Dual, Low Noise, High-Speed Audio Operational Amplifier ($A_{VCL} \geq 3$)

SSM-2139

FEATURES

- Ultra-Low Voltage Noise .... 3.2nV/√Hz
- High Slew Rate 11V/µs
- Excellent Gain Bandwidth Product 30MHz
- Low Supply Current (Both Amplifiers) 4mA
- Low Offset Voltage 500µV
- High Gain 1,700V/mV
- Compensated for Minimum Gain of 3
- Low Cost
- Industry Standard 8-Pin Plastic Dual Pinout

APPLICATIONS

- Microphone Preamplifiers
- Audio Line Drivers
- Active Filters
- Phono and Tape Head Preamplifiers
- Equalizers

ORDERING INFORMATION

PACKAGE		OPERATING TEMPERATURE RANGE
PLASTIC 8-PIN	16-PIN SOL	
SSM2139P	SSM2139S	XIND*

* XIND = −40°C to +85°C

For availability on SOL package, contact your local sales office.

GENERAL DESCRIPTION

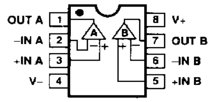
The SSM-2139 is a low noise, high-speed dual audio operational amplifier which has been internally compensated for gains equal to, or greater than three.

This monolithic bipolar op amp offers exceptional voltage noise performance of 3.2nV/√Hz (typical) with a guaranteed specification of only 5nV/√Hz MAX @ 1kHz.

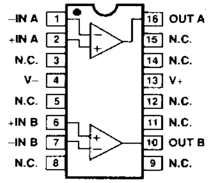
The high slew rate of 11V/µs and the gain-bandwidth product of 30MHz is achieved without compromising the power consumption of the device. The SSM-2139 draws only 4mA of supply current for both amplifiers.

Continued

PIN CONNECTIONS

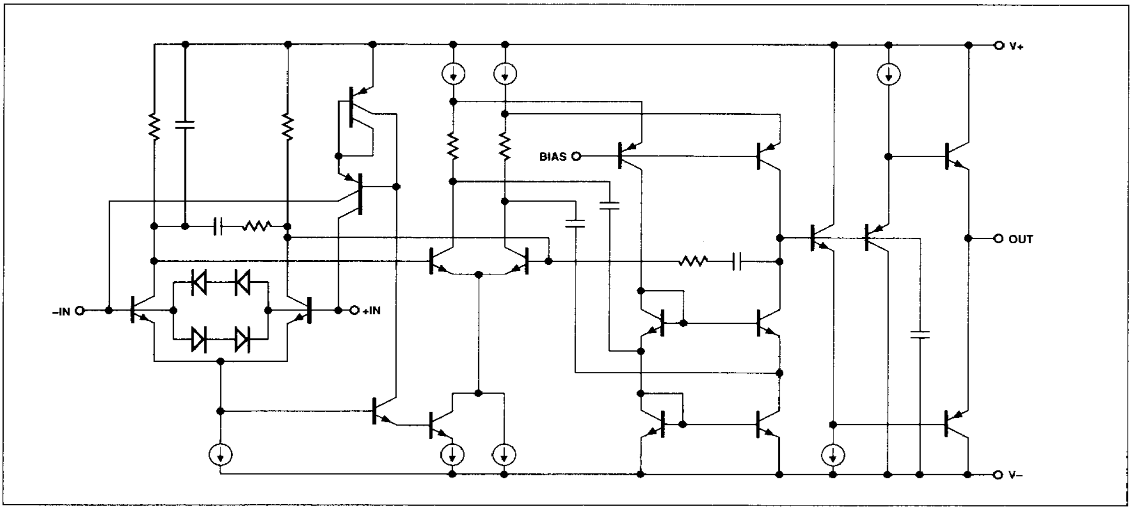


8-PIN PLASTIC MINI-DIP (P-Suffix)



16-PIN SOL (S-Suffix)

SIMPLIFIED SCHEMATIC (One of two amplifiers is shown.)



