ANALOG DEVICES

Quad Current-Controlled Amplifier

SSM-2024

FEATURES

- Four VCAs in One Package
- Ground Referenced Current Control Inputs
- 82dB S/N at 0.3 % THD
- Full Class A Operation
- −40dB Control Feedthrough (Untrimmed)
- Easy Signal Summing
- 6% Gain Matching

APPLICATIONS

- Electronic Musical Instruments
- Noise Gating
- Compressor/Limiters
- Signal Mixing
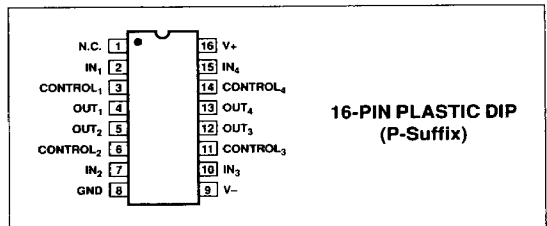- Automatic Gain Control
- Voltage-Controlled Oscillators

ORDERING INFORMATION

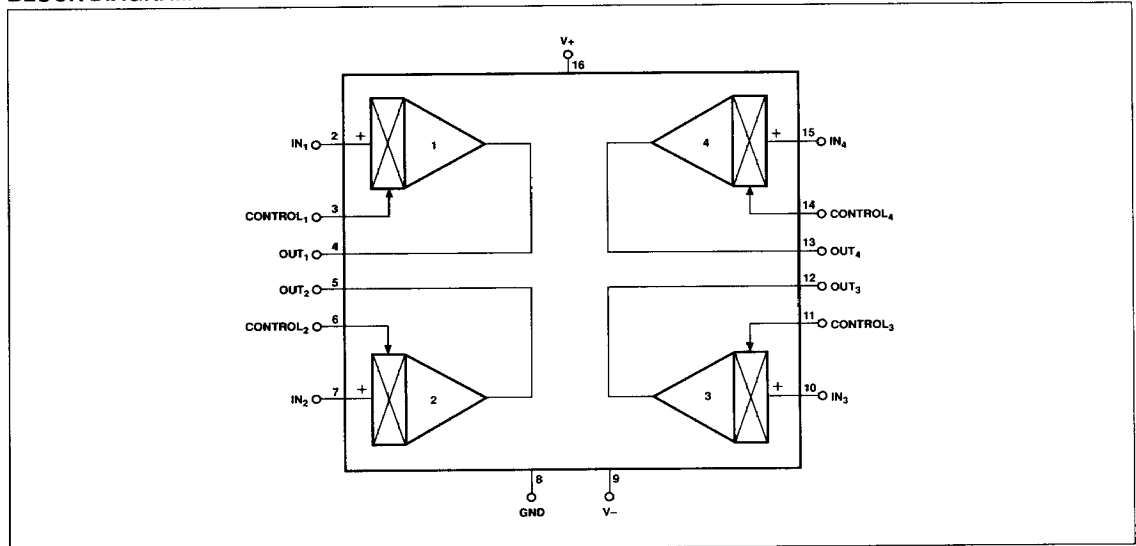| PACKAGE	OPERATING TEMPERATURE RANGE
PLASTIC 16-PIN	
SSM2024P	−10°C to +50°C

GENERAL DESCRIPTION

The SSM-2024 is a quad Class A noninverting current-controlled transconductance amplifier. Each of the four VCAs is completely independent and includes a ground referenced linear current gain control. These voltage-in/current-out amplifiers offer over 82dB S/N at 0.3% THD. Other features include low control voltage feedthrough and minimal external components for most applications. With four matched VCAs in a single IC, the SSM-2024 provides a convenient solution for applications requiring multiple amplifiers. The pinout groups the four outputs for easy signal summing for circuits such as four-channel mixers.

PIN CONNECTIONS

N.C. [1]	[16] V+
IN₁ [2]	[15] IN₄
CONTROL₁ [3]	[14] CONTROL₄
OUT₁ [4]	[13] OUT₄
OUT₂ [5]	[12] OUT₃
CONTROL₂ [6]	[11] CONTROL₃
IN₂ [7]	[10] IN₃
GND [8]	[9] V−

16-PIN PLASTIC DIP
(P-Suffix)

BLOCK DIAGRAM

REV. A

SSM-2024

ABSOLUTE MAXIMUM RATINGS

Supply Voltage .... 36V or ±18V
Junction Temperature .... +150°C
Operating Temperature Range .... −10 to +50°C
Storage Temperature Range .... −65 to +150°C
Maximum Current into Any Pin 10mA
Lead Temperature Range (Soldering, 60 sec) .... 300°C

| PACKAGE TYPE	Θ_{JA} (Note 1)	Θ_{JC}	UNITS
14-Pin Plastic DIP (P)	90	47	°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.

