

4Z1c Real-Time Volume Imaging Transducer

ACUSON SC2000 Volume Imaging Ultrasound System

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Introduction

Breakthrough imaging technologies often require a paradigm shift from conventional methods and approaches. Optimal volume imaging and enhanced echocardiography workflow demand full cardiac volumes, high frame rates and superior image quality. Designed as a single transducer solution for comprehensive adult echo imaging, the 4Z1c transducer combines the latest advances in materials, electronics and ergonomic design to deliver unprecedented imaging of the entire heart at high volume rates without gated acquisition and stitching. The 4Z1c transducer achieves this performance by using a proprietary technology to control the function of thousands of elements using integrated circuits in the transducer handle that precisely transmit ultrasound beams into tissue. The resulting heat generated in the handle electronics is effectively dissipated with patented active cooling technology.

Integrated Electronics

With the advent of real-time volumetric imaging, the transducer has grown in both electro-mechanical and electronic complexity. A one-dimensional transducer array with one to two hundred elements is sufficient for conventional B-mode imaging. However, a two-dimensional transducer array with an order of magnitude more elements is necessary for real-time volumetric imaging as illustrated in **Figure 1**.

The two-dimensional transducer array with one to two thousand elements poses a multitude of technical challenges. The two main challenges are: 1) the electrical impedance mismatch between small piezo-ceramic elements and electrical cables reduces the signal-to-noise ratio; and 2) the number of wires from the transducer to the system results in an unacceptably large cable. With the 4Z1c transducer, both of these challenges are circumvented by moving a portion of the beamforming electronics from the system into the transducer handle. The 4Z1c contains six miniaturized circuit boards with over 120 custom integrated circuits as shown in **Figure 2**.

In the past, the transducer has been primarily responsible for conversion of electrical signals to ultrasound waves on transmit and vice-versa on receive. The timing and control of the electrical signals for focusing and scanning the ultrasound beam have been generated within the system. By having most of the beamforming electronics in the transducer handle in 2D transducers, Siemens is able to achieve partial-beamforming that 1) improves the electrical impedance mismatch; and 2) reduces the number of electrical cables that must transmit the signals from the transducer to the system.

