# SSI2160

## PROCIRCUIT™ VOLTAGE CONTROLLED AMPLIFIER

The SSI2160 is a low cost single-channel VCA building block for high-performance audio applications. Voltage control of current-mode inputs and outputs allow an exponential gain range of +20dB to –100dB, with control provided by a ground-referenced –31mV/dB constant.

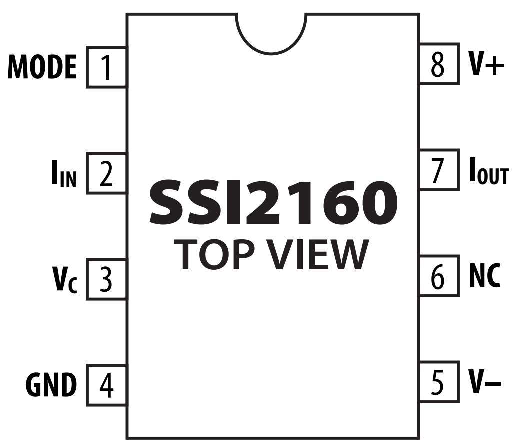
The device offers considerable flexibility for a wide range of design goals and applications. A unique mode control allows selection of Class A, Class AB, or in-between using a single resistor. The SSI2160 can be used as a high-quality building block for a variety of applications such as dynamic range processors, voltage controlled filters, exponential generators, and antilog converters. The SSI2160 is particularly well-suited for one-knob compressor designs – see the application later in this data sheet.

The SSI2160 will operate on supplies as low as +8V for battery-powered devices such as guitar pedals, or up to ±18V in systems where maximum headroom is desired.

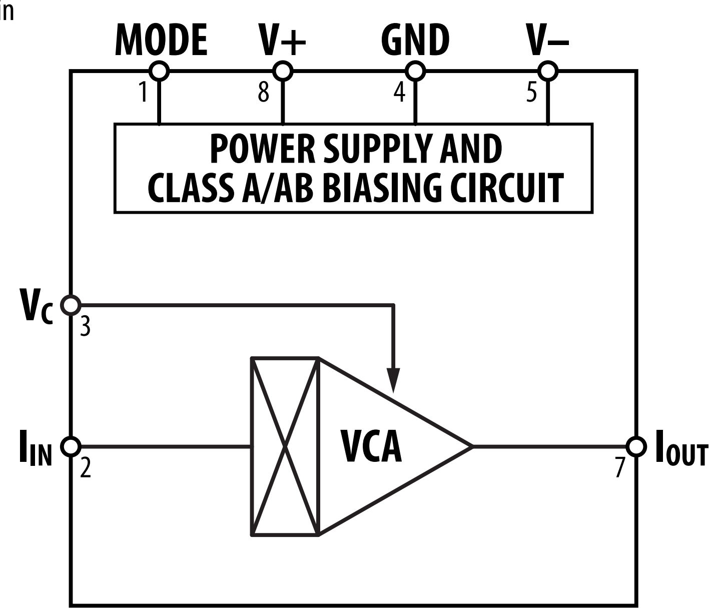
The SSI2160 is part of a family of affordable high-performance VCA's from Sound Semiconductor. The SSI2162 offers two channels with a small PCB footprint, the single-channel SSI2161 provides best SNR, and the SSI2164 Quad VCA has become the industry-standard workhorse in countless applications.

### FEATURES

- **Pro-Grade Exponential VCA**
- **High Input Current Handling: 1mA**
- **Pin-Selectable Class A or AB Operation**
- **119dB Signal-to-Noise Ratio (Class AB)**
- **Low Distortion: Typical 0.025% (Class A)**
- **Large Gain Range: –100dB to +20dB**
- **±4V to ±18V Operation**
- **No Trimming Required**
- **Low Control Feedthrough: Typical –60dB**
- **Compact SOP8 Package**
- **Low Cost**




**PIN CONNECTIONS**
**8-LEAD SOP**




**FUNCTIONAL BLOCK DIAGRAM**

## SPECIFICATIONS ($V_S = \pm15V$, $V_{IN} = 0.775V_{RMS}$, f = 1kHz, $A_V = 0dB$, Class AB, $T_A = 25°C$; using Figure 1 circuit)

| Parameter | Symbol | Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| POWER SUPPLY | | | | | | |
| Supply Voltage Range | $V_S$ | | ±4 | | ±18 | V |
| Supply Current | $I_S$ | Class AB, $V_C$ = GND | | ±1.7 | ±2.0 | mA |
| Supply Current | $I_S$ | Class A, $V_C$ = GND, $I_M$ = 1mA | | ±3.0 | | mA |
| Power Supply Rejection Ratio | PSRR | 60Hz | | 90 | | dB |
| CONTROL PORT | | | | | | |
| Input Impedance | | | 9 | 10 | 11 | kΩ |
| Gain Constant | | After 60 seconds of operation | | –31 | | mV/dB |
| Gain Constant Temp. Coefficient | | | | –3300 | | ppm/°C |
| Control Feedthrough | | $A_V$ = 0dB to –40dB | | –60 | | dB |
| Gain Accuracy | | $A_V$ = 0dB | | +0.30 | | dB |
| | | $A_V$ = +20dB | | -0.20 | | dB |
| | | $A_V$ = –20dB | | +0.20 | | dB |
| Maximum Attenuation | | | | –100 | | dB |
| Maximum Gain | | | | +20 | | dB |
| SIGNAL INPUT | | | | | | |
| Input Bias Current | $I_B$ | | | ±15 | | nA |
| Input Current Handling | | | | 1 | | $mA_P$ |
| SIGNAL OUTPUT | | | | | | |
| Output Offset Current | | $V_{IN}$ = GND | | ±150 | | nA |
| Output Compliance | | | | ±100 | | mV |
| PERFORMANCE | | | | | | |
| Output Noise | | Class AB *(20Hz -20kHz, unweighted)* | | | | |
| ([1]$I_M$ = <1mA) | | $R_{IN/OUT}$ = 30kΩ | | –95 | | dBu |
| | | $R_{IN/OUT}$ = 20kΩ | | –97 | | dBu |
| | | $R_{IN/OUT}$ = 15kΩ | | –100 | | dBu |
| | | $R_{IN/OUT}$ = 7.5kΩ | | –103 | | dBu |
| | | Class A *(20Hz -20kHz, unweighted)*[1] | | | | |
| | | $R_{IN/OUT}$ = 30kΩ | | –82 | | dBu |
| | | $R_{IN/OUT}$ = 20kΩ | | –86 | | dBu |
| | | $R_{IN/OUT}$ = 15kΩ | | –88 | | dBu |
| | | $R_{IN/OUT}$ = 7.5kΩ | | –94 | | dBu |
| Headroom | HR | 1% THD | | +22 | | dBu |
| Total Harmonic Distortion | THD | Class AB (*80kHz BW)* | | | | |
| ([1]$I_M$ = <1mA) | | $A_V$ = 0dB | | 0.05 | | % |
| | | $A_V$ = 0dB, $V_{IN}$ = –17dBu | | 0.025 | | % |
| | | $A_V$ = +20dB | | 0.20 | | % |
| | | $A_V$ = –20dB | | 0.045 | | % |
| | | Class A (*80kHz BW)*[1] | | | | |
| | | $A_V$ = 0dB | | 0.025 | | % |
| | | $A_V$ = 0dB, $V_{IN}$ = –5dBu | | 0.015 | | % |
| | | $A_V$ = +20dB | | 0.17 | | % |
| | | $A_V$ = –20dB | | 0.025 | | % |
| Unity Gain Bandwidth | | $C_F$ = 100pF | | 500 | | kHz |
| Slew Rate | SR | $C_F$ = 100pF | | 700 | | µA/µs |

[1]$I_M$ (mode current) = 1mA

## ABSOLUTE MAXIMUM RATINGS

| | |
|---|---|
| Supply Voltage | ±20V |
| Storage Temperature Range | -65°C to +150°C |
| Operating Temperature Range | -40°C to +85°C |
| Lead Temperature (Soldering, 10 sec) | 260°C |
| Mode Current ($I_M$; Pin 1 to Pin 8 via $R_M$) | 2.0mA |
| Control Pin Voltage (Pin 3) | V- to V+ |

