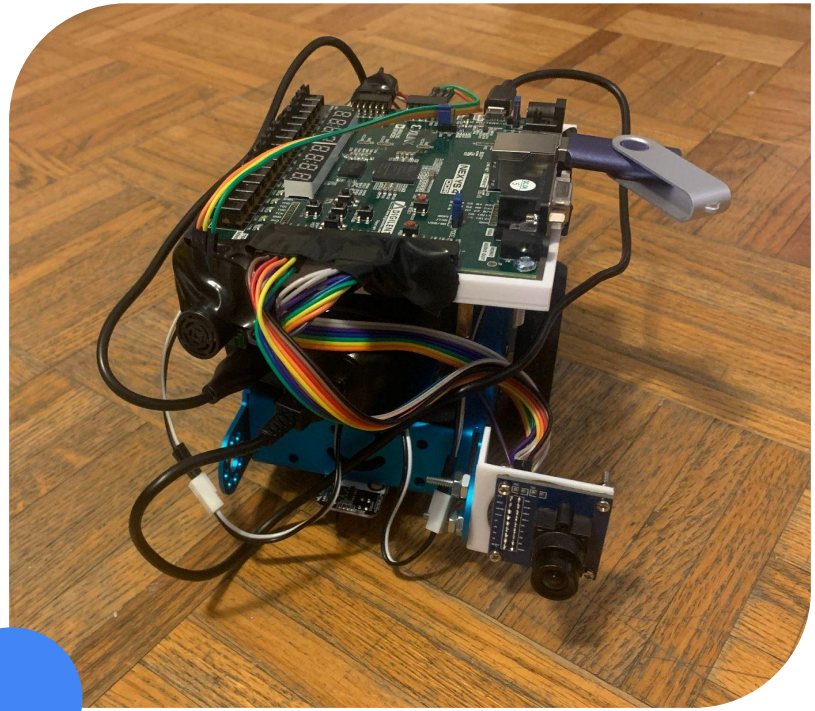
Autonomous Search and Rescue Robot Using FPGA-based Audio Localization



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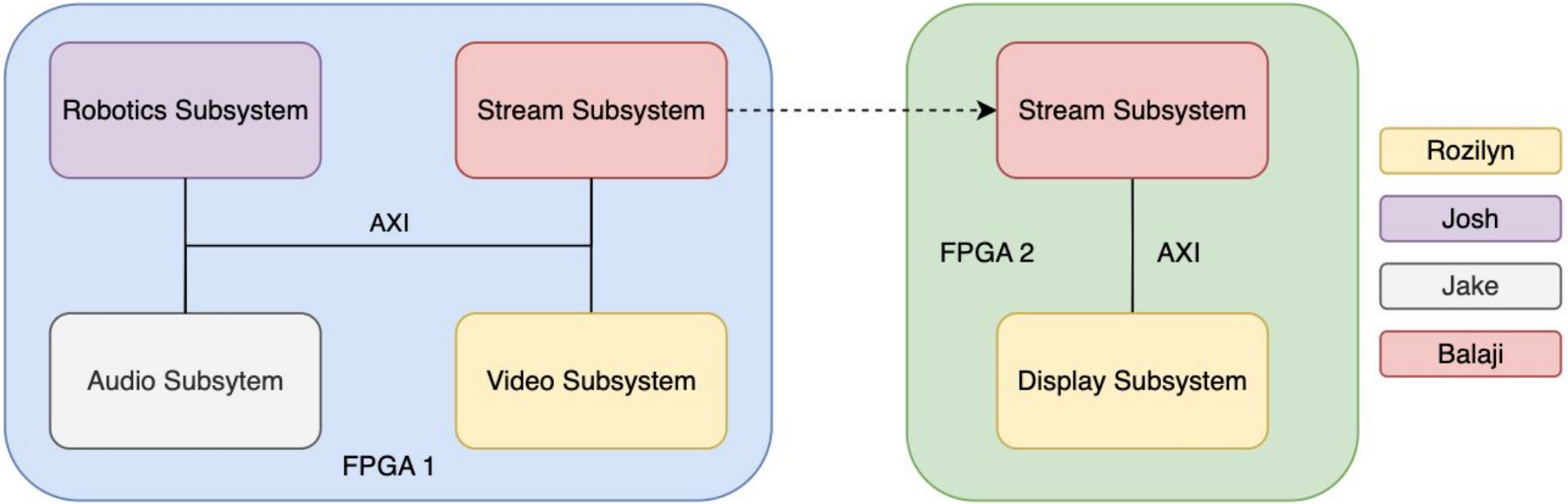
Project Description & Block Diagram