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

PARAMETER	SYMBOL	CONDITIONS	SSM-2024 MIN	SSM-2024 TYP	SSM-2024 MAX	UNITS
Positive Supply Current	$+I_{SY}$	I_{CON} (1-4) = 0 $V_S = \pm15V$	0.95	1.40	1.85	mA
		I_{CON} (1-4) = 0 $V_S = \pm16.5V$	1.05	1.55	2.05	
Negative Supply Current	$-I_{SY}$	I_{CON} (1-4) = 0 $V_S = \pm15V$	1.05	1.55	2.05	mA
		I_{CON} (1-4) = 0 $V_S = \pm16.5V$	1.20	1.65	2.25	
Gain	G	I_{CON} (1-4) = ±500µA	3842	4085	4330	µmhos
Gain Matching	ΔG	I_{CON} (1-4) = ±500µA	–	–	±6	%
Input Offset Voltage	V_{OS}	$V_{IN} = 0V$ I_{CON} (1-4) = ±500µA I_{CON} (1-4) = +250µA	–	±.4	±1.3	mV
Change in Offset Voltage	ΔV_{OS}	+2.5µA ≤ I_{CON} (1-4) ≤ +250µA +250nA ≤ I_{CON} (1-4) ≤ +250µA	– –	±100 ±250	±840 ±840	µV
Output Leakage	I_{OL}	I_{CON} (1-4) = 0	–	0.1	±5	nA
Control Rejection (Untrimmed)	CVR	I_{CON} (1-4) = 500µA V_{IN} (1-4) = 40mV$_{P-P}$	30	41.5	–	dB
Signal-to-Noise	S/N	V_{IN} (1-4) = 40mV$_{P-P}$	–	82	–	dB
Distortion	THD	V_{IN} (1-4) = 40mV$_{P-P}$	–	0.3	–	%
Threshold Input Control Voltage	V_{TCI}	I_{OUT} (1-4) = 0	+160	–	+220	mV

NOTE: Specifications subject to change; consult latest data sheet.

SIMPLIFIED SCHEMATIC (1 OF 4 AMPLIFIERS)
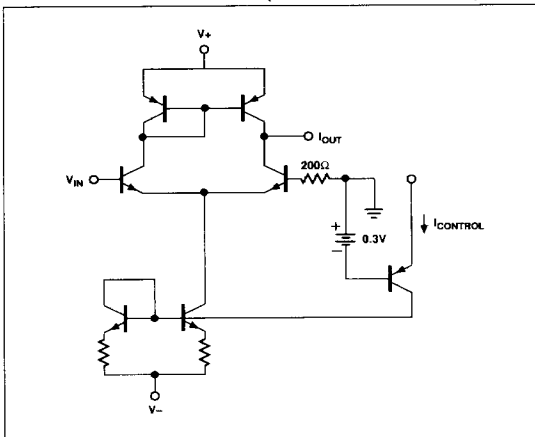
THEORY OF OPERATION

The SSM-2024 is a quad transconductance amplifier. Its voltage-in/current-out transfer functions are controlled by ground referenced linear current inputs. As shown in the simplified schematic, the control current is mirrored in the input stage current source. This sets the operating level for the input differential pair. The operating level established by $I_{CONTROL}$ will determine the slope of the I_{OUT}/V_{IN} transfer characteristic. Each independent device is configured as a noninverting transconductance amplifier and rated for ±15V operation.

SIGNAL INPUTS

The signal inputs offer the best offset and control rejection when shunted with 200Ω to ground. This resistor along with R_{IN} form the voltage divider to scale the input signal. Select R_{IN} to set the maximum operating level for the largest input signal.

This selection will determine the VCAs operating levels which have tradeoffs as shown in Figures 1 and 2. As the input signal level is increased, the effective signal-to-noise and control rejection will increase (improve). However, a larger input signal also means more THD.

