ANALOG DEVICES

Ultra Low Noise Differential Audio Preamplifier

SSM-2016

FEATURES

- **Ultra Low Voltage Noise .... 800pV/√Hz Typ**
- **High Slew Rate .... 10V/μs Typ**
- **Very Low Harmonic Distortion .... @ G = 1000 0.009% Typ**
- **Wide Bandwidth .... @ G = 1000 650kHz Typ**
- **Very Wide Supply Voltage Range .... ±9V to ±36V**
- **High Output Drive Capability .... ±40mA Min**
- **High Common-Mode Rejection .... 100dB Typ**
- **Low Cost**

APPLICATIONS

- **Low Noise High-Gain Microphone Preamplifier**
- **Bus Summing Amplifier**
- **Differential Line Receiver**
- **Low Noise Instrumentation Amplifier**

ORDERING INFORMATION

PACKAGE PLASTIC 16-PIN	OPERATING TEMPERATURE RANGE
SSM2016P	−25°C to +55°C

GENERAL DESCRIPTION

The SSM-2016 is an ultra low noise, low distortion differential audio preamplifier. The input referred noise of the SSM-2016 is about 800pV/√Hz which will result in a noise figure of 1dB when operated with a 150Ω source impedance. This ensures that a large number of inputs can be paralleled without seriously degrading the signal-to-noise ratio. In addition, this device provides exceptionally low harmonic distortion of only 0.009%(G = 1000, f = 1kHz) Typ.

Fabricated on a high voltage process, the SSM-2016 is capable of operating from a wide supply voltage range of ±9V to ±36V. A copper lead- frame DIP package is used to permit 1.5W of dissipation when driving heavy loads or operating from elevated supplies.

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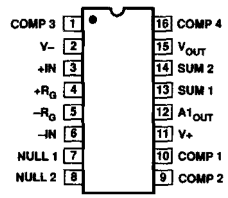
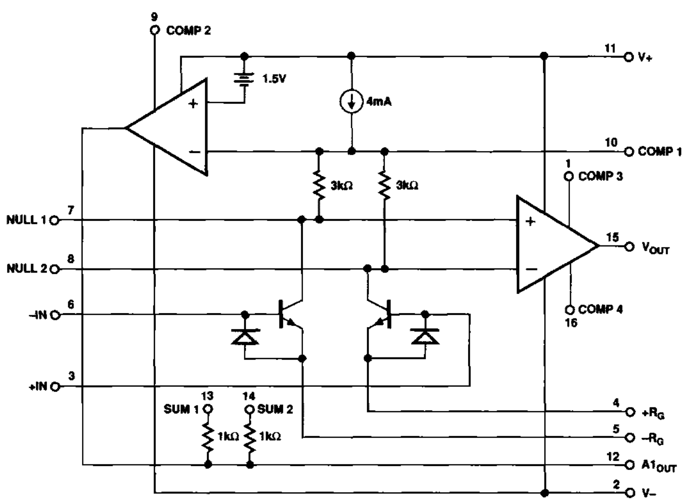
PIN CONNECTIONS



16-PIN PLASTIC DIP (P-Suffix)

BLOCK DIAGRAM



The SSM-2016 has been granted mask work protection under the Semiconductor Chip Protection Act of 1983.

GENERAL DESCRIPTION *Continued*

The SSM-2016 can source or sink a minimum of 40mA allowing a jack-field to be driven directly.

At low gains, the SSM-2016 offers a bandwidth of about 1MHz and 650kHz at 60dB of gain. Slew rate is typically 10V/µs at all gains.

The SSM-2016 is packaged in a 16-pin epoxy DIP and performance and characteristics are guaranteed over the operating temperature range of –25°C to +55°C.

ABSOLUTE MAXIMUM RATINGS (Note 1)

Supply Voltage .... ±38V
Recommended Supply Voltage Range .... ±9V to ±36V
Current Into Any Pin (Except Pins 2, 11, and 15) 40mA
Lead Temperature (Soldering, 60 sec) .... 300°C
Storage Temperature .... –65°C to +150°C
Package Dissipation 2W
Short-Circuit Duration (Note 1) .... Indefinite
Operating Temperature Range .... –25°C to 55°C

PACKAGE TYPE	Θ_{jA} (Note 2)	Θ_{jC}	UNITS
16-Pin Plastic DIP (P)	76	33	°C/W

NOTES:
1. Short-circuit duration is indefinite, provided dissipation limit is not exceeded.
2. Θ_{jA} is specified for worst case mounting conditions, i.e., Θ_{jA} is specified for device in socket for P-DIP package.

