AN702 APPLICATION NOTE

A Flexible 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. Figure1 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.

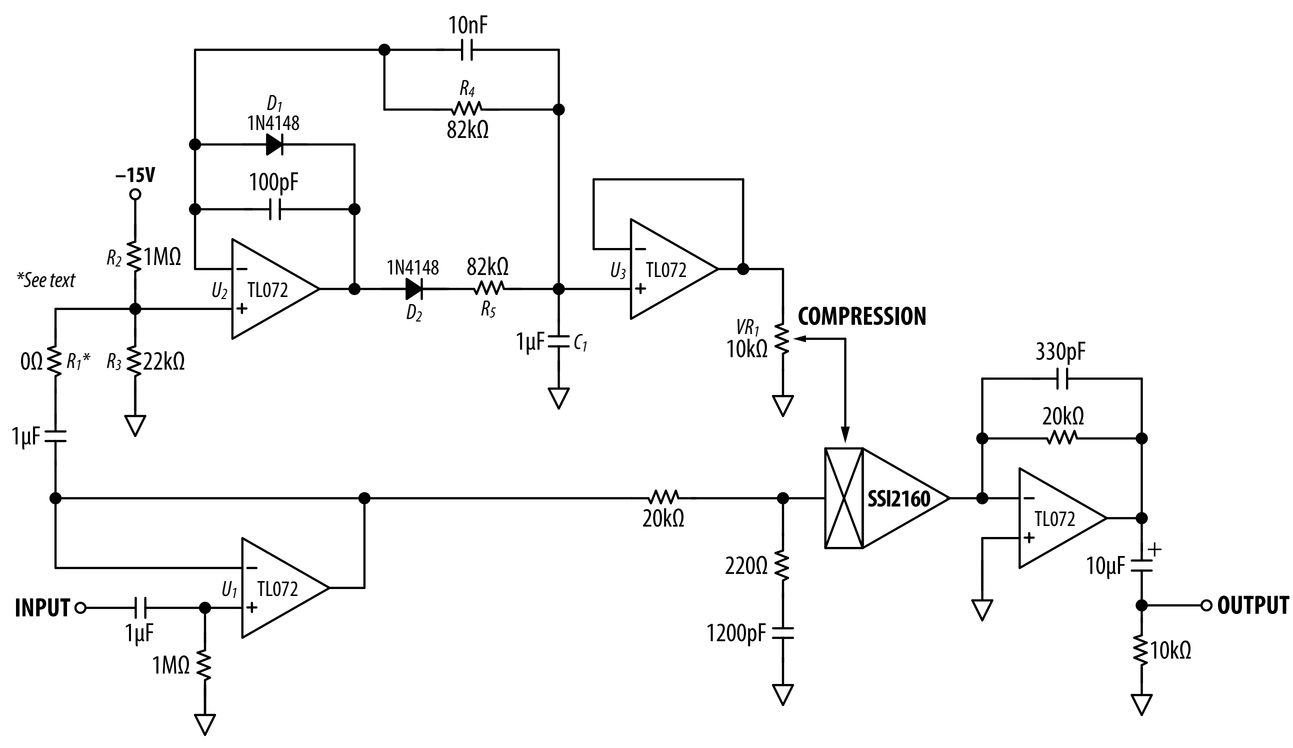

Figure 1: SSI2160-Based One-Knob Compressor

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Design 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.

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 $20V_{P\text{-}P}$ 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 ($10V_{P\text{-}P}$ 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 2 shows a modified envelope detector circuit with R4 and R5 augmented with potentiometers VR2 and VR3 to control

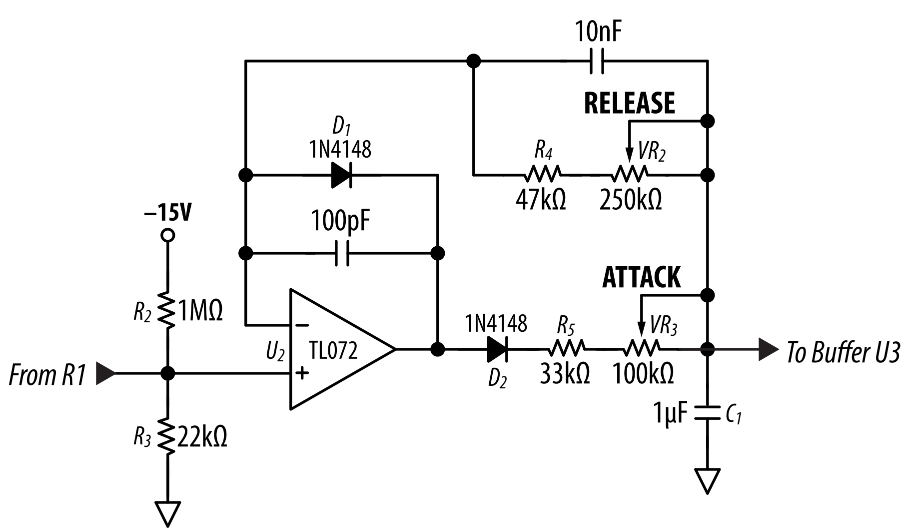

Figure 2: Envelope Detector with Attack and Release Controls

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.

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 3. 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.

