The following figures show the three typical output configurations for outputs of logic gates and microcontrollers.



## Application Information (Continued)

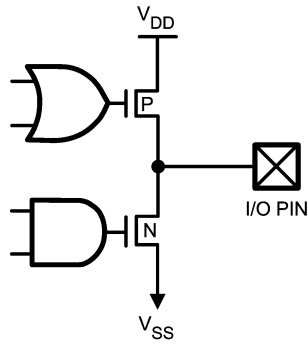


Figure 2A

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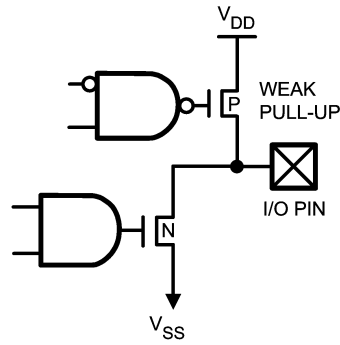


Figure 2B

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FIGURE 2.

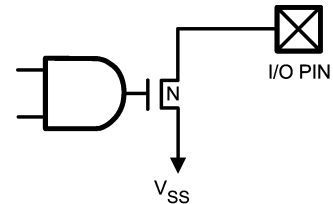


Figure 2C

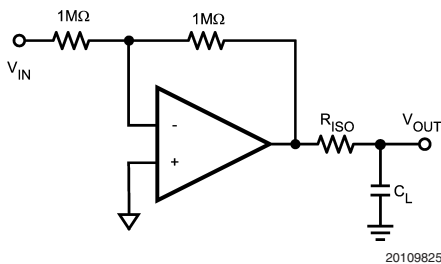
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### CAPACITIVE LOAD TOLERANCE

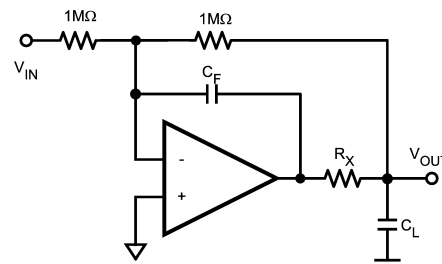
The LMV422 is optimized for maximum bandwidth when operating at a minimum closed loop gain of +2 or -1, therefore, it is not recommended to be configured as a buffer. Like many other op amps, the LMV422 may oscillate when the applied load appears capacitive. The threshold of the oscillation varies both with load and circuit gain, see phase margin vs. gain for various capacitive loads curves. The load capacitance interacts with the amplifier's output resistance to create an additional pole. If this pole frequency is suffi-

ciently low, it will degrade the amplifier's phase margin so that the amplifier is no longer stable.

Figure 3 shows the addition of a small value resistor  $R_{ISO}$  or  $R_X$  (50  $\Omega$  to 100 $\Omega$ ) in series with the op amps output, and a capacitor  $C_F$  (5 pF to 10 pF) from the inverting input to the output pin. This addition returns the phase margin to a safe value without interfering with lower frequency circuit operation. Note that in all cases, the output will ring heavily when the load capacitance is near the threshold for oscillation.



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FIGURE 3.

### AC COUPLED CIRCUITS

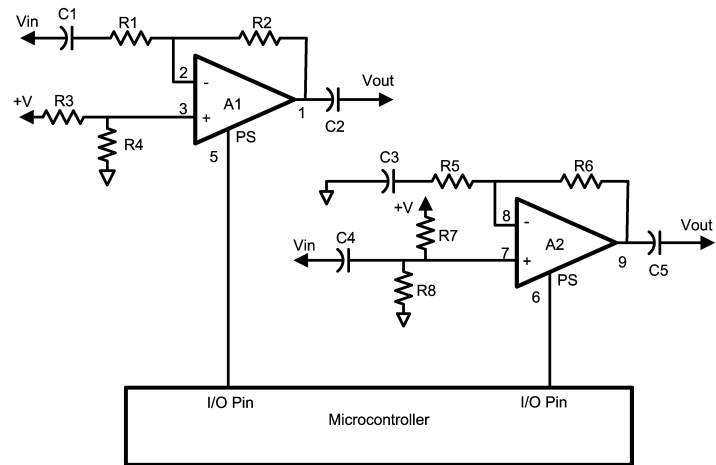
Figure 4 shows a schematic of an inverting and non-inverting AC coupled amplifiers using the LMV422 with the PS pins controlled by I/O ports of a microcontroller.

