January 2003

LMV771 Low Offset, Low Noise, RRO Operational Amplifier in SC70-5

General Description

The LMV771 is a low noise and low cost precision operational amplifier intended for use in a wide range of applications. Other important characteristics of the device include extended operating temperature range, –40˚C to 125˚C, tiny SC70-5 package, and low input bias current.

The LMV771 is designed for precision, low noise, low voltage, and miniature systems. It provides rail-to-rail output swing into heavy loads. The maximum input offset voltage is 850µV at room temperature and the input common mode voltage range includes ground.

The LMV771 is offered in the space saving SC70-5 package.

Features

(Typical 2.7V Supply Values; Unless Otherwise Noted)

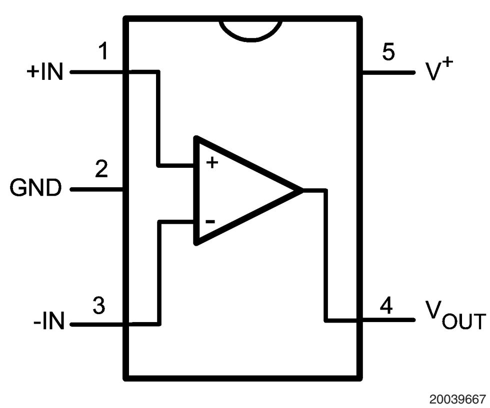
- Guaranteed 2.7V and 5V specifications
- Maximum V_{OS} 850µV (limit)
- Voltage noise (1kHz) $9nV/\sqrt{Hz}$
- Rail-to-Rail output swing
  - — w/600Ω load 100mV from rail
  - — w/2kΩ load 50mV from rail
- Silicon Dust™, SC70-5 package 2.0x2.0x1.0mm
- Open loop gain w/2kΩ load 100dB
- V_{CM} 0 to V^+ -0.9V
- Supply current 550µA
- Gain bandwidth product 3.5MHz
- Temperature range –40˚C to 125˚C

Applications

- Transducer amplifier
- Instrumentation amplifier
- Precision current sensing
- Data acquisition systems
- Active filters and buffers
- Sample and hold
- Portable/battery powered electronics

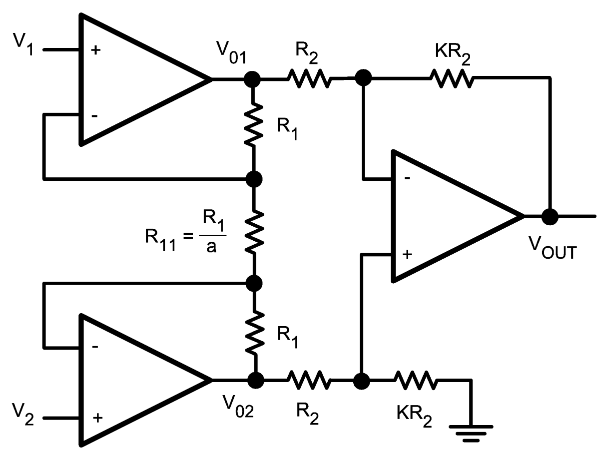
Connection Diagram

SC70-5



Top View

Instrumentation Amplifier



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	200V
Human Body Model	2000V
Differential Input Voltage	± Supply Voltage
Supply Voltage ($V^+ – V^-$)	6.5V
Output Short Circuit to V^+	(Note 3)
Output Short Circuit to V^-	(Note 4)
Storage Temperature Range	−65˚C to 150˚C
Junction Temperature (Note 5)	150˚C
Mounting Temp.	
Infrared or Convection (20 sec)	235˚C
Wave Soldering Lead Temp (10 sec)	260˚C

Operating Ratings (Note 1)

Temperature Range	−40˚C to 125˚C
Thermal Resistance (θ_{JA})	
SC70-5 Package	440 ˚C/W

2.7V DC Electrical Characteristics (Note 10)

Unless otherwise specified, all limits guaranteed for T_J = 25˚C. V^+ = 2.7V, V^- = 0V, $V_{CM} = V^+/2$, $V_O = V^+/2$ and R_L > 1MΩ. **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Condition	Min (Note 7)	Typ (Note 6)	Max (Note 7)	Units
V_{OS}	Input Offset Voltage			0.30	0.85 **1.0**	mV
TCV_{OS}	Input Offset Voltage Average Drift			−0.45		µV/˚C
I_B	Input Bias Current			−0.1	100	pA
I_{OS}	Input Offset Current			0.004	100	pA
I_S	Supply Current			550	900 **910**	µA
CMRR	Common Mode Rejection Ratio	$0.5 \le V_{CM} \le 1.2V$	74 **72**	80		dB
PSRR	Power Supply Rejection Ratio	$2.7V \le V^+ \le 5V$	82 **76**	90		dB
V_{CM}	Input Common-Mode Voltage Range	For CMRR ≥ 50dB	0		1.8	V
A_V	Large Signal Voltage Gain (Note 8)	R_L = 600Ω to 1.35V, V_O = 0.2V to 2.5V	92 **80**	100		dB
		R_L = 2kΩ to 1.35V, V_O = 0.2V to 2.5V	98 **86**	100		dB
V_O	Output Swing	R_L = 600Ω to 1.35V V_{IN} = ± 100mV	0.11 **0.14**	0.084 to 2.62	2.59 **2.56**	V
		R_L = 2kΩ to 1.35V V_{IN} = ± 100mV	0.05 **0.06**	0.026 to 2.68	2.65 **2.64**	V
I_O	Output Short Circuit Current	Sourcing, V_O = 0V V_{IN} = 100mV	18 **11**	24		mA
		Sinking, V_O = 2.7V V_{IN} = −100mV	18 **11**	22		mA

2.7V AC Electrical Characteristics

Unless otherwise specified, all limits guaranteed for T_J = 25˚C. V^+ = 5.0V, V^- = 0V, $V_{CM} = V^+/2$, $V_O = V^+/2$ and R_L > 1MΩ. **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Conditions	Min (Note 7)	Typ (Note 6)	Max (Note 7)	Units
SR	Slew Rate	(Note 9)		1.4		V/µs
GBW	Gain-Bandwidth Product			3.5		MHz
Φ_m	Phase Margin			79		Deg

2.7V AC Electrical Characteristics (Continued)

Unless otherwise specified, all limits guaranteed for T_J = 25˚C. V^+ = 5.0V, V^- = 0V, V_{CM} = $V^+/2$, V_O = $V^+/2$ and R_L > 1MΩ. **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Conditions	Min (Note 7)	Typ (Note 6)	Max (Note 7)	Units
G_m	Gain Margin			–15		dB
e_n	Input-Referred Voltage Noise (Flatband)	f = 10KHz		7.5		$nV/\sqrt{Hz}$
e_n	Input-Referred Voltage Noise (l/f)	f = 100Hz		17		$nV/\sqrt{Hz}$
i_n	Input-Referred Current Noise	f = 1kHz		0.001		$pA/\sqrt{Hz}$
THD	Total Harmonic Distortion	f = 1kHz, A_V = +1 R_L = 600Ω, V_{IN} = 1 V_{PP}		0.007		%

