iFunction: Design and Implementation of a Programmable Function Generator IP Core for ISAAC Technology

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About Me

- From Daytona Beach, Florida

- Pursuing B.S. in Computer Engineering at the University of South Florida
Outline

- Problem
- Background
  - FPGAs
  - ISAAC
  - Direct Digital Synthesis
- iFunction
- Q&A
A field-programmable gate array (FPGA) is an integrated circuit with reconfigurable digital logic functionality.

- Wide range of applications:
  - Instrument Control and Computing
  - Digital Signal Processing
  - Rapid Prototyping

- Programmed with a hardware description language (HDL) such as VHDL or Verilog.
ISAAC (Instrument ShAred Artifact for Computing)

- FPGA based instrument computing and control platform
- Reusable
- Modular
- High Performance
- Significantly reduce high non-recurring engineering costs.
ISAAC (Instrument ShAred Artifact for Computing)
- FPGA-based shared instrument control/computing platform

**iTool**
- An integrated toolchain providing an end-to-end design flow to digital system designers

**iBench**
- A suite of benchmarks for instrument data stream and underlying hardware/software

**iCore**
- Computing and Control IP modules
- Instrument-specific DSP IP modules
- Fault tolerance IP modules
- Parameterizable

**iPackage**
- Model-based instrument control
- Science library
- Instrument command/telemetry protocol
- Real-Time Operating Systems
- BSP, Bootloader

**iBus**
- Compile-time hardware/software interface standard
- Run-time execution environment

**iBoard**
- Xilinx FPGA with 2 CPUs and 8 million reprogrammable fabric
- EDAC-protected NVM and SDRAM
- Common instrument control/computing interfaces (LVDS/RS42/15533/SpaceWire/I2C)
iBoard

- FPGA-based hardware substrate
  - High-performance computing element
  - Xilinx Virtex-5 FX130T with 8 million programmable fabric
  - Fast volatile and non-volatile on-board storage
  - Versatile I/O interface with wide range of bandwidths (Kbps to Gbps)
- Path-to-Flight (Currently in 4th iteration)
**Background - DDS**

- **Direct Digital Synthesis** – Method to digitally synthesize arbitrary waveforms using an phase accumulator and look-up table

![Phase Accumulator Diagram](image)

- **Waveform Memory**
- **Generated Signal (21 MHz)**
- **Sample Clock (100 Ms/s)**

![Signal Generation Diagram](image)
Problem

- ISAAC developers need sinusoidal and arbitrary waveform generation
  - Digital radios and modems
  - Modulation Schemes
  - Clock generation
  - Testing and debugging hardware

- Waveform synthesis must be
  - Intuitive
  - Quickly implemented
  - Verifiable
Objectives

iFunction

- Programmable function generator IP Code for ISAAC technology
- Serial communications system for external control and verification
- Waveform viewable on iPanel
Objectives

• Design and Implement iFunction 1.0 Hardware
  • iFunction_Synth
    • Synthesize sinusoidal waves of user defined frequency / amplitude on iBoard
  • iFunction_Comms
    • Transmit packets over UART at user defined sampling frequency / size
    • Receive command packets that define waveform characteristics, trigger sample collections, reset system modules

• Design and Implement iFunction PC Control Panels
  • Command-line control panel
    • Stand alone application to aid in development and debugging
  • iPanel control panel
    • GUI
    • Functionality with multiple ISAAC instruments
iFunction Block Diagram
Problems
iFunction Control Panel

1) Turn Off
2) Turn On
3) Update Frequency
4) Reset Comms
5) Reset All
6) Capture Data in File
7) Get Graph
8) Print Serial Data
9) Change Sample Size
   a) Change Sine Coefficient
   b) Change Cosine Coefficient
   c) Change Sampling Rate
   d) Exit
Choice: 1
iFunction iPanel Control
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Q&A