Input Limiter for ADCs

The circuits within this application note feature THAT218x to provide the essential function of voltage-controlled amplifier (VCA) and THAT 2252 as an rms-level detector (RMS). Since writing this note, THAT has introduced a new dual VCA, as well as several Analog Engines®. Analog Engines combine a VCA and am 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 and 2252:

- Analog Engine (VCA, RMS, opamps): 4301
- Analog Engine with low supply voltage and power consumption (VCA, RMS, opamps): 4320
- Analog Engine with low cost, supply voltage, and power consumption (VCA, RMS): 4315
- Analog Engine with low cost and power consumption (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.

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This circuit is composed of an input attenuator to accommodate both pro and consumer levels, a THAT 2252 level detector with a non-linear timing capacitor for optimum response, a side-chain, and a THAT2181A VCA.

RMS Level Detector

The RMS detector acts by rectifying the signal in the current domain, logging and squaring it, and then averaging the result in a log filter. On the THAT 2252, there are three parameters the designer is required to set:

The timing current

The bias current

The zero dB reference level.

In this circuit, the attack and release behavior is determined by the non-linear capacitor. More information on the design and behavior of the non-linear capacitor can be found in Design Note 107 and at the end of Design Note 03 (formerly Application Note 103).

Timing Current

The simplest linear averaging filter consists of a series resistor and a shunt capacitor. This sort of filter would give erroneous results to a signal that is already in the log domain. Consequently, the level detector in the THAT 2252 uses a log domain filter, which consists of a series diode, and a shunt capacitor, where the effective nominal resistance of the diode is inversely proportional to its g_m , which is determined by the DC current running through it.

$$R_{EQ} = \frac{1}{g_M} = \frac{V_T}{I_T} g \text{ , where } V_T \cong 26 \text{ mV at } 27^\circ C$$

In this circuit, we have set the timing current to 7.5 μA, as recommended in the data sheet

$$R18 = \frac{V_+ + 2V_D}{I_T} = \frac{15V + 2 \times 0.7V}{7.5\,\mu A} = 2.2 \text{ M}\Omega$$

Bias Current

Set the level detector's bias current to 24 μA as recommended in the data sheet.

$$R17 = \frac{V_+ + 3V_D}{I_{BIAS}} = \frac{15V - 3 \times 0.7V}{24\,\mu A} \cong 560 \text{ k}\Omega$$

Zero dB Reference Point

In order for the threshold setting to be centered properly, the RMS level detector needs to have its zero dB reference point set at a known level. There is a particular level of input current, which is dependent on the timing current, that will result in zero volts out of the RMS detector.

This level of input current is the zero dB reference current, or I_{in0} , and can be derived from the timing current and the bias current using the formula:

$$I_{in_0} = \frac{\sqrt{I_{BIAS} \times I_T}}{2.9} = \frac{\sqrt{24\,\mu A \times 7.5\,\mu A}}{2.9} \cong 4.6\,\mu A$$

In this design, we have chosen -4 dBu as the maximum zero dB reference level at the input, which is equivalent to -10 dBu at the output of the input attenuator. This results in

$$V_{in_0} = 0.775 \times 10^{\frac{-10dBu}{20}} = 0.245\, V_{RMS}$$

at the input of the detector. Using V_{in0}, we can calculate R16, the level detectors input resistor:

$$R16 = \frac{V_{in_0}}{I_{in_0}} \cong 51\, k\Omega$$

Note that the zero dB reference level has a ±3 dB tolerance, which we will compensate for later.

RMS Detector Output

By convention, one always references the control voltage constant ($K_{control}$) from the VCA control port back and then applies a sign that will result in positive gain at that control port. One must then take into account the number of inversions in the side chain AND which port of the VCA is being driven, with the upshot of this being that by the time you work your way back to the RMS detector, the sign of $K_{control}$ will depend on the function that you're implementing. For a compressor, $K_{control}$ at the output of the RMS will be negative (higher signals cause less gain, lower signals cause more gain). For an expander, the sign will be positive. The magnitude will depend on the ratio that's being implemented. We usually label things as if the ratio control on a compressor is at infinity to 1, but on some schematics it might be fixed at some lower ratio. Thus, one can envision a fixed 4:1 ratio compressor where you would end up with a scaling at the RMS output of -1.5 mV/dB. In this design, the $K_{control}$ at the output of the level detector is -6.1 mV/dB.

Threshold Amplifier and Adjustment

The VCA has a gain of one (zero dB) when its control port is at zero volts. The threshold amplifier, otherwise known as an operational rectifier, keeps the control port at zero volts until the signal exceeds the threshold level and the VCA begins compressing.

While the input is below threshold, U2B servos its input via D2, and D1 isolates the threshold amplifier from the control voltage buffer.

When the input rises above the threshold level, U2B's feedback loop is closed via D1, and the resulting gain of this stage is

$$A_V = \frac{-R5}{R3} = \frac{-10\, k\Omega}{4.99\, k\Omega} = -2$$

As a consequence, the $K_{control}$ is 12.2 mV/dB (referenced to the VCA's control port) at this point in the circuit. At the input to the VCA and RMS detector, which is after the input attenuator, the threshold level is still at -10 dBu, or 0.245 mV_{RMS}. R12 is included as a means of offsetting the threshold, and its value can be calculated with the equation

$$R12 = \frac{10.0\ k\Omega \times 15\ V}{0.0122\ V \times (threshold - (-10\ dBu))}$$

VR2 is available to compensate the ±3 dB tolerance in the zero dB reference level.