The advantage of the low power active mode for AC coupled amplifiers is the elimination of the time needed to reestablish a quiescent operating point when the amplifier is switched to a Full Power mode. When amplifiers without a low power active mode are used in low power applications, there are two ways to minimize power consumption. The first is turning off the amplifiers by switching off power to the op amps using a transistor switch. The second is using an amplifier with a shut down pin. Both of these methods have the problem of allowing the coupling capacitors, C1, C2, C3, C4, and C5, to discharge the quiescent DC voltage stored on them when placed in the shut down state. When the amplifiers are turned on again, the quiescent DC voltages must reestablish

themselves. During this time, the amplifier's output is not usable because the output signal is a mixture of the amplified input signal and the charging voltage on the coupling capacitors. The settling time can range from a several milliseconds to several seconds depending on the resistor and capacitor values.

When the LMV422 is placed into the low power mode the power consumption is minimal but the amplifier is active to maintain the quiescent DC voltage on the coupling capacitors and the transition back to the operational high power mode is fast, within few hundred nanoseconds. The active low power mode of the LMV422 separates the two critical aspects of a low power AC amplifier design. The values of the gain resistors, bias resistors, and coupling capacitors can be chosen independently of the turn on and stabilization time.

## Application Information (Continued)



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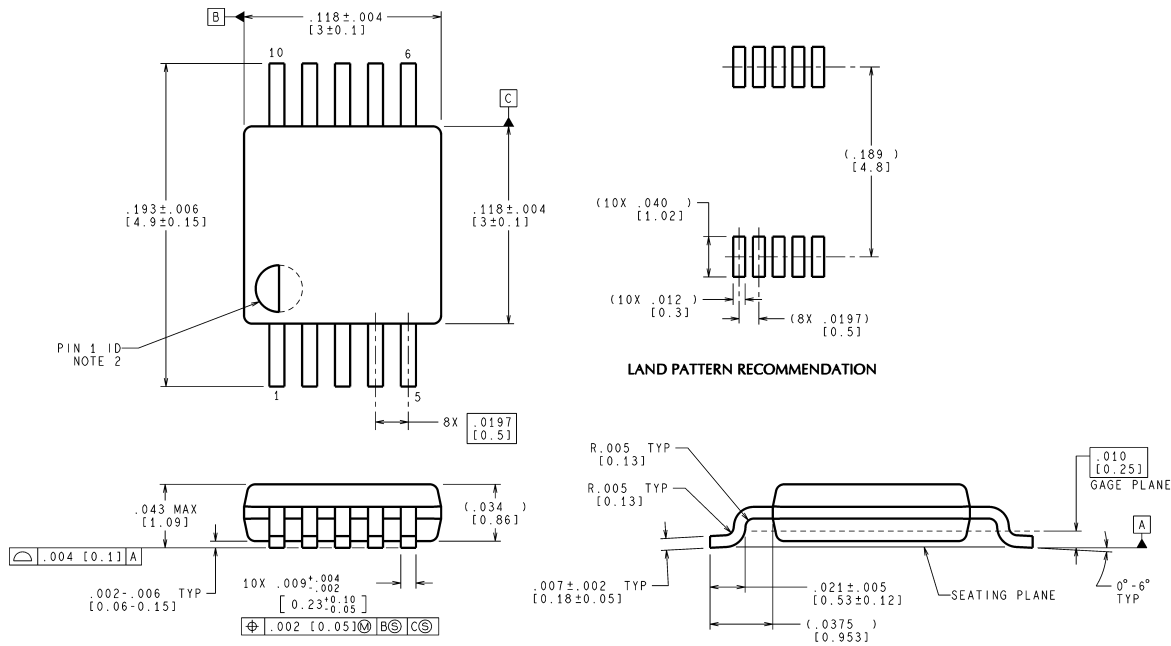
**FIGURE 4.**

### RESISTIVE LOAD

The LMV422 has a minimum current drive of 3 mA in full power mode. The minimum resistive load should be 10 K $\Omega$

The current drive in the low power mode is 140  $\mu$ A, the minimum resistive load should be 100 K $\Omega$

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



CONTROLLING DIMENSION IS INCH  
VALUES IN [ ] ARE MILLIMETERS  
DIMENSIONS IN ( ) FOR REFERENCE ONLY

MUB10A (Rev B)

**10-Pin MSOP  
NS Package Number MUB10A**

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