5.0V DC Electrical Characteristics

Unless otherwise specified, all limits guaranteed for T_J = 25˚C. V^+ = 5.0V, V^- = 0V, V_{CM} = $V^+/2$, V_O = $V^+/2$ and R_L > 1MΩ. **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Condition	Min(Note 7)	Typ (Note 6)	Max (Note 7)	Units
V_{OS}	Input Offset Voltage			0.25	0.85 **1.0**	mV
TCV_{OS}	Input Offset Voltage Average Drift			–0.35		μV/˚C
I_B	Input Bias Current			–0.23	100	pA
I_{OS}	Input Offset Current			0.017	100	pA
I_S	Supply Current			600	950 **960**	μA
CMRR	Common Mode Rejection Ratio	0.5 ≤ V_{CM} ≤ 3.5V	80 **79**	90		dB
PSRR	Power Supply Rejection Ratio	2.7V ≤ V^+ ≤ 5V	82 **76**	90		dB
V_{CM}	Input Common-Mode Voltage Range	For CMRR ≥ 50dB	0		4.1	V
A_V	Large Signal Voltage Gain (Note 8)	R_L = 600Ω to 2.5V, V_O = 0.2V to 4.8V	92 **89**	100		dB
		R_L = 2kΩ to 2.5V, V_O = 0.2V to 4.8V	98 **95**	100		
V_O	Output Swing	R_L = 600Ω to 2.5V V_{IN} = ± 100mV	0.15 **0.23**	0.112 to 4.9	4.85 **4.77**	V
		R_L = 2kΩ to 2.5V V_{IN} = ± 100mV	0.06 **0.07**	0.035 to 4.97	4.94 **4.93**	
I_O	Output Short Circuit Current	Sourcing, V_O = 0V V_{IN} = 100mV	35 **35**	75		mA
		Sinking, V_O = 2.7V V_{IN} = –100mV	35 **35**	66		

5.0V AC Electrical Characteristics

Unless otherwise specified, all limits guaranteed for T_J = 25˚C. V^+ = 5.0V, V^- = 0V, V_{CM} = $V^+/2$, V_O = $V^+/2$ and R_L > 1MΩ. **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Conditions	Min (Note 7)	Typ (Note 6)	Max (Note 7)	Units
SR	Slew Rate	(Note 9)		1.4		V/μs

5.0V AC Electrical Characteristics (Continued)

Unless otherwise specified, all limits guaranteed for T_J = 25˚C. V^+ = 5.0V, V^- = 0V, V_{CM} = $V^+/2$, V_O = $V^+/2$ and R_L > 1MΩ. **Boldface** limits apply at the temperature extremes.

Symbol	Parameter	Conditions	Min (Note 7)	Typ (Note 6)	Max (Note 7)	Units
GBW	Gain-Bandwidth Product			3.5		MHz
Φ_m	Phase Margin			79		Deg
G_m	Gain Margin			–15		dB
e_n	Input-Referred Voltage Noise (Flatband)	f = 10KHz		6.5		$nV/\sqrt{Hz}$
e_n	Input-Referred Voltage Noise (l/f)	f = 100Hz		12		$nV/\sqrt{Hz}$
i_n	Input-Referred Current Noise	f = 1kHz		0.001		$pA/\sqrt{Hz}$
THD	Total Harmonic Distortion	f = 1kHz, A_V = +1 R_L = 600Ω, V_{IN} = 1 V_{PP}		0.007		%

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, 1.5kΩ in series with 100pF. Machine model, 0Ω in series with 20pF.

Note 3: Shorting output to V^+ will adversely affect reliability.

Note 4: Shorting output to V^- will adversely affect reliability.

Note 5: 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 6: Typical Values represent the most likely parametric norm.

Note 7: All limits are guaranteed by testing or statistical analysis.

Note 8: R_L is connected to mid-supply. The output voltage is set at 200mV from the rails. V_O = GND+0.2V and V_O = V^+ −0.2V

Note 9: Connected as Voltage follower with $2V_{PP}$ step input. Number Specified is the slower of positive and negative slew Rates.

Note 10: Electrical Table values apply only for factory testing conditions at the temperature indicated. Factory testing conditions result in very limited self-heating of the device such that $T_J = T_A$. No guarantee of parametric performance is indicated in the electrical tables under the conditions of internal self-heating where $T_J > T_A$. Absolute Maximum Rating indicated junction temperature limits beyond which the device may be permanently degraded, either mechanically or electrically.

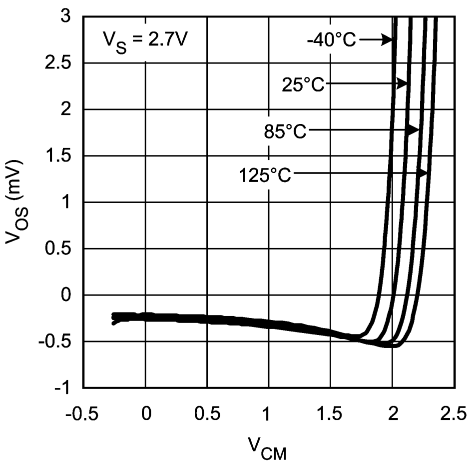
Note 11: Continuous operation of the device with an output short circuit current larger than 35mA may cause permanent damage to the device.

Ordering Information

Package	Part Number	Package Marking	Transport Media	NSC Drawing
SC70-5	LMV771MG	A75	1k Units Tape and Reel	MAA05A
	LMV771MGX		3k Units Tape and Reel	

Typical Performance Characteristics

V_{OS} vs. V_{CM} Over Temperature



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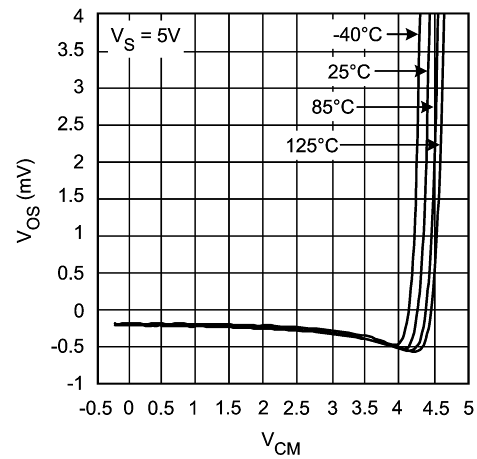
V_{OS} vs. V_{CM} Over Temperature



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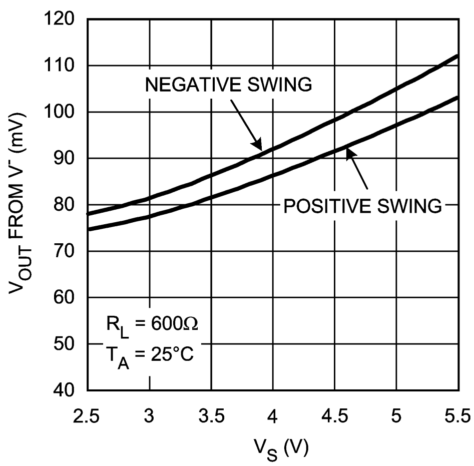
Output Swing vs. V_S