These characteristics make the SSM-2139 an ideal choice for use in high quality professional audio equipment, instrumentation, and control circuit applications.

The low offset voltage V_{OS} of 500μV MAX (20μV typical) and offset voltage drift of only 2.5μV/°C MAX assures system accuracy and eliminates the need for external V_{OS} adjustments.

The SSM-2139's outstanding open-loop gain of 1,700,000 and its exceptional gain linearity eliminate incorrectable system nonlinearities and provides superior performance in high closed-loop gain applications, such as preamplifiers.

The SSM-2139 is offered in an 8-pin plastic DIP and Small Outline (SO) package and its performance and characteristics are guaranteed over the extended industrial temperature range of –40°C to +85°C.

ABSOLUTE MAXIMUM RATINGS

Supply Voltage .... ±18V
Differential Input Voltage (Note 2) .... ±1.0V
Differential Input Current (Note 2) .... ±25mA
Input Voltage .... Supply Voltage
Output Short-Circuit Duration .... Continuous
Storage Temperature Range .... –65°C to +150C
Lead Temperature Range (Soldering, 60 sec) .... 300°C
Junction Temperature (T_J) .... –65°C to +150°C
Operating Temperature Range
SSM-2139 (P, S) .... –40°C to +85°C

PACKAGE TYPE	Θ_{jA} (Note 1)	Θ_{jC}	UNITS
8-Pin Plastic DIP (P)	96	37	°C/W
16-Pin SOL (S)	92	27	°C/W

NOTES:
1. Θ_{jA} is specified for worst case mounting conditions, i.e., Θ_{jA} is specified for device in socket for P-DIP package; Θ_{jA} is specified for device soldered to printed circuit board for SOL package.
2. The SSM-2139 inputs are protected by back-to-back diodes. Current limiting resistors are not used in order to achieve low noise performance. If differential voltage exceeds ±1.0V, the input current should be limited to ±25mA.

ELECTRICAL CHARACTERISTICS at V_S = ±15V, T_A = 25°C, unless otherwise noted.

PARAMETER	SYMBOL	CONDITIONS	SSM-2139 MIN	TYP	MAX	UNITS
Input Noise Voltage	$e_{np\text{-}p}$	0.1Hz to 10Hz (Note 1)	–	80	200	$nV_{p\text{-}p}$
Input Noise Voltage Density	e_n	f_O = 10Hz	–	3.6	6.5	nV/√Hz
		f_O = 100Hz	–	3.2	5.5	
		f_O = 1kHz (Note 2)	–	3.2	5.0	
Input Noise Current Density	i_n	f_O = 10Hz	–	1.1	–	pA/√Hz
		f_O = 100Hz	–	0.7	–	
		f_O = 1kHz	–	0.6	–	
Slew Rate	SR		7	11	–	V/μs
Gain Bandwidth Product	GBW	f_O = 100kHz	–	30	–	MHz
Full Power Bandwidth	BWp	$V_O = 27V_{p\text{-}p}$, R_L = 2kΩ (Note 3)	–	130	–	kHz
Supply Current (All Amplifiers)	I_{SY}	No Load	–	4	6.5	mA
Total Harmonic Distortion	THD	R_L = 2kΩ, $V_O = 3V_{RMS}$, f_O = 1kHz	–	0.002	–	%
Input Offset Voltage	V_{OS}		–	20	500	μV
Input Offset Current	I_{OS}	V_{CM} = 0V	–	1	50	nA
Input Bias Current	I_B	V_{CM} = 0V	–	5	80	nA
Large-Signal Voltage Gain	A_{VO}	V_O = ±10V, R_L = 10kΩ	1000	1700	–	V/mV
		R_L = 2kΩ	500	900	–	
		R_L = 600Ω	–	900	–	
Output Voltage Swing	V_O	R_L ≥ 2kΩ	±12	±13.5	–	V
	V_O+	R_L ≥ 600Ω	–	+13	–	
	V_O-	R_L ≥ 600Ω	–	–10	–	
Common-Mode Rejection	CMR	V_{CM} = ±12V	94	115	–	dB

