ADI's Medical Ultrasound Solutions

Medical Ultrasound System Theory and Typical Architecture

By transmitting acoustic energy into the body and receiving and processing the returning reflections, ultrasound systems can generate images of internal organs and structures, map blood flow and tissue motion, and provide highly accurate blood velocity information.

Ultrasound systems include transducers, high voltage multiplexing, high voltage transmitters, Tx/Rx switches, receive-path analog front end (AFE), beamformers, beamformed digital signal processing display processing and peripherals. The AFE includes a low-noise amplifier (LNA), a variable-gain amplifier (VGA); an anti-alias filter (AAF), and an analog-to-digital converter (ADC). There are two kinds of beamformers: digital beamformers and analog beamformers, for different applications.

Medical Ultrasound System Design Considerations and Major Challenges

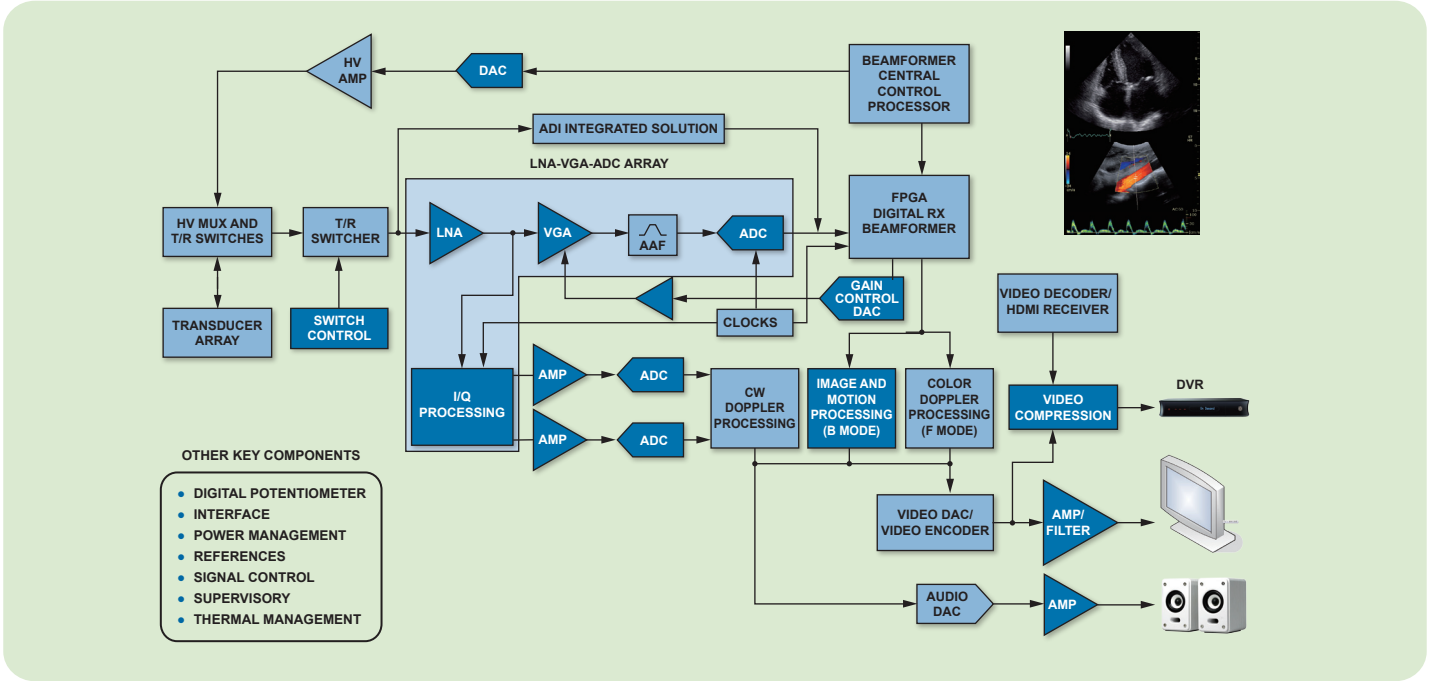
- Receiver AFE circuit performance: noise performance, SNR (signal-to-noise ratio), DR (dynamic range), typically required for high-end systems, DR is 70 dB for B mode, 130 dB for PWD (pulse wave doppler), and 160 dB for CWD (continuous wave doppler).
- Transmit voltage: High transmit voltages are needed to improve signal single word and for harmonic imaging. The acoustic power grows as the transmit voltage is increased, but it is limited by safety requirements from agencies such as the FDA.
- Beam-former complexity: high image quality requires a large number of beam forming channels. The increased complexity leads to higher power dissipation and requires more imaging volume to implement.
- Heat dissipation: heat dissipation is an important issue for miniaturized devices, particularly when improved image quality is the goal.

