Continuous Wave (CW) Signal Conditioning in Ultrasound Systems Using ADS92x4R

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Description

In medical imaging systems, Continuous Wave (CW) Doppler is used to measure the blood flow inside the human body. During CW, a sine wave is transmitted continuously by half of the transducer array as shown in Figure 1 and the other half of the array receives the reflected signal. The system usually uses high-frequency waves (several MHz or more) to image body structures. The reflected signal is weak and has a small signal amplitude (uV to mV range), so the ADC selected for in signal conditioning path must have both high speed and precision. Also, under a trend of home health care, portable ultrasound device are becoming more and more popular, which brings the challenge of reducing solution size while keeping the high performance intact.

This document discusses how I and Q signals are measured after an AFE in an ultrasound system, as well as how the features of the ADS92x4R family of dual-channel, simultaneous, 14- or 16-bit 3.0 MSPS SAR ADCs with a space-saving 5 mm x 5 mm VQFN package, which makes the ADS92x4R device family the default choice for ultrasound CW Doppler applications.

Typical Architecture of an Ultrasound Imaging System

Figure 1 shows a typical ultrasound system block diagram, which mainly includes two sections: a transmitter section and a receiver section. A T/R switch between the two sections controls the ultrasound transmission and reception. There are two kinds of transmitters: pulse transmitter and linear transmitter. Linear transmitter has more signal amplitude flexibility compared to pulse transmit due to the DAC control.

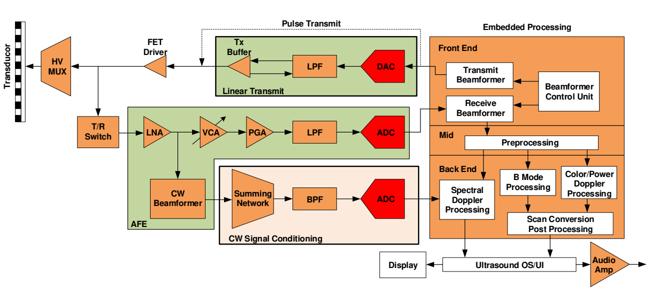

Figure 1. Typical Architecture of an Ultrasound Imaging System

At the receiver section, an AFE integrated with a CW beam former produces two signal paths: time gain compensation (TGC) path that produces digital signal for imaging and a CW path that produces analog signal for Doppler processing. The receiver receives the reflected ultrasound signal through a low noise amplifier (LNA) in the first stage, then it divides signal into two paths mentioned above. One path following a voltage controlled amplifier (VCA), a programmable gain amplifier (PGA), and an ADC produces digitized output to the receive beam former; another path following a CW beam former demodulates the Doppler frequencies and produces I and Q signals. Multiple I and Q signals from different channels in the same AFE are summed at a low-noise summer.

Continuous Wave (CW) Signal Conditioning

The continuous-wave Doppler is a key function in mid-end to high-end ultrasound systems. The AFE58xx series TI AFE devices have already integrated the CW path. The incident and reflected waves are mixed together to measure the shift in the frequency, and the wave mixed process produces In-phase (I) and Quadrature (Q) signal in the CW path to present the direction and speed of blood flow.

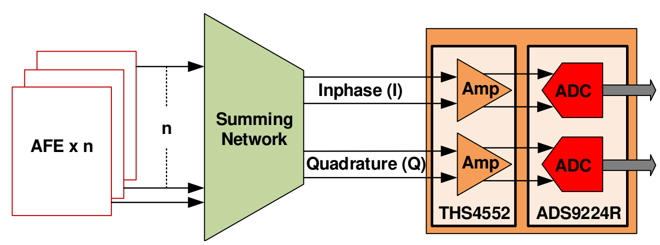

Figure 2. CW Doppler Receiver Chain Signal Conditioning

The typical post-treatment circuit of I and Q signal usually consists of a simple R-C summing stage, two high-speed driver amplifiers, and two high-precision ADCs. Figure 2 shows the typical block diagram. The summing network sums all the I and Q signals from the output channels, then produces differential I and Q signals for analysis. The maximum signal frequency of I and Q signal can be in the range of 10 kHz to 100 kHz. The ADC used to digitize these signals should have sampling speed at least 10 times higher than the maximum input frequency. Besides, high-resolution of 16-bits or more is needed for precise measurement of blood speed. For better signal conditioning of input signals, a fully differential amplifier (FDA) is usually used to drive the ADC. High-speed and low-noise performance must be taken into consideration while selecting ADC driver amplifier. For more information on how to drive a SAR ADC, refer to TI ADC Precision Labs.

