Application Report
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Interfacing the VCA8617 with High-Speed Analog-to-Digital Converters

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ABSTRACT

The VCA8617 is an 8-channel variable gain amplifier ideally suited for portable and mid-range ultrasound applications. Each channel consists of a Low Noise Amplifier (LNA) and a Variable Gain Amplifier (VGA). The VGA contains two parts: a voltage-controlled attenuator (VCA) and a programmable gain amplifier (PGA). The PGA output feeds directly into an integrated 3-pole low-pass Butterworth filter. This integrated filter prevents the need for an external filter between the VCA and the analog-to-digital converter (ADC). This application report discusses different methods of interfacing the VCA8617 with various ADCs, particularly the ADS527x and ADS512x families.

1 Using the VCA8617 with the ADS527x

The ADS527x family of ADCs from Texas Instruments is a series of octal 3.3V converters that offer high-performance, 12-bit solutions at various speed nodes, except for the ADS5277, which is a 10-bit, 65MSPS solution.

The VCA8617 output pins sit at a nominal common-mode dc voltage of 1.5V. The input pins of the ADS527x family sit at 1.5V common-mode dc voltage, as well. This correlation means that it is possible to dc-couple the VCA8617 with the ADS527x family in a fairly straightforward manner. DC-coupling would eliminate the space required by 16 capacitors placed between the VCA8617 and any of the ADS527x devices.

The VCA8617 output impedance is very low. Consequently, a 25Ω to 50Ω resistor is recommended, placed in series between the VCA8617 and the ADS527x. Best results are obtained when a small capacitor (5pF to 10pF) is used between the positive and negative inputs of the ADS527x.

The ADS527x family has an internal 600Ω resistor from each input pin to common-mode. The small 25Ω to 50Ω series resistor, in conjunction with the 600Ω shunt resistor, provides a small attenuation factor. Users should take this attenuation factor into account when interfacing the VCA8617 with an ADS527x device. Note also that this 600Ω resistor is fixed.

Figure 1 illustrates this solution.