ELECTRICAL CHARACTERISTICS at V_S = ±18V, $R_1 = R_2$ = 5kΩ, $R_3 = R_4$ = 2kΩ, T_A = +25°C, unless otherwise noted.

PARAMETER	SYMBOL	CONDITIONS	SSM-2016 MIN	SSM-2016 TYP	SSM-2016 MAX	UNITS
Total Harmonic Distortion	THD	$V_O = 10V_{RMS}$, R_L = 2kΩ, G = 1000, f = 1kHz	–	0.009	0.015	%
		f = 10kHz	–	0.015	0.02	
		G = 100, f = 1kHz	–	0.003	0.005	
		f = 10kHz	–	0.005	0.007	
		G = 10, f = 1kHz	–	0.002	0.003	
		f = 10kHz	–	0.003	0.005	
		$V_O = 10V_{RMS}$, R_L = 600Ω, V_S = ±20V, G = 1000, f = 1kHz	–	0.025	0.04	
		f = 10kHz	–	0.06	0.09	
		G = 100, f = 1kHz	–	0.008	0.015	
		f = 10kHz	–	0.02	0.04	
		G = 10, f = 1kHz	–	0.005	0.008	
		f = 10kHz	–	0.008	0.015	
Input Referred Voltage Noise (Note 1)	e_n	20kHz Bandwidth, G = 1000	–	0.11	0.16	μV_{RMS}
		G = 100	–	0.20	0.30	
		G = 10	–	0.80	1.2	
Input Current Noise (Note 1)	I_n	20 kHz Bandwidth	–	350	550	$pA/_{RMS}$
Slew Rate	SR		–	10	–	V/µs
–3dB Bandwidth (Note 2)	GBW	G = 1000	–	0.55	–	MHz
		G ≤ 100	–	1	–	
Input Offset Voltage	V_{OS}	G = 1000	–	0.5	2.5	mV
		G = 100	–	1.5	10	
		G = 10	–	5	8	
Input Bias Current	I_B	V_{CM} = 0V	–	9	25	µA
Input Offset Current	I_{OS}	V_{CM} = 0V	–	1.5	5.0	µA
Common-Mode Rejection Ratio	CMRR	G = 1000	96	100	–	dB
		G = 100	80.5	95	–	
		G = 10	64	75	–	
Power Supply Rejection Ratio	PSRR	V_S = ±9V to ±36V	90	100	–	dB
Common-Mode Voltage Range	CMVR		±7	±10	–	V

ELECTRICAL CHARACTERISTICS at $V_S = \pm18V$, $R_1 = R_2 = 5k\Omega$, $R_3 = R_4 = 2k\Omega$, $T_A = +25°C$, unless otherwise noted.
Continued

PARAMETER	SYMBOL	CONDITIONS	SSM-2016 MIN	TYP	MAX	UNITS
Common-Mode Input Impedance	R_{INEM}		–	20	–	MΩ
Differential-Mode Input Impedance	R_{IN}	G = 1000	–	0.3	–	MΩ
		G = 100	–	3	–	
		G = 10	–	10	–	
Output Voltage Swing (Note 1)	V_O	$R_L = 2k\Omega$	±15	±17	–	V
		$R_L = 600\Omega$, $V_S = \pm20V$	±15	±17	–	
Output Current (Note 3)	I_{OUT}	Source	40	70	–	mA
		Sink	40	70	–	
Supply Current	I_{SY}	$V_{CM} = 0V$	10	12	16	mA
Error From Gain Equation			–	0.1	0.3	dB

NOTES:
1. Sample tested.
2. Bandwidth will be slew-rate limited at high output levels.
3. Output is protected from short circuits to ground or either supply.

Specifications subject to change; consult latest data sheet.

