•Jet Propulsion Laboratory
•California Institute of Technology

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

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Section 3493 – Advanced Computer Systems & Technologies
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About Me

- From Daytona Beach, Florida
- Pursuing B.S. in Computer Engineering at the University of South Florida

Outline

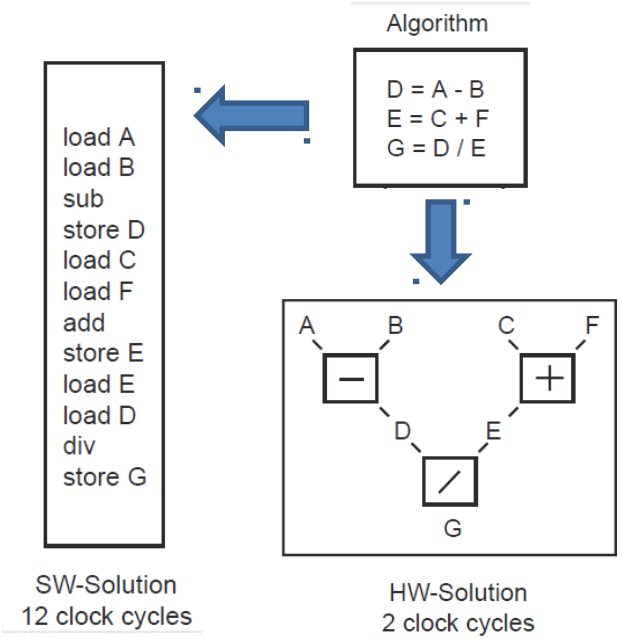
- Problem
- Background
  - FPGAs
  - ISAAC
  - Direct Digital Synthesis
- iFunction
- Q&A

Background - FPGAs

- 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

ISAAC (**I**nstrument **S**h**A**red **A**rtifact for **C**omputing)

- FPGA based instrument computing and control platform

- Reusable
- Modular
- High Performance

- Significantly reduce high non-recurring engineering costs.

ISAAC

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

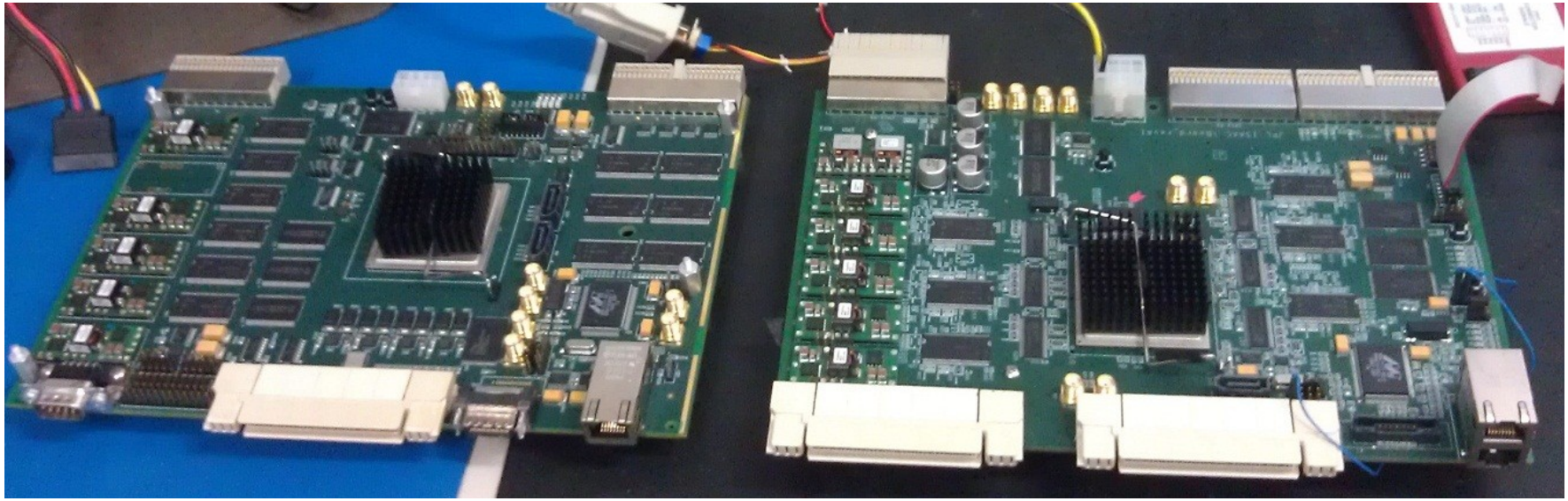
iPackage
- Model-based instrument control
- Science library
- Instrument command/telemetry protocol
- Real-Time Operating Systems
- BSP, Bootloader