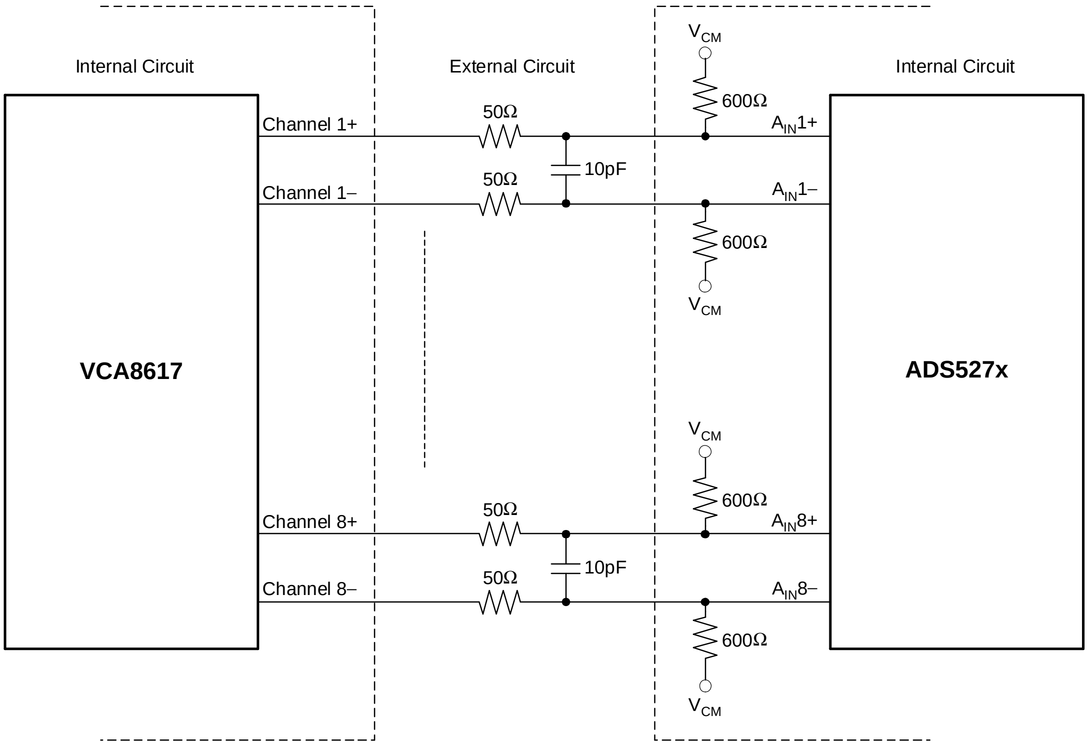

Figure 1. DC-Coupled Interface Between VCA8617 and ADS527x

While dc-coupling appears to be the simplest possible method to interface the VCA8617 with the ADS527x, ac-coupling is the recommended solution. There are several reasons why ac-coupling may provide increased functionality for end-user applications.

First, there is an inherent output common-mode variation associated with the output pins of the VCA8617. This variation increases as the PGA gain setting increases. Final test measurements show that at the highest post gain (PG) gain setting of 11, this variation can be as high as 100mV to 150mV. (Note that most production units fall within ±50mV of 1.5V, which is also within the tolerance of the ADS527x input pins. However, there are units which may shift slightly more.) This variation decreases as the PG gain settings decrease; at the lowest PG setting of 00, this variation seems to be less than half the variation observed at the highest PG gain setting.

One other point of note here is that between the positive and negative output pins, the offset of any one channel is almost negligible. It is only the absolute value that appears to vary. The problem is that the offset shift might generate a slight loss in overall dynamic range. This variation is observed over PG gain settings from channel to channel as well as from device to device. AC-coupling the VCA8617 and the ADS527x resolves this problem.

Second, there is also a settling time observed at the output of the VCA8617 when the control voltage is pulsed. The output settles after several time constants; the time constant is set by the internal value of an RC circuit between the VCA and PGA. AC-coupling at the output can override this internal time constant and can enable the VCA8617 to recover quickly. The shorter the acceptable time constant, the more quickly the VCA8617 appears to settle.

An ac-coupling capacitor value of 500pF was tested by Texas Instruments, and appears to provide no degradation in performance. Keep in mind that there is an internal 600Ω resistor inside the ADS527x, from each input pin to common-mode.

While the combination of the 500pF capacitor in series with a 50Ω resistor and the internal 600Ω resistor seems to work well, TI recommends that each user come to his or her own conclusion by trying various combinations, and choosing that combination which works best to fit the system requirements.

Figure 2 illustrates one approach to this solution.