ELECTRICAL CHARACTERISTICS at $V_S = \pm15V$, $T_A = 25°C$, unless otherwise noted. *Continued*

PARAMETER	SYMBOL	CONDITIONS	SSM-2139 MIN	TYP	MAX	UNITS
Power Supply Rejection Ratio	PSRR	$V_S = \pm4.5V$ to $\pm18V$	105	120	–	dB
Input Voltage Range	IVR	(Note 4)	±12.0	±12.5	–	V
Output Short-Circuit Current	I_{SC}	Sink	–	20	–	mA
		Source	–	40	–	mA
Input Resistance Common-Mode	R_{INCM}		–	20	–	GΩ
Input Resistance Differential-Mode	R_{IN}		–	0.4	–	MΩ
Input Capacitance	C_{IN}		–	3	–	pF
Channel Separation	CS	$V_O = 20V_{p-p}$, $f_O = 10Hz$ (Note 1)	125	175	–	dB

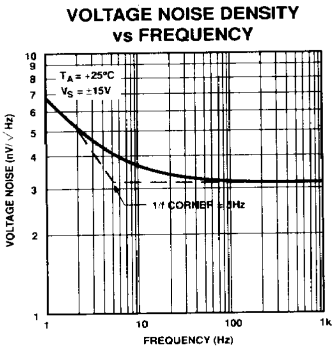
NOTES:
1. Guaranteed but not 100% tested.
2. Sample tested.
3. $BW_p = SR/2\pi V_{PEAK}$.
4. Guaranteed by CMR test.

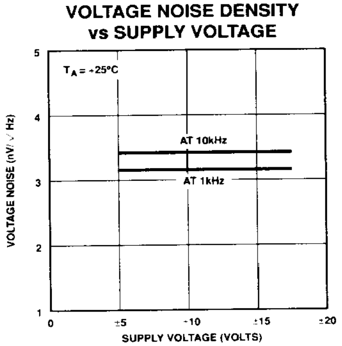
ELECTRICAL CHARACTERISTICS at $V_S = \pm15V$, $-40°C \le T_A \le 85°C$, unless otherwise noted.

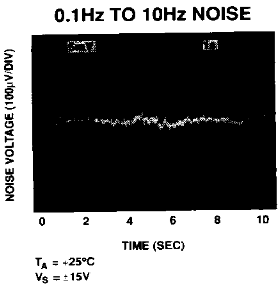
PARAMETER	SYMBOL	CONDITIONS	SSM-2139 MIN	TYP	MAX	UNITS
Supply Current (All Amplifiers)	I_{SY}	No Load	–	4.4	7.2	mA
Output Voltage Swing	V_O	$R_L \ge 2k\Omega$	±12	±13	–	V
Large-Signal Voltage Gain	A_{VO}	$V_O = \pm10V$, $R_L = 10k\Omega$	500	1400	–	V/mV
		$R_L = 2k\Omega$	250	700	–	V/mV
Input Offset Voltage	V_{OS}		–	45	700	μV
Average Input Offset Voltage Drift	TCV_{OS}		–	0.4	2.5	μV/°C
Input Offset Current	I_{OS}	$V_{CM} = 0V$	–	1.5	60	nA
Input Bias Current	I_B	$V_{CM} = 0V$	–	6	90	nA
Common-Mode Rejection	CMR	$V_{CM} = \pm12V$	94	115	–	dB
Power Supply Rejection Ratio	PSRR	$V_S = \pm4.5$ to $\pm18V$	100	115	–	dB
Input Voltage Range	IVR	(Note 1)	±12	±12.5	–	V

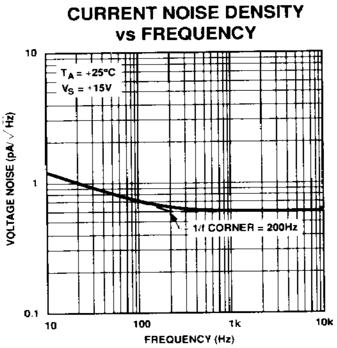
NOTES:
1. Guaranteed by CMR test.