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)

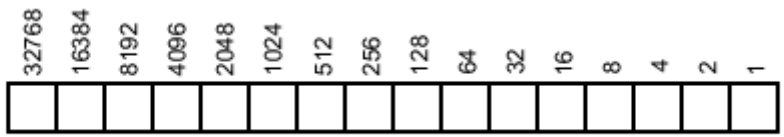
iBoard

- 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)

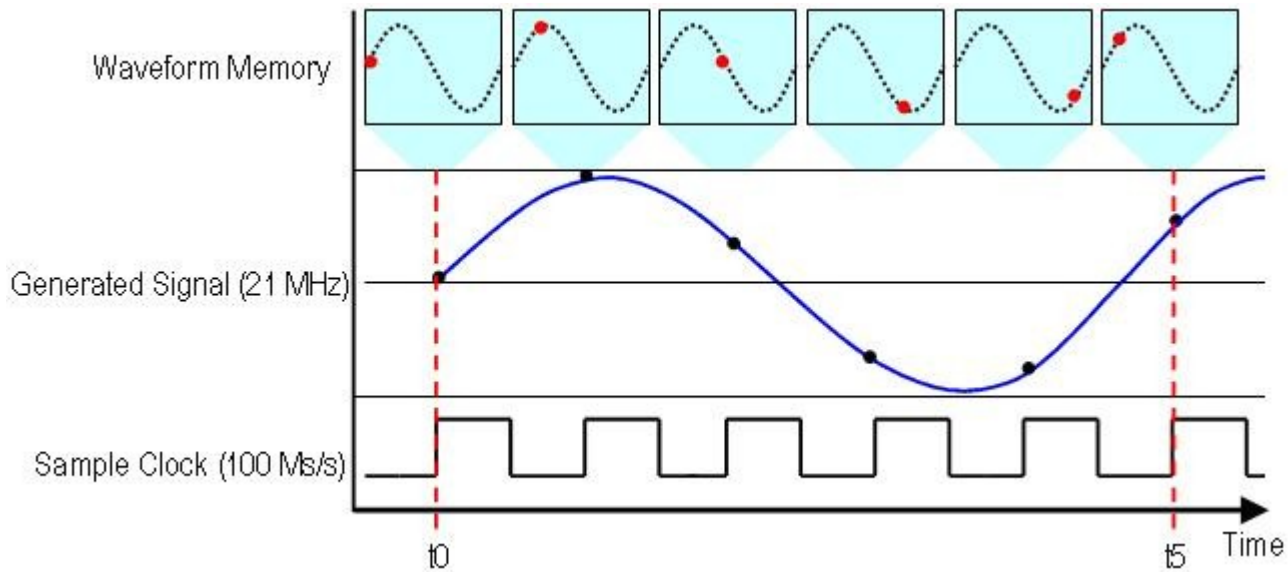


Background - DDS

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