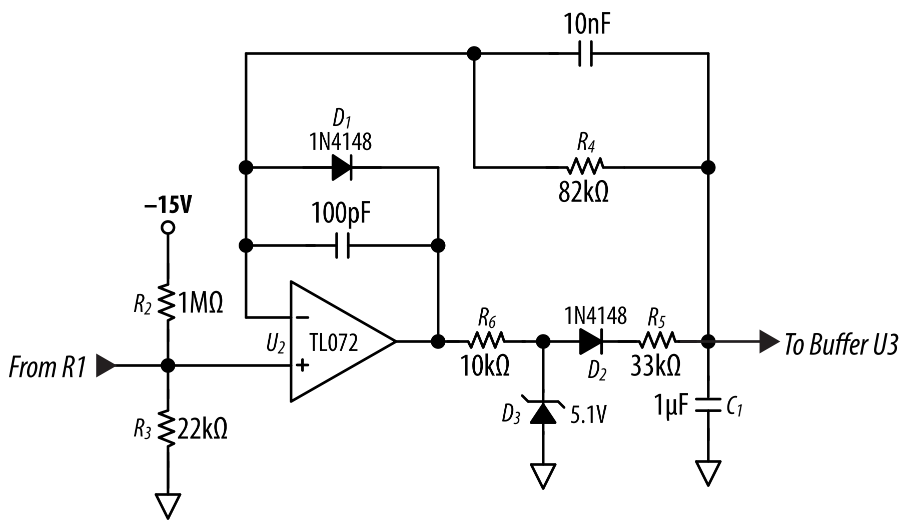

Figure 3: Envelope Detector with Voltage Clamp

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.

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}.

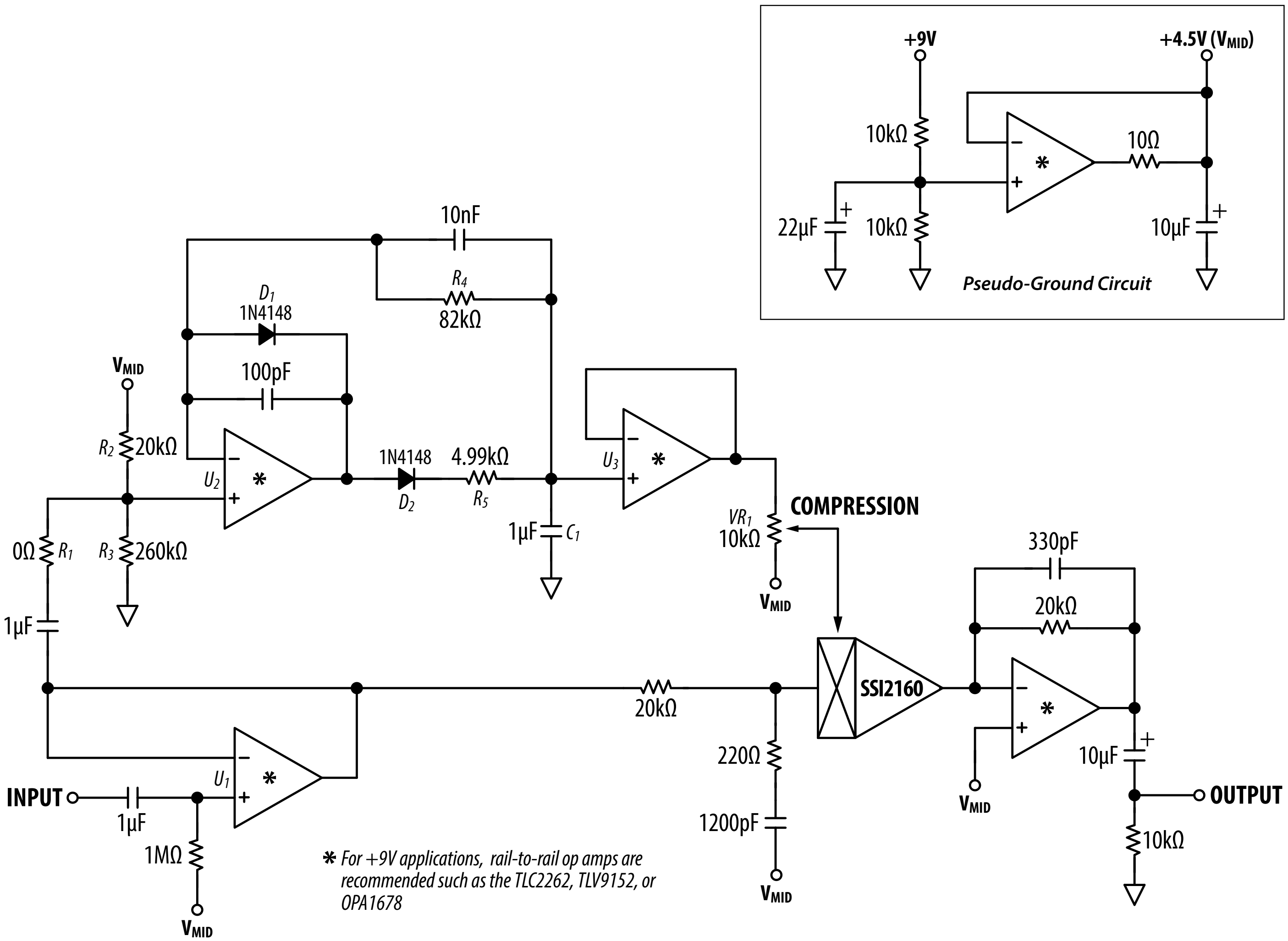

Figure 4: Compressor Modified for +9V Systems

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 4, 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.