

Integrated Components Offer Flexibility in Ultrasound System Design

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IDEA IN BRIEF

Multichannel integration of preamplifiers, VGAs, and high speed ADCs provides better dynamic range and improved ultrasound image quality. The lower power and smaller size can bring these improvements to lower cost portable units.

In today's ultrasound marketplace, portability and performance are key metrics for system designers. Portability pushes the system's boundaries to satisfy the desire for complex tools that are consumer "pocketable" and portable, while performance needs dictate the dynamic range of the overall system. Higher dynamic range, or lower noise, provides higher quality images that enable better diagnoses. Providing doctors and clinicians with high performance, portable ultrasound machines places increased demands on the system designer, and on the components used within the system.

This article will review the up-front considerations that must be addressed to offer portable, performance-based products that provide the ultrasound system designer with the flexibility required to bring new imaging products to this global market.

System Trade-Offs

Ultrasound systems remain complicated, even though years of research and development have produced significant technological advancements. As with other complex systems, many approaches to system partitioning exist.

For many years, manufacturers implemented these complicated systems by designing their own custom application specific integrated circuits (ASICs). This solution usually consisted of two ASICs, which implemented most of the time-gain compression (TGC) and receive/transmit (Rx/Tx) paths, as shown in Figure 1.



Figure 1. ASIC Approach to Ultrasound Signal-Processing Channel

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This approach was common before multichannel voltagecontrolled amplifiers (VGAs), analog/digital converters (ADCs), and digital/analog converters (DACs) became widely available. The custom circuits, which allowed designers to incorporate low-cost, flexible functions, provided cost savings over time, because incorporating much of the signal chain in them minimized the number of external components.

Unfortunately, as time went on, the technology available via these lithographies showed its age in both scale and power consumption. ASICs have a high number of gates, but their digital technology is not optimized to successfully implement analog functions such as high performance ADCs. ASICs also limit the system designer, due to the limited number of suppliers.

Although high performance imaging can be achieved using this partitioning method, it is not optimal in terms of portability, size, and power consumption. The advent of quad-channel and octal-channel TGCs, ADCs, and DACs has allowed both the size and power to be reduced, but without compromising performance, thus bringing new system approaches and new players into these markets.

Multichannel components allow the designer to put devices closer together, increasing the number of channels in the

system. They also allow the designer to divide the sensitive circuits between two or more boards to complete the system. This allows for effective reuse of the electronic circuits over many platform developments.

Note that as channel counts increase, this leads to dynamic range improvement. Effectively, noise can be treated as uncorrelated in the system. By doubling the number of channels in a system, the noise is halved and the dynamic range increases by 3 dB. Therefore, a 64-channel system can add as much as 12-dB improvement in dynamic range over a 16-channel system. But there are disadvantages: an increase in channel count can make printed-circuit board (PCB) trace routing a nightmare, forcing the designer to use lower channel-count devices in some cases. This also poses new thermal challenges for mechanical designers, increasing both the system cost and the fan noise.

Today, IC manufacturers are able to integrate complete multichannel TGC paths, Figure 2. Multichannel, multicomponent integration makes the design approach easier, reducing PCB size and power dissipation without sacrificing performance. As higher level integration schemes become more predominant, advantages once again follow in cost, size, and power reduction, leading to less heat in the system and longer battery life.



Figure 2. Commonly Sought Integration Paths for Multichannel Designs

Technical Article

An ultrasound subsystem, such as Analog Devices' AD9272/AD9273, which integrates the low noise amplifier (LNA), VGA, antialiasing filter (AAF), ADC and crosspoint switch, implements the complete time-gain compression path, the most common receiver path found in an ultrasound system. The two devices offer the system designer the flexibility to trade performance for power consumption: the high performance AD9272 features low noise (0.75nV/rt-Hz), while the low power AD9273 consumes only 100 mW per entire TGC channel at 40 MSPS. Since pin count and housing size are critical, the pincompatible devices employ serial I/O. The compact, 14 mm × 14 mm × 1.2 mm packages reduce per-channel area and power dissipation by more than 33% as compared to multichip solutions.