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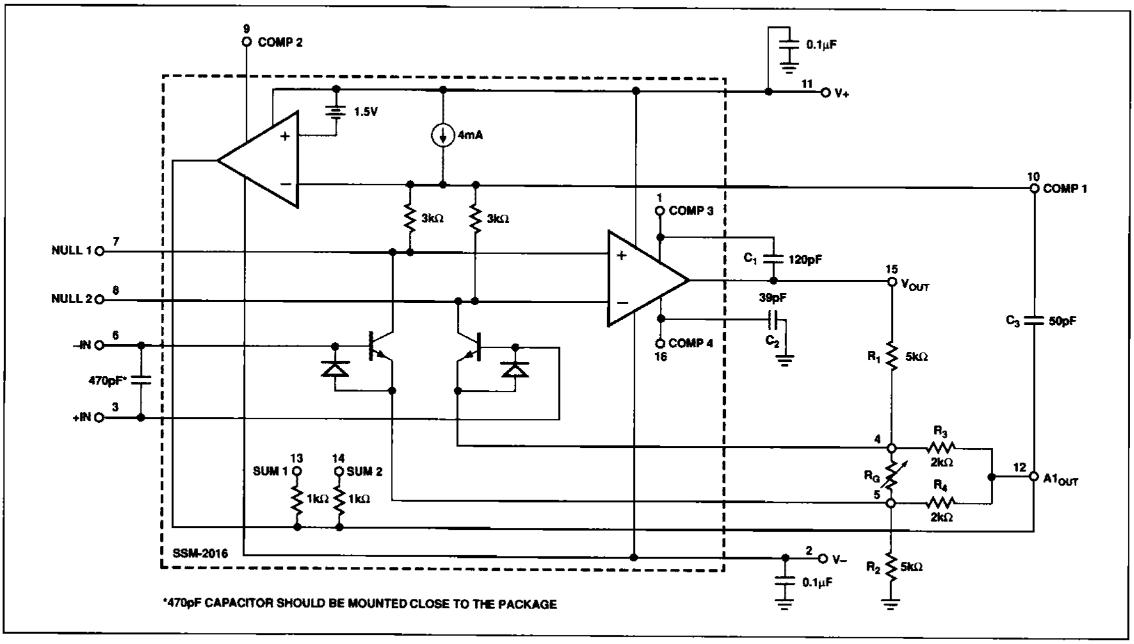


FIGURE 1: *Typical Preamplifier Amplification*

APPLICATIONS INFORMATION

PRINCIPLE OF OPERATION

The SSM-2016 operates as a true differential amplifier with feedback returned directly to the emitters of the input stage transistors by R_1 (See Figure 1). The differential pair is fed by a current source at the collectors and the required emitter current is supplied by a nulling (servo) amplifier through the external resistors R_3 and R_4 (Figure 1). This system produces both optimum noise and common-mode rejection while retaining a very high input impedance. The internal "servo" amplifier is used to control the input stage current independently of common-mode voltage and its output is accessible via pin 12.

GAIN SETTING

The nominal gain of the SSM-2016 is given by:

$$G = \frac{R_1 + R_2}{R_g} + \frac{R_1 + R_2}{R_3 + R_4} + 1$$

or

$$G = \frac{10k\Omega}{R_g} + 3.5 \text{ For } R_1 = R_2 = 5k\Omega, R_3 = R_4 = 2k\Omega$$

R_1 and R_2 should be equal to 5kΩ for best results. It is vital that good quality resistors be used in the gain setting network, since low quality types (notably carbon composition) can generate significant amounts of distortion and, under some conditions, low frequency noise.

The SSM-2016 is capable of operating at gains down to 3.5 at full performance. Gain range can be extended further by increasing R_3 and R_4 in Figure 1, but at the penalty of reduced common-mode input range. Gains below 2.5 are not practical unless the negative supply voltage is increased.

Note that tolerance of R_1 - R_4 directly affects the gain error and that good matching between R_1 - R_4 is essential to prevent degradation of the common-mode rejection performance.

The SSM-2016 provides internal 1kΩ resistors to replace R_3 and R_4 in applications where distortion is not too critical.

FREQUENCY COMPENSATION

The SSM-2016's internal "servo" amplifier is compensated by C_3, while C_1 and C_2 (see Figure 1) compensate the overall amplifier. The values shown maintain a very wide bandwidth with a good symmetrical slew rate. If desired, the bandwidth can be reduced by increasing the value of C_1.

