FPGA Solutions for 4D Imaging-based Therapy

Introduction

4D imaging and 4D radiation therapy promise radical improvements in the diagnosis and treatment of cancer. These techniques study, characterize, and reduce the effects of patient movement during imaging and radiotherapy, adding the dimension of time to 3D body-scanning technology such as computed tomography (CT), magnetic resonance imaging (MRI), and advanced ultrasound systems. By visually freezing a 3D model or by showing an animated 3D image, 4D imaging techniques make it easier for clinicians to identify targets and focus treatment on tumors, reducing the impact of radiation therapy or surgery on surrounding tissue.

Motorized Assembly in Imaging

An important aspect of 4D medical processing is compensating for patient motion, a vital consideration in radiotherapy. A radiation source must be focused on a tumor even if there is a sudden movement that might otherwise expose normal tissue to the treatment. Even shallow breathing can cause the radiation source to miss its tiny target and irradiate surrounding tissue, increasing the risk of damaging side effects from the treatment.

As a result, an increasingly important part of 4D imaging-based radiotherapy systems is the motorized assembly that directs the treatment head. Driven by the analysis performed by the analysis system, high-resolution motors can ensure that the radiation is always directed towards the tumor and nowhere else. Such high-resolution motor control demands very high performance from software running on DSPs or microprocessors. It is not just computationally intensive but the high interrupt frequency needed to continually check on motor position incurs a high overhead.

FPGAs provide a more efficient way of implementing highly responsive motor-control algorithms. By keeping loop times low through the use of hardware rather than software control, FPGA implementation improves interrupt latencies and provides finer-grained control over motor position, ensuring that a radiation source can compensate for patient motion accurately. In the case of SmartFusion devices, hardware responsiveness can be combined with fine-tuning through software running on an industry-standard ARM® Cortex™-M3 processor. Integrated analog I/O blocks under the control of an analog compute engine (ACE) implemented in hardware ensures that the motor actuators are updated with the correct information without delay.

Microsemi FPGA Solutions for Radiotherapy

Not all FPGAs are suited to use in radiotherapy. The SRAM cells in many FPGAs are highly susceptible to radiation, particularly single-event errors in which alpha and neutron radiation causes loss of configuration data. Programmable logic devices based on SRAM technology, for example, are susceptible to soft errors and firm errors. A soft error is the transient corruption of a single bit of data, and a firm error is the loss of the underlying FPGA configuration, which can cause system-level functional failure. However, neutron and alpha radiation do not have adverse effects on true nonvolatile flash-based FPGAs at ground and sea levels or at high altitudes, making them far more suitable for medical applications. Failure cannot be tolerated in medical applications, but radiation levels in the system are likely to be higher than in the general environment.

Proprietary algorithms provide the basis for effective 4D imaging. Microsemi's flash-based FPGAs have a further benefit over SRAM-based products: design security. Once programmed, it is not possible to decode the configuration bitstream that was used. In contrast, SRAM-based FPGAs always have to read in their configuration data at boot time, potentially revealing key design information to someone attempting to reverse-engineer the design.

The design security goes further, helping to ensure that users of these advanced systems can only use approved spares and subsystems. Every Microsemi FPGA can store encryption keys internally at the time of manufacture. A challenge-response system can use those keys to ensure that only the correct parts are present in the system when it boots up.

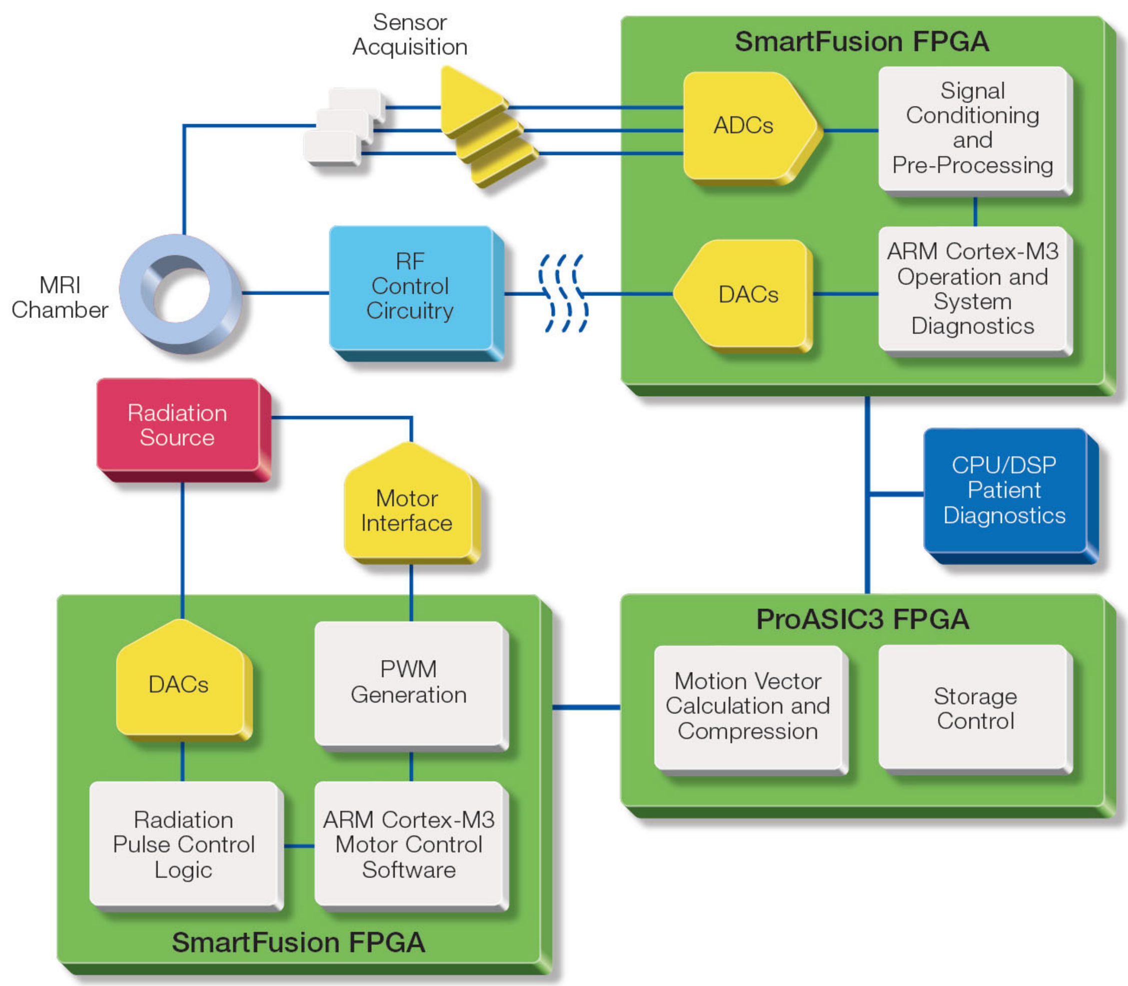

Figure 1 • **Block Diagram of a 4D Imaging-Based Radiotherapy System**

Summary

Although there are a number of FPGA solutions on the market, only one technology—made exclusively by Microsemi—provides all the features required by makers of 4D medical imaging equipment.

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