

A Low-Cost VCA Limiter

The circuits within this application note feature THAT218x to provide the essential function of voltage-controlled amplifier (VCA). Since writing this note, THAT has introduced a new dual VCA, as well as several Analog Engines®. Analog Engines combine a VCA and an RMS detector (RMS) with optional opamps in one part. With minor modifications, these newer ICs are generally applicable to the designs shown herein, and may offer advantages in performance, cost, power consumption, etc., depending on the design requirements. We encourage readers to consider the following alternatives in addition to the 218x:

- *Analog Engine (VCA, RMS, opamps): 4301*
- *Analog Engine with low supply voltage and low power (VCA, RMS, opamps): 4320*
- *Analog Engine with low cost, low supply voltage, and low power (VCA, RMS): 4315*
- *Analog Engine with low cost and low power (VCA, RMS): 4305*
- *Dual (VCA only): 2162*

For more information about making these substitutions, please contact THAT Corporation's technical support group at apps_support@thatcorp.com

THAT Corporation

45 Sumner St, Milford, MA 01757-1656 USA; www.thatcorp.com; info@thatcorp.com

Introduction

THAT Corporation's VCAs, with their exponential control ports, and RMS Detectors, with their logarithmic outputs, make it possible to easily design a variety of compressors, expanders, and other dynamics processors, since the mathematics for these circuits is greatly simplified when working in the log regime. Additionally, with their predictable control functions, these devices allow designers to create circuits with repeatable compression or expansion ratios without having to match a specific detector to a given level-control device. This makes mass production a more reasonable proposition. However, these ICs are often the two most expensive components in a given dynamics processor. A common low cost application for these devices would be in protecting sub-woofers, and this design note attempts to demonstrate a technique for doing this in a cost effective manner.

To this end, consider the feedback compressor discussed in DNO3 (formerly AN103). We calculated that the compression ratio of a feedback limiter would be

$$C.R. = \frac{V_{in\ dB}}{V_{out\ dB}} = 1 + A$$

where A is the side chain gain. At very high compression ratios, A would be quite large. If A were 20, then the compression ratio would be 21:1, and for a signal 20 dB over threshold, the output would only change by less than one dB and consequently, the detector output would only change by approximately 6 mV! When the detector's excursion is this small, the output is operating on an essentially linear portion of the logarithmic output curve. Thus, in this special situation, one could readily substitute a linear detector in place of the RMS detector, and potentially save most of the cost of the detector.

A Really Inexpensive Limiter for Sub-woofers

The circuit in Figure 1 implements a feedback compressor with a VCA and a relatively cheap, linear peak detector. The VCA portion of the circuit uses a THAT 21B1, and is quite similar to the recommended application circuit, though we've omitted the symmetry adjustment, and increased the input and output resistors. U2A acts as a trans-impedance amplifier to convert the VCA's current output back into a voltage.

We've chosen not to adjust symmetry since this circuit is intended for low cost applications. Lowering the input and output currents often compensates to some degree for not adjusting symmetry, by maintaining the VCA in Class A operation for a wider range of input signals, though this does degrade noise performance somewhat. In any event, this particular circuit is aimed at applications (such as a sub-woofer) where a certain amount of 2nd harmonic THD would be, at worst, inconsequential, and in some cases, might actually be beneficial. If the THAT 21B1's maximum un-trimmed THD of 0.7% is unacceptable, the designer might want to consider the THAT 21B0LC, a cost effective, factory trimmed VCA which is pin compatible with the THAT 21B1.