The signal at the input of the device will be:

$$V_{IN}{'} = V_{IN} \left(\frac{200}{R_{IN} + 200} \right)$$

(where V_{IN} is the **applied** input). The circuit transconductance $I_{OUT}/V_{IN}{'}$ is:

$$g_m = 8.17\ I_{CONTROL} = \frac{I_{OUT}}{V_{IN}{'}}$$

Therefore, the output current expressed as a function of the control current and the applied input signal is:

$$I_{OUT} = 8.17\ I_{CONTROL} = \left(\frac{200}{R_{IN} + 200} \right) V_{IN}$$

A graph of some typical operating levels is shown in Figure 3. Note this plot is for a general application where

$$R_{IN} = R_{CONTROL} = 10k\Omega$$

For output voltage vs. V_{IN} see the right axes of the graph using

$$R_{OUT} = 10k\Omega.$$

CONTROL INPUTS

Each control input is a low impedance, ground referenced linear current control input. When operated in its active region, input impedance is approximately 250Ω. When operating with an applied control voltage, connect a series resistor. Select R_{CON} so $V_{CONTROL}$ max/R_{CON} is no more than 500µA.
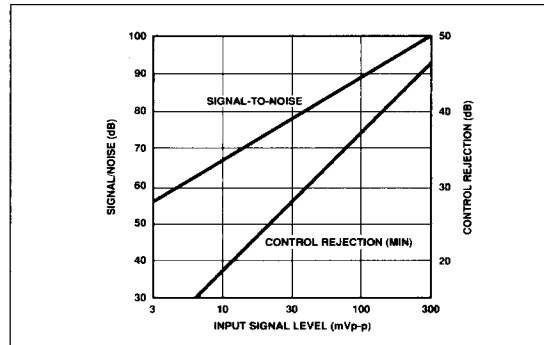
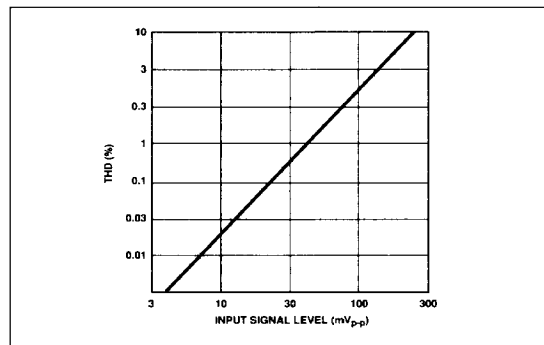

FIGURE 1: Text for figures is italic, normal
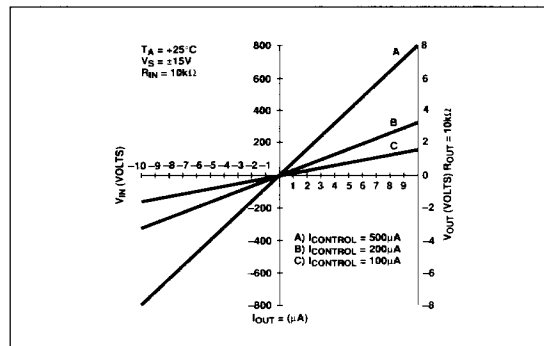

FIGURE 2

FIGURE 3: *SSM-2024* $g_m = I_{OUT}/V_{IN}$

7

SSM-2024

The VCA will turn completely off as the control voltage drops below approximately 200mV. The control pin can go as low as V– with no adverse effects. Control voltages usually do not exceed 10V. It is possible to operate at higher voltages with current limiting. If the control pin is shorted directly to V+, however, the power dissipation rating of the package will be exceeded within 10 to 20 seconds.

OUTPUTS

The SSM-2024 is a current output device. Operating in the current mode as virtual grounds, the outputs have a voltage compliance of only about 500mV. For large output voltages an op amp is used as a current-to-voltage converter as shown in Figure 4. Selecting R_{OUT} will determine the output voltage range as

$$V_{OUT} = I_{OUT} (R_{OUT}).$$

The outputs can be used directly in many applications where voltage ranges are small, such as the exponential input of a voltage-controlled filter or other logarithmic-control voltage devices.

Outputs are conveniently located together at the center of the package for easy connections in signal summing applications.

DISTORTION

As shown in Figure 2, operation at higher signal levels will increase THD (Total Harmonic Distortion). For many applications such as control paths where a single input signal is being processed, distortion effects are minimal. This is because distortion only slightly alters the harmonic structure of a saw, pulse or triangle shaped waveform already rich in harmonics.