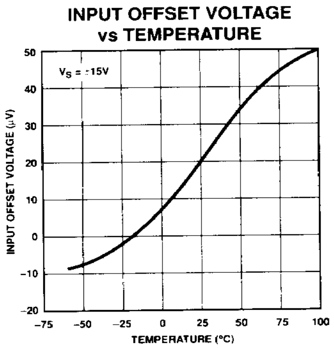
TYPICAL PERFORMANCE CHARACTERISTICS

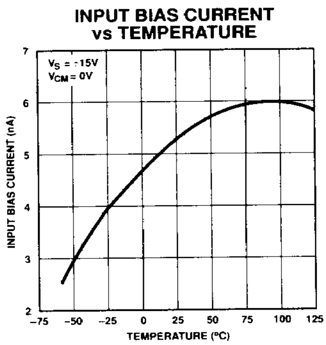


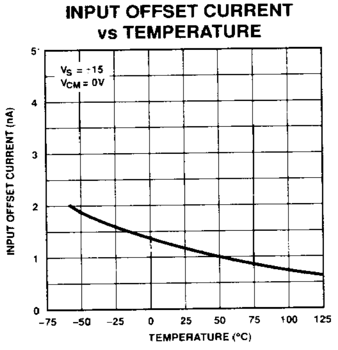


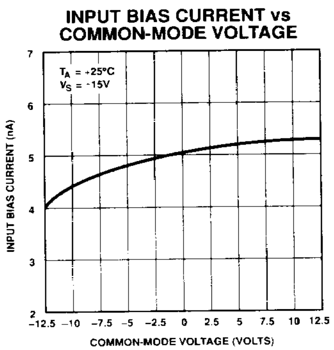


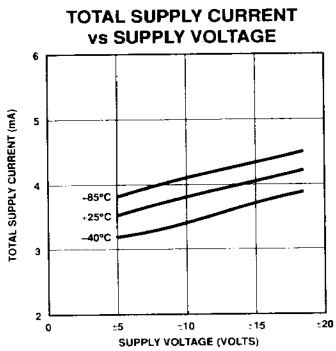






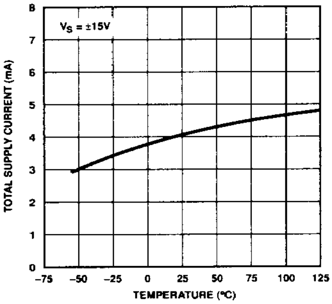




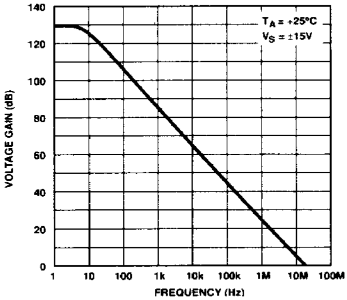


TYPICAL PERFORMANCE CHARACTERISTICS *Continued*

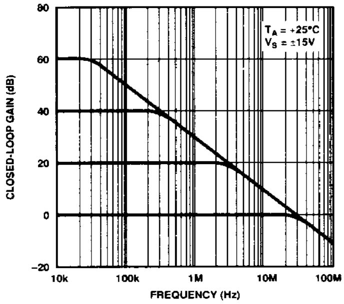
TOTAL SUPPLY CURRENT vs TEMPERATURE



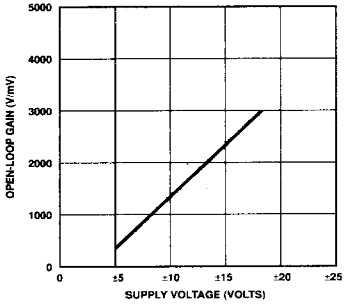
OPEN-LOOP GAIN vs FREQENCY



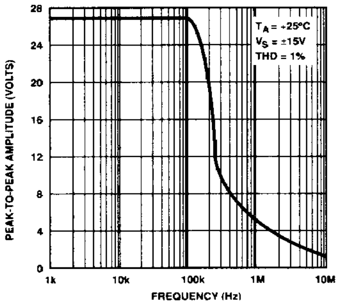
CLOSED-LOOP GAIN vs FREQUENCY



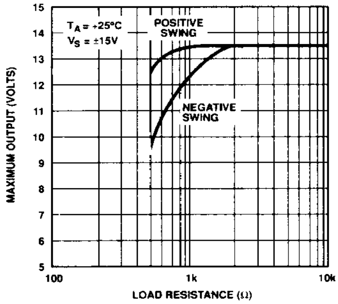
OPEN-LOOP GAIN vs SUPPLY VOLTAGE



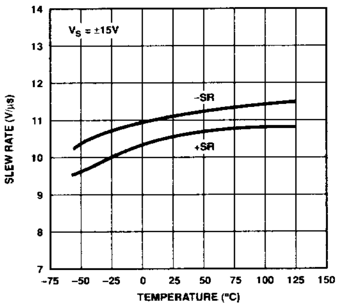
MAXIMUM OUTPUT SWING vs FREQUENCY



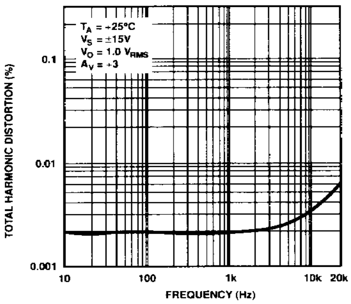
MAXIMUM OUTPUT VOLTAGE vs LOAD RESISTANCE