Most ultrasound companies acknowledge that their critical intellectual property (IP) lies within the probe and beamformer technology. Multichannel ICs are quickly becoming commodity devices, putting an end to high-cost components, and the endless tweaking and optimization of individual TGC path, needed to complete the system and get that extra bit of performance or savings in power. Other portions of the ultrasound system are being considered for further integration; studies have shown that if the front-end electronics were closer to the probe, there would be less probe loss and better signal sensitivity, allowing system designers to relax the requirements on the front-end components (LNA/VGA). Integration of these portions of the signal chain might prove beneficial.

Trends in Ultrasound

With so many applications requiring ultrasound technologies, the demand for both performance and portability is high. Performance-driven applications, such as cardiology and 4-D image processing, contain the largest number of channels, features, and options. Power is not a driving factor because these systems are used at the patient's bedside, operating room suite, or nurses' triage, but performance is key as these systems are used for human diagnoses.

Portable ultrasound offers a different array of application opportunities, especially in locations where reliable electrical power is scarce or does not exist, such as remote village clinics, emergency medical services, animal farming, bridges, and large machinery inspections, Figure 3.

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Figure 3. Portable Ultrasound Systems Used forLarge-Animal Farming and Breeding

Ultrasound systems can generally be divided into three classes: high-end, mid-range, and low-end. High-end ultrasound systems are at the forefront of the most recent technology and market features, produce the best images, and are more expensive. Mid-range systems generally have a sub-set of the features that a high-end ultrasound system offers without much sacrifice in image quality. Low-end systems are scaled down even further and, in some cases, serve a particular application, which can be clinical or other. Trends due to technology advancements show the low-end systems are beginning to catch up on the image quality with mid-range systems, making diagnoses precise, noninvasive, and timely.

A New Tool in Ultrasound Design

Ultrasound covers a wide range of varying applications, so the tradeoffs a system designer must make have increased. Each modality has limitations that are defined generally by performance vs. power. Today these challenges have been met with components that allow the designer to scale the performance vs. power ratio within the IC, thus cutting down on time to market. The AD927x from Analog Devices offers a host of configurability within the IC to scale input range, bias, sample rate, and gain. Depending on which imaging modality or probe type is required, the system designer can literally system-scale the design appropriately in real-time, offering the maximum performance at minimum power.

In a typical application, the system needs to acquire images from a 5-MHz probe producing a 0.5-Vpp signal. If the LNA that has 0.86 nV/rt-Hz of noise, or 1.4 nV/rt-Hz for the entire channel, and is source terminated with 50 ohms, the input dynamic range of the system would be 92 dB, thus producing a noise figure (NF) of 3.8 dB. This translates to an

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Figure 4. AD9272/9273 Graphical Configuration Tool

output dynamic range of 66.3 dB, allowing the system designer to maintain optimum performance while only dissipating 191 mW/channel at 40 MSPS.

If the system performance exceeds expectations, the system designer may decide that a 2 dB reduction in input dynamic range could be justified in the system. if it saves 50 mW channel. The system designer could experiment with gain, bias, termination, and other parameters to see if this is feasible, but it can be difficult to understand the system tradeoffs when changing all these parameters.

A graphical configuration tool, such as the one offered by Analog Devices for its AD927x family, Figure 4, makes it convenient for the system designer to evaluate performance. In this tool, all the system features have been put in place, allowing the system designer to make these tradeoffs quickly and system scaling to be pushed down into the IC-level directly. As a result, the designer no longer needs to change real hardware, and produce cumbersome image-processing tests to validate these tradeoffs. Furthermore, the configuration tool will translate the optimized configuration parameters to digital settings and generate a file that can replicate the part's final configuration setup for the system.

Conclusion

Advances in integrated multichannel devices are pushing system flexibility even further today. New innovative products and configuration tools make the system designer's life easier without a doubt. This provides a means of developing diversified ultrasound products that are configurable and scalable, depending on the imaging modality, when it comes to performance versus power.

RESOURCES

For information on ultrasound and other healthcare applications, visit www.analog.com/healthcare.

Products Referenced in This Article

Product	Description
AD9272/AD9273	Octal LNA/VGA/AAF/ADC and Crosspoint Switch

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