A Hardware/Software Codesign Capstone Project in Computer Engineering

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Computer Engineering Capstone Project - the past...

- Students were given an ISA for a simple 8-bit µP and were tasked with the design of an implementation using FPGAs:
It was a good project, but...

- The 35VEE8 project does not include any real software component
  - At best, the students write a few additional assembly language programs to further test the processor, but some groups only run the provided benchmarks
- The project does not include any real hardware/software codesign aspects
- The project does not involve the use of any microcontrollers or other embedded computer systems
- The project does not readily lend itself to inclusion of the ABET “professional components” of the major design experience:
  - economic
  - environmental
  - sustainability
  - manufacturability
  - ethical
  - health and safety
  - societal
  - political
- The project doesn’t have a “gee whiz” factor that really grabs the students attention, and it doesn’t really “demo” well

The Solution - Advanced Digital Design Capstone Project

- Project is based on a commercial hobby robot chassis - the Hexapod II from Lynxmotion (http://www.lynxmotion.com)
- Six-legged robot was chosen to provide more of a challenging control problem than a simple wheeled robot
- A microcontroller is used to perform the “higher-level” functions and a custom digital IC is used to perform the basic control functions
- Additional hardware is necessary to generate servo positioning pulses within specified time limits
  - Pulses (regardless of size) must repeat at 10 ms intervals
  - Servo position controlled by pulse width of 0.5 ms to 2.5 ms intervals
Autonomous Robot Basic System Architecture

Microcontroller performs high level functions and decision making

Analog sensors detect signals from the environment

Actel 1020B FPGA

Custom digital hardware takes instructions from microcontroller and sends the right signals to the servos to move the legs

Hexapod Servos

Control State Machine

10ms Timer

Down-counter based PWM Generators

Register File

Hexapod Servos move legs

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Analog sensors detect signals from the environment

Example Robot Project
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Actel FPGAs  PIC microcontroller  power supply

Example Robot Project Group
HALFRO - the “ultimate” solution

HALFRO

PIC μC - main controller
Actel FPGA
AVR μC - bowtie controller
diagnostic display
HALFRO beacons

- Beacons use a small Atmel AVR microcontroller to produce a PWM signal on the LEDs that HALFRO uses to distinguish between the “object” and “home” beacons.

HALFRO in action
The future - the MERCAL platform

- MERCAL - Miniature Embedded, Reconfigurable Computer and Logic
- Project sponsored by NASA to develop a small, powerful, low-cost, easily programmed, reconfigurable hardware/software system
- Hardware is based on Xilinx, Spartan II FPGAs
- Software is based on JumpTec sub credit card sized DIMMPC
- The MERCAL final version of the MERCAL boards are being developed at VCU this summer and will form the basic HW/SW system for future projects

Conclusions

- It is possible to provide students with a complete HW/SW codesign problem in a tractable, low-cost, low-complexity manner
- Students really enjoyed the “mechanical” nature of the project and the opportunity for innovation
- New MERCAL system as a generic HW/SW platform promises many advantages:
  - powerful 133MHz processor running familiar OS and development environment
  - up to 180,000 gate equivalent hardware
  - flexible, many times reprogrammable system
  - possibility for including reconfigurable computing in senior projects