VCA8617: Response to Step Change in Gain Control

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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 (A/D) converter. This application report discusses the response of the VCA8617 when a user increases the gain control voltage by a step change.

1   Mechanism of Response to a Step Change in the Gain Control Voltage

Figure 1 shows a simplified block diagram of the VCA8617.
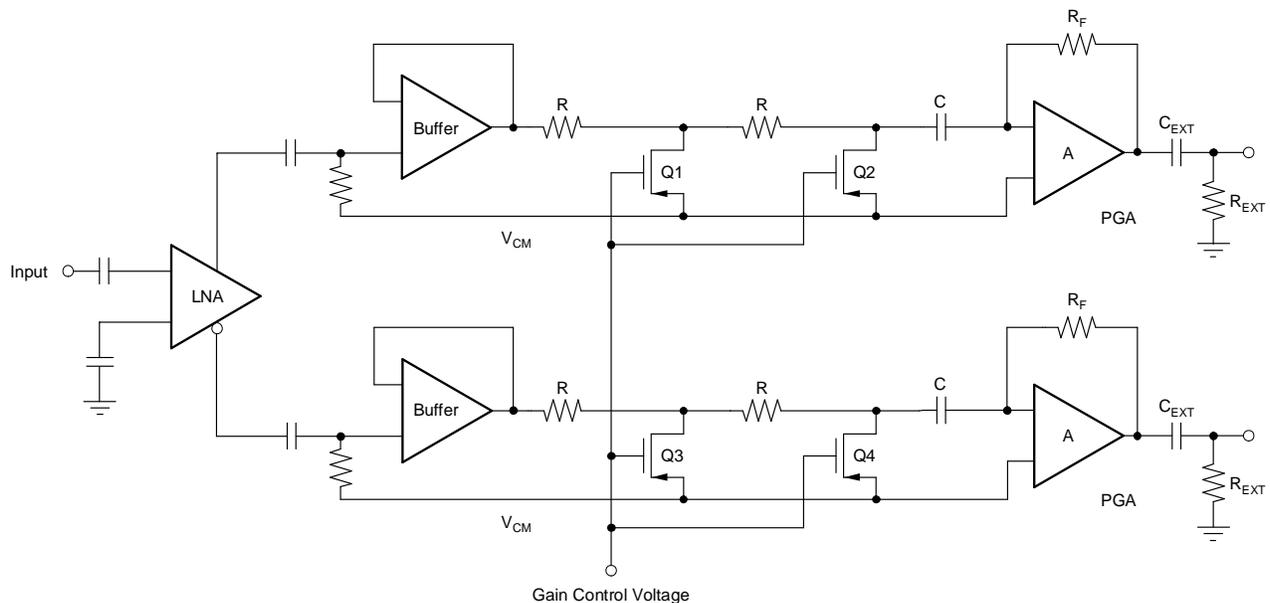
Figure 1. Block Diagram of the VCA8617

The VCA8617 has a short settling time when the gain control voltage is pulsed. The mechanism of this response is described in detail below.

Assume that the gain control voltage (GCV) is initially set to about 0V. At this voltage, the attenuator is set to the maximum attenuation as FETs Q1 through Q4 all have a low impedance of about 10Ω. The value of R is approximately 100Ω. Therefore, through either Q2 or Q4, voltage V_{CM} is on one side of capacitor C. Feedback resistor R_F causes the other side of capacitor C to be equal to V_{CM} as well. Therefore, the voltage across capacitor C is also at 0V, because the input to the attenuator has no effect since the attenuator has about 40dB of attenuation. When the gain control voltage is set to $\pm V_{CM}$, the FETs are turned off.

