FPGA-BASED SYSTEM SUPPORTING ACOUSTIC EVENT DETECTION AND PROCESSING

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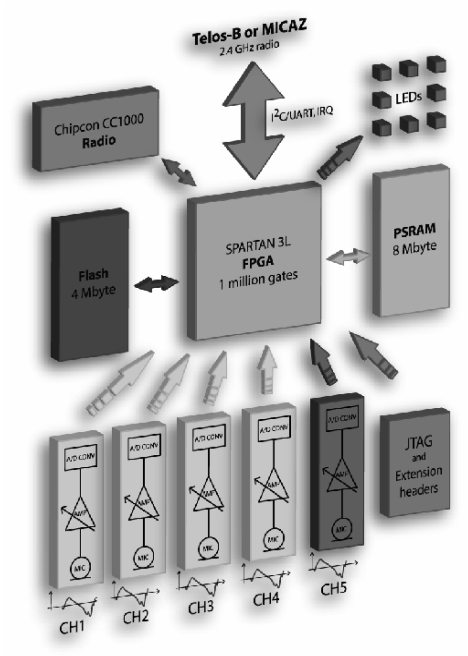
I. Introduction

Hardware-based implementation of acoustic localization algorithms requires a flexible test environment. The Sensor Board 2 is a new custom designed board which has been implemented to be the basis of a joint research project of several universities. A high performance wireless sensor network can be built by connecting the board to the Telos-B [1] or Mica2/MicaZ [2] motes supporting distributed signal processing.

II. Structure of the Sensor Board 2

The Sensor Board 2 consists of a high performance FPGA, on-board memories, one precision and four fast analog channels and an ISM-band radio module.

The system is built around the Xilinx Spartan-3L FPGA having 1 million equivalent gates. The configuration process of the FPGA starts automatically from a Xilinx Platform Flash after applying the power source. The digital and analog parts of the board have distinct power supplies. The SB2 can be powered by either the LOGSYS development cable or four AA batteries. System uptime varies between 20-50 hours depending on the application.



The SB2 has two types of memories. The first is a 8 Mbyte (4Mx16) pseudo-SRAM having 70 ns access time, the other is a 90 ns 4 Mbyte (2Mx16) NOR-type flash. Independent connection of the memories makes it possible to create real Harvard architecture. Operating from the on-board 20 MHz quartz crystal oscillator the maximum memory bandwidth for the PSRAM is 107 Mbit/s in single word mode, which means that data from all analog channels can be stored real-time. The PSRAM can be used as sensor data buffer or as temporary storage for intermediate variables. Program code and data storage is possible in the flash.

The Sensor Board 2 has five analog channels. As high temporal resolution is necessary for transient event detection applications, four of them have 12-bit A/D converters supporting sampling frequencies up to 1MSPS. These are operated synchronously from the FPGA. The fifth channel has 16-bit A/D converter and supports sampling frequencies up to 100 kSPS and has separate control lines. It can be used for vehicle tracking where preciseness is more important than speed. All five channels have a two-stage gain amplifier with an overall gain of 165-1815x (44-65 dB) which can be controlled separately for all the channels in 64 steps with digital potentiometers. In order to reduce noise coming from the digital switching parts of the SB2, the analog channels have separate power and ground planes. The SB2 supports two types of microphones by installing or removing a resistor.

The SB2 can be used alone or together with the TELOS-B or Mica2/MicaZ motes. The power supply for the FPGA and the second stage of the analog channels can be switched on and off by either motes. As the first stage is still operational, the TELOS-B can monitor the fifth analog channel and the Mica2/MicaZ the four other channels with their A/D converters via dedicated lines for activity. The SB2 connects to the motes via I^2C, SPI or UART. Several general purpose input/output and interrupt pins of the motes are also connected to the FPGA.

The Chipcon CC1000 radio module can be used for interference based sensor localization algorithm [3] thanks to a very special feature, the high resolution frequency tuning. Measuring the envelope of the received signal strength is necessary for the algorithm and can be done with a 12-bit A/D, which is of the same type that is used for the four analog channels.

The three extension headers on the SB2 allow the connection of optional components.

III. System architecture

The system is built around the FPGA and the drivers for each component must have been implemented first. The drivers for the analog-digital converters, the digital potentiometers, the PSRAM and the flash were created in VHDL paying attention to modularity and standard interfaces. These IPs occupy only small part (<5% of slices) of the FPGA and can be used for different applications.

IV. Sample application – transient event detection and recording

In order to be able to compare the properties of different localization algorithms in MATLAB, real data is required. The full system consisting of Telos-B nodes with attached sensor boards can be controlled via a graphical user interface implemented in MATLAB. The communication is bidirectional, commands can be issued and status messages along with data can be received. The user commands are forwarded to the base station which broadcasts them to the single nodes. Data from the nodes can be collected similarly, using the base station as a bridge. Time synchronization is implemented in the motes. The SB2 and the Telos-B communicates via UART and dedicated lines for time critical signaling (eg. requesting timestamp). When a start command is issued by the user, all the sensor boards start sampling and the detectors on each channel are looking for transient events. Meanwhile, a short period of samples is stored in temporary circular buffers. If the detectors signal the onset of a transient event, the contents of the buffers are copied to the SRAM along with the new samples, until the detection of the end. Late false detections are eliminated by disabling detectors after most of the sensor boards detected. Data from SRAM is forwarded to the base station on request, and also stored in flash with metadata (recording size, timestamp) and can be read out later directly to a PC.

V. Results, future plans and acknowledgement

The newly developed SB2 is working properly. Future plans include collecting data with the created system and evaluating multiple acoustic source localization algorithms based on the recordings. The ultimate goal is the hardware implementation of these algorithms inside the FPGA.

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References

[1] Telos-B platform, URL: http://www.xbow.com/Products/Product_pdf_files/Wireless_pdf/TelosB_Datasheet.pdf

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