NOISE PERFORMANCE

The SSM-2016's input referred noise is 0.11µV_{RMS} (20kHz bandwidth) at 60dB of gain, 0.2µV_{RMS} at 40dB, and 0.8µV_{RMS} at 20dB. The apparent increase at low gains is due to noise incurred in the feedback resistors and second stage becoming dominant. This noise is actually present at all times but becomes masked by input stage noise as the gain is increased.

The SSM-2016 is optimized for source impedances of 1kΩ or less and under these conditions, the noise performance is equal to the best discrete component designs. Considering that a "standard" microphone with impedance of 150Ω generates 1.6nV/$\sqrt{Hz}$ of thermal noise, the SSM-2016's 800pV/$\sqrt{Hz}$ of voltage noise or the corresponding noise figure of typically 1dB make the device virtually transparent to the user.

In applications where higher source impedances than 1kΩ are desired, the SSM-2015 preamplifier is recommended.

Another source of noise degradation is the chip's total power dissipation, since any increase in temperature will increase the noise. This effect is more pronounced at higher gains. As a result, the SSM-2016 uses a copper lead-frame package which greatly helps the power dissipation and the noise performance. The best noise performance of the SSM-2016 can be achieved at low supply voltages while driving light loads.

TOTAL HARMONIC DISTORTION

Figures 2 - 5 show the distortion behavior of SSM-2016. All measurements were taken at a 10V_{RMS} output to ensure a true "worst case" condition. No crossover distortion is observed at lower ouput levels. At 20dB of gain (Figure 2) total harmonic distortion (plus noise) is well below 0.01% at all audio frequencies. At 40dB of gain (Figure 3) some loading effects are evident, especially at higher frequencies, but the overall THD is still very low. The measurements at 60dB of gain (Figure 4) are a little misleading because the noise floor is at an equivalent level of 0.0085% at this gain. In fact, the real distortion components are not greatly increased from the 40dB case.

Figure 5 shows the intermodulation distortion performance of the SSM-2016. A basic SMPTE type test was performed with the main generator swept from 2.5kHz to 20kHz. The 60dB reading is once more mostly noise.