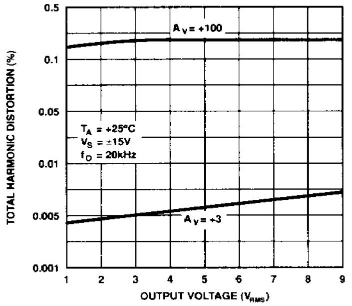
SLEW RATE vs TEMPERATURE



TOTAL HARMONIC DISTORTION vs FREQUENCY



TOTAL HARMONIC DISTORTION vs OUTPUT VOLTAGE



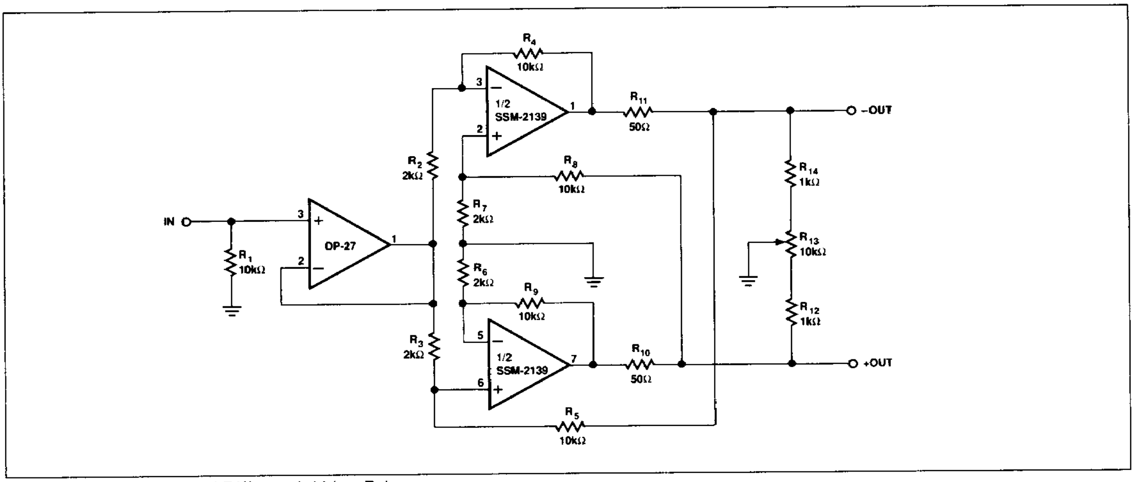


FIGURE 1: *High-Speed Differential Line Driver*

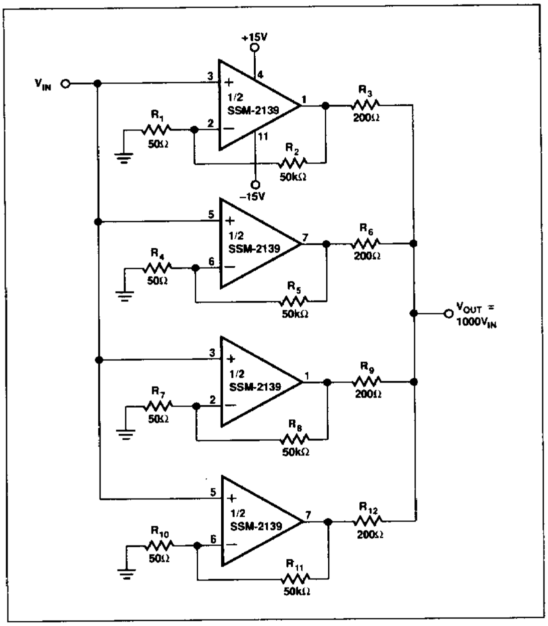


FIGURE 2: *Low Noise Amplifier*

APPLICATIONS INFORMATION

HIGH-SPEED DIFFERENTIAL LINE DRIVER

The circuit of Figure 1 is a unique approach to a line driver circuit widely used in professional audio applications. With ±18V supplies, the line driver can deliver a differential signal of 30Vp-p into a 1.5kΩ load. The output of the differential line driver looks exactly like a transformer. Either output can be shorted to ground without changing the circuit gain of 5, so the amplifier can easily be set for inverting, noninverting, or differential operation. The line driver can drive unbalanced loads, like a true transformer.

LOW NOISE AMPLIFIER