The Phase Accumulator, a 16-bit binary counter



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

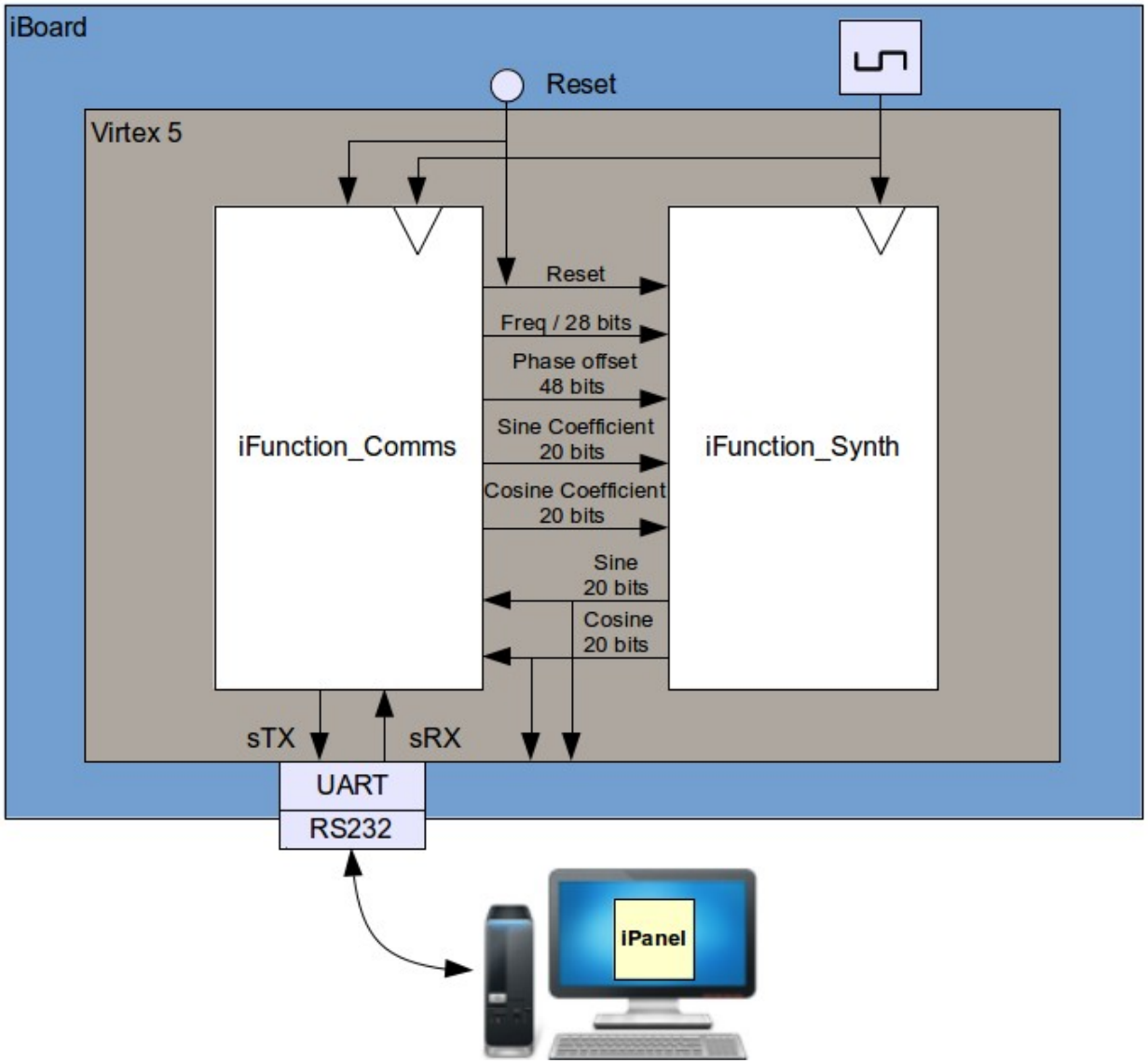
- Waveform viewable on iPanel

Objectives

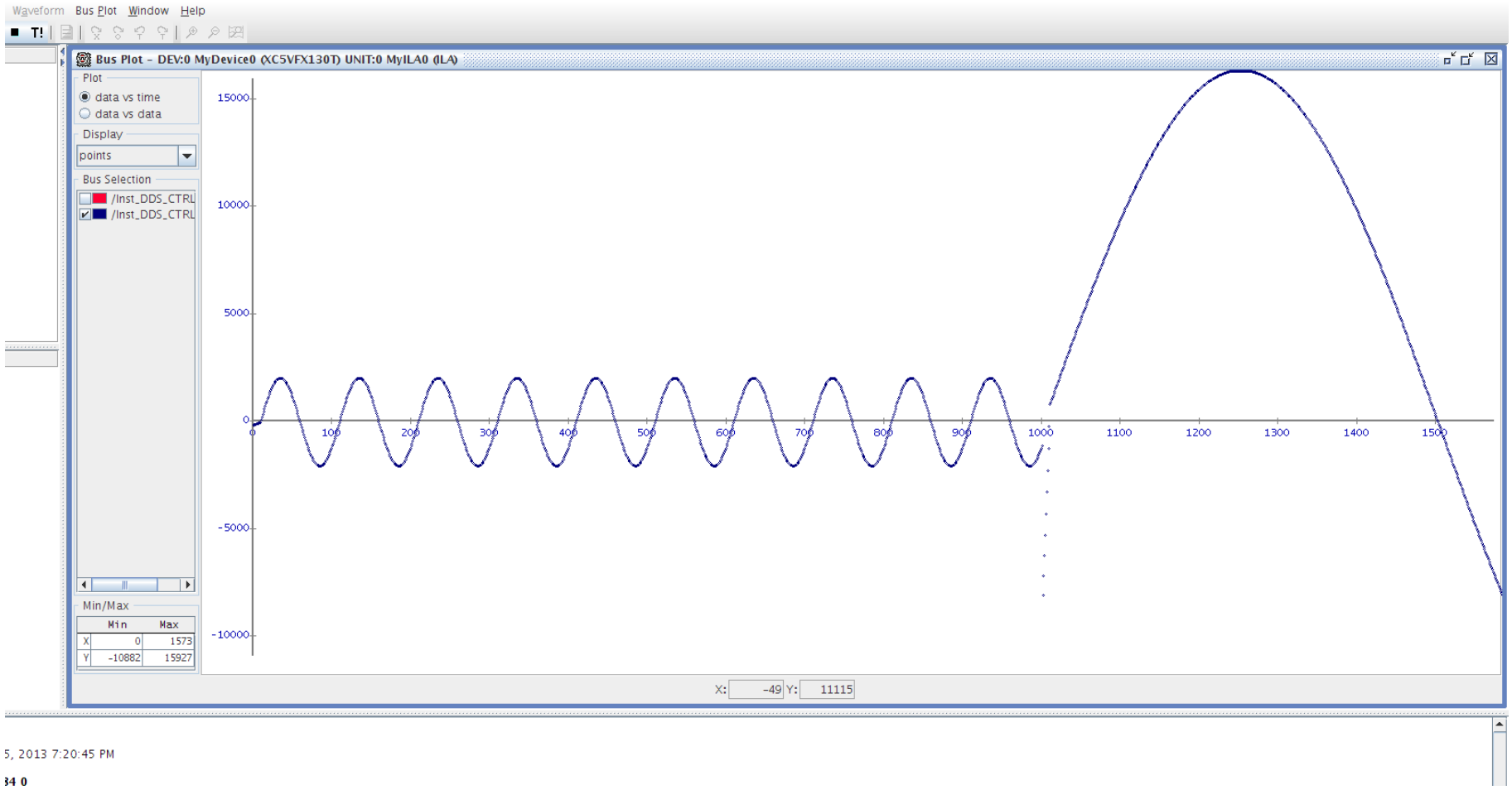
- Design and Implement iFunction 1.0 Hardware
  - iFunction_Synth
    - Synthesize sinusoidal waves of user defined frequency / amplitude on iBoard
  - iFunction_Comms
    - Transmit packets over UART at user defined sampling frequency / size
    - Receive command packets that define waveform characteristics,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