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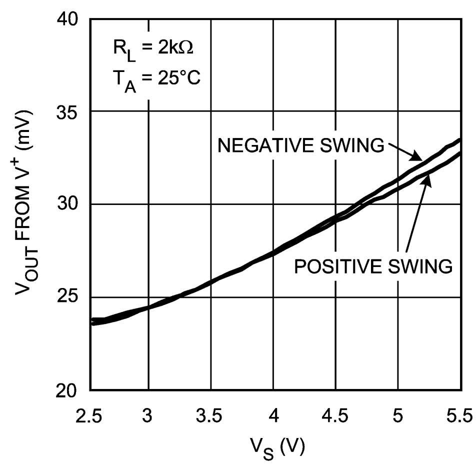
Output Swing vs. V_S



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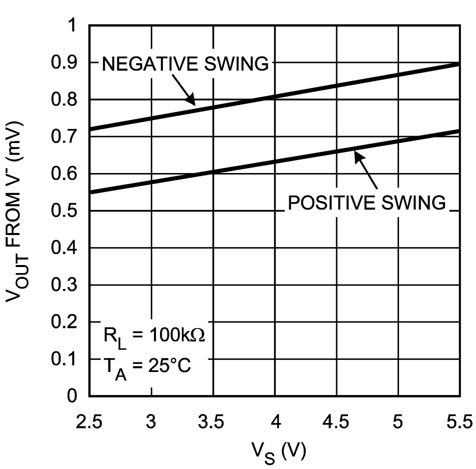
Output Swing vs. V_S



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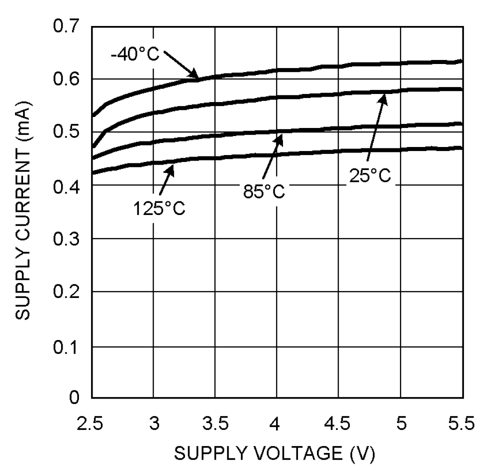
I_S vs. V_S Over Temperature



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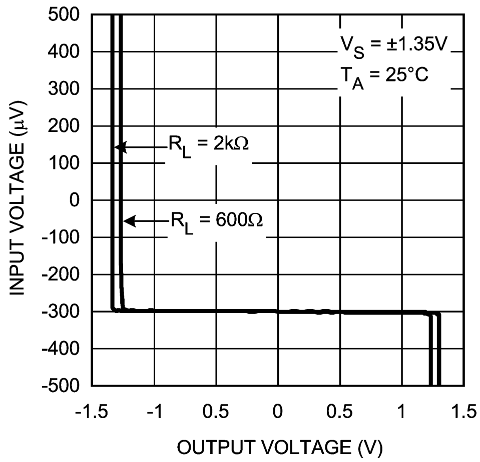
Typical Performance Characteristics (Continued)

V_{IN} vs. V_{OUT}



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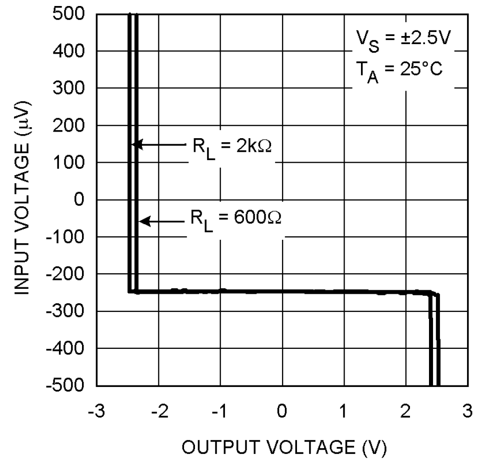
V_{IN} vs. V_{OUT}



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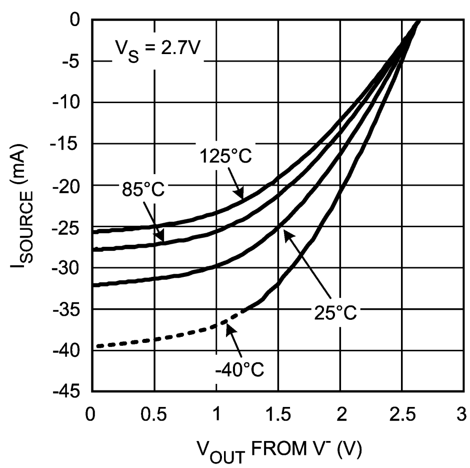
Sourcing Current vs. V_{OUT} (Note 11)



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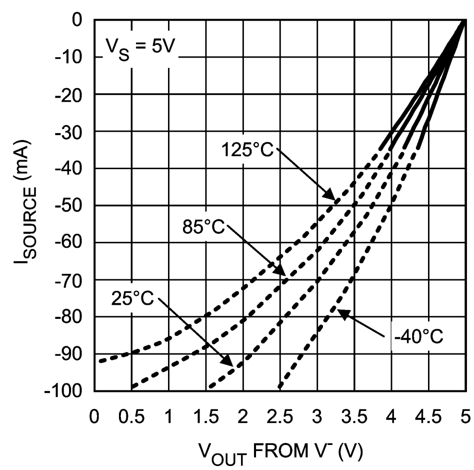
Sourcing Current vs. V_{OUT} (Note 11)



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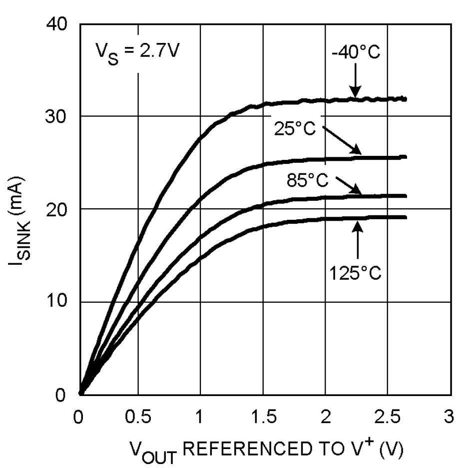
Sinking Current vs. V_{OUT} (Note 11)



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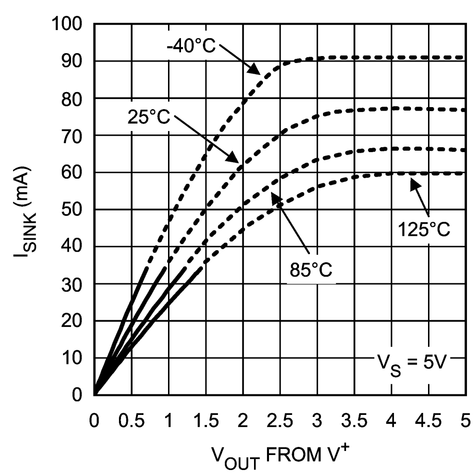
Sinking Current vs. V_{OUT} (Note 11)



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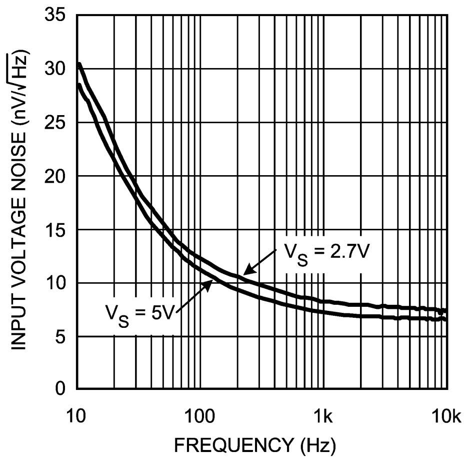
Typical Performance Characteristics (Continued)