Control Voltage Buffer

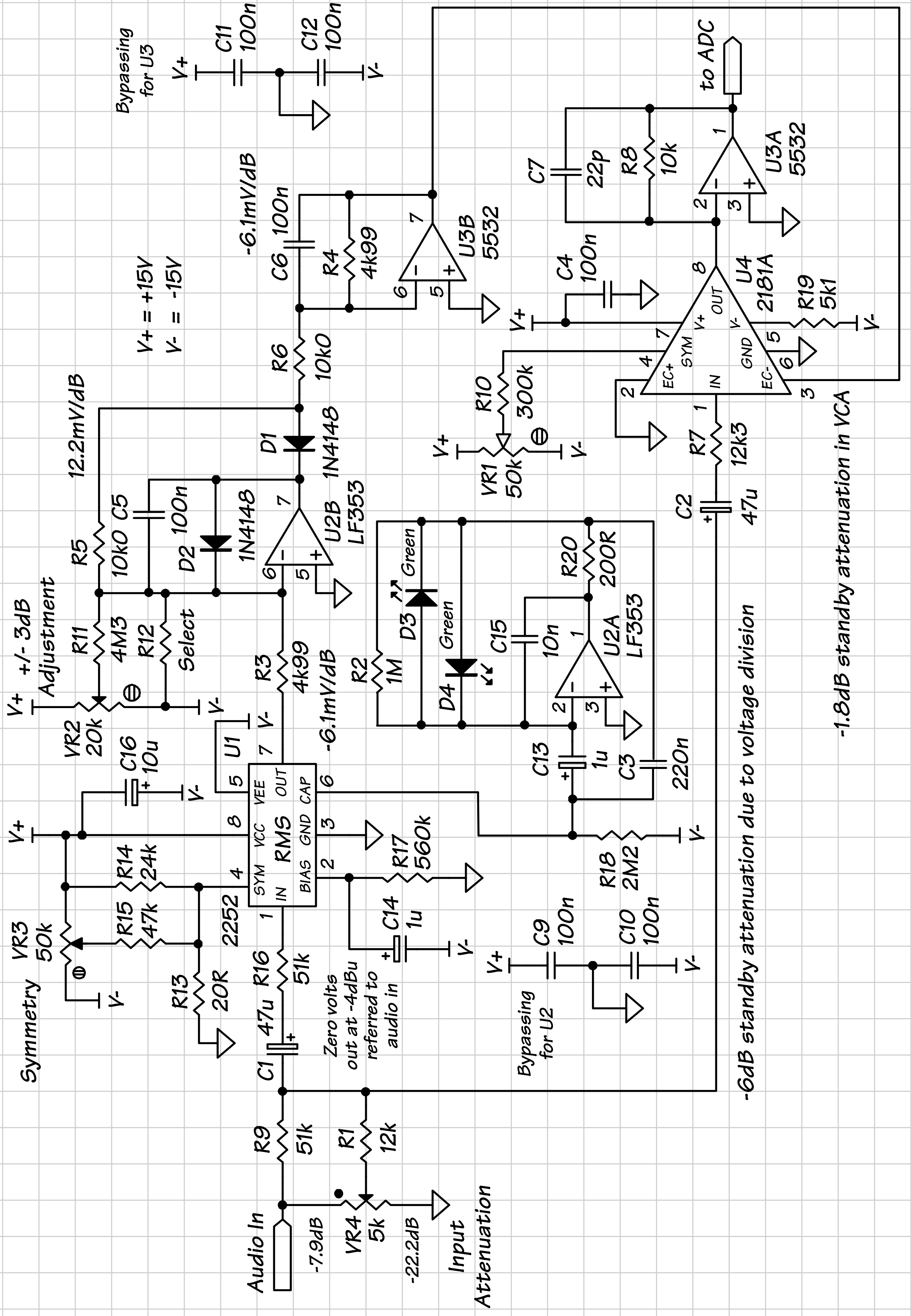
The control voltage buffer scales the control voltage appropriately, and ensures that the control port sees a sufficiently low impedance. This amplifier has a signal gain of -0.5, which returns the $K_{control}$ to -6.1 mV/dB

The VCA

In this design, we have chosen a THAT 2181A VCA. This device is THAT Corporation's best VCA. It is fabricated in a complementary, dielectrically isolated IC process, and exhibits the best performance available in any IC VCA. It has lower noise and lower distortion, particularly at higher frequencies, than any other IC VCA available. The factory pre-trimmed version of this device, the 2180X, is also available, but in SIP package only. If using the 2180X, VR1 and R10 can be omitted.

The level detector in this circuit has a finite response time, and as such, there will be a short period of time where the ADC may clip, before the compressor can adequately limit the gain. Most ADCs clip gracefully, and the result is inaudible when using a compressor to limit longer excursions. However, if your ADC cannot tolerate any excursion beyond its normal input range, you may need to add a hard clipper to limit the signal during transient volume peaks.

Both the level detector and the VCA have PTAT temperature coefficients. Thermally coupling the two devices minimizes gain errors, since these devices tend to compensate each other.



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