## ORDERING INFORMATION

| Part Number | Package Type/Container | Quantity |
|---|---|---|
| SSI2160S-TU | 8-Lead SOP* - Tube | 100 |
| SSI2160S-RT | 8-Lead SOP* - Tape and Reel | 4000 |

*SSI Package ID "**PSL8**", compliant with JEDEC MS-012-AA
Mechanical drawing available at www.soundsemiconductor.com

## PIN DESCRIPTIONS

| Pin(s) | Name | Description |
|---|---|---|
| 1 | MODE | Current into this pin sets VCA core to operate as Class A (lowest THD), AB (lowest noise), or inbetween, set by external resistor. Leave open for Class AB operation. |
| 2 | $I_{IN}$ | Ground-referenced current input; requires RC network. |
| 3 | $V_C$ | Ground-referenced control port with a –31mV-per-dB constant. |
| 4 | GND | Connect to analog signal ground with short, low inductance trace. |
| 5 | V– | Negative supply. Recommend 100nF local decoupling capacitor placed as close to package as possible with a low inductance trace to ground. |
| 6 | NC | Leave this pin unconnected. |
| 7 | $I_{OUT}$ | Ground-referenced current ouput. |
| 8 | V+ | Positive supply. Recommend 100nF local decoupling capacitor placed as close to package as possible with a low inductance trace to ground. |

## USING THE SSI2160

The SSI2160 is a single-channel voltage controlled amplifier with a control range from +20dB to –100dB. The VCA is a current-in, current-out device with a separate voltage control port. Basic operation is described below; see the "Principles of Operation" section for further details on inner workings of the device and an application section that follows.

### Signal Input

Figure 1 shows the basic application circuit. Resistor $R_{IN}$ converts the input voltage to a current, and a 221Ω resistor in series with a 1200pF capacitor connected to ground ensures stable operation. The SSI2160 is quite tolerant of RC network selection, but 221Ω/1200pF has been proven to work well over a wide range of $R_{IN}$ values.

A 20kΩ value for $R_{IN}$ is recommended for most applications, but can range from 7.5kΩ to 100kΩ – lower values will produce the best noise performance at some cost in distortion and headroom.

Maximum input current handling is approximately 1mA peak. This input current "headroom" is only likely to be a consideration when using $R_{IN}$ values of 10kΩ and below with supplies of ±12V and higher. In such cases, one may want to design the signal chain for a maximum input current of 900µA to allow adequate headroom.

An optional series-connected 10µF capacitor is recommended for improved control feedthrough.

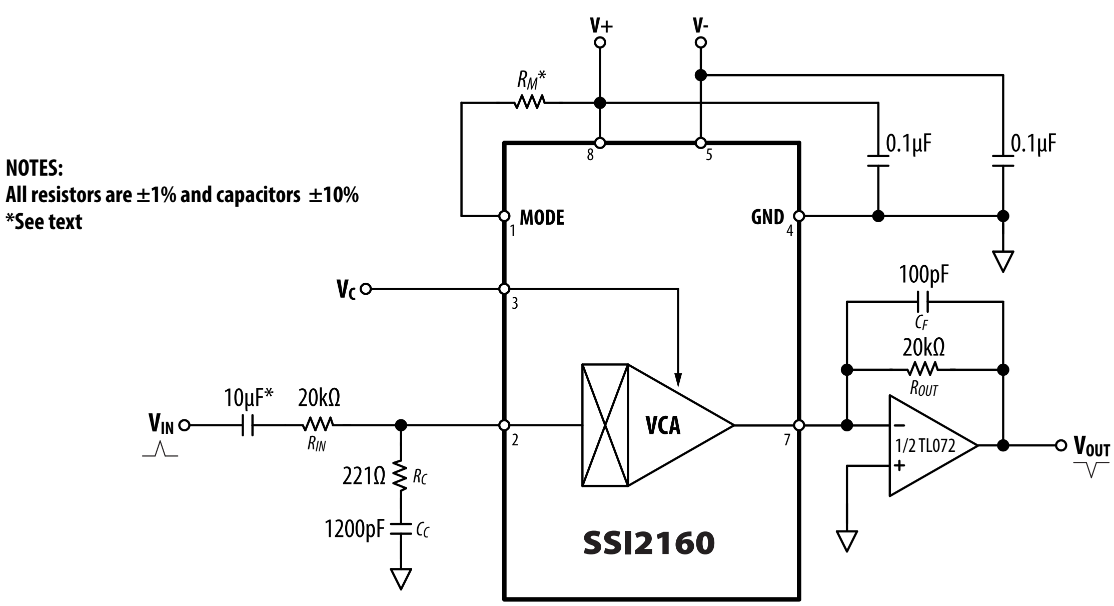



**Figure 1: Typical Application Circuit**

### Signal Output

The output current pin should be maintained at virtual ground using an external amplifier such as a TL072; feedback shown results in unity gain. Many op-amps require a feedback capacitor to preserve phase margin. A value of 100pF will suffice in most cases; larger values can be used to reduce high-frequency noise at the expense of bandwidth. In most cases, headroom will be limited by the op amp – increased headroom can be achieved by using a rail-to-rail amplifier or operating on separate supplies.

The direction of current out of the SSI2160 mimics that of a resistor: current flowing into the input then flows out of the output, and vice versa. This greatly simplifies overall design in filter applications. For audio level applications where the VCA is used only to vary the signal level (e.g., mixer automation, synthesizer VCA module, etc) the combination of SSI2160 VCA and opamp (Figure 1) produces an output whose phase is inverted.

### Control Port

The SSI2160 provides exponential control with gain constant of -31mV/dB; to realize the full gain range of +20dB to -100dB, control voltage should span from -620mV to 3.1V, respectively. If only attenuation is desired, the control port can be driven directly from a low impedance voltage-output DAC.

The control input has a nominal impedance of 10kΩ, with an internal 10:1 resistor divider. Because of this, any resistance in series with $V_C$ will attenuate the control signal somewhat. If precise control of gain and attenuation is required, buffering the control voltage is suggested.

The 31mV/dB control voltage law is essentially set by transistor physics, and has the property of being proportional to absolute temperature, or approximately 0.33%/°C. This is low enough to be unimportant in most applications, but can be reduced with external temperature-dependent networks. One example is shown in Figure 2 using an inexpensive NTC thermistor (such as Vishay NTCLE100E3103JB0 or similar).

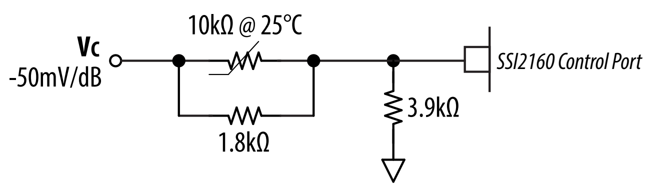



**Figure 2: Temperature-Compensated Control Port**

### Class A Mode Current

The SSI2160's gain core can be biased as Class A, AB, or in-between. Class AB will yield the best noise performance which is achieved with Pin 1 left open. Class A offers lowest distortion and requires connection of resistor $R_M$ between Pin 1 and V+.

As Figure 3 shows, mode current $I_M$ affects both noise and distortion. For most applications, a 1mA mode current provides the best overall Class A pertformance. One can reduce THD further by increasing mode current, but at a significant cost in noise. In addition, increased mode current increases supply current. For example, supply current is typically ±3mA with a 1.0mA mode current, but jumps to ±4mA at 1.5mA. Under no circumstances should mode current exceed 2mA. For some applications, the designer might consider mode current below 1mA for improved Class A noise and power dissipation.

