State-of-the-Art IC: Transmitter in Ultrasound Devices

Lower voltage IC technologies now enable ultrasound receiver chips with unprecedented high gain and low noise numbers.

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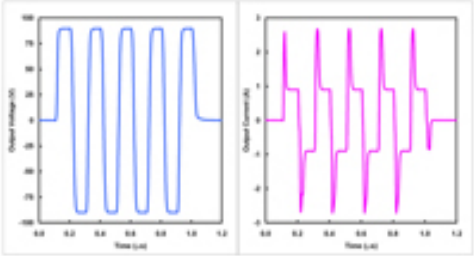
The medical imaging field is benefiting greatly from research and development in applied physics and electronics, especially in areas such as instrumentation, image acquisition and modeling. Resulting from its fully non-invasive nature, ultrasound holds a special position among the imaging modes, providing a reliable method for the study of internal organs. The ultrasound technique has been used for medical purposes for over half a century. However, the necessary equipment has been quite bulky and expensive, and until recently made exclusively out of discrete components.

By virtue of advances made in semiconductor process technologies, this trend is changing. It is now possible to manufacture an ultrasound transceiver entirely out of semiconductor ICs. Lower voltage IC technologies now enable ultrasound receiver chips with significantly high-gain and low-noise performance. Similarly, on the higher voltage side, there is growing interest in making transmitter ICs that drive the ultrasound transducer. This article surveys advancements as well as challenges when designing ultrasound transmitter chips.

Ultrasound System Overview: Transmit and Receive Functions

In simple terms, an ultrasound system's operation principle consists of generating acoustic waves to be used on a patient, followed by receiving and processing the reflected signals to create an image of the body. The original acoustic waves being sent into the body are generated by a transducer, which typically is excited by electrical pulses generated by a transmitter. Similarly, the reflected acoustic waves are received by the transducer and converted back into electrical form. The resulting signal is finally processed to determine the internal structure of the body

parts of interest.



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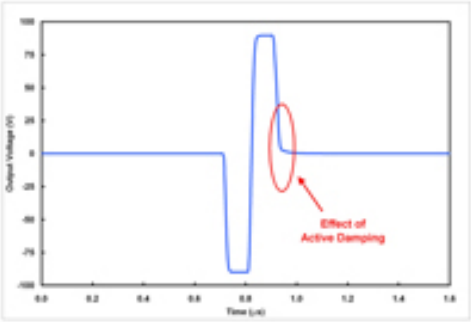
Typical construction of a complete medical ultrasound system is shown in Figure 1. The transmit path can be realized in several different ways. This path may consist of a beamformer, level translators, gate drivers and high-voltage switches whose output is sent to the ultrasound transducer. The transducer, usually made of a piezoelectric material, converts the high-voltage electrical signal into an acoustic wave, which is the final output of the system.

In some systems, the signal's digital nature is preserved from beginning to end across the transmit path where the output stage is driven with digital logic. However, you can also create and transmit the signal to the transducer in an analog fashion. This involves a digital-to-analog converter (DAC) to convert the output of the beamformer into analog format. Then, analog amplification is used on the resulting signal before sending it to the transducer.

With an ultrasound system's receive path, an analogous approach is used. Because the received signal is far lower in amplitude than the transmitted signal, the front-end consists of a low-noise amplifier followed by some sort of gain control block. After filtering out the higher frequency components not of interest, the resulting signal is converted into digital format through an analog-to-digital converter (ADC) whose output is processed by a beamformer.

Other important pieces of the ultrasound transceiver system include a multiplexer to interleave the activities of multiple channels, and a transmit/receive switch to control the signal traffic between the transducer and the transceiver electronics. A critical function of the transmit/receive switch is to protect the receiver during transmit events, which involve much higher voltages across the transmission line than what the receiver block can withstand.

Transmit Path Challenges Voltage Range and Frequency of Operation



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The ultrasound system described thus far is expected to create various signal patterns to meet the requirements of different imaging modes. At one extreme of the range, you can find high-voltage (60 to 100 V), low-duty cycle (0.5 to 2.0%) signals required by B-mode and harmonic imaging applications. At the other extreme, there are low-voltage (3 to 10 V), 100% duty cycle signals required by continuous-wave (CW) Doppler-type imaging modes. This means that the ultrasound system's transmitter circuit is required to create output voltages ranging from ±3 V to ±100 V under commensurate duty cycle conditions, at a fundamental frequency ranging from 1 to 20 MHz.

It is quite obvious that the ±100 V requirement on the transmitter output requires high-voltage switches. When the transmitter consists of an IC, this requirement translates into high-voltage transistors, which are optimized to withstand large electric fields. As such, they underperform at low voltages (