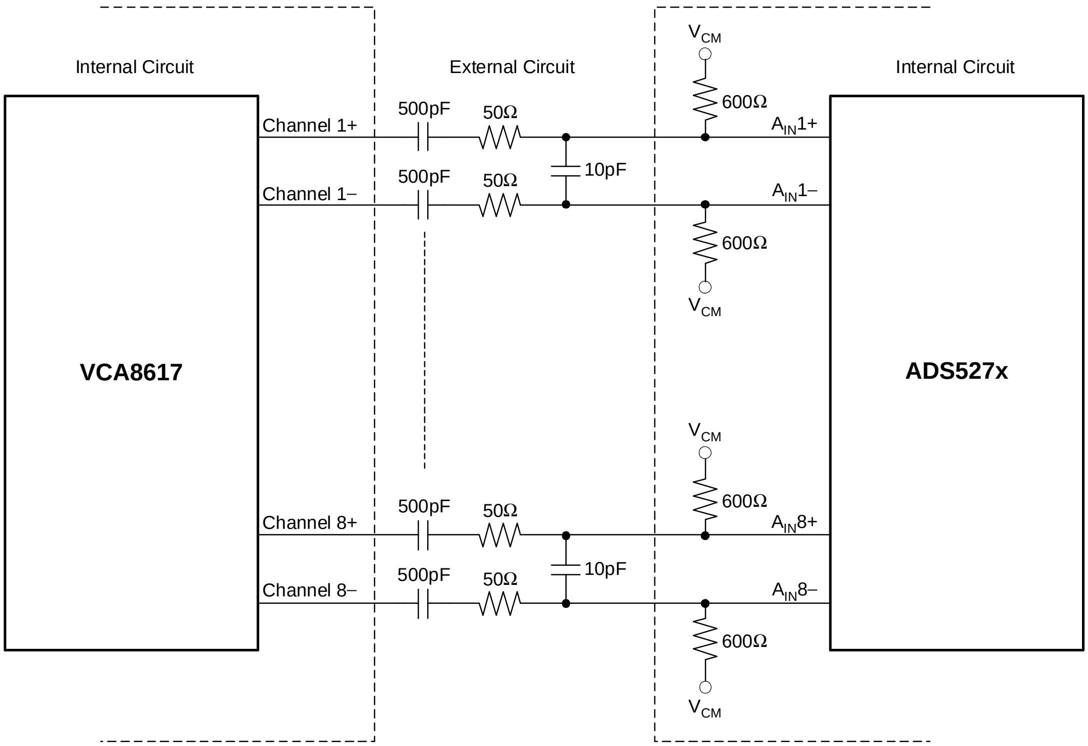

Figure 2. AC-Coupled Interface Between VCA8617 and ADS527x

2 Overload Conditions

The VCA8617 output pins can output more than $1V_{PP}$ in single-ended mode, or greater than $2V_{PP}$ in differential mode. Back-to-back clipping diodes across the input and output of the PGA limit the output signal of the VCA8617 to approximately 0.6V to 0.7V peak on each output. This limited output means that the clipping diodes turn on when the signal reaches roughly $2.4V_{PP}$ to $2.5V_{PP}$ in differential mode. Under heavy overload conditions, even when the signal is clipped, the VCA8617 can output slightly more than $3V_{PP}$. Since the input of the ADS527x can only handle $2V_{PP}$ in the linear region, the ADS527x ADC will overload when the VCA8617 output exceeds $2V_{PP}$. The ADS527x will recover to 1% accuracy within 3 to 4 clock cycles. This rate means that a recovery to 1% accuracy occurs within 80ns at 50MSPS. If this recovery time is sufficient, then the above-described solutions should work well in all systems.

If it is necessary to protect the ADS527x ADC further, TI then recommends that the user increase the value of the series resistor from between 25Ω to 50Ω to approximately 300Ω. This increase ensures that the ADS527x ADC will never overload, even when the VCA8617 is severely overloaded. The downside to this solution, however, is that the 300Ω series resistor in conjunction with the 600Ω shunt resistor will cause a 33% attenuation factor, even at low signal levels when no attenuation is required.

3 Interfacing the VCA8617 with the ADS512x family

The ADS512x devices are an octal, 1.8V ADC family that provides 10-bit solutions. The input common-mode of the ADS512x family is $1V_{PP}$. Please note that the input pins require external biasing. Consequently, it is not possible to dc-couple the VCA8617 with the ADS512x family. AC-coupling is the only option available to users who wish to combine the two devices. TI recommends an ac-coupling capacitor of at least 300pF and a resistor value of at least 1kΩ to the external common-mode of 1V.

Once again, a small series resistor (20Ω to 50Ω) is recommended between the VCA8617 and the ADS512x inputs. A 47pF capacitor is also recommended between the positive and negative inputs of the ADS512x. Figure 3 illustrates the suggested solution.