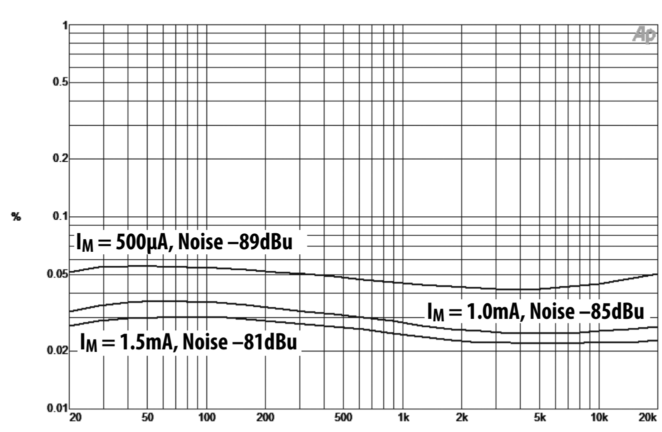



**Figure 3: SSI2160 Class A THD+N At Varying Mode Currents**

*$R_{IN}$ = 20kΩ, $V_{IN}$ = 0dBu, $A_V$ = 0, $V_S$ = ±15V, 22Hz - 80kHz Filter*

Resistor $R_M$ can be calculated by:

$$R_M = \frac{+V - 0.65V}{I_M}$$

See the "Principles of Operation" section for further discussion on gain core biasing.

### Supplies

Supplies from ±4V to ±18V are possible, which should be regulated and include normal design practices such as bypass capacitors as shown in Figure 1. Since internal protections were added to prevent catastrophic failure that may be experienced during SSM/V2164 asymmetrical power-up, the typical Schottky diode solution is no longer necessary. In most applications, no diode is needed. Modular synthesizer sub-systems may want to include a standard 1N4148-style diode as an extra measure of protection since "hot" plugging of modules may be experienced.

Single supply operation is described in the Applications section.

## PRINCIPLES OF OPERATION

### VCA Core

The simplified schematic in Figure 4 shows the basic structure of the VCA cell. The gain core is comprised of matched differential pairs Q1 – Q4 and current mirrors Q5, Q6 and Q7, Q8. The current input pin, $I_{IN}$, is connected to the collectors of Q1 and Q7 and the difference in current between these two transistors is equivalent to $I_{IN}$. For example, if 100 µA is flowing into the input, Q1's collector current will be 100 µA higher than Q7's collector current.

The control voltage $V_C$ steers the signal current from one side of each differential pair to the other, resulting in either gain or attenuation. For example, a positive voltage on $V_C$ steers more current through Q1 and Q4 and decreases the current in Q2 and Q3. The current output pin, $I_{OUT}$, is connected to the collector of Q3 and the current mirror (Q6) from Q2. With less current flowing through these two transistors, less current is available at the output. Thus, a positive $V_C$ attenuates the input and a negative $V_C$ amplifies the input. The VCA has unity gain for a control voltage of 0.0V where the signal current is divided equally between the gain core differential pairs.

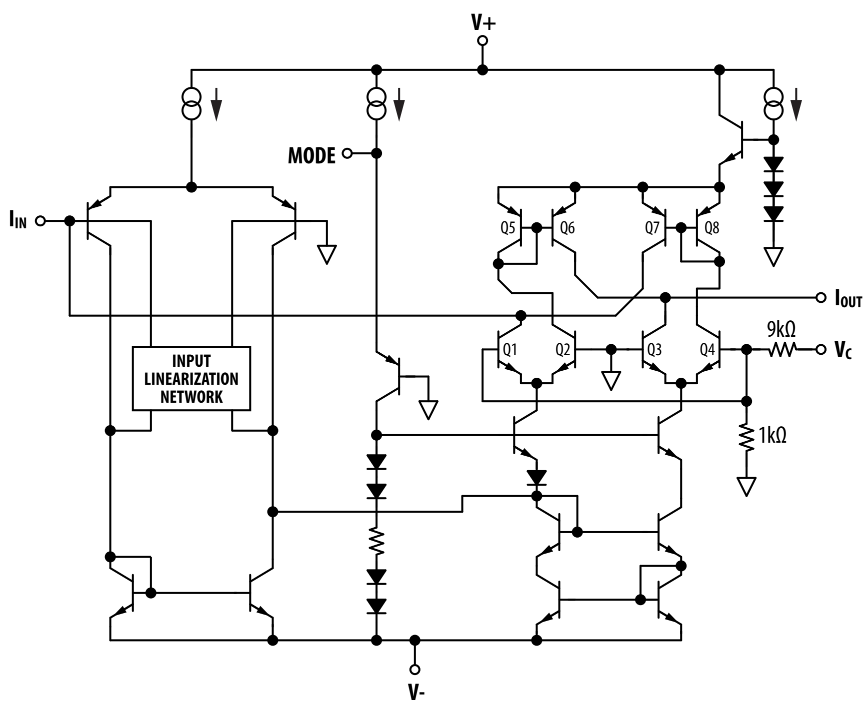



**Figure 4: SSI2160 Simplified Schematic**

### Biasing the VCA Core

VCA's operate by modulating differential currents in a transistor core, a fraction of which is steered to the output in a value set by the control voltage. Such VCA's are generally classified as Class A, Class B and Class AB; terms borrowed from radio transmitter jargon.

In Class A operation the quiescent current in the transistor core is designed to be greater than the maximum input current, so all the transistors remain active at all signal levels. This type of operation produces the lowest distortion, but the high quiescent current level has a severe impact on noise floor and control feedthrough rejection.

In Class B operation the core transistor current is zero and only half the transistors conduct signal at any point of time. Such operation would yield the lowest possible noise floor and near perfect control rejection, but is unfortunately impractical in practice. This is because the transistors effectively disconnect feedback inside the VCA during zero-crossings and low signal levels, potentially causing latch-up or instability. The solution is to arrange the circuit to operate in class A at low signal levels and enter Class B at larger ones. This is known a Class AB operation.

In some applications, distortion may be more important than noise or control feedthrough, in which case it is desirable to raise the point at which the transition from class A to class B takes place. This can be affected by injecting current into the Mode pin. The relationship between the input current transition point and the current injected into the Mode pin is intentionally non-linear. Figure 5 shows the relationship between the two.

For example, supposing the desired transition point is at a peak input voltage of one volt. With a 20kΩ input resistor this would correspond to an input current of 50µA, and extrapolating from Figure 5 would require a current of about 650µA to be injected into the mode pin. The mode pin is biased about 0.65V above ground, so a resistor placed between this pin and V+ would see a voltage of 14.35V with a +15V supply. Therefore a resistor value of 22kΩ would work well.

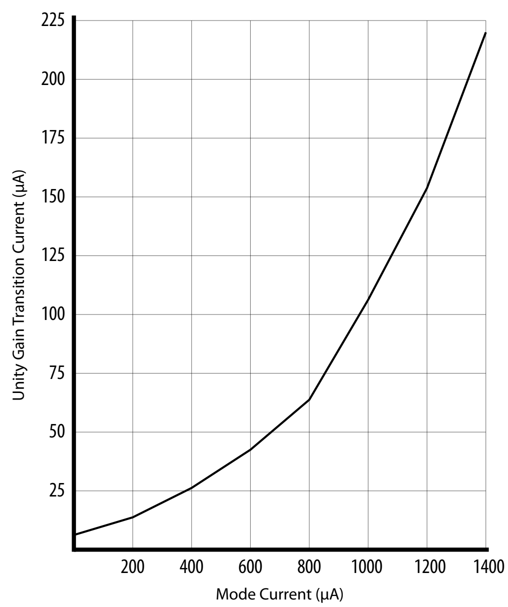



**Figure 5: Class A Mode Current to Transition Current Association**

## APPLICATION INFORMATION

### SINGLE SUPPLY OPERATION

By referencing to a pseudo-ground point ("$V_{MID}$") midway between V+ and V-, the SSI2160 can operate from a single supply between +8V and +36V. An op amp provides a low-impedance reference, from which all ground connections are made.

As shown in Figure 6, a voltage divider comprised of two 10kΩ resistors connected to the non-inverting input provides ground voltage reference $V_{MID}$, the output of which is connected to ground on the SSI2160. The SSI2160's input can be referenced to the same ground, or AC coupled as shown in Figure 6. The 10Ω resistor and 22µF capacitor filter noise that may otherwise be present in the pseudo-ground. The control port provides unity gain when $V_C$ is equal to $V_{MID}$, or 4.5V in the case of Figure 6.