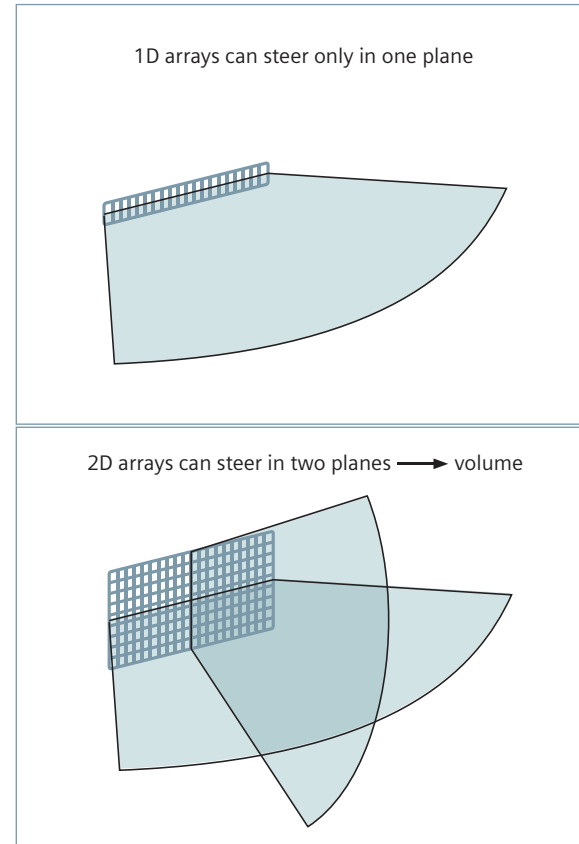


Figure 1. 1D array versus 2D array

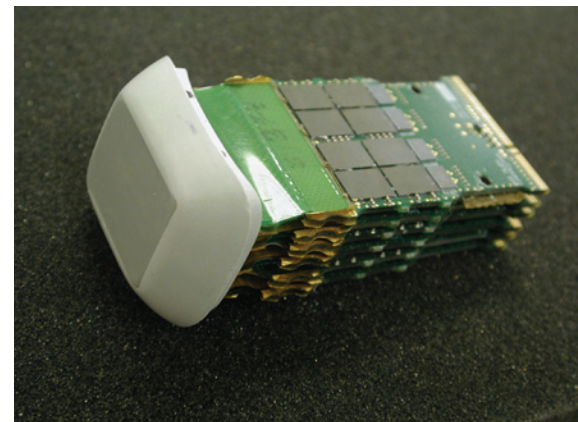


Figure 2. Photograph of 4Z1c electronics



Figure 3. Photograph of the 4Z1c transducer



Figure 4. Ergonomic "palmar grip" of the 4Z1c

Ergonomic Design

Siemens has been working with the Society of Diagnostic Medical Sonographers (SDMS) in development of ergonomic designs for both ultrasound systems and transducers. Investigations by the SDMS have led to the development of industry standards for the prevention of work-related musculoskeletal disorders.¹ To enhance the operator usability of the 4Z1c, the transducer has four distinctive features related to ergonomics — size, shape, and texture of the transducer handle and cable management (see **Figure 3**) — all focused on reducing operator use-related injury.

Ultrasound transducers in general are getting smaller and smaller in size. This reduction in size leads the sonographer to hold the slippery, gel covered transducer with a strong pinch grip in order to maintain control over the transducer. Pushing against the patient to maintain or improve access to the optimal chest window during scanning adds to the hand strain. This pinch grip tightens the smaller wrist muscles and tendons and promotes sonographer injuries.^{2,3} With the larger size and rounded shape of the 4Z1c transducer, the "palmar grip" can be used to hold and maneuver the transducer as illustrated in **Figure 4**. With this positioning, the 4Z1c can be held with the whole hand and pushed from the bottom of the

transducer using all of the larger muscles in the arm and shoulder. To assist with holding and positioning, the 4Z1c transducer is covered by an elastomeric compound (Softflex) that helps maintain a positive hand grip during scanning, even when covered with gel.

As a final ergonomic feature, the cable insertion to the transducer is offset and to the side. This complements the palmar shape by allowing the sonographer to hold and push from the back of the transducer, avoiding the pinch grip. The offset cable also allows better access from the apical position with the cabling coming away from the bed, and allowing access under the apex more easily without interference from the cable.

Designed to operate across all traditional imaging modes yet specialized for full-volume, single beat acquisitions, the 4Z1c offers a single transducer solution for adult echo imaging. Promoting good ergonomic design while removing the need for transducer changes within an exam and the necessity to pivot and roll the transducer to access the multiple planar images, the 4Z1c is anticipated to reduce fatigue and related injuries.