Historically, the large number of high-performance transmitters and receivers required to implement these imaging systems resulted in large and expensive cart-based implementations. Recently, advances in integration have allowed system designers to migrate to smaller, lower cost, and more portable imaging solutions with performance approaching cart based systems. The challenge moving forward is to continue to drive the integration of these solutions, while increasing their performance and diagnostic capabilities.

Total Solutions from ADI

ADI provides an extensive selection of amplifier, data conversion, signal processing, and power management solutions to maximize image quality and reduce power consumption and cost in cart-based and portable ultrasound equipment. In addition, ADI provides evaluation boards, gerber files, simulation tools and applications expertise to support customer design and development efforts.

Main Signal Chain

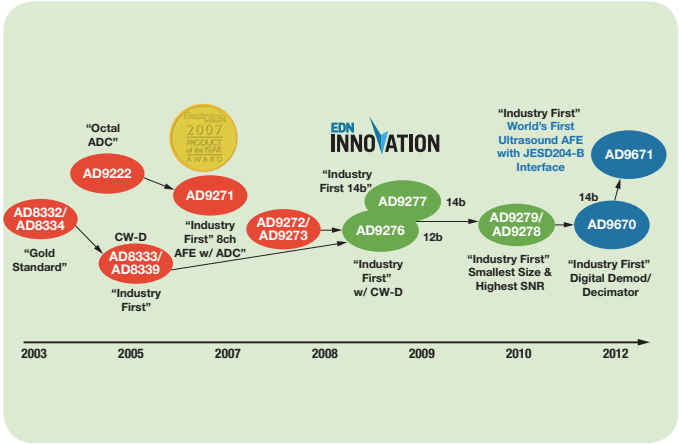


Notes: The signal chains above are representative of medical ultrasound systems. The technical requirements of the blocks vary, but the products listed in the table are representative of ADI's solutions that meet some of those requirements.

Integrated Analog Front End	VGA	LNA	I/Q Demodulator	ADC (TGC Path)	ADC (CWD Path)	Amplifier
AD9272/AD9273/ AD9276/AD9277/ AD9278/AD9279/ AD9670/AD9671	AD8331/ AD8332/ AD8334	AD8432/ADA4897/ ADA4896/ADA4899	AD8333/ AD8339	AD9637/ AD9257/ AD9253	AD7982/ AD7980/ AD7986/ AD7686	ADA4841/ADA4897/ ADA4896/ADA4938/ ADA4930/AD8692
Transmit Tx DAC	**TGC Control DAC**	**Clocking**	**Power**	**Analog Switch**	**Video Processing**	**Audio Processing**
AD9106/AD9709/ AD9763/AD9765/ AD9767/	AD9709/AD9706/ AD9742/AD5424/ AD5433/AD5445	AD951x/AD952x/ ADCLK8xx/ADCLK9xx/ ADN4670	ADP2116/ADP2114/ ADP1741/ADP1740/ ADP3338/ADP3339/ ADM106x/ADM116x	ADG714/ ADG619	ADV712x/ADV739x/ ADV202/ADV212/ ADV216/ADV7180/ ADV7441/ADA4420/ ADA4417	ADAU1361/ADAU1761/ SSM2604/SSM2356

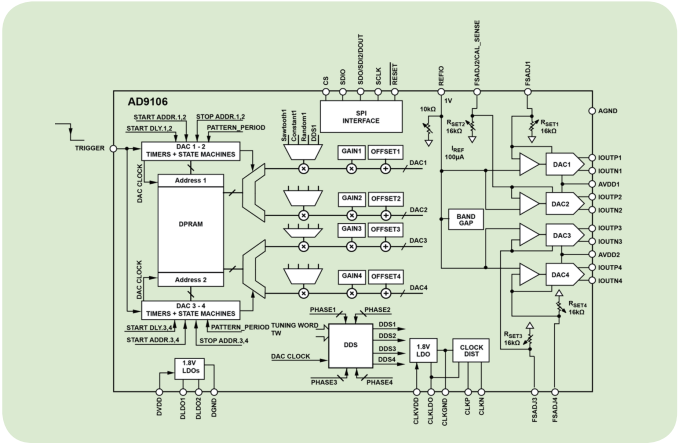
Integration AFE Introductions

ADI's AD927x series and newest AD9670/AD9671 integrated analog front ends (AFE) provide more options to address ultrasound system design challenges. Customers can select an AFE to best match Rx requirements for performance, power consumption, and imaging mode to use in different application platforms with easy and flexible pin-to-pin compatible designs.