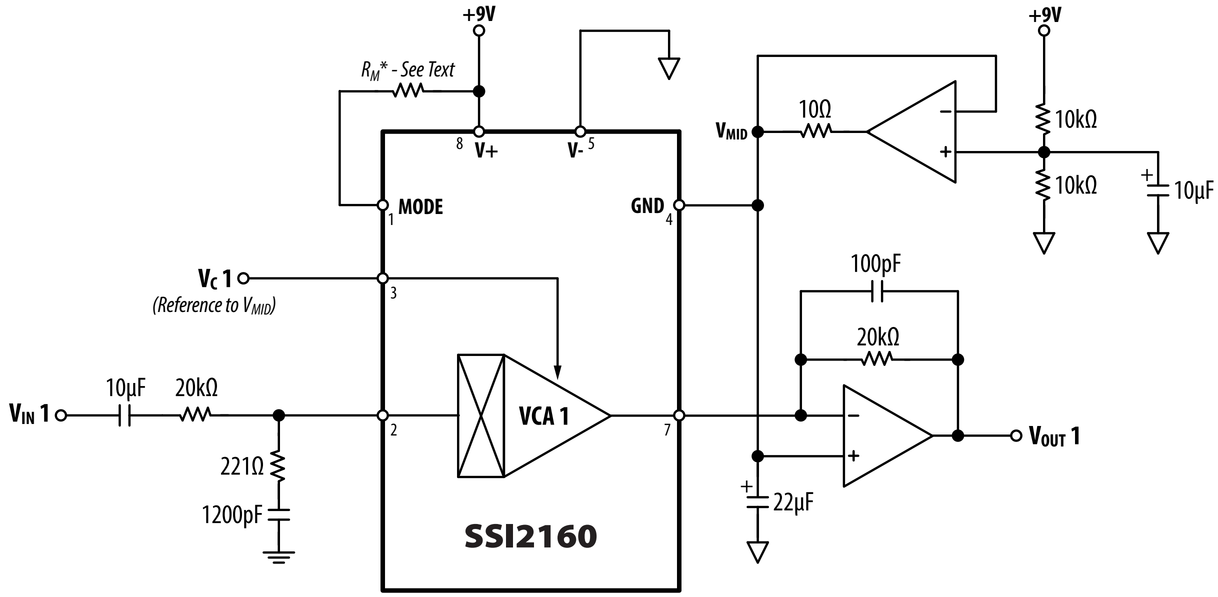



**Figure 6: Single-Supply Operation**

To bias SSI2160 gain core as class A, the mode resistor value calculation is modified slightly to:

$$R_M = \frac{V_{MID} - 0.65V}{I_M}$$

For example, if using 9V supplies $R_M$ should be 3.9kΩ.

## ONE-KNOB COMPRESSOR

Audio compressors are an essential tool in signal processing, designed to automatically reduce the dynamic range of audio signals. At its core, a compressor monitors the input signal level and reduces the output signal level to balance audio levels. This results in a decrease in the loudest sounds, and with the use of makeup gain can also increase the quietest sounds, making the overall volume more consistent.

Single knob compressors have grown in popularity because they offer streamlined solutions for users who want effective dynamic control without the complexity of traditional multi-parameter designs. By consolidating the essential functions into a single intuitive control, such compressors make it easy for musicians, engineers, and producers to achieve professional-sounding results quickly. This simplicity is particularly appealing in environments like analog mixer channel strips, pedals, and modular synths where space and workflow efficiency are at a premium. While advanced users might miss the ability to fine-tune every aspect, the accessibility and ease of single knob compressors help bring high-quality compression to a broader audience.

Key parameters in the design include attack and release times, compression threshold level, and ratio. Attack and release times determine how quickly the compressor responds to changes in signal level and how soon it returns to normal operation after the input signal level decreases. The threshold parameter determines the signal level at which the compressor begins to reduce the gain of the signal input, and the ratio parameter determines how much the signal is reduced once it exceeds the threshold level.

In a one-knob audio compressor, the single control performs double duty by simultaneously adjusting both the threshold and ratio parameters in a way that maintains intuitiveness for the user. As the control is increased, the compressor automatically lowers the threshold – meaning it begins compressing at lower signal levels – and increases the ratio, resulting in stronger signal reduction. Figure 7 demonstrates how a basic, yet powerful and versatile single knob compressor can be realized with one SSI2160 VCA and a few op amp stages. The result is high quality audio compression while keeping parts count and cost low.

### Overview

This one-knob compressor uses an envelope detector circuit to sense the input signal's amplitude and a VCA to control the signal gain. The input, buffered by op amp U1, is split and fed to both the VCA gain and the non-inverting input of the envelope detector U2. The output of U2 along with capacitor C1 forms the core of the envelope detector. The output of the envelope detector is buffered and fed to the control pin of the VCA gain cell through the compression control potentiometer VR1, which simultaneously dictates both threshold and ratio.

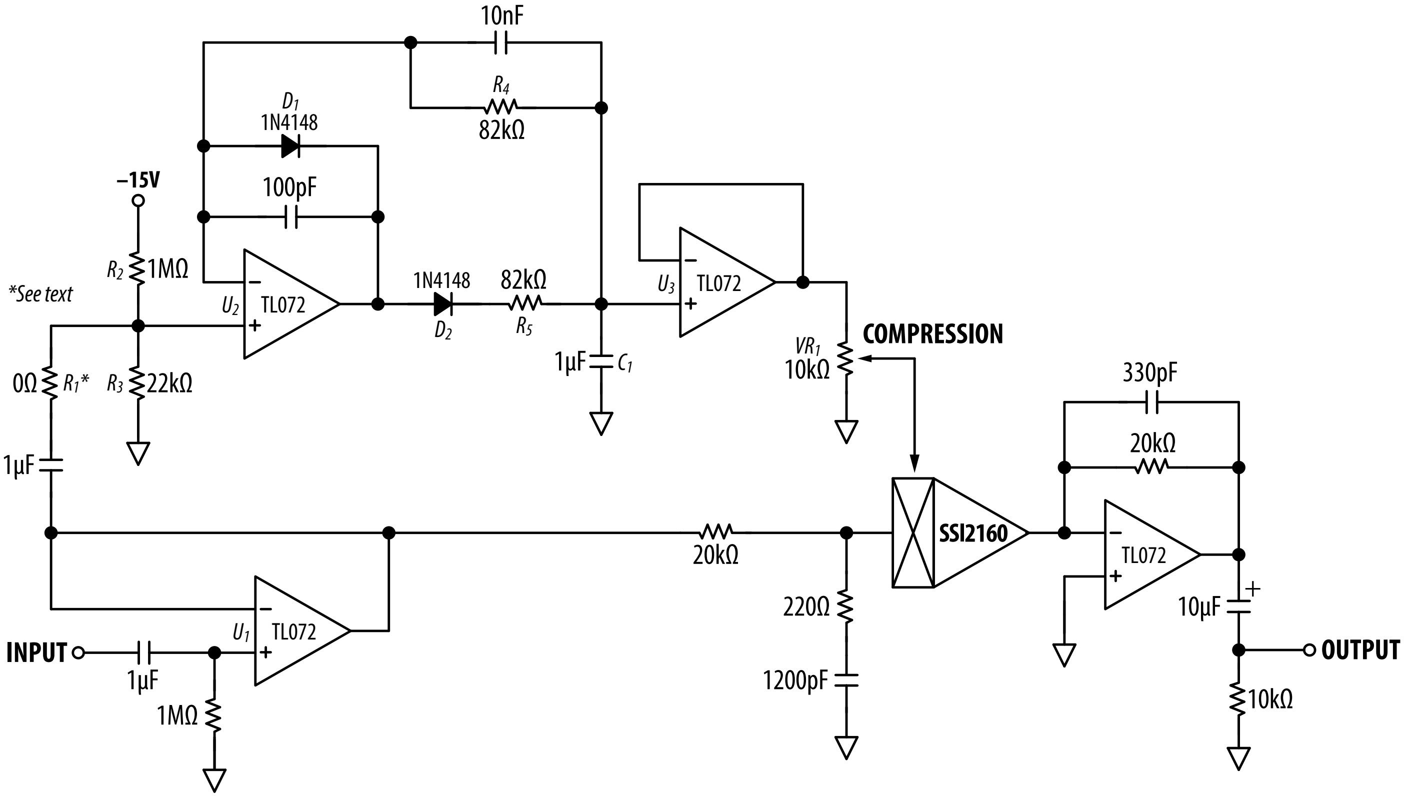



**Figure 7: SSI2160-Based One-Knob Compressor**

## Envelope Detector

When a signal is introduced to the input of U2, the output of the operational amplifier begins charging capacitor C1 through diode D2 and resistor R5. The resistance value of R5 determines the capacitor's charging rate, thereby regulating the compressor's attack time. Higher values of R5 will result in longer attack times.