Input Voltage Noise vs. Frequency



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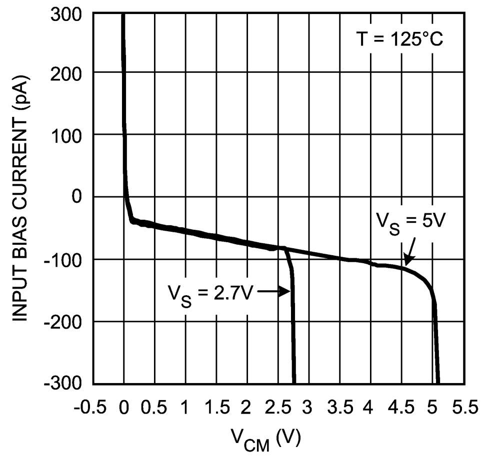
Input Bias Current Over Temperature



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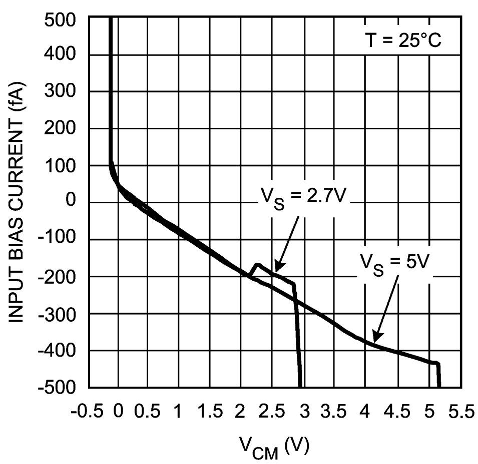
Input Bias Current Over Temperature



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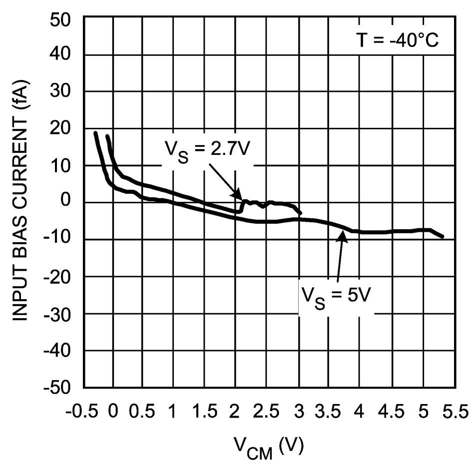
Input Bias Current Over Temperature



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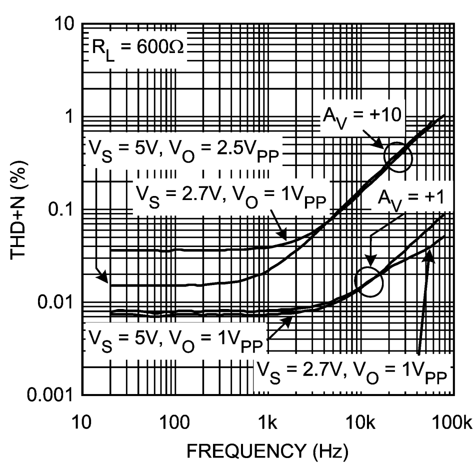
THD+N vs. Frequency



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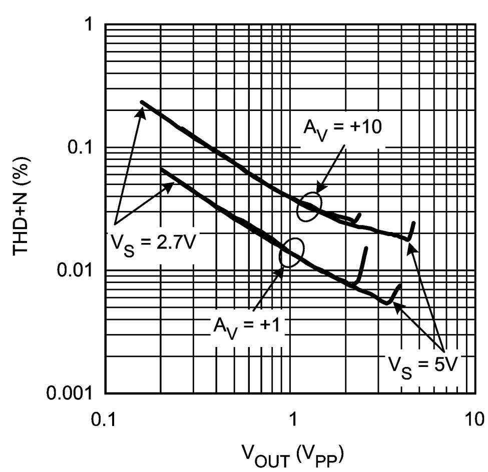
THD+N vs. V_{OUT}



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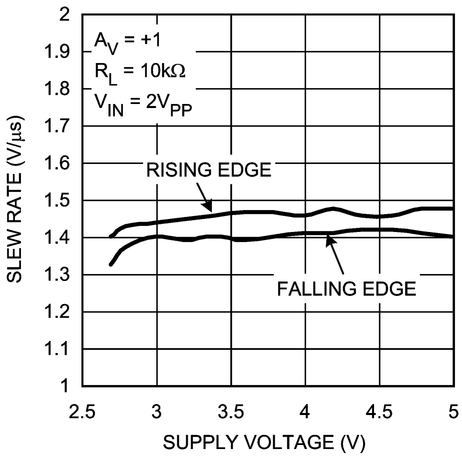
Typical Performance Characteristics (Continued)

Slew Rate vs. Supply Voltage



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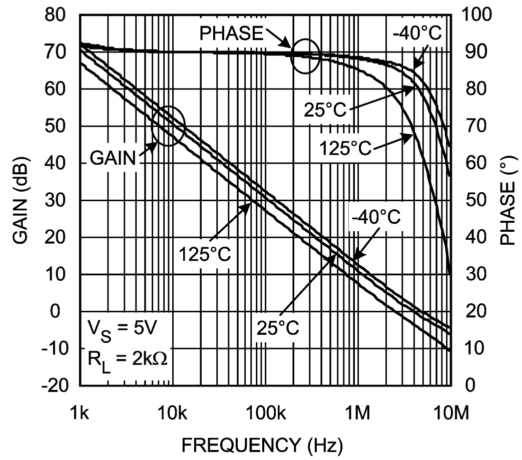
Open Loop Frequency Response Over Temperature



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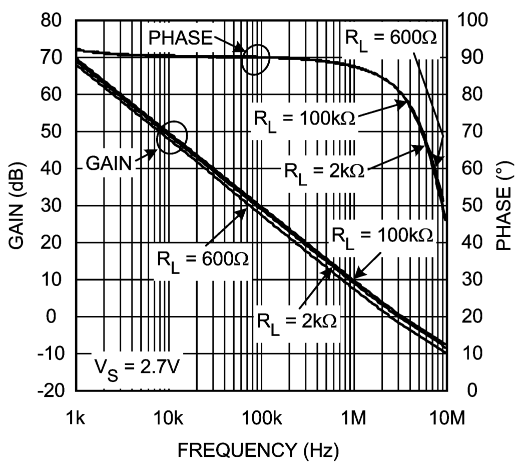
Open Loop Frequency Response



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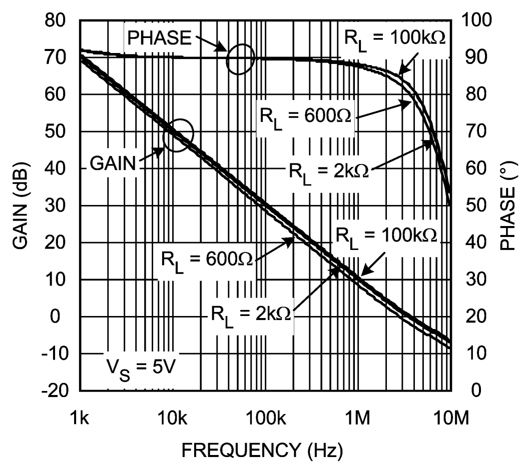
Open Loop Frequency Response