A simple method of reducing amplifier noise is by paralleling amplifiers as shown in Figure 2. Amplifier noise, depicted in Figure 3, is around $2nV/\sqrt{Hz}$ @ 1kHz (R.T.I.). Gain for each paralleled amplifier and the entire circuit is 1000. The 200Ω resistors limit circulating currents and provide an effective output resistance of 50Ω.

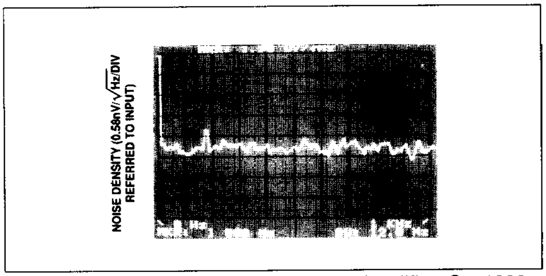


FIGURE 3: *Noise Density of Low Noise Amplifier, G = 1000*

VOLTAGE AND CURRENT NOISE

The SSM-2139 is a low noise, high-speed dual op amp, exhibiting a typical voltage noise of only $3.2nV/\sqrt{Hz}$ @ 1kHz. The exceptionally low noise characteristics of the SSM-2139 is in part achieved by operating the input transistors at high collector currents since the voltage noise is inversely proportional to the square root of the collector current. Current noise, however, is directly proportional to the square root of the collector current. As a result, the outstanding voltage noise performance of the SSM-2139 is gained at the expense of current noise performance, which is normal for low noise amplifiers.

To obtain the best noise performance in a circuit, it is vital to understand the relationship between voltage noise (e_n), current noise (i_n), and resistor noise (e_t).