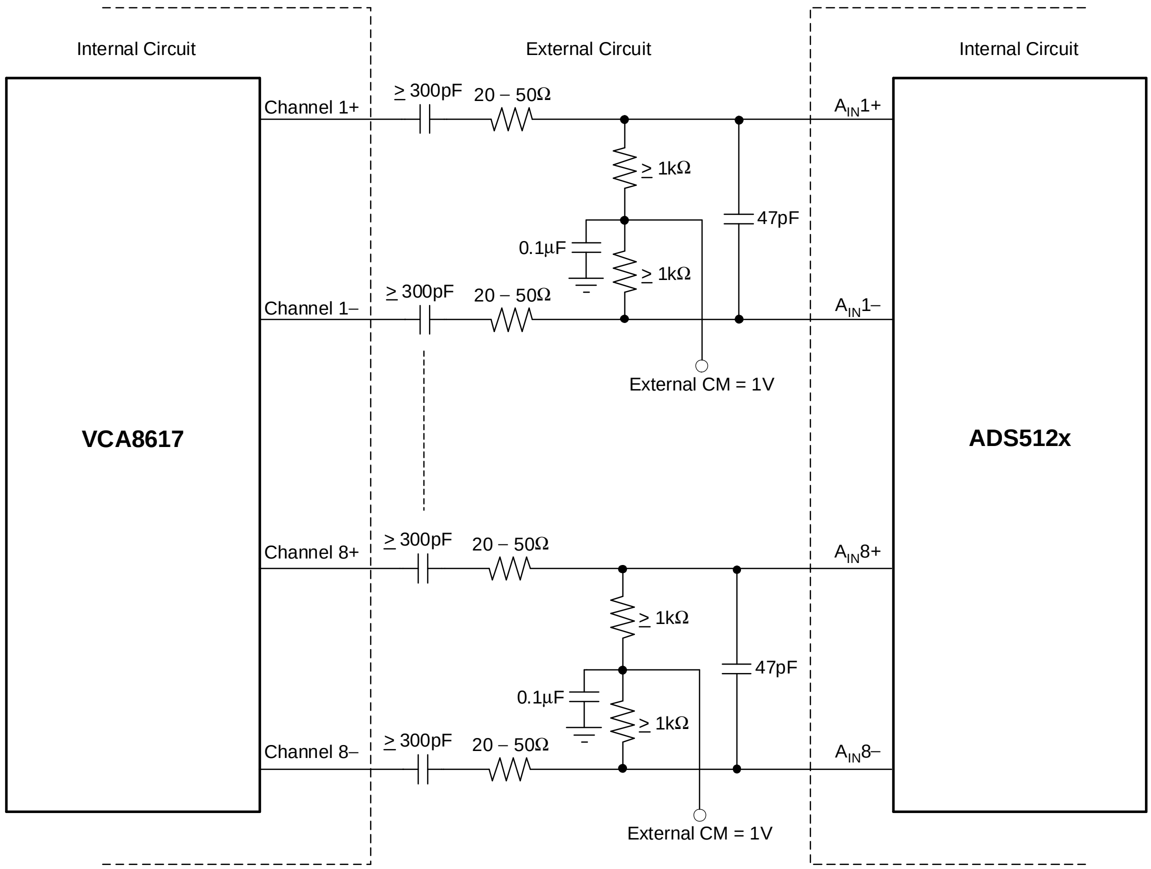

Figure 3. AC-Coupled Interface Between VCA8617 and ADS512x

Texas Instruments recommends that users test and validate their own values of capacitors and resistors in order to identify the combination that works best in their respective applications with the VCA8617 and the ADS512x.

4 Overload Conditions

The ADS512x family can handle a maximum signal amplitude of $1V_{PP}$ differential in the linear region. This means that any signal amplitude in excess of $1V_{PP}$ at the output of the VCA8617 will overload the ADS512x.

Since the ADS5121 operates on a low 1.8V supply voltage, its differential input signal range is limited to $1V_{PP}$ full-scale. Most devices suitable to drive the ADS5121, including the VCA8617, have the capability of delivering a much larger signal swing on the outputs, and can therefore put the ADS5121 into an overload condition. Here, two conditions should be considered. The first condition is that the input signal exceeds the full-scale range, but remains within the supply rails (0V, 1.8V). Second, the input signal exceeds the supply rails by more than 0.3V, which means that the input signal approaches the absolute maximum ratings for the device and should be avoided if possible.

In the first case, if the signal amplitude swings above 1.34V or below 0.82V (approximately), the ADC output will read either all '1's or all '0's. The output code remains at these endpoints as long as the overload condition persists, and will not roll over. Once the output signal returns to the normal full-scale range, the ADS5121 will recover within 20ns (typically) at 40MSPS. In addition, it may take a 6.5 clock cycles (data latency) to flush the pipeline and discard the invalid data.

Care should be taken to avoid the second condition in which the input signal swings above or below the supply rails. Such an incident can cause the internal protection diode to conduct and open a low-impedance path to ac-ground. No dc current will flow because the VCA8617 is ac-coupled; however, this condition could severely load the VCA outputs.

5 Conclusion

The VCA8617 can be interfaced with TI's ADS527x family as well as the ADS512x family of high-speed data converters. While the VCA8617 can be dc-coupled to the ADS527x, it is recommended that customers ac-couple the VCA8617 with the ADS527x family instead because of the inherent output common-mode variation in the VCA8617. The VCA8617 must be ac-coupled when interfaced with the ADS512x.

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