Linear Transmit Introductions

ADI provides a linear transmit solution for medical ultrasound, which results in great advantages in harmonic imaging (HI) and SNR improvement. The linear Tx solution uses a high speed TxDAC ®. ADI's AD9106 is a high performance 12-bit, 175 MSPS quad TxDAC integrating on-chip pattern memory for complex waveform generation with one output direct digital synthesizer (DDS) and SPI interface to configure and load waveform data.



Introduction of Main Products for Medical Ultrasound

Part	Description	Benefits
Integrated Analog Front End (AFE)		
AD9272	Eight channels of a 0.75 nV/√Hz @ 21.3 dB VN RTI LNA with a 42 dB VGA, an AAF with LPF 8 MHz to 18 MHz and HPF, and a 12-bit, 10 MSPS to 80 MSPS ADC. 191 mW/ch@40 MSPS, also an 8 × 8 differential crosspoint switch is included for CW doppler.	Low cost, low noise, small size, and ease of use for medical ultrasound application.
AD9273	Eight channels of a 1.26 √Hz @ 21.3 dB VN RTI LNA with a 42 dB VGA, an AAF with LPF 8 MHz to 18 MHz and HPF, and a 12-bit, 10 MSPS to 50 MSPS ADC. 104 mW/ch @ 40 MSPS, also an 8 × 8 differential crosspoint switch is included for CW doppler.	Low cost, low power, small size, and ease of use for medical ultrasound application.
AD9276	Eight channels of a 0.75 nV/√Hz @ 21.3dB VN RTI LNA with a 42 dB VGA, an AAF with LPF 8 MHz to 18 MHz and HPF, and a 12-bit, 10 MSPS to 80 MSPS ADC. 191 mW/ch @ 40 MSPS, also an I/Q demodulator with programmable phase rotation for CW doppler.	Low cost, low noise, small size, and ease of use for medical ultrasound application.
AD9277	Eight channels of a 0.75 nV/√Hz @ 21.3 dB VN RTI LNA with a 42 dB VGA, an AAF with LPF 8 MHz to 18 MHz and HPF, and a 14-bit, 10 MSPS to 50 MSPS ADC. 191 mW/ch @ 40 MSPS, also an I/Q demodulator with programmable phase rotation for CW doppler.	Low cost, low noise, high resolution, small size, and ease of use for medical ultrasound application.
AD9278	Eight channels of a 1.3 nV/√Hz @21.3 dB VN RTI LNA with a 45 dB VGA, an AAF with LPF 8 MHz to 18 MHz and HPF, and a 12-bit, 10 MSPS to 65 MSPS ADC. 88 mW/ch @ 40 MSPS, also an I/Q demodulator with programmable phase rotation for CW doppler.	Low cost, small size, lowest power and ease of use for medical ultrasound application.
AD9279	Eight channels of a 0.75 nV/√Hz @21.3 dB VN RTI LNA with a 45 dB VGA, an AAF with LPF 8 MHz to 18 MHz and HPF, and a 12-bit, 10 MSPS to 80 MSPS ADC. 141 mW/ch @ 40 MSPS, also an I/Q demodulator with programmable phase rotation for CW doppler.	Low cost, low noise, small size, and ease of use for medical ultrasound application.

Introduction of Main Products for Medical Ultrasound (continued)