Capacitor C1 is also connected to the inverting terminal of op amp U2 through resistor R4, which governs the release time of the compressor. When the input signal drops below the voltage present on C1, the output of U2 saturates low and begins discharging capacitor C1 through resistor R4 and diode D1. The discharge rate is dictated by the resistance of R4 and controls the compressors release time. Higher values of R4 will result in longer release times. This dynamic charging and discharging of C1 tracks the amplitude of the input signal and generates the control voltage envelope for the compressor.

## Compression Control and Makeup Gain

U3 buffers the voltage from capacitor C1 to the VCA gain cell's control pin through "compression" potentiometer VR1. This buffer is needed as the input impedance of the SSI2160 control pin is only 10k ohm. If the compression potentiometer were to be connected directly to capacitor C1, the control envelope amplitude and attack/decay times would be heavily dependent on the position of the compression potentiometer. Decoupling the compression potentiometer from the envelope capacitor via a buffer ensures that attack and release times remain constant for all settings of the compression control.

At its minimum position, the compression control grounds the SSI2160 CV control pin, setting the VCA at unity gain and resulting in zero compression. Increasing the compression control allows more of the voltage from the envelope detector circuit to be applied to the control pin of the VCA. As input levels rise, the envelope detector boosts the control voltage, resulting in increased compression by further attenuating the VCA output.

At its maximum position, the compression control can result in too much gain reduction, lowering the volume of all signal levels. To counter this reduction, makeup gain in the form of a DC voltage offset is applied to the control pin of the VCA in addition to the control voltage envelope. Resistors R2 and R3 form a voltage divider that is fed by a –15V supply voltage. The divider applies a negative DC voltage offset of about –320mV to the input of the envelope detector. This DC voltage offsets the control voltage envelope and results in a negative offset being applied to the control pin of the VCA. This negative offset voltage increases the gain of the compressor to compensate for the over reduction of signal level at high compression settings. The effects of the envelope detector result in gain reduction for the loudest portions of the input signal, and with the addition of this makeup gain voltage offset, the output signal will decay to unity volume as the input levels decrease. Since the makeup gain offset voltage is applied to the input of the envelope detector, this offset is also affected by the compression control. No makeup gain is applied to the VCA when the compression control is as its minimum setting and the maximum makeup gain is applied when the compression control is at its maximum setting.

### Input Signal Levels

When powered by ±15V rails, this compressor is capable of passing very large signal levels of at least $20V_{P-P}$ with minimal distortion. Depending on the input signal amplitude, the input to the envelope detector may need to be adjusted to accommodate larger or smaller signals. The component values in the schematic above work well for average instrument signal levels of 100s of mV. However, larger signals such as those seen in Eurorack synthesizer ($10V_{P-P}$ or greater) would result in far too large of a signal being sent to the envelope detector. The solution to this is to reduce the amplitude of the signal applied to the input of the envelope detector while still allowing the full signal to be sent to the VCA. Resistor R1 allows for the input signal sent to the envelope detector to be reduced by forming a voltage divider with the parallel combination of resistors R2 and R3. Increasing the value of R1 will reduce the overall input signal applied to the envelope detector circuit. The following equation can be used to determine the value R1 based on the desired gain reduction:

$$R1 = \left(\frac{R3 \times R2}{R3 + R2}\right) \times \left(\frac{1 - A}{A}\right)$$

where *A* is the desired amplitude reduction value

A value of 0Ω (a short) works well for instrument levels such as those seen with electric guitar and bass. For larger input signal levels such as line level and Eurorack synthesizers, the value of R1 should be increased to reduce the signal level present at the envelope detector input. The following table provides suggested amplitude reduction values and values for resistor R1 given different input signal levels:

| Input Signal Level | Application | Amplitude Reduction | R1 Value |
|---|---|---|---|
| 100s of mV RMS | Typical Electric Guitar | No Reduction | 0Ω |
| 100s of mV RMS | Consumer Line Level | No Reduction | 0Ω |
| ~1.228V RMS | +4dBu Line Level | 0.5 | 22kΩ |
| ~3V RMS | Eurorack Synthesizer | 0.2 | 86kΩ |

The values presented in this table are applicable when the compressor is powered by ±15V power supplies. The value for R1 may require slight adjustments if the compressor is powered by different supplies (see "Power Supply Voltages").

### Adjustments and Expanding the Controls

In this design, the attack and release times are set by the fixed resistors R4 and R5. The value of 82kΩ for both R4 and R5 was found to give an attack time of about 25ms and a release time of about 100ms. Both times are generally considered medium compression attack and release times. The following tables give suggested values for R4 and R5 for short, medium, and long attack and release times. The values presented here were measured on a circuit powered by ±15V supplies.

| Speed | Time | R5 Value |
|---|---|---|
| Fast | 8ms | 33kΩ |
| Medium | 20ms | 82kΩ |
| Slow | 40ms | 120kΩ |

*Resistor R5 Values for Setting Attack Times*

| Speed | Time | R4 Value |
|---|---|---|
| Fast | 40ms | 47kΩ |
| Medium | 100ms | 82kΩ |
| Slow | 200ms | 160kΩ |

*Resistor R4 Values for Setting Release Times*

Of course, R4 and R5 need not be fixed resistors. Either or both could be replaced with potentiometers to give the user control over the attack and release times. Figure 8 shows a modified envelope detector circuit with R4 and R5 augmented with potentiometers VR2 and VR3 to control attack and release. R4 and R5 are retained as series resistors to set minimum attack and release times when controls are at their minimum position.

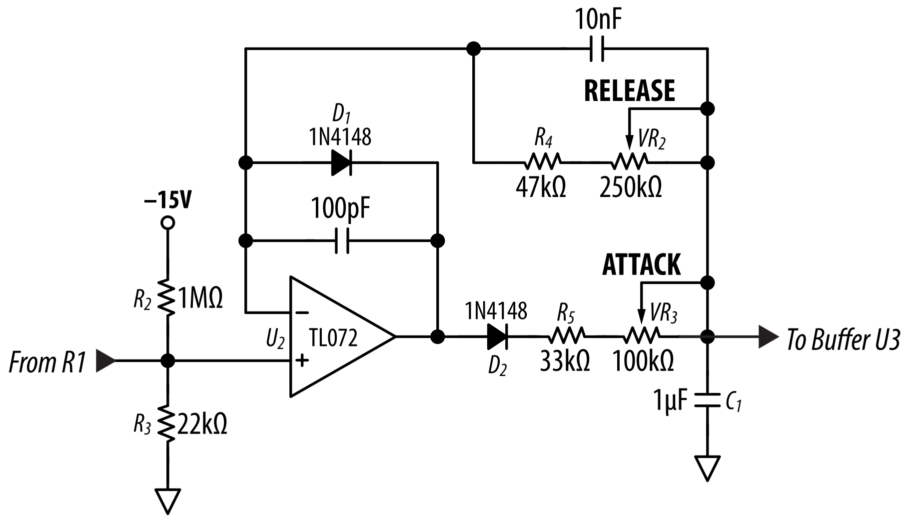



**Figure 8: Envelope Detector with Attack and Release Controls**

### Power Supply Voltage

In the examples above, the SSI2160 VCA and op amps are supplied by ±15V supplies, but the compressor can be powered by other common supply voltages such as ±12V for Eurorack applications or ±9V for guitar applications (see below for single-supply 9V-specific systems). If a power supply voltage other than ±15V is used, the value of the attack resistor R5 will require adjustment along with the offset gain voltage divider resistors R2 and R3 as the value of these components are dependent on power supply voltage.