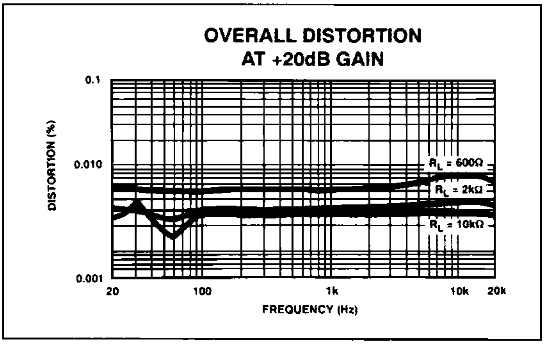


FIGURE 2

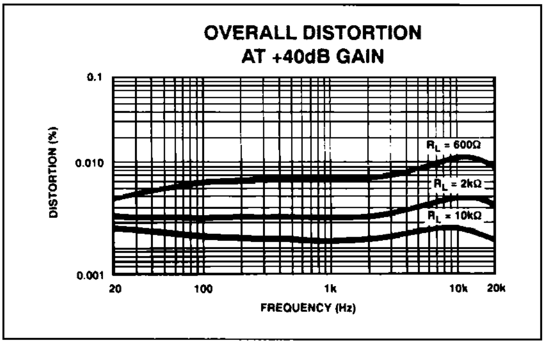


FIGURE 3

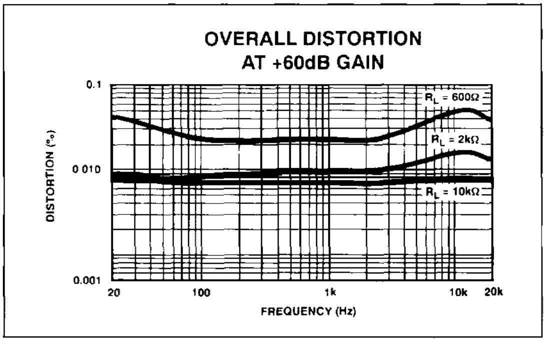


FIGURE 4

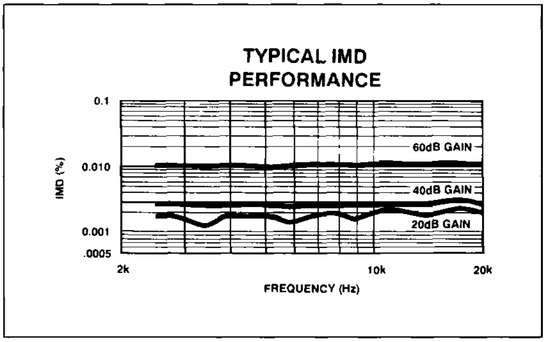


FIGURE 5

DRIVE CAPABILITY

Fabricated on a high voltage process, the SSM-2016 is capable of operating from ±9V to ±36V supplies. In addition, the powerful output stage is designed to drive a jack-field directly. The SSM-2016 is capable of driving a $10V_{RMS}$ sine wave into 600Ω load using ±18V supplies. However, ±20V or greater supplies are recommended to give a more comfortable headroom. A copper lead-frame DIP package is used to permit 1.5W of dissipation when driving heavy loads or operating from elevated supplies.

INPUTS

The SSM-2016 offers protection diodes across the base-emitter junctions of the input transistors. These prevent accidental avalanche breakdown which could seriously degrade noise performance. Additional clamp diodes are also provided to prevent the inputs from being forced too far beyond the supplies.

Although the SSM-2016's inputs are fully floating, care must be exercised to ensure that both inputs have a DC bias connection capable of maintaining them within the input common-mode range. The usual method of achieving this is to ground one side of the transducer as in Figure 6a, but an alternative way is to float the transducer and use two resistors to set the bias point as in figure 6b. The value of these resistors can be up to 10kΩ, but they should be kept as small as possible to limit common-mode pickup. Noise contribution by resistors themselves is negligible since it is attenuated by the transducer's impedance. Balanced transducers give the best noise immunity, and interface directly as in Figure 6c.