Part	Description	Benefits
Integrated Analog Front End (AFE) (continued)		
AD9670	Eight channels of a 0.78 nV/√Hz @ 21.6 dB VN RTI LNA with a 45 dB VGA, an AAF with LPF 8 MHz to 18 MHz or 13.5 MHz to 30 MHz and HPF, a 14-bit, 10 MSPS to 125 MSPS ADC. 130 mW/ch @ 40 MSPS, and a digital demodulator and decimator for data processing and bandwidth reduction, also an I/Q demodulator with programmable phase rotation.	Low cost, low noise, high resolution, small size, reduces FPGA I/O and computational rate for beam former and processors.
AD9671	Eight channels of a 0.78 nV/√Hz @ 21.6 dB VN RTI LNA with a 45 dB VGA, an AAF with LPF 8 MHz to 18 MHz or 13.5 MHz to 30 MHz and HPF, a 14-bit, 10 MSPS to 125 MSPS ADC. 130 mW/ch @ 40 MSPS, and a digital demodulator and decimator for data processing and bandwidth reduction, also an I/Q demodulator with programmable phase rotation.	Four configurable 5-Gbps serial JESD204B CML data lanes provide an interface for further data processing. Reduces the number of FPGA I/O and components
LNA		
AD8432	Dual-channel ultralow noise amplifier. VN RTI =0.85 nV/√Hz @ 12.04 dB, G = 12.04 dB, 18.06 dB, 21.58 dB, and 24.08 dB, bandwidth=200 MHz @ 12.04 dB.	Low power, low noise with selectable gain and active impedance matching
VGA		
AD8332/ AD8334	Ultralow noise 48 dB VGAs with preamplifier and programmable RIN; Vn RTI= 0.74 nV/√Hz; In RTI = 2.5 pA/√Hz , bandwidth=100 MHz	Precise linear-in-dB, excellent gain matching and bandwidth uniformity suitable for ultrasound applications
I/Q Demodulator		
AD8333/ AD8339	DC to 50 MHz, Quad I/Q Demodulator and Phase Shifter; 16 phase select on each output (22.5° per step). Dual version: AD8333	The only stand-alone ultrasound CW I/Q demodulator in the market.
ADC		
AD7982	18-bit, 1 MSPS, 7 mW, PulSAR differential ADC; pin-pin compatible with 18-bit version: AD7984 (1.33 MSPS), AD7986 (2 MSPS) and 16-bit version: AD7980 (1 MSPS)	High speed and accuracy; pin-pin compatible series can be flexibly selected for ultrasound CW path
AD9257	Eight channels of 12-bit, 65 MSPS serial LVDS ADC; pin-pin compatible with 12-bit version AD9637 and quad channel 12-bit version: AD9253	Small package; pin-pin compatible series can be flexibly selected for ultrasound TGC path
Amplifiers		
ADA4897/ ADA4896	Low wideband noise 1 nV/√Hz and 2.8 pA/√Hz ; low 1/f noise 2.4 nV/√Hz @ 10 Hz, 80 mA output current, rail-to-rail output	Suitable for ultrasound CW path I/V, summing and ADC driver application
ADA4841	Low wideband noise 2.1 nV/√Hz and 1.4 pA/√Hz ; low 1/f noise 7 nV/√Hz @ 10 Hz and 13 pA/√Hz @ 10 Hz, rail-to-rail output	Suitable for ADC driver, low noise for small signal conditioning
ADA4938	Low noise 2.1 nV/√Hz , ultralow distortion: –106 dBc HD2 @ 10 MHz, high speed differential amplifier	Suitable for ultrasound TGC gain control differential driver circuits
Tx DAC		
AD9106	Quad, 12-bit, 175 MSPS DAC integrating 4096 × 12 on-chip pattern memory for complex waveform generation with one output direct digital synthesizer (DDS) and SPI interface to configure and load waveform data. Phase noise @ 1 kHz output, 175MSPS, 8 mA: –140 dBc/Hz	Suitable for ultrasound linear transmit signal waveform generation and also transmit beamformer. Small size and low power consumption
DAC		
AD5424/ AD5433/ AD5445	AD5424/AD5433/AD54451 are CMOS 8-bit, 10-bit, and 12-bit current output DACs, respectively. Update rate: 20.4 MSPS.	Suitable for ultrasound TGC gain control circuits
AD9706	12-bit current output DAC, update rate: 175 MSPS. Pin-pin compatible with 8-bit/10-bit/14-bit version: AD9704/AD9705/AD9707	Suitable for ultrasound TGC gain control high speed differential circuits
Analog Switch		
ADG714	Octal SPST (single-pole, single-throw) switch controlled via a 3-wire serial interface, 0.6 Ω on-resistance flatness. t_{ON} = 35 ns (typical) and t_{OFF} = 11 ns (typical)	Low on resistance and fast on/off time guarantees the signal integration
ADG619	Single-pole double-throw (SPDT) switches, 0.8 Ω (maximum) on-resistance flatness. t_{ON} = 80 ns (typical) and t_{OFF} = 45 ns (typical)	Low drift and high accuracy benefit ADC sampling performance
Clocking		
ADCLK8xx/ ADCLK9xx	Multi-output fan-out buffer optimized for low jitter and low power operation. Additive broadband jitter less than 500 fs.	Well suited for low jitter ultrasound clock distribution
AD951x/ AD952x	Multi-output clock distribution functions with sub picosecond jitter performance, along with an on-chip PLL and VCO.	Well suited for low jitter ultrasound clock divide and distribution
Audio Amplifiers		
SSM2356	2W × 2W into 4 Ω load and 2 W × 1.4 W into 8 Ω load at 5.0 V supply with <1% total harmonic distortion, 92% efficiency at 5.0 V, 1.4 W into 8 Ω speaker, 103 dB SNR	High efficiency, low distortion suited for ultrasound Doppler audio output
Audio DAC		
ADAU1361	Low power, stereo audio codec that supports stereo 48 kHz record and playback at 14 mW. 24-bit stereo audio ADC and DAC: >98 dB SNR	Suitable for ultrasound Doppler audio application