Using ADS9224R and THS4552 to Simplify Circuit Design

As described in CW signal conditioning block diagram, at least two FDAs and two ADCs are needed to complete the post-processing of differential I and Q signals. Furthermore, ADCs need a reference voltage to define the full-scale voltage range, and FDAs need a common mode voltage to define the output common-mode voltage. As portable ultrasound systems have size limitations, it is preferred to have the signal conditioning unit as small as possible while keeping system accuracy intact at the same time.

The ADS9224R SAR ADC has two simultaneous channels with zero-latency, which is suitable for continuous I and Q signal sampling. The fully differential signal chain reduces even-order harmonics and minimizes common-mode noise, which enables a SNR of 94 dB and THD of -110 dB. Meanwhile, the three MSPS sampling rate with 16- bits resolution fulfills both the speed and precision requirements of I and Q output signals. Besides, the device includes a REFby2 buffer for setting the common-mode voltage required by the converter modules. The REFby2 output can be used to drive the VOCM common-mode input pin of the fully differential amplifiers. The REFby2 output can be increased by 100 mV for providing headroom from GND for the fully differential amplifier. Moreover, this device features an enhanced-SPI digital interface that allows the host controller to operate at slower SCLK speeds and still achieve the 3 MSPS throughput. Figure 3 shows the AC performance of the ADS9224R with respect to input signal frequency range (at 3 MSPS sampling speed). The user can opt for the ADS9224R internal averaging feature or post data processing inside host processors to further improve the noise performance.

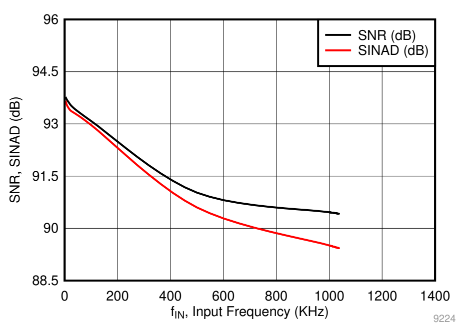

Figure 3. ADS9224R SNR and SINAD Performance Versus Input Frequency

Addressing Solution Size in Portable Ultrasound Systems with ADS9224R and THS4552

Portable device consideration is becoming important in ultrasound devices to address home care products. As a result, small size layout solutions in portable ultrasound devices are popular. The ADS9224R comes in 5 mm x 5 mm VQFN package, and the THS4552 has 4 mm x 4 mm VQFN package. Figure 4 shows the layout using the ADS9224R and THS4552 with VQFN package. The total signal conditioning solution size for key components THS4552 and ADS9224R is only 33 mm x 20 mm.

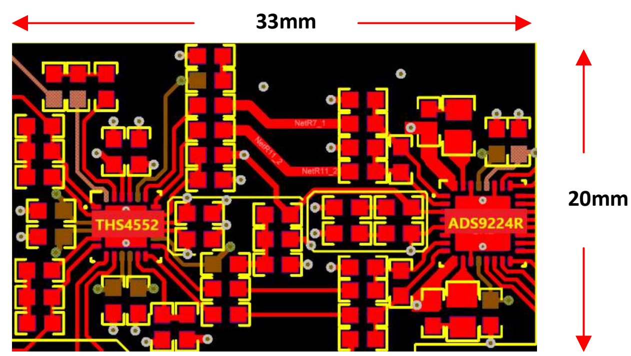

Figure 4. Layout Dimensions for THS4552 and ADS9224R Signal Conditioning Block

Conclusion

Post process of CW voltage in ultrasound systems is important to precisely show the measurement of blood flow. The ADS92x4R device family of dual-channel, 14/16- bits SAR ADCs were specifically designed to fulfill the I and Q signals conditioning in ultrasound system while meeting the market trend requirements of reducing cost, size, and power in all portable home care applications.

Table 1. Alternative Device Recommendations

Device	Description
ADS9234R	14-bit, 3.5-MSPS, dual, simultaneous-sampling SAR ADC with internal reference and enhanced SPI
ADS7057	14-Bit, 2.5MSPS, Differential Input, Small-Size Low-Power SAR ADC

Table 2. Adjacent Tech Notes and TI Designs

Texas Instruments, *Adjusting the Input Common-Mode Voltage for SAR ADCs to Avoid Amplifier Output Swing Limitations* Tech Note
Texas Instruments, *High-Resolution, High-SNR True Raw Data Conversion Reference Design for Ultrasound CW Doppler* Reference Design
Texas Instruments, *Simplify Isolation Designs Using an Enhanced-SPI ADC Interface* Tech Note