In the final VCA, however, where two or more signals are present, the effects of IMD (Intermodulation Distortion) become more significant. Intermodulation distortion is unwanted sideband signals produced by the circuit at frequencies that are the sums and differences of the harmonics present at the inputs.

In a Class A VCA, IMD will increase with increasing input signal level at the same rate as THD. For such applications, we recommend use of the SSM-2024 at signal levels corresponding to THD of no more than 0.3% (see Figure 2).

APPLICATIONS

The following examples were developed for musical instrument applications but also illustrate general methods of use. Applications for the SSM-2024 are numerous in programmable music systems. A waveform mixer following tone sources is shown in Figure 4. This type of mixer can be configured in several ways to allow the various waveforms and tone sources to be mixed under program control. Choice of mixer configurations depends on system philosophy and the number of tone and noise sources to be considered.

The SSM-2024 can also be used as the final VCA/volume and filter controls. This would make keyboard tracking and envelope sweep programmable.
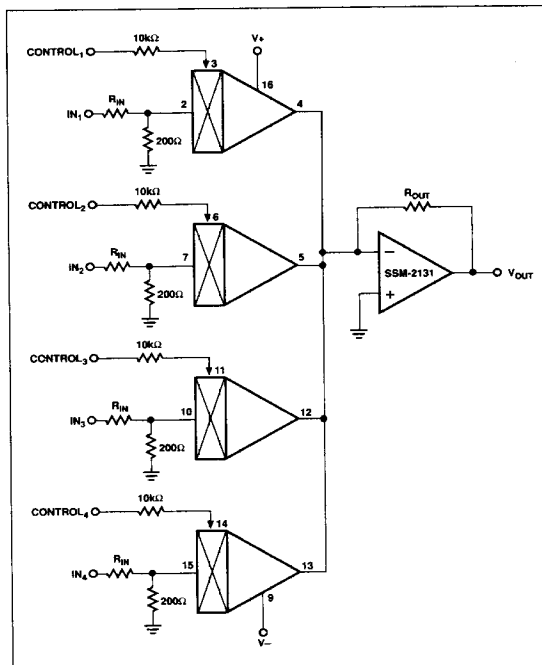

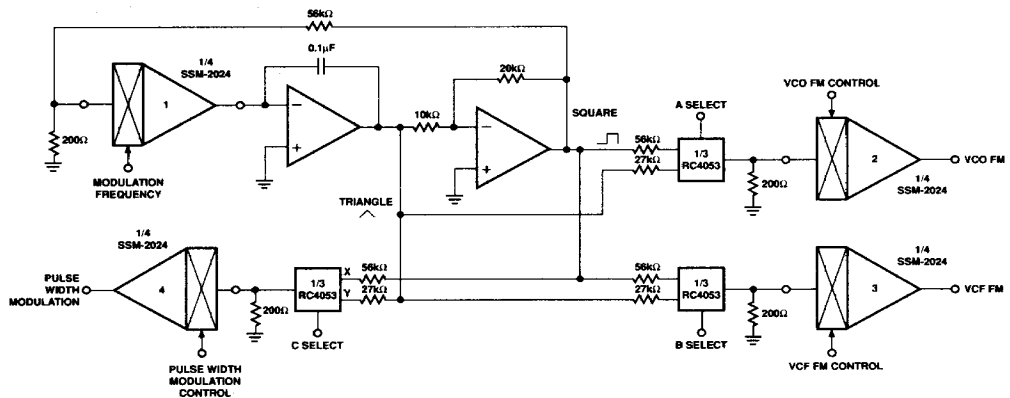**FIGURE 4:** *Four-Channel Mixer (4–1)*

FIGURE 5: *Modulation Oscillator*

A practical modulation oscillator is shown in Figure 5. Here, the device is used in the circuit to control the oscillator frequency and the amount of modulation signal onto the modulation buses.