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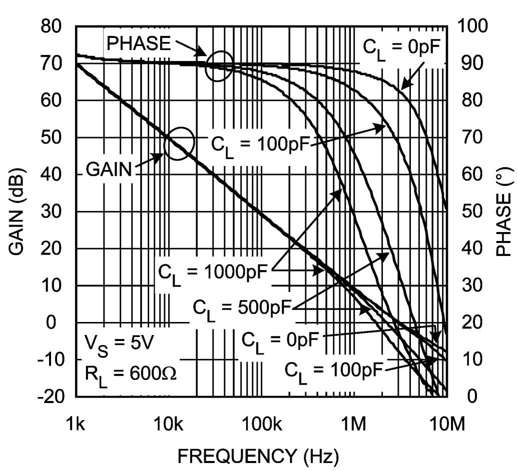
Open Loop Gain & Phase with Cap. Loading



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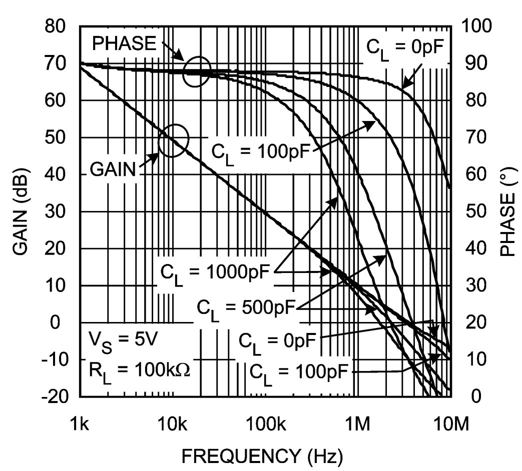

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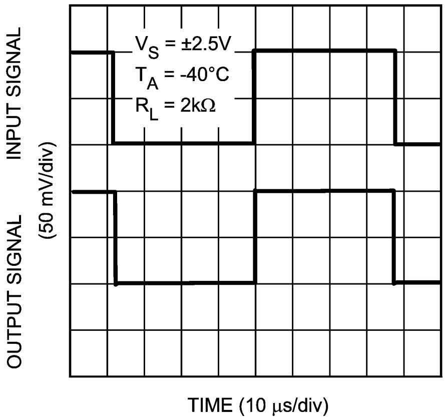
Typical Performance Characteristics (Continued)

Non-Inverting Small Signal Pulse Response



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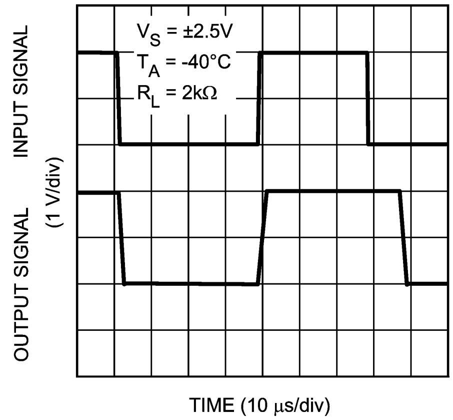
Non-Inverting Large Signal Pulse Response



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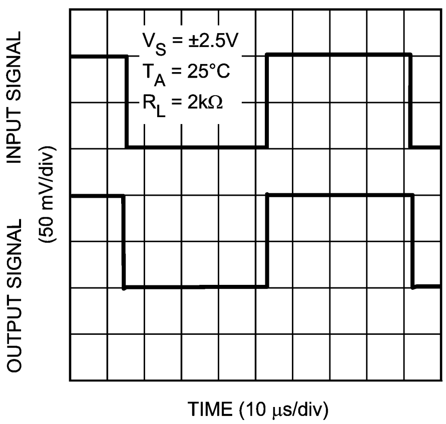
Non-Inverting Small Signal Pulse Response



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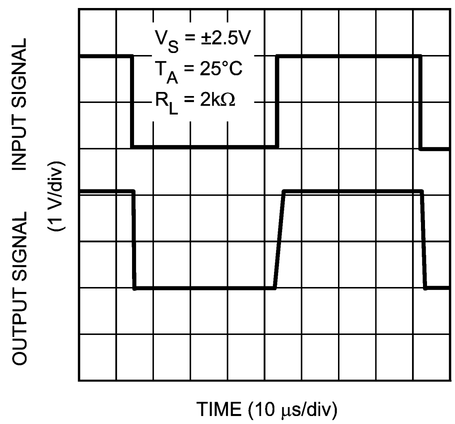
Non-Inverting Large Signal Pulse Response



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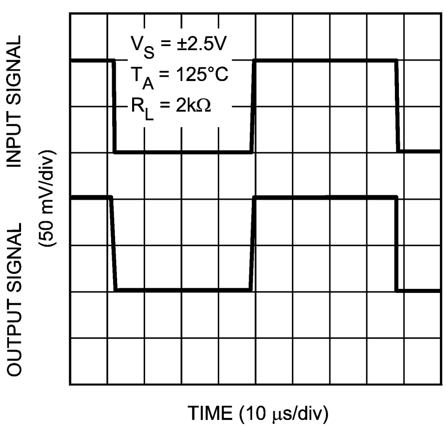
Non-Inverting Small Signal Pulse Response



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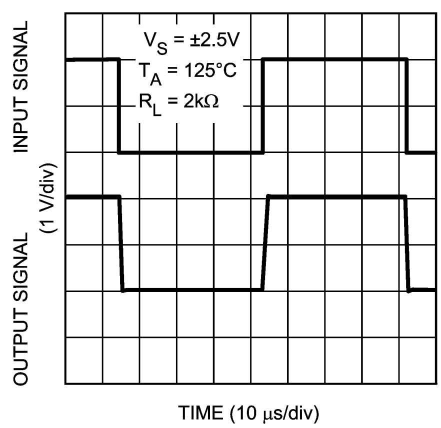
Non-Inverting Large Signal Pulse Response



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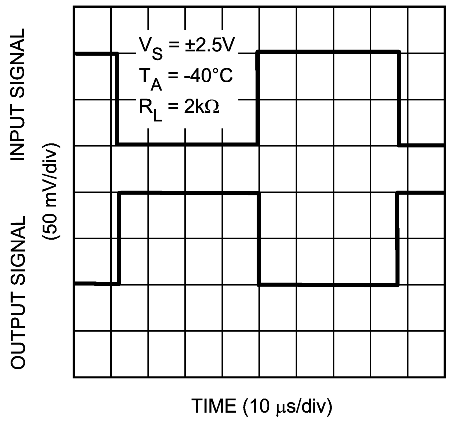
Typical Performance Characteristics (Continued)