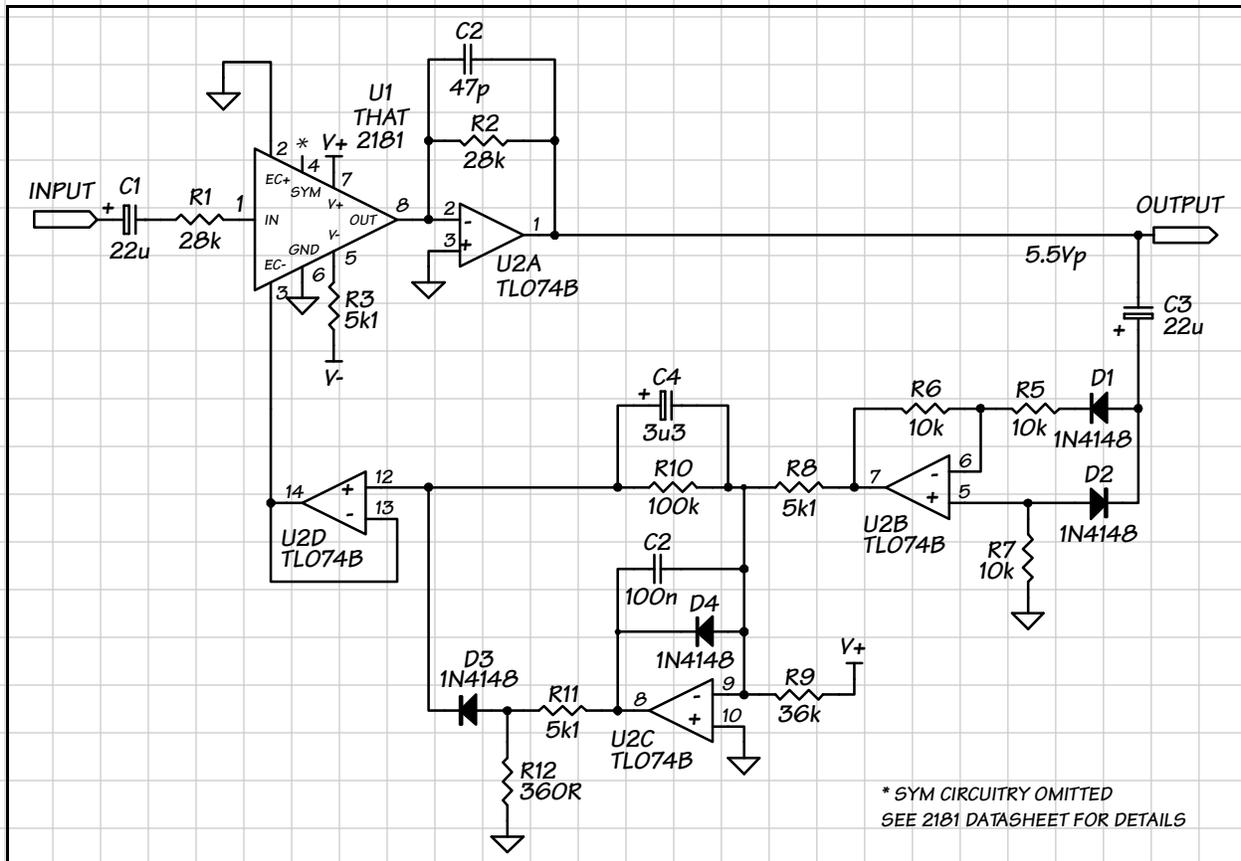


Figure 1. A single VCA feedback limiter

The output of the circuit is connected through a coupling capacitor to an inexpensive full wave rectifier circuit composed of U2B and its surrounding components. During the positive half-cycle, D1 is conducting, and the amplifier acts as an inverting amplifier with a gain of

$$A_V = \frac{-R_6}{R_5} = -1$$

During the negative half-cycle, D2 is conducting, and D1 is turned off. This results in the amplifier acting as a follower with a gain of one. The end result is that the output of U2B is a full wave rectified version of the VCA's output, minus a diode drop. The forward drops of D1 and D2 have a -2.2 mV/°C temperature coefficient, and this will affect the level at which limiting occurs. To minimize this effect, it is important that the VCA output level be large (relative to 2.2 mV) at the limit threshold.

U2C and its surrounding components comprise the threshold amplifier with a gain of 20. This circuit also performs peak detection. U2D is a simple buffer for the control port. Assume that we want to limit at 8 V_{PP} or 4 V_P. This will leave us with a signal of about 3.5 V_P after the forward drops of D1 and D2. The result is a full wave rectified wave form at the output of U2B. The average DC level of this wave form is

$$V_{Avg} = 3.5 V_{PP} \times 0.63 = 2.2 V_{Avg}$$

Thus, the average current through R8 is

$$I_{Avg} = \frac{2.2 V_{Avg}}{5.1 k\Omega} = 430 \mu A$$

R9 injects an offset to modify the threshold. The current through R9 must equal the current through R8 at the threshold level. Assuming $\pm 15V$ supplies, the value that R9 is required to be is

$$R9 = \frac{15 V}{430 \mu A} \cong 36 k\Omega$$

This value is reflected in Figure 1.

