ACT4: A HIGH-PRECISION, MULTI-FREQUENCY ELECTRICAL IMPEDANCE TOMOGRAPH

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ABSTRACT

This dissertation describes the design and architecture of ACT 4, Rensselaer's 4th generation electrical impedance tomograph. ACT 4 has a modular design that can support up to 72 electrodes. The instrument is able to apply either voltages or currents to all the electrodes simultaneously and to measure the resulting currents or voltages. ACT 4 is also able to work with discrete excitation frequencies in the range from 300 Hz to 1 MHz. To implement this high-speed, high-precision, multi-channel instrument, the analog electronics are augmented with a distributed digital system, including a computer, Digital Signal Processors (DSPs) and Field-Programmable Gate Arrays (FPGAs). The computer provides a user interface to control the instrument and to display the results for analysis along with algorithms to calibrate the hardware. We use FPGAs mainly to implement the signal generation, voltmeter and control for the ACT 4 analog circuits. In our application we need 16 bits of control for the sources and 16 to 19 bits of precision for the voltmeters. The signal generator design reported here includes a Direct Digital Synthesizer (DDS) and a complex modulator to generate sinusoidal waveforms with controllable amplitude, frequency and phase. The voltmetering is performed using a complex matched filter that produces estimates of both the real and quadrature parts of the voltage. The implementation of 8 signal generators and voltmeters in a single Xilinx Virtex-II FPGA is presented. FPGAs are also used to implement the communication protocol between multiple channels through a VME64x backplane, and between the computer and the instrument through LVDS protocols. The overall system architecture is presented as well as the implementation in FPGA firmware. The dissertation also describes the simulation and debugging tools that were used for system integration. Experimental results are presented that validate system performance.