TOTAL NOISE AND SOURCE RESISTANCE

The total noise of an op amp can be calculated by:

$$E_n = \sqrt{(e_n)^2 + (i_n R_S)^2 = (e_t)^2}$$

where:

E_n = total input referred noise

e_n = op amp voltage noise

i_n = op amp current noise

e_t = source resistance thermal noise

R_S = source resistance

The total noise is referred to the input and at the output would be amplified by the circuit gain.

Figure 4 shows the relationship between total noise at 1kHz and source resistance. For $R_S < 1k\Omega$, the total noise is dominated by the voltage noise of the SSM-2139. As R_S rises above $1k\Omega$, total noise increases and is dominated by resistor noise rather than by voltage or current noise of the SSM-2139. When R_S exceeds $20k\Omega$, current noise of the SSM-2139 becomes the major contributor to total noise.

Figure 5 also shows the relationship between total noise and source resistance, but at 10Hz. Total noise increases more quickly than shown in Figure 4 because current noise is inversely proportional to the square root of frequency. In Figure 5, current noise of the SSM-2139 dominates the total noise when $R_S > 5k\Omega$.

From Figures 4 and 5, it can be seen that to reduce total noise, source resistance must be kept to a minimum.

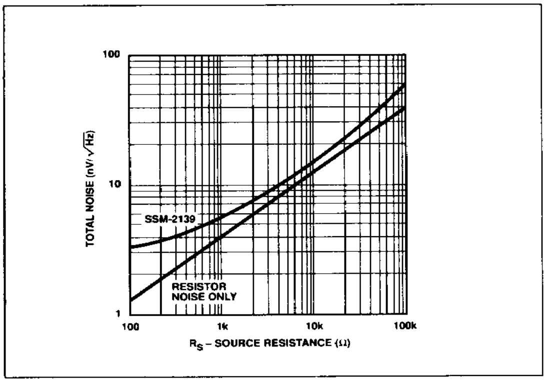


FIGURE 4: *Total Noise vs. Source Resistance (Including Resistor Noise) at 1kHz*

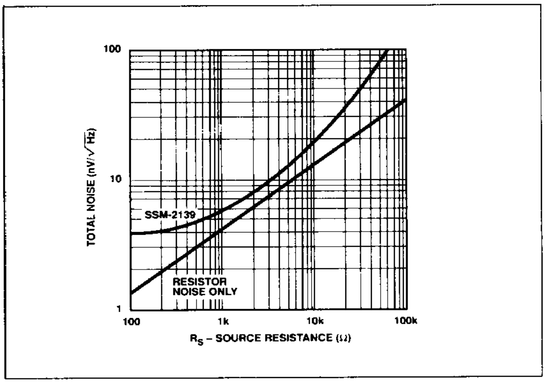


FIGURE 5: *Total Noise vs. Source Resistance (Including Resistor Noise) at 10Hz*

Figure 6 shows peak-to-peak noise versus source resistance over the 0.1Hz to 10Hz range. Once again, at low values of R_S, the voltage noise of the SSM-2139 is the major contributor to peak-to-peak noise with current noise the major contributor as R_S increases.

For reference, typical source resistances of some signal sources are listed in Table 1.

For further information regarding noise calculations, see "Minimization of Noise in Op Amp Applications," Application Note AN-15.

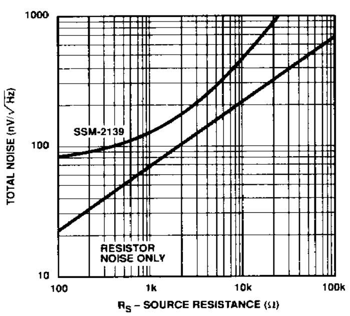


FIGURE 6: *Peak-to-Peak Noise (0.1Hz to 10Hz) vs. Source Resistance (Includes Resistor Noise)*

TABLE 1

DEVICE	SOURCE IMPEDANCE	COMMENTS
Strain Gauge	<500Ω	Typically used in low-frequency applications.
Magnetic Tapehead, Microphone	<1500Ω	Low I_B very important to reduce self-magnetization problems when direct coupling is used. SSM-2139 I_B can be neglected.
Magnetic Phonograph Cartridge	<1500Ω	Similar need for low I_B in direct coupled applications. SSM-2139 will not introduce any self-magnetization problem.
Linear Variable Differential Transformer	<1500Ω	Used in rugged servo-feedback applications. Bandwidth of interest is 400Hz to 5kHz.