Figure 2 shows the waveforms that result when the GCV undergoes a step change. If the GCV experiences a step change, the voltage at the junction of resistor R, Q2 and capacitor C goes to the output voltage of the buffer, which is $(V_{CM} + V_{OFF})$. V_{OFF} is the offset of the Buffer. The step change will also be seen at the output of the PGA amplified by the PGA gain.
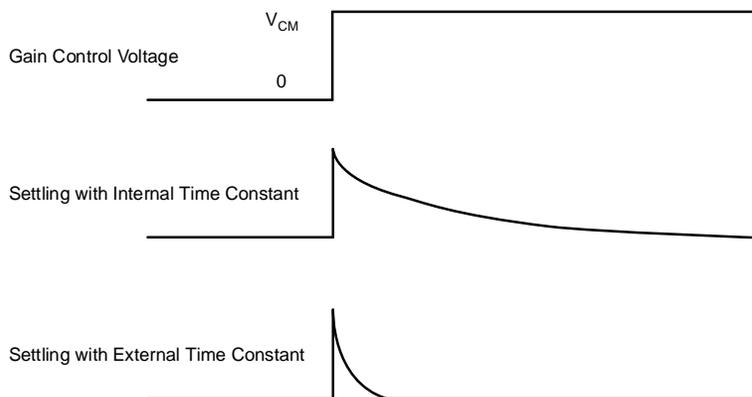
Figure 2. Settling with Internal and External Time Constants

The PGA output will then decay based upon the time constant given by the formula in Equation 1:

$$T = \frac{R}{(1+A)} \cdot C$$

(1)

where A is the PGA gain. This time constant was made to be about 30µs in order to achieve low 2nd-harmonic distortion when the PGA overloads. Another reason for the length of this time constant is that as the time constant increases, the VCA behaves more like a DC-coupled system, which in turn helps improve the distortion of the VCA under pulsed sine wave conditions.

2 Reducing the VCA8617 Settling Time when the Gain Control is Pulsed

A much faster time constant, together with a shorter recovery time, can be achieved by connecting the VCA output to an external time constant. The value of the 2nd-harmonic distortion is not affected when measured through the external time constant. Figure 2 shows the effect of an external time constant versus an internal time constant.

Measurements were performed in the lab in order to show external time constant effects on settling time.

Figure 3 illustrates the gain control pulse performance of the VCA8617. Channel 1 shows the gain control being pulsed. Channel 2 shows the settling time using an external time constant of 10µs. Channel 3 shows the settling time using an external time constant of 800ns. Channel 4 shows the settling time using an external time constant of 350ns, where the settling time is less than 1µs.
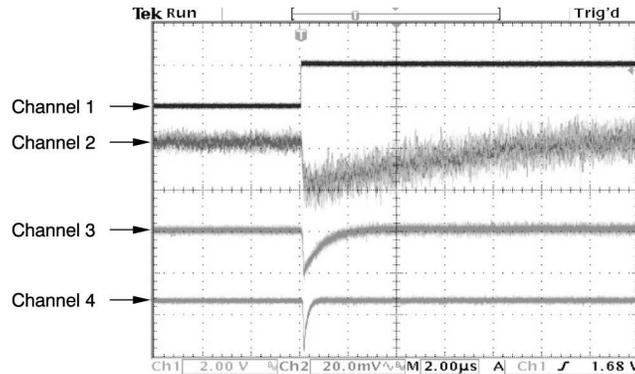
Figure 3. Gain Control Pulse Performance of the VCA8617

If the $V_{CONTROL}$ pulse does not instantaneously rise from 0V to 2V, then we can possibly reduce the external time constant even further; for example, down to 200ns. This decrease would produce a low frequency –3dB bandwidth of roughly 800 kHz.

Please note that users are advised to come up with their own combination of external capacitor and resistor values that best fit the performance of their individual systems. The numbers that TI provides are only recommendations, and serve as good starting points.

Also note that the use of an external capacitor means that if the VCA8617 was interfaced with an A/D converter, then the user is basically AC-coupling the VCA with the A/D converter. Such a configuration would also reduce any dynamic range loss issues if the VCA output common-mode did not match with the converter input common-mode.

3 Conclusion

The VCA8617 has a short settling time when a step change is introduced in the gain control voltage input. This settling time can be further reduced by using an external time constant at the output of the VCA8617.

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