Waveform Bus Plot Window Help
Bus Plot – DEV:0 MyDevice0 (XC5VFX130T) UNIT:0 MyILA0 (ILA)
Plot
data vs time
data vs data
Display
points
Bus Selection
/Inst_DDS_CTRL
/Inst_DDS_CTRL
Min/Max
Min Max
X 0 1573
Y -10882 15927
15000
10000
5000
0
-5000
-10000
0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500
X: -49 Y: 11115
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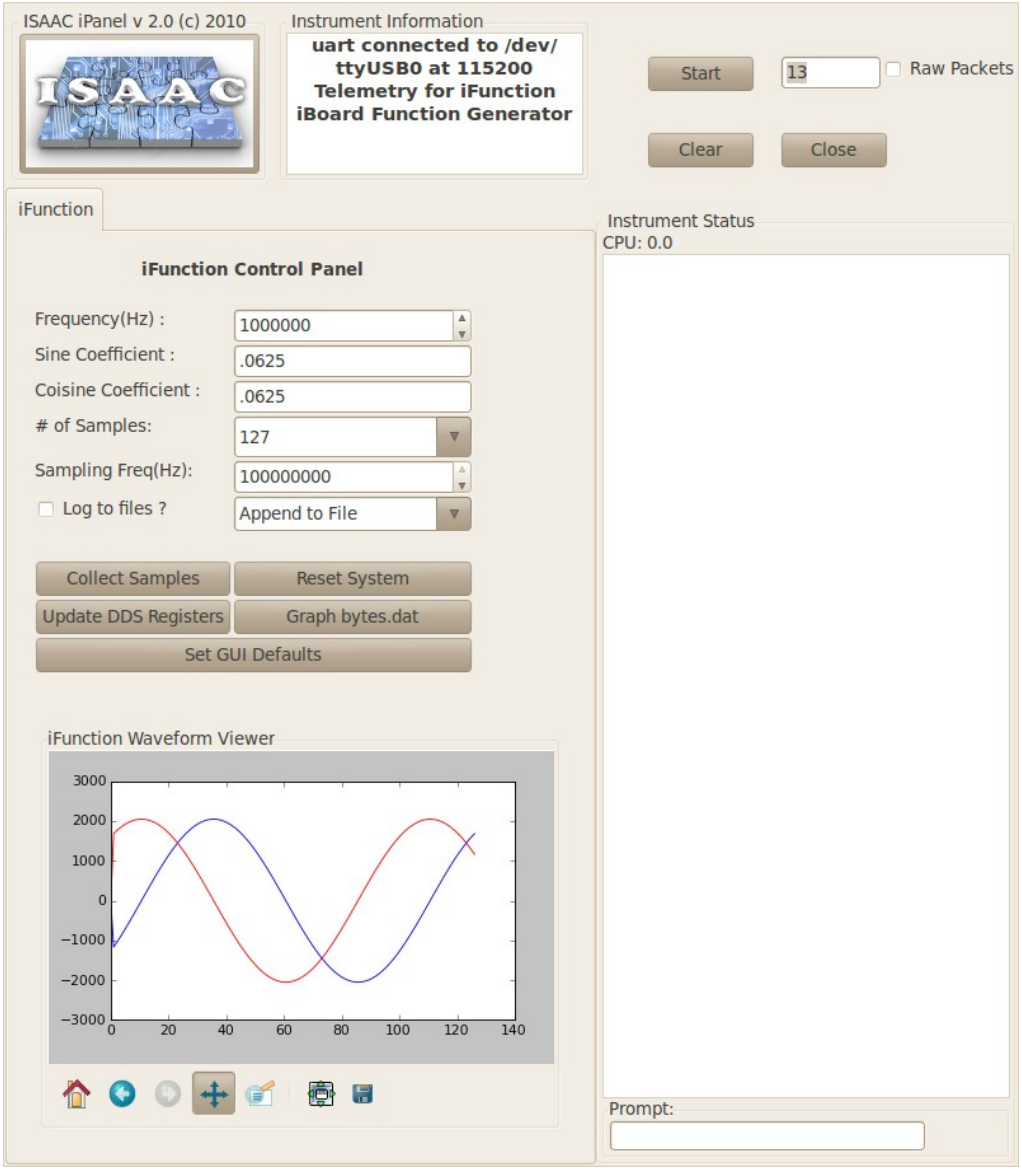
34 0

iFunction Control Panel

```
File  Edit  View  Terminal  Help
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:
```

iFunction iPanel Control



Acknowledgements

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Q&A