NOISE MEASUREMENTS – PEAK-TO-PEAK VOLTAGE NOISE

The circuit of Figure 7 is a test setup for measuring peak-to-peak voltage noise. To measure the 200nV peak-to-peak noise specification of the SSM-2139 in the 0.1Hz to 10Hz range, the following precautions must be observed:

1. The device has to be warmed-up for at least five minutes. As shown in the warm-up drift curve, the offset voltage typically changes 2μV due to increasing chip temperature after power-up. In the 10-second measurement interval, these temperature-induced effects can exceed tens-of-nanovolts.
2. For similar reasons, the device has to be well-shielded from air currents. Shielding also minimizes thermocouple effects.

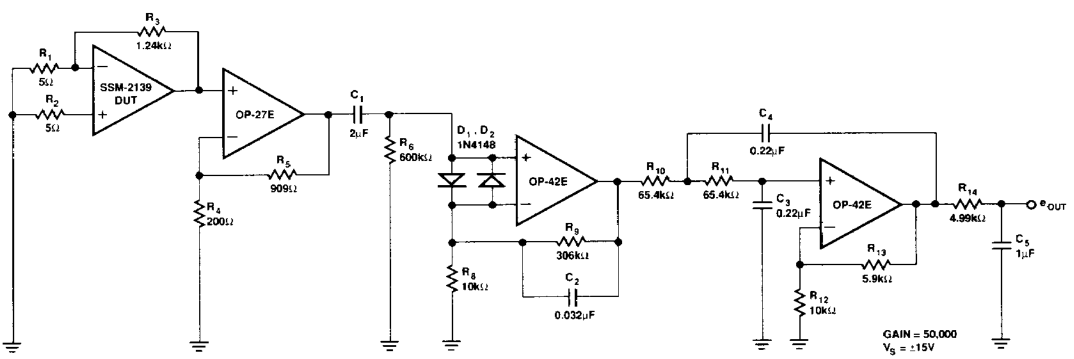


FIGURE 7: *Peak-to-Peak Voltage Noise Test Circuit (0.1Hz to 10Hz)*

3. Sudden motion in the vicinity of the device can also "feed-through" to increase the observed noise.
4. The test time to measure 0.1Hz to 10Hz noise should not exceed 10 seconds. As shown in the noise-tester frequency-response curve of Figure 8, the 0.1Hz corner is defined by only one pole. The test time of 10 seconds acts as a additional pole to eliminate noise contribution from the frequency band below 0.1Hz.
5. A noise-voltage-density test is recommended when measuring noise on a large number of units. A 10Hz noise-voltage-density measurement will correlate well with a 0.1Hz-to-10Hz peak-to-peak noise reading, since both results are determined by the white noise and the location of the 1/f corner frequency.
6. Power should be supplied to the test circuit by well bypassed low-noise supplies, e.g. batteries. These will minimize output noise introduced via the amplifier supply pins.

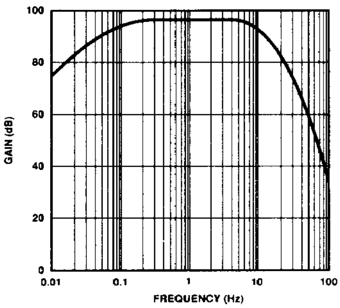


FIGURE 8: *0.1Hz to 10Hz Peak-to-Peak Voltage Noise Test Circuit Frequency Response*

CHANNEL SEPARATION TEST CIRCUIT