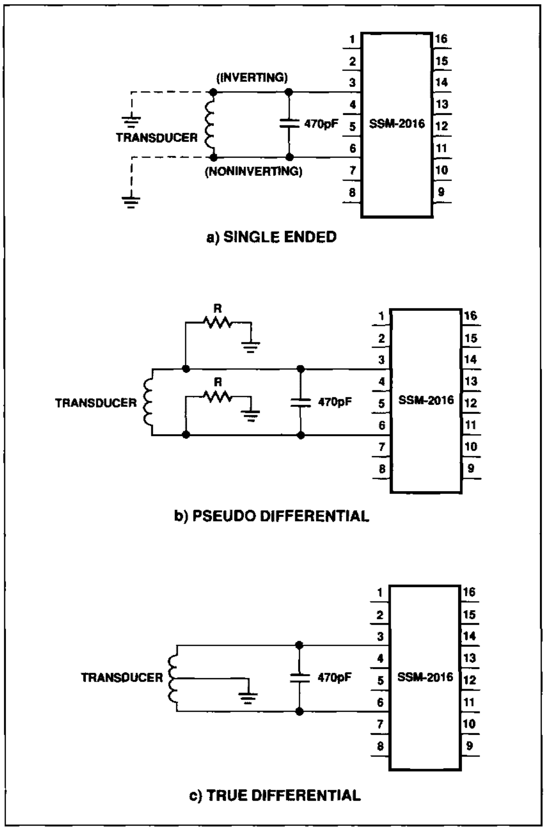


FIGURE 6: *Three Ways of Interfacing Transducers for High-Noise Immunity*

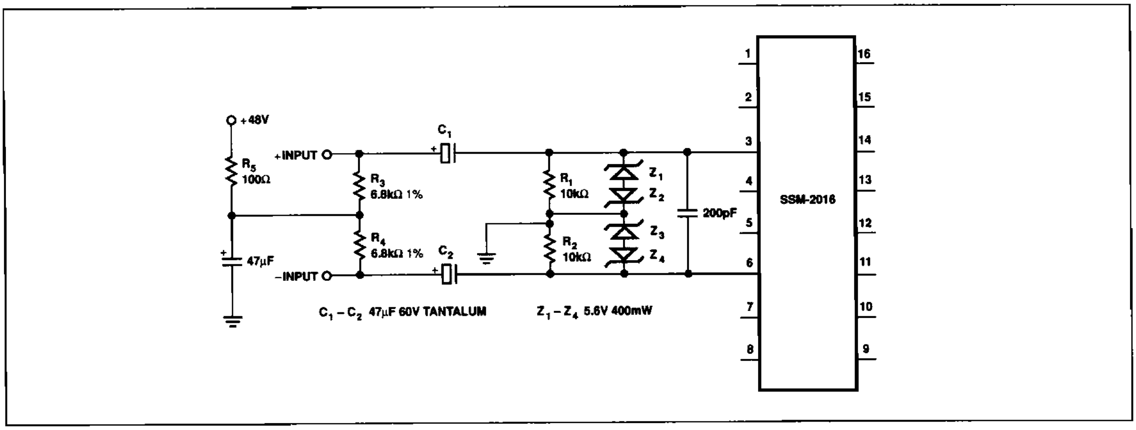


FIGURE 7: *SSM-2016 with Phantom Power*

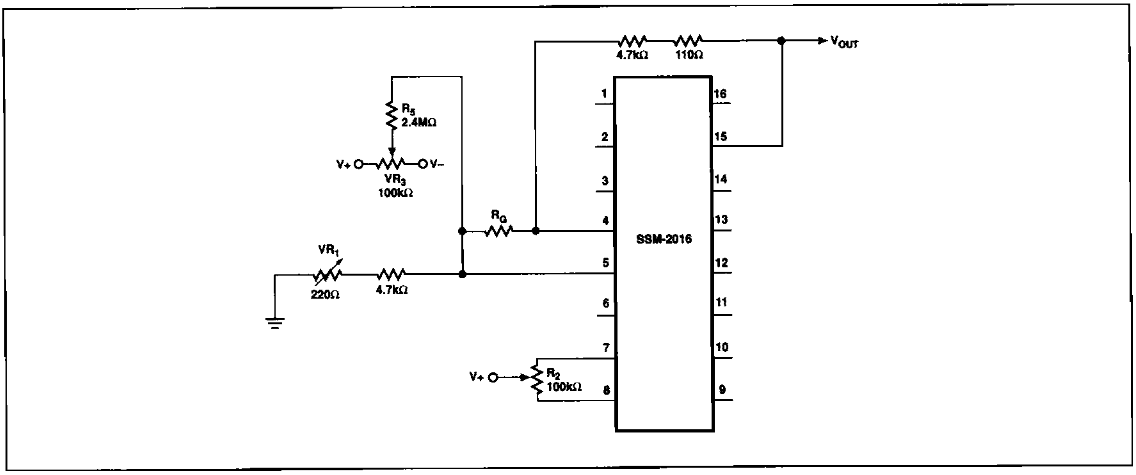


FIGURE 8: *Trimming Circuit*

PHANTOM POWERING

A typical phantom microphone powering circuit is shown in Figure 7. Z_1 through Z_4 provide transient overvoltage protection for the SSM-2016 whenever microphones are plugged in and out.

TRIMMING

The SSM-2016 accommodates four types of trimming: gain, high-gain offset, low-gain offset, and common-mode rejection. All four can be accomplished with the circuits shown in Figure 8.

Gain trim on the SSM-2016 is readily accomplished by adjusting R_G. VR_1 adjusts the common-mode rejection, VR_2 the high-gain offset, and VR_3 the low-gain offset. Common-mode rejection is best adjusted by applying an 8Vp-p 60Hz (50Hz in Europe) sine wave to both inputs and adjusting VR_1 for minimum output. Interaction is minimized by trimming the high-gain offset first, followed by the CMR and finally the low-gain offset. A two-pass trim is recommended for best results. Note that the overall gain has been reduced slightly to allow convenient values of resistors.

If the low-gain offset trim is not used, then gain control feedthrough can still be reduced by adjusting the high-gain offset to equal the low-gain offset by means of VR_2.

BUS SUMMING AMPLIFIER

In addition to its use as a microphone preamplifier, the SSM-2016 can be used as a very low noise summing amplifier. Such a circuit is particularly useful when many medium impedance outputs are summed together to produce a high effective noise gain.

The principle of the summing amplifier is to ground the SSM-2016 inputs . Under these conditions, pins 4 and 5 are AC virtual grounds sitting about 0.65V below ground. Any current injected into these points must flow through the feedback resistor (R_1) and hence are amplified to appear in the the output. Moreover, both positive (pin 5) and negative (pin 6) transfer characteristics are available simultaneously in contrast to the usual "inverting only" configuration.