Introduction of Main Products for Medical Ultrasound (continued)

Part	Description	Benefits
Video DAC		
ADV739x	ADV739x are a family of high speed video encoders on single monolithic chips. Three 2.7 V/3.3 V 10-bit video DACs provide support for composite (CVBS), S-Video (Y/C), or component (YPrPb/RGB) analog outputs in either standard-definition (SD) or high-definition (HD) video formats.	Suitable for ultrasound image display and video application.
ADV7125	Triple, high speed, digital-to-analog converter on a single monolithic chip. It consists of three 8-bit video DACs with complementary outputs, a standard TTL input interface, and high impedance analog output current source.	Suitable for analog VGA output in ultrasound image display.
Power Management		
ADP2114	2.75 V to 5.5 V input, configurable, dual 2 A/single 4 A, synchronous step-down dc-to-dc regulator. Pin-pin compatible with dual 3A version: ADP2116	Low noise and synchronous function suited for ultrasound application
ADP3338	2.7 V to 8 V input, 1 A output current, 190 mV ultralow dropout voltage LDO. Pin-pin compatible with 1.5 A version: ADP3339	Low dropout and big output current suited for ultrasound application
ADP1740	1.6 V to 3.6 V input, 2 A output current, 160 mV ultralow dropout voltage LDO with 7 fixed output voltage options, Pin-pin compatible with adjustable version: ADP1741	Low dropout and big output current suited for ultrasound application
ADM106x	Configurable supervisory/sequencing device that offers a single-chip solution for supply monitoring and sequencing in multiple (up to 10) supply systems.	Suitable for ultrasound system power sequence control and monitor

Design Tools

Analog Front End (AFE)

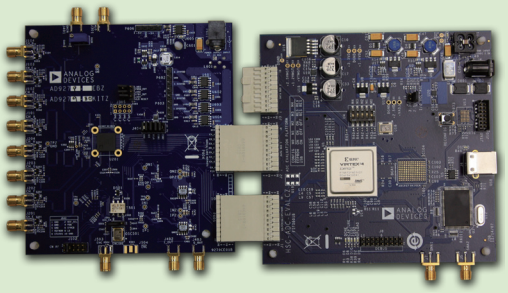
- AD9272/AD9273/AD9276/AD9277/AD9278/AD9279 and AD9670/AD9671 Evaluation Board With Schematic and PCB Layout Gerber File
- High Speed FPGA-Based Data Capture Board (HSC-ADC-EVALCZ)
- VisualAnalog™ Software
- AFE SPI Interface Software (SPI Controller)
- AD927x Configuration Tool
- ADIsimADC Modeling Tool AFE SPI Interface Software (SPI Controller)
- AD9279/AD9278/AD9273 BGA PCB Layout Gerber Files
- AD8331/AD8332/AD8334 Evaluation Board with Schematic and PCB Layout Gerber File
- AD8333/AD8339 Evaluation Board with Schematic and PCB Layout Gerber File

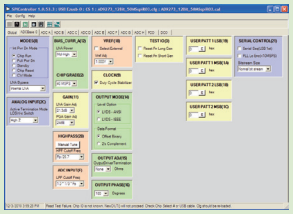
Clocking

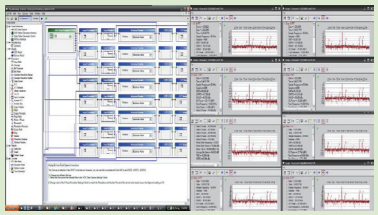
- ADIsimCLK Modeling Tool
- AD951x/AD952x Evaluation Software and Board

PMP

- ADIsimPower
- Evaluation Board







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