A simple solution to make the compressor's attack time independent of supply voltage is to add series resistor R6 and Zener diode D3 to the output of U2 to form a voltage clamp, as shown in Figure 9. This Zener diode will clamp the voltage feeding C1 when U2 saturates high, keeping it stable regardless of supply voltage feeding the op amp. The value of the Zener diode is not critical but should be greater than 3.3V and less than the positive power supply voltage.

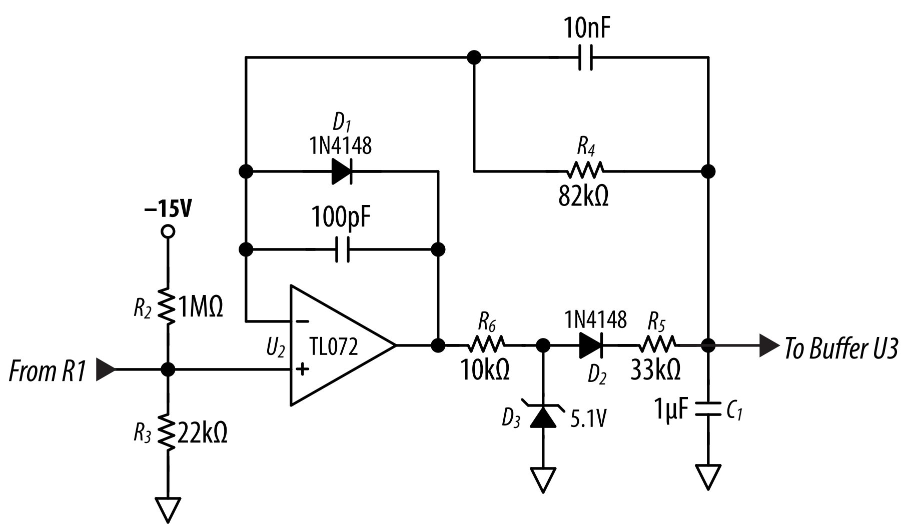



**Figure 9: Envelope Detector with Voltage Clamp**

The value of Zener diode was chosen to be 5.1V to support power supply voltages from ±9V to ±15V. In addition, the value of 5.1 V was chosen because near this voltage, the Zener effect and the avalanche breakdown effect are close to equal (but opposite in polarity) and tend to cancel leading to a very low temperature coefficient. This results in stable voltage clamping across varying thermal conditions.

The following table gives values for the attack resistor R5 for the circuit above. Because of inclusion of the voltage clamp, this circuit will maintain these attack times regardless of the power supply voltage.

| **Speed** | **Time** | **R5 Value** |
|---|---|---|
| Fast | 8ms | 10kΩ |
| Medium | 20ms | 24kΩ |
| Slow | 40ms | 36kΩ |

*Resistor R5 Values for Setting Attack Times for Circuit with Voltage Clamp*

In the example schematic above, the negative offset voltage is introduced to the envelope detector via a voltage divider fed by the negative power supply rail. For most applications, deriving this offset voltage directly from the power supplies is sufficient, however for applications requiring greater gain consistency, noise performance, and temperature stability this offset voltage should be derived from a separate, fixed voltage reference. If a fixed voltage reference is used, the values of R2 and R3 would require adjustment to produce the proper offset voltage given the selected reference voltage.

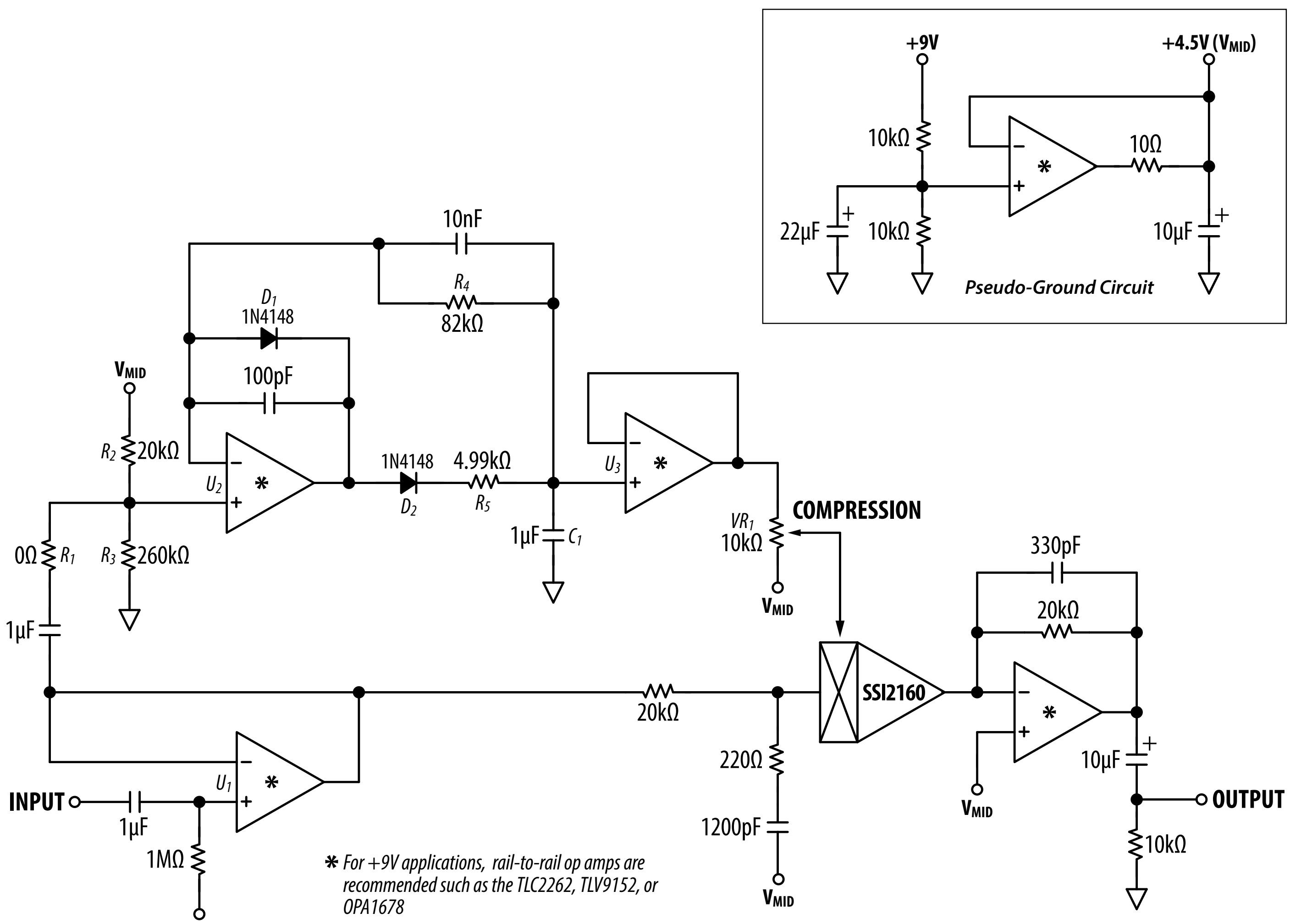



**Figure 10: Compressor Modified for +9V Systems**

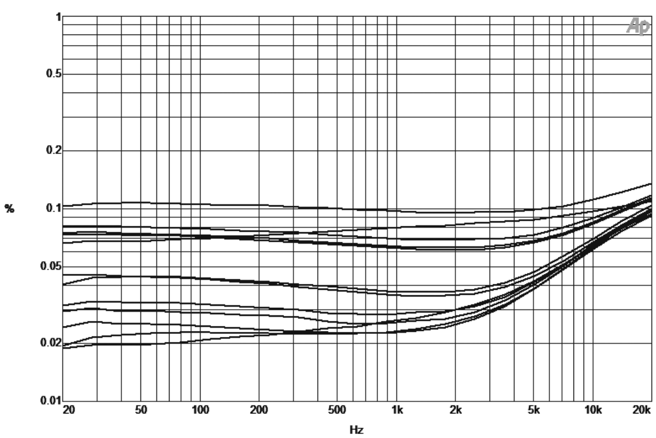
With only minor modifications, this compressor circuit can be adapted for single supply applications such as guitar pedals where only +9V is available. An additional op amp is used to generate a ½ supply reference that serves as a pseudo ground ("$V_{MID}$"). The SSI2160 and all op amps in the circuit are then referenced to $V_{MID}$.