To remove the 0.65V offset, the circuit of Figure 9 is recommended.

A_2 forms a "servo" amplifier feeding the SSM-2016's inputs. This places pins 4 and 5 at a true DC virtual ground. R_6 in conjunction with C_6 remove the voltage noise of A_2 and in fact just about any operational amplifier will work well here since it is removed from the signal path. If the DC offset at pins 4 and 5 is not too critical, then the servo loop can be replaced by the diode biasing scheme of Figure 9a. If AC coupling is used throughout, then pins 3 and 6 may be directly grounded.

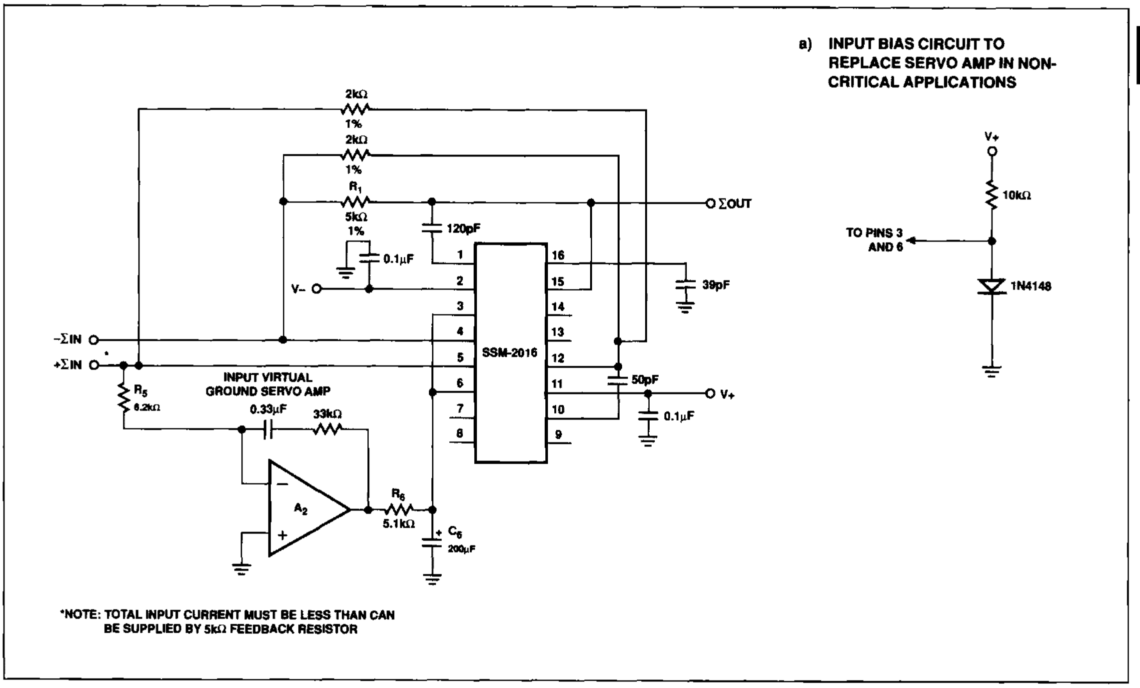
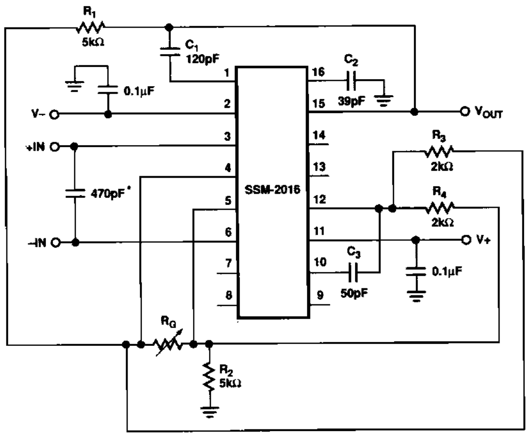


FIGURE 9: *Bus Summing Amplifier*



VOLTAGE GAIN = $\frac{10k\Omega}{R_G} + 3.5$

*470pF CAP MOUNTED CLOSE TO PACKAGE

FIGURE 10: *Typical Connection for Breadboarding Purposes*