When the signal is below threshold, the current sourced by R9 is sunk through D4, and the control port buffer's output stays at zero volts. As the output crosses the threshold, the output of U2C goes positive, and D3 begins to conduct. Since the op-amp's feedback loop is now closed through R10, the gain of the threshold amplifier is

$$A_V = \frac{-R10}{R8} = -20$$

resulting in a compression ratio of 21:1. As such, this circuit meets the criteria that we originally established for using a linear detector with an exponential VCA in a limiter application.

The transfer function for this circuit is shown in Figure 2. Note that below the threshold, the signal is passed unmodified, though there is a slight gain error due to a combination of

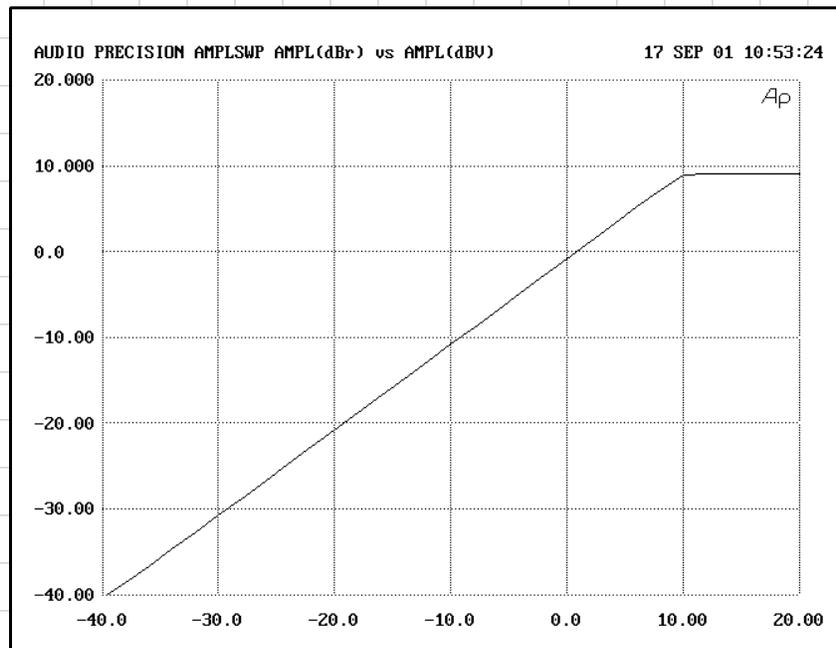


Fig 2. Transfer function of a single VCA compressor

mismatches of input and output resistors, and the V_{05} of U2D, which was measured to be 4 mV or approximately two thirds of a dB. The threshold is at

$$\text{Threshold} = 10^{\frac{9\text{dB}}{20}} \times \sqrt{2} \cong 4 V_P$$

For all practical purposes, the signal is infinitely compressed above this level.

Earlier, we mentioned that there is a $-2.2 \text{ mV}^\circ\text{C}$ temperature coefficient associated with the forward drop of D1 and D2. When the circuit's output is large, then the effect is

$$\text{T.C.} = \frac{2.2\text{mV}}{3.5\text{V}} \times 100 = 0.063\% / ^\circ\text{C} ,$$

which is significantly lower than the $0.33\% / ^\circ\text{C}$ temperature coefficient of the VCA's control port.

While this circuit works very effectively as an infinite compressor, it is not without its limitations (pun intended). Near-infinite compression is the only compression ratio that can be used. Furthermore, since this uses a peak detector, compressor artifacts like pumping are exacerbated compared to a compressor using an RMS or averaging detector. As a consequence, the designer may want to consider allowing this compressor to limit only a selected band of frequencies, such as a sub-woofer channel, or by using the limiter in a multi-band system like that described in THAT's design note DNO4 (formerly application note AN104).