Because of the lower supply voltage and the $V_{MID}$ reference, the input resistor values must be adjusted to provide a positive offset voltage and makeup gain offset. In Figure 10, R2 is 20kΩ and referenced to the +4.5V $V_{MID}$ while R3 is 260kΩ and connected to circuit ground. These two resistors are configured to produce a voltage of approximately 4.18V at the non-inverting terminal of U2. This voltage is 320mV lower than the 4.5V of $V_{MID}$ and serves the same purpose as the makeup gain discussed above.

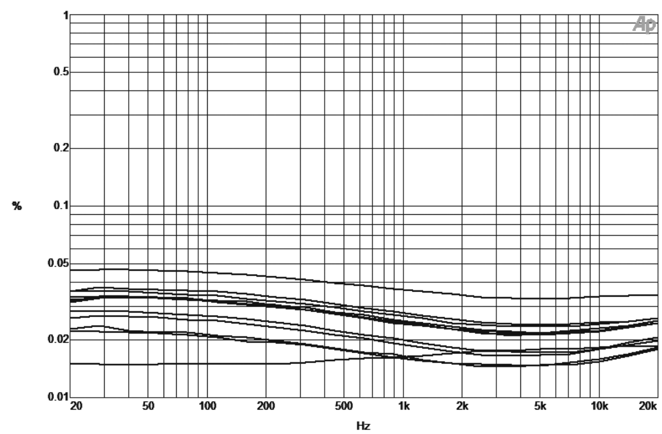
The lower supply voltage also results in a lower output voltage on U2 compared to the dual supply examples above. Because of this lower voltage, the attack resistors value will require adjustment to maintain the same ranges given above. A value of 4.99kΩ for the attack resistor was found to give an attack time of approximately 20ms.

## TYPICAL PERFORMANCE GRAPHS*

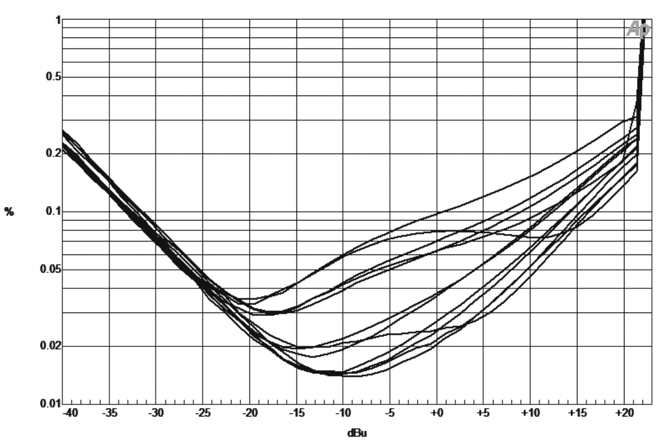
Figure 1 Application Circuit at $V_S = \pm15V$, $A_V = 0dB$, $V_{IN} = 0.775V_{RMS}$ , $R_{IN/OUT} = 20k\Omega$, f = 1kHz; unless otherwise noted



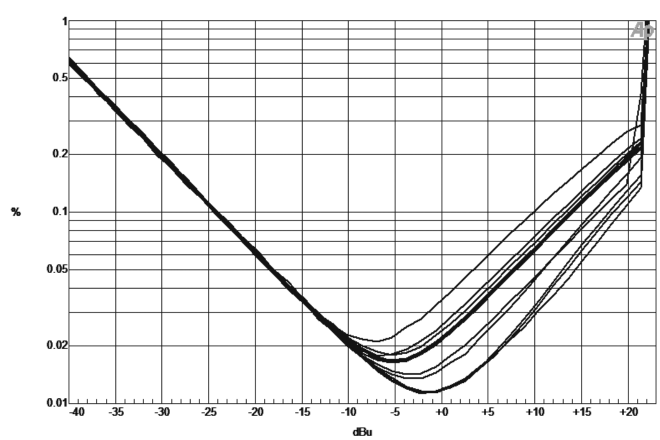

**THD+N vs. Frequency Distribution - 12 Channels**
*Class AB, 22Hz - 80kHz Filter*




**THD+N vs. Frequency Distribution - 12 Channels**
*Class A, 22Hz - 80kHz Filter*

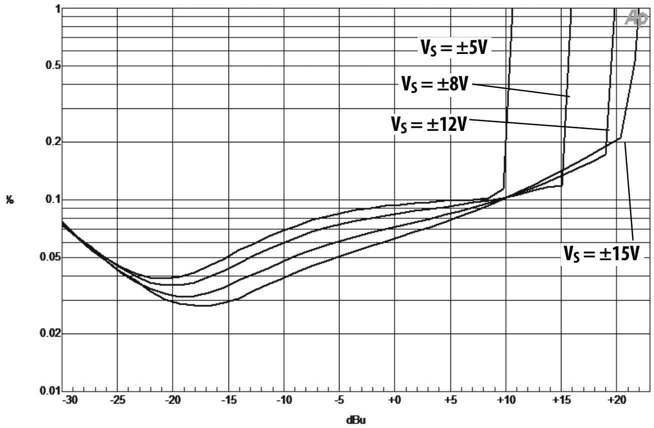



**THD+N vs. Amplitude Distribution - 12 Channels**
*Class AB, <10Hz - 22kHz Filter*

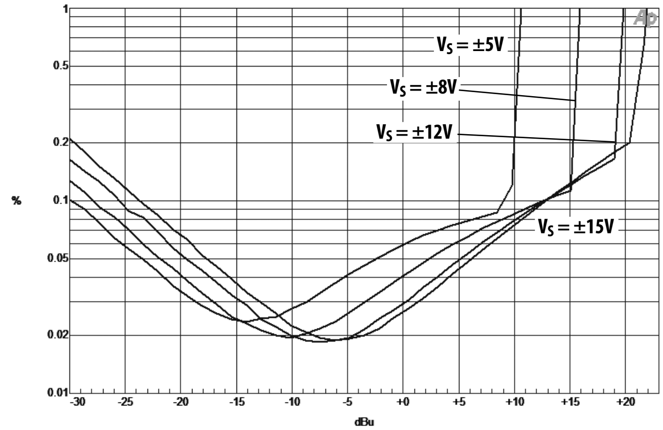



**THD+N vs. Amplitude Distribution - 12 Channels**
*Class A, <10Hz - 22kHz Filter*

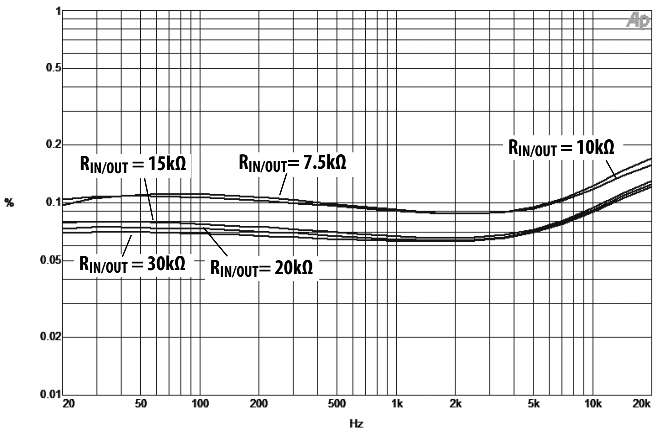
***About THD+Noise data.** As the name implies, THD+N measures total harmonic distortion *and* noise. In all cases, THD *without* noise will be lower than shown. The noise component will increasingly dominate graph data as signal levels decrease, for example, in THD+N vs. Amplitude graphs. Similarly, an otherwise "apples to apples" comparison between two lines under different noise conditions such as Class A vs. Class AB or differing $R_{IN}$ values may be affected. While one might dismiss the value of THD+N noise measurements, recall that both distortion and noise are undesirable so such information therefore shows all the things you *don't* want, which may be very useful when setting design limits.