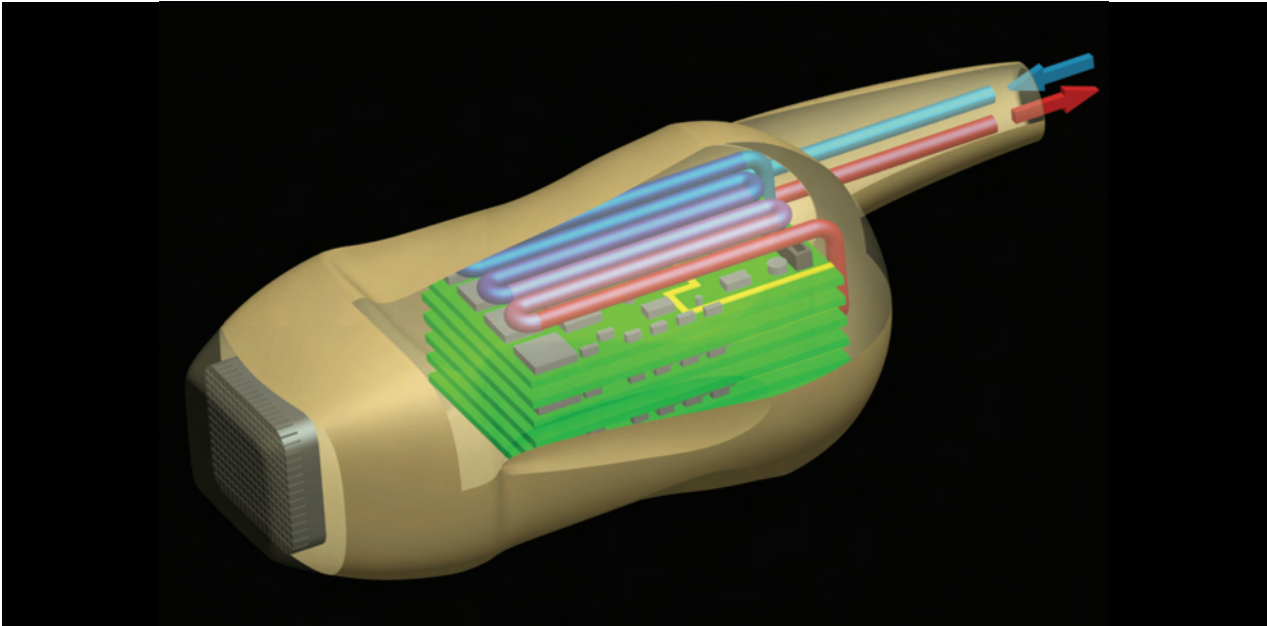


Figure 5. Active cooling coils draw heat away from the transducer

Active Cooling

Real-time volume imaging is a key enabler for improving clinical workflow and quantification in echocardiography.⁴ Since image quality, volume size and volume rate can be traded off against each other, it is important to evaluate these parameters in combination. Information rate is a quantitative measure of the combination of image quality, size of the imaging volume and the volume rate that relates to the amount of information obtained from within the body, and is directly proportional to energy transmitted into the body from the transducer. In general, the higher the energy transmitted into the body, the higher the achievable information rate. This translates into clinical benefits of larger imaging volumes, higher volume rates, and improved image quality.

Conventional volume imaging uses a large number of focused transmit events that trade off volume rate versus image quality. Each focused transmit takes a fixed amount of time for the sound pulse to travel to a given imaging depth and back. In order to improve volume rate, fewer transmits can be made, but at the cost of image quality. Alternatively, image quality can be maintained, but

volume rate suffers such that a reduced volume size must be acquired, and the full 90 degree x 90 degree volume is formed by stitching together multiple smaller volumes. Coherent Volume Formation is a proprietary technology that uses very few transmits but maintains the image quality, and therefore circumvents the image quality versus volume rate tradeoff.

Although information rate increases with energy transmitted into the body, regulatory limits constrain the energy transmitted into the body through limits on thermal dosage at the skin surface and inside the body. For volume imaging, managing the acoustic energy or the skin temperature at surface is typically the limiting factor. The skin temperature is proportional to the amount of energy transmitted into the body and the temperature of the transducer electronics. By actively reducing the temperature of the transducer electronics, skin temperature can be reduced. This in turn allows imaging at maximum transmitted energy under regulatory limits to achieve the highest possible information rate.

In order to maximize information rate related to volume size, rate and image quality, the 4Z1c uses active cooling to pull heat away from the skin surface. This facilitates transmitting the maximum allowable thermal energy into the body. It is accomplished by using high heat-conductive materials inside the transducer handle to draw heat into a heat exchanger where small tubes circulate an inert, high heat-capacity cooling fluid as illustrated in **Figure 5**. The fluid carries the heat from the transducer to the transducer connector where the fluid is cooled before being circulated back into the transducer. A first within the diagnostic ultrasound industry, active cooling allows the 4Z1c to image with full output power under regulatory limits enabling peak performance. This results in improved penetration, reduced noise in the image and faster volume acquisition rates as compared to other conventional 3D transducers.

Conclusion

The unique, palmar shaped ergonomic design enhances the 4Z1c as the single transducer solution for adult echo imaging. Active cooling technology, in combination with Coherent Volume Formation enables the 4Z1c transducer to image at significantly higher information rates, resulting in improvements in imaging volume, volume rate and image quality.

References

1. *Industry Standards for the Prevention of Work-Related Musculoskeletal Disorders in Sonography. Journal of Diagnostic Medical Sonography* 2003; 19: 283.
2. Kroemer K, Grandjean E. *Fitting the Task to the Human: A Textbook of Occupational Ergonomics*. 5th ed. Philadelphia: Taylor & Francis, 1997.
3. Salvendy G. *Handbook of Human Factors and Ergonomics*. New York: John Wiley, 1997.
4. Hung J, Lang R, Flachskampf F, Shernan SK, McCulloch ML, Adams DB, Thomas J, Vannan M, Ryan T. *3D Echocardiography: A Review of the Current Status and Future Directions. Journal of the American Society of Echocardiography* 2007; 20: 213-233.

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