A VCA with programmable amplitude modulation control is shown in Figure 6. This circuit also exhibits direct interface to the SSM-2044 VCF without adding an op amp or offset adjustments.
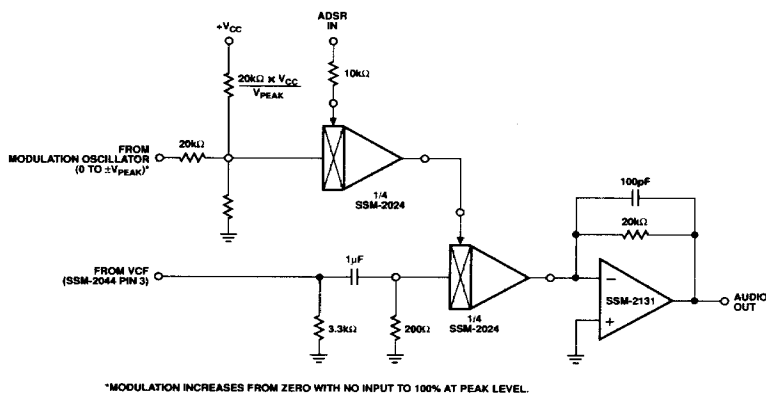
7

FIGURE 6: *VCA with Amplitude Modulation*

SSM-2024

Two of the SSM-2024 channels can be used with the SSM-2220 dual PNP transistor in an exponential cross-fade circuit. Figure 7 shows how the PNP splits a common linear control current according to the bias of the PNP pair. Here, the voltage called "exponential cross-fade control" will determine the relative amount of the two signals at the inputs of the VCAs in the mix.

The transfer characteristic of this circuit is shown in Figure 8. This plot is normalized to the balance point where each VCA has equal current (250µA). This is plotted as the 0dB or unity-gain point. As the control voltage is swept positive or negative, the control current in each VCA is varied logarithmically. As the control voltage is increased, VCA B receives increased current as VCA A's current attenuates at a more rapid logarithmic rate. This applies inversely for decreasing control voltages. At the maximum positive or negative control voltages, VCA B or VCA A receives virtually all 500µA and is 6dB above the balance point.

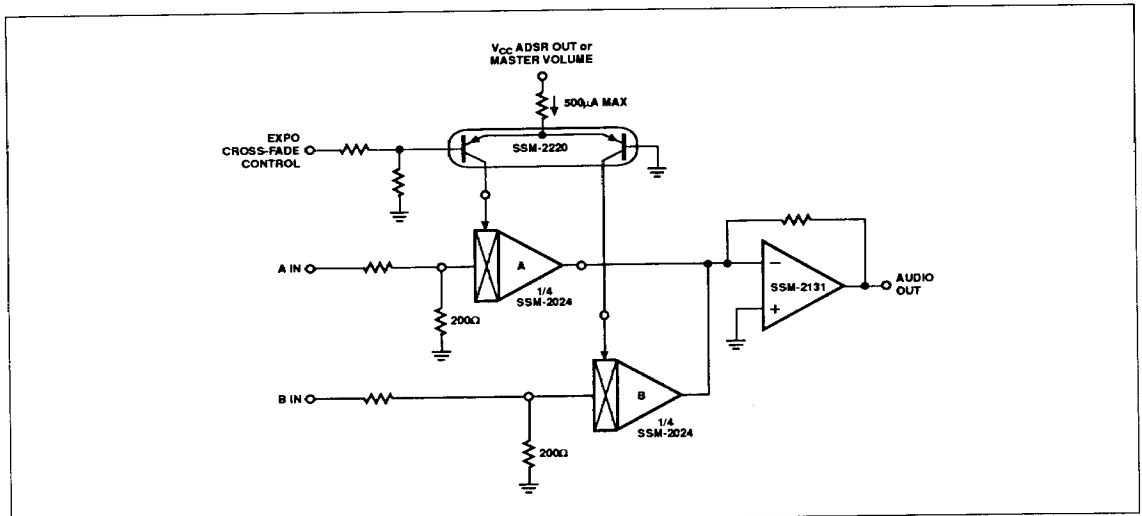To operate a single VCA with exponential control sensitivity, simply ground the collector of the unused PNP.
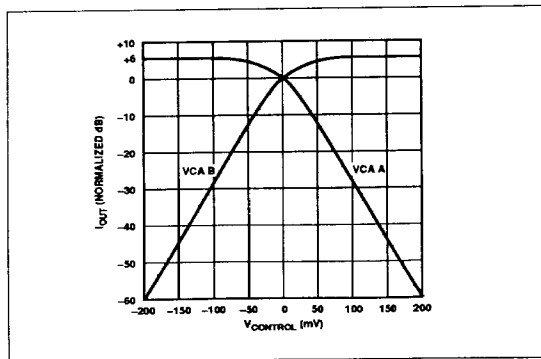

FIGURE 7: *Exponential Cross-Fade Controller*

FIGURE 8: *Normalized Transfer Characteristic of a Exponential Cross-Fade Controller*