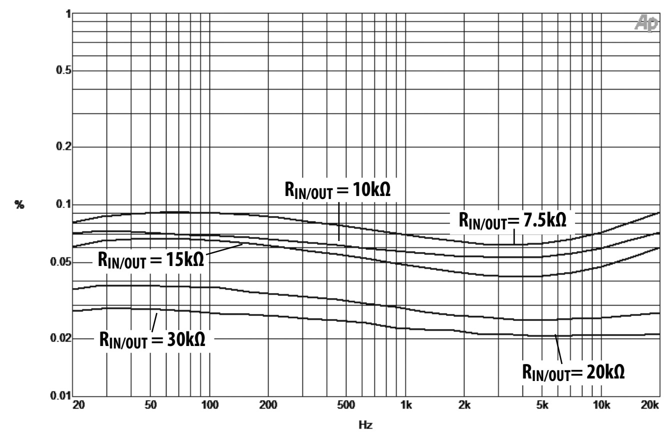

**THD+N vs. Amplitude vs. Supply Voltage**
*Class AB, <10Hz - 22kHz Filter*



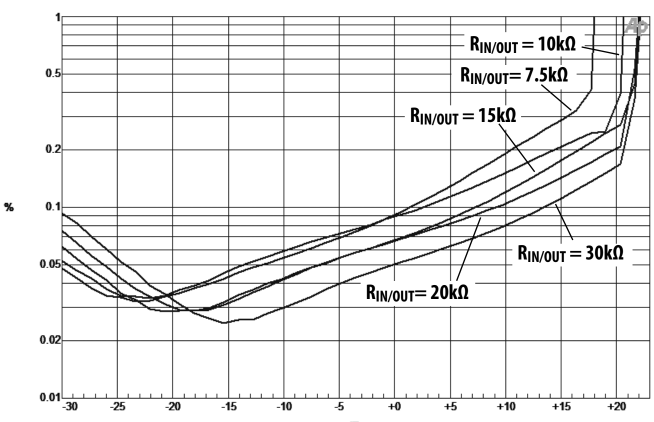

**THD+N vs. Amplitude vs. Supply Voltage**
*Class A, <10Hz - 22kHz Filter*



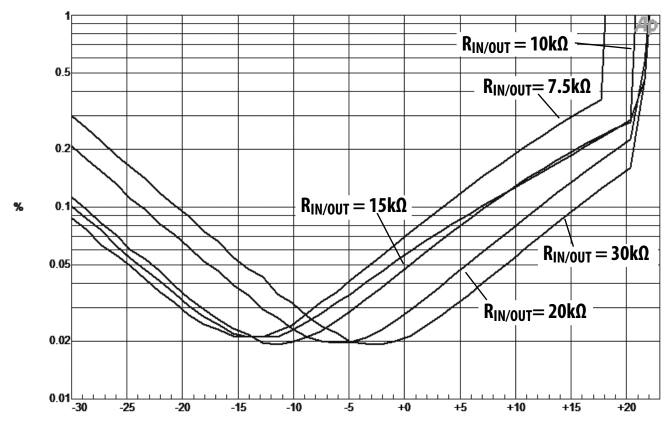

**THD+N vs. Frequency vs. $R_{IN/OUT}$**
*Class AB, 22Hz - 80kHz Filter*



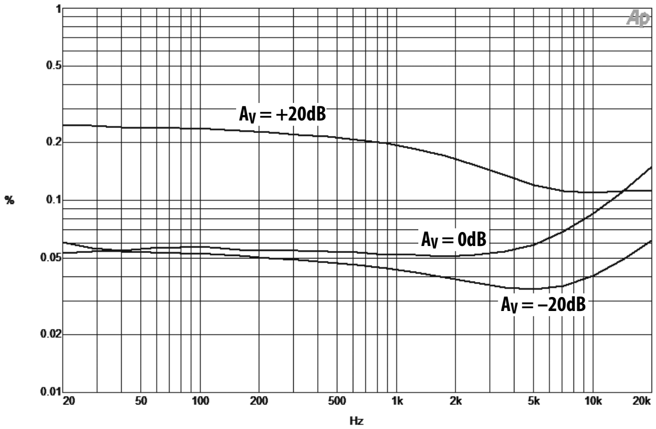

**THD+N vs. Frequency vs. $R_{IN/OUT}$**
*Class A, 22Hz - 80kHz Filter*



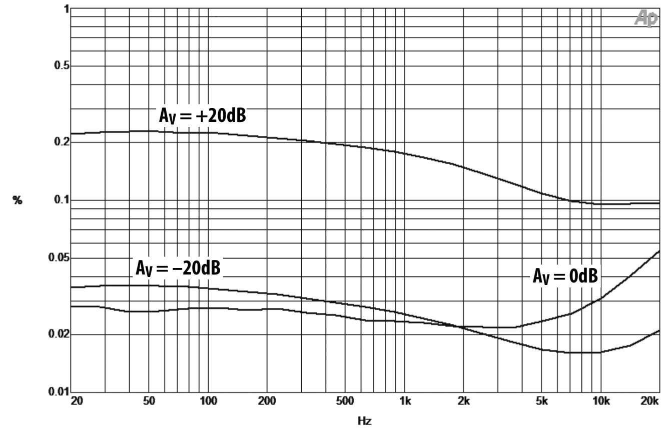

**THD+N vs. Amplitude vs. $R_{IN/OUT}$**
*Class AB, <10Hz - 22kHz Filter*



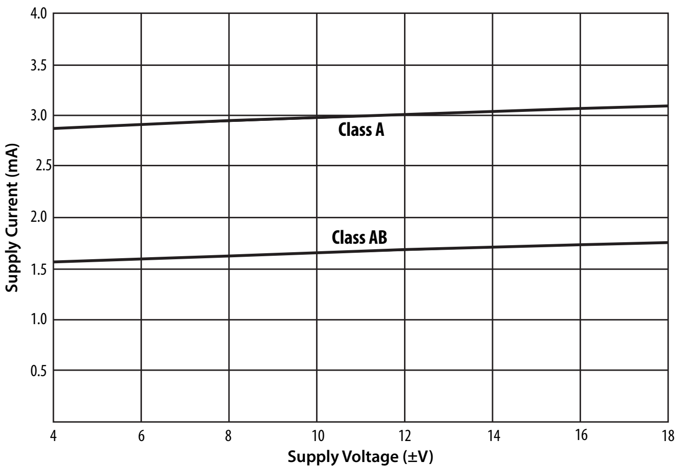

**THD+N vs. Amplitude vs. $R_{IN/OUT}$**
*Class A, <10Hz - 22kHz Filter*



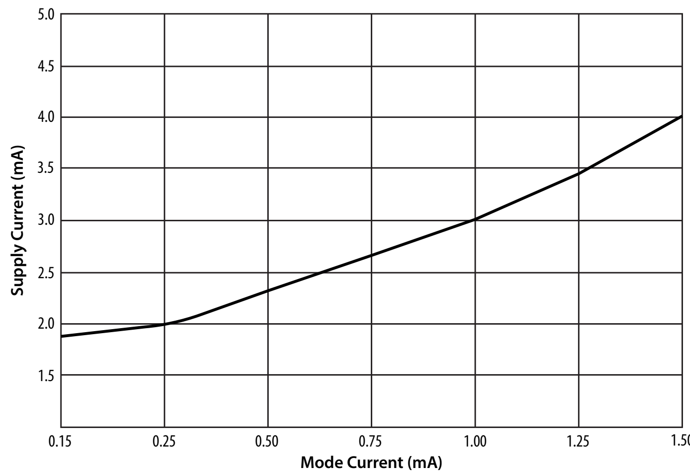

**THD+N vs. Frequency vs. Gain**
*Class AB, 22Hz - 80kHz Filter*




**THD+N vs. Frequency vs. Gain**
*Class A, 22Hz - 80kHz Filter*




**Supply Current vs. Supply Voltage**




**Supply Current vs. Mode Current**