Inverting Small Signal Pulse Response



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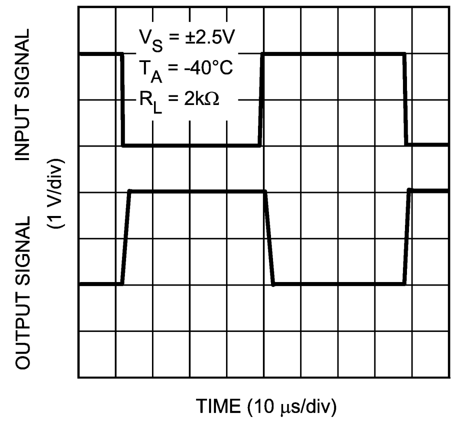
Inverting Large Signal Pulse Response



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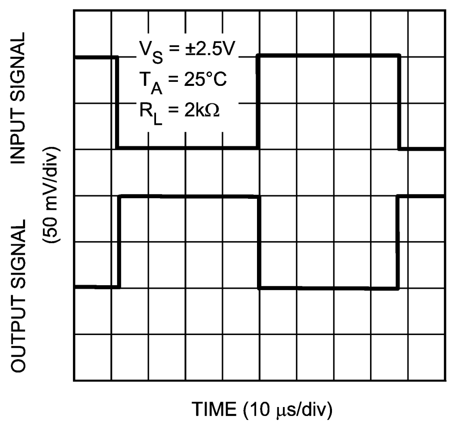
Inverting Small Signal Pulse Response



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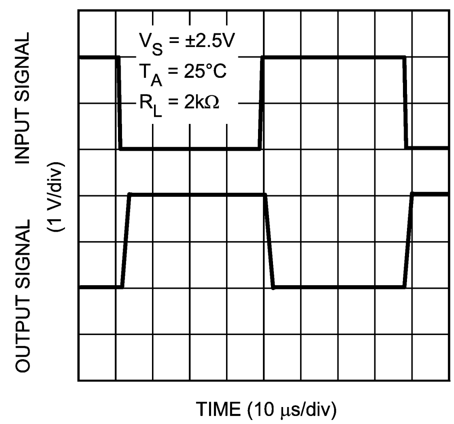
Inverting Large Signal Pulse Response



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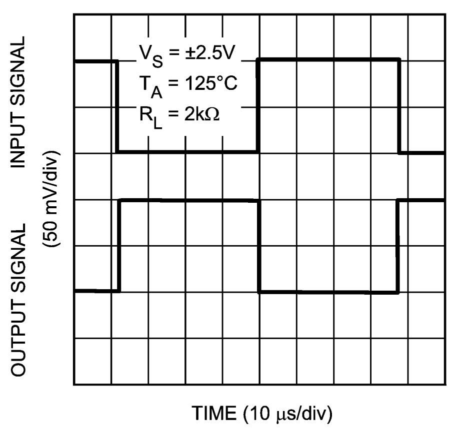
Inverting Small Signal Pulse Response



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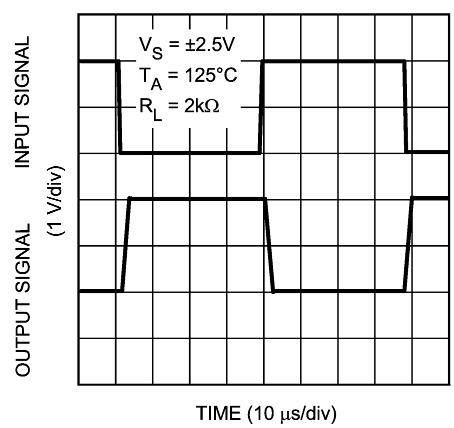
Inverting Large Signal Pulse Response



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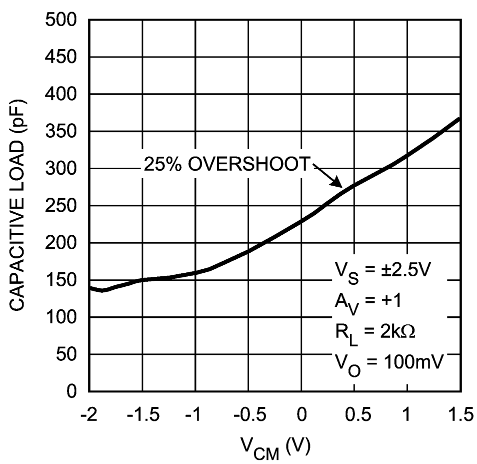
Typical Performance Characteristics (Continued)

Stability vs. V_{CM}



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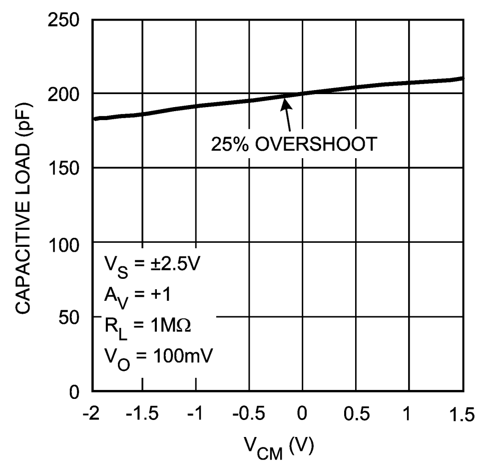
Stability vs. V_{CM}



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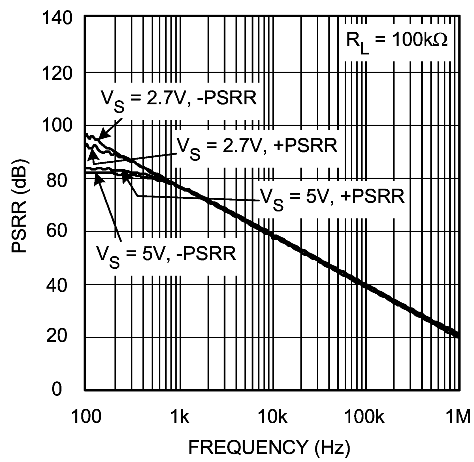
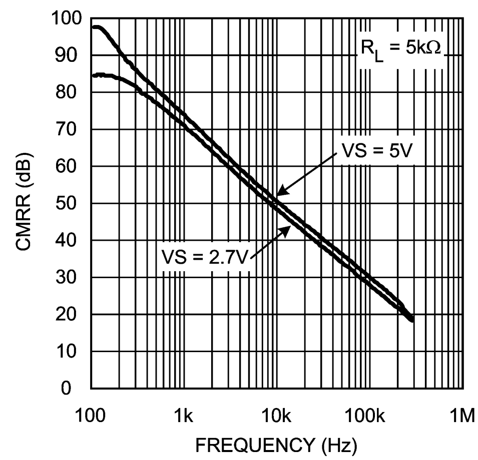
PSRR vs. Frequency



20039668

CMRR vs. Frequency



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Application Note

LMV771

The LMV771 is a single, low cost precision amplifier with very low noise and ultra low offset voltage.

INSTRUMENTATION AMPLIFIER

Measurement of very small signals with an amplifier requires close attention to the input impedance of the amplifier, gain of the overall signal on the inputs, and the gain on each input since we are only interested in the difference of the two inputs and the common signal is considered noise. A classic solution is an instrumentation amplifier. Instrumentation amplifiers have a finite, accurate, and stable gain. Also they have extremely high input impedances and very low output impedances. Finally they have an extremely high CMRR so that the amplifier can only respond to the differential signal. A typical instrumentation amplifier is shown in *Figure 1*.

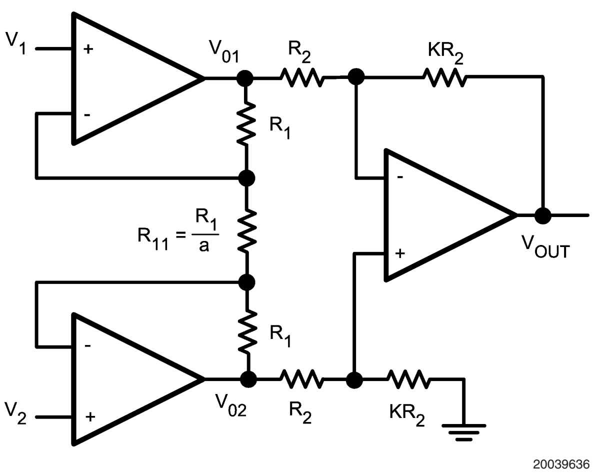

FIGURE 1.

There are two stages in this amplifier. The last stage, output stage, is a differential amplifier. In an ideal case the two amplifiers of the first stage, input stage, would be set up as buffers to isolate the inputs. However they cannot be connected as followers because of real amplifiers mismatch. That is why there is a balancing resistor between the two. The product of the two stages of the gain will give the gain of the instrumentation amplifier. Ideally, the CMRR should be infinity. However the output stage has a small non-zero common mode gain which results from resistor mismatch.

In the input stage of the circuit, current is the same across all resistors. This is due to the high input impedance and low input bias current of the LMV771. With the node equations we have:

$$\text{GIVEN: } I_{R_1} = I_{R_{11}} \tag{1}$$

By Omh's Law:

$$\begin{aligned} V_{O1} - V_{O2} &= (2R_1 + R_{11})\, I_{R_{11}} \\ &= (2a + 1)\, R_{11} \bullet I_{R_{11}} \\ &= (2a + 1)\, V_{R_{11}} \end{aligned} \tag{2}$$

However:

$$V_{R_{11}} = V_1 - V_2 \tag{3}$$

So we have:

$$V_{O1} - V_{O2} = (2a + 1)\,(V_1 - V_2) \tag{4}$$

Now looking at the output of the instrumentation amplifier:

$$\begin{aligned} V_O &= \frac{KR_2}{R_2}\,(V_{O2} - V_{O1}) \\ &= -K\,(V_{O1} - V_{O2}) \end{aligned} \tag{5}$$

Substituting from equation 4:

$$V_O = -K\,(2a + 1)\,(V_1 - V_2) \tag{6}$$

This shows the gain of the instrumentation amplifier to be: K(2a+1)

Typical values for this circuit can be obtained by setting: a = 12 and K= 4. This results in an overall gain of −100.

ACTIVE FILTER

Active Filters are circuits with amplifiers, resistors, and capacitors. The use of amplifiers instead of inductors, which are used in passive filters, enhances the circuit performance while reducing the size and complexity of the filter.

The simplest active filters are designed using an inverting op amp configuration where at least one reactive element has been added to the configuration. This means that the op amp will provide "frequency-dependent" amplification, since reactive elements are frequency dependent devices.

LOW PASS FILTER

The following shows a very simple low pass filter.

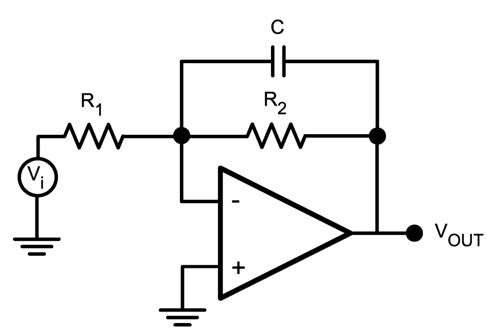

FIGURE 2.

Application Note (Continued)

The transfer function can be expressed as follows:
By KCL:

$$\frac{-V_i}{R_1} - \frac{V_O}{\left[\frac{1}{jwc}\right]} - \frac{V_O}{R_2} = O \tag{7}$$

Simplifying this further results in:

$$V_O = \frac{-R_2}{R_1}\left[\frac{1}{jwcR_2 + 1}\right]V_i \tag{8}$$

or

$$\frac{V_O}{V_i} = \frac{-R_2}{R_1}\left[\frac{1}{jwcR_2 + 1}\right] \tag{9}$$

Now, substituting ω=2πf, so that the calculations are in f(Hz) and not ω(rad/s), and setting the DC gain $\left[-\frac{R_2}{R_1} = H_O\right]$ and $H = \frac{V_O}{V_i}$

$$H = H_O\left[\frac{1}{j2\pi fcR_2 + 1}\right] \tag{10}$$

Set: $f_O = \frac{1}{2\pi R_2 C}$

$$H = H_O\left[\frac{1}{1 + j\,(f/f_o)}\right] \tag{11}$$

Low pass filters are known as lossy integrators because they only behave as an integrator at higher frequencies. Just by looking at the transfer function one can predict the general form of the bode plot. When the f/f_O ratio is small, the capacitor is in effect an open circuit and the amplifier behaves at a set DC gain. Starting at f_O, –3dB corner, the capacitor will have the dominant impedance and hence the circuit will behave as an integrator and the signal will be attenuated and eventually cut. The bode plot for this filter is shown in the following picture:

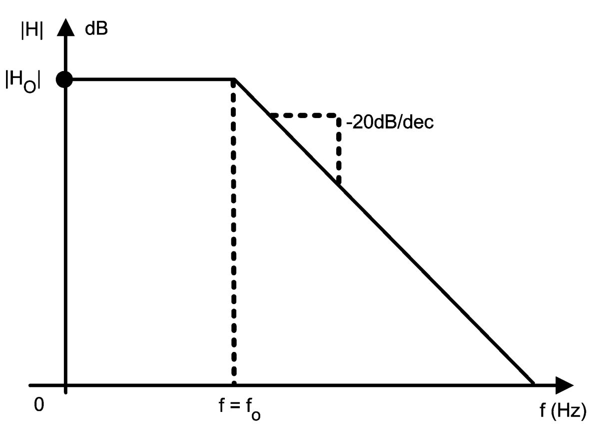

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FIGURE 3.

HIGH PASS FILTER

In a similar approach, one can derive the transfer function of a high pass filter. A typical first order high pass filter is shown below:

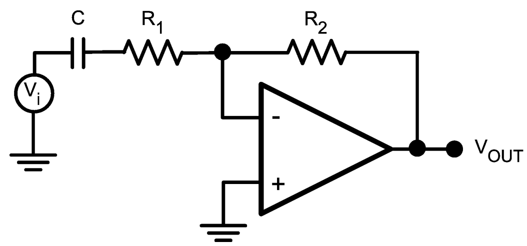

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FIGURE 4.

Writing the KCL for this circuit :
(V_1 denotes the voltage between C and R_1)

$$\frac{V_1 - V_i}{\frac{1}{jwC}} = \frac{V_1 - V^-}{R_1} \tag{12}$$

$$\frac{V^- + V_1}{R_1} = \frac{V^- + V_O}{R_2} \tag{13}$$

Solving these two equations to find the transfer function and using:

$$f_O = \frac{1}{2\pi R_2 C}$$

(high frequency gain) $H_O = \frac{-R_2}{R_1}$ and $H = \frac{V_O}{V_i}$
Which results:

$$H = H_O\,\frac{j\,(f/f_o)}{1 + j\,(f/f_o)} \tag{14}$$

Looking at the transfer function, it is clear that when f/f_O is small, the capacitor is open and hence no signal is getting in to the amplifier. As the frequency increases the amplifier starts operating. At $f = f_O$ the capacitor behaves like a short circuit and the amplifier will have a constant, high frequency, gain of H_O. The bode plot of the transfer function follows:

Application Note (Continued)

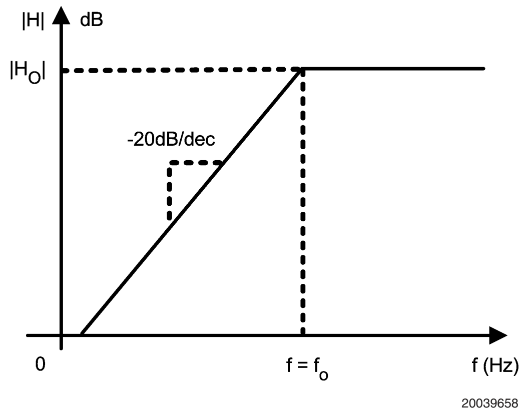


FIGURE 5.

BAND PASS FILTER

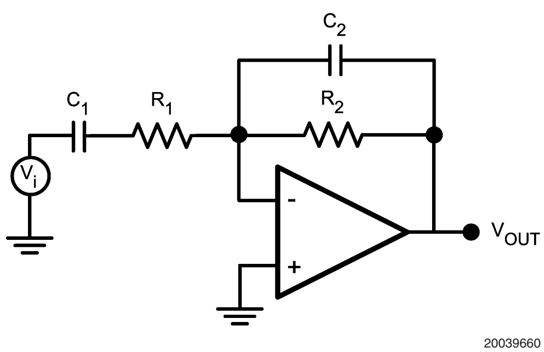


FIGURE 6.

Combining a low pass filter and a high pass filter will generate a band pass filter. In this network the input impedance forms the high pass filter while the feedback impedance forms the low pass filter. Choosing the corner frequencies so that $f_1 < f_2$, then all the frequencies in between, $f_1 \leq f \leq f_2$, will pass through the filter while frequencies below f_1 and above f_2 will be cut off.

The transfer function can be easily calculated using the same methodology as before.

$$H = H_O \frac{j\,(f/f_1)}{[1 + j\,(f/f_1)]\;[1 + j\,(f/f_2)]} \tag{15}$$

Where

$$f_1 = \frac{1}{2\pi R_1 C_1}$$

$$f_2 = \frac{1}{2\pi R_2 C_2}$$

$$H_O = \frac{-R_2}{R_1}$$

The transfer function is presented in the following figure.

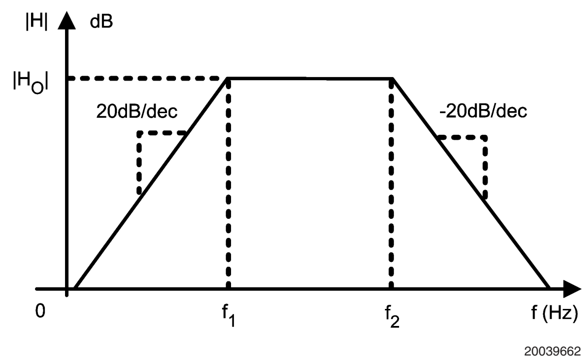
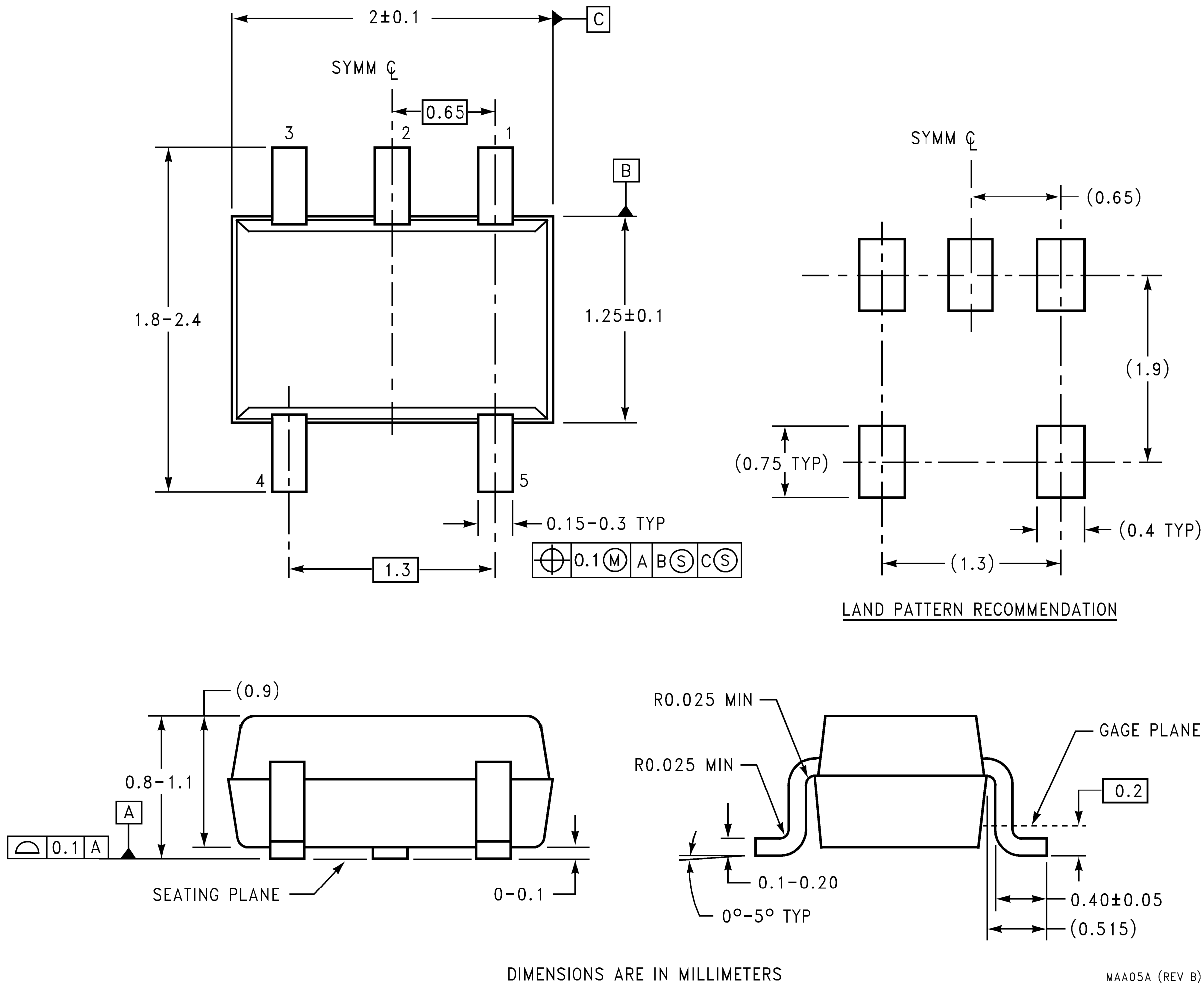


FIGURE 7.

Physical Dimensions inches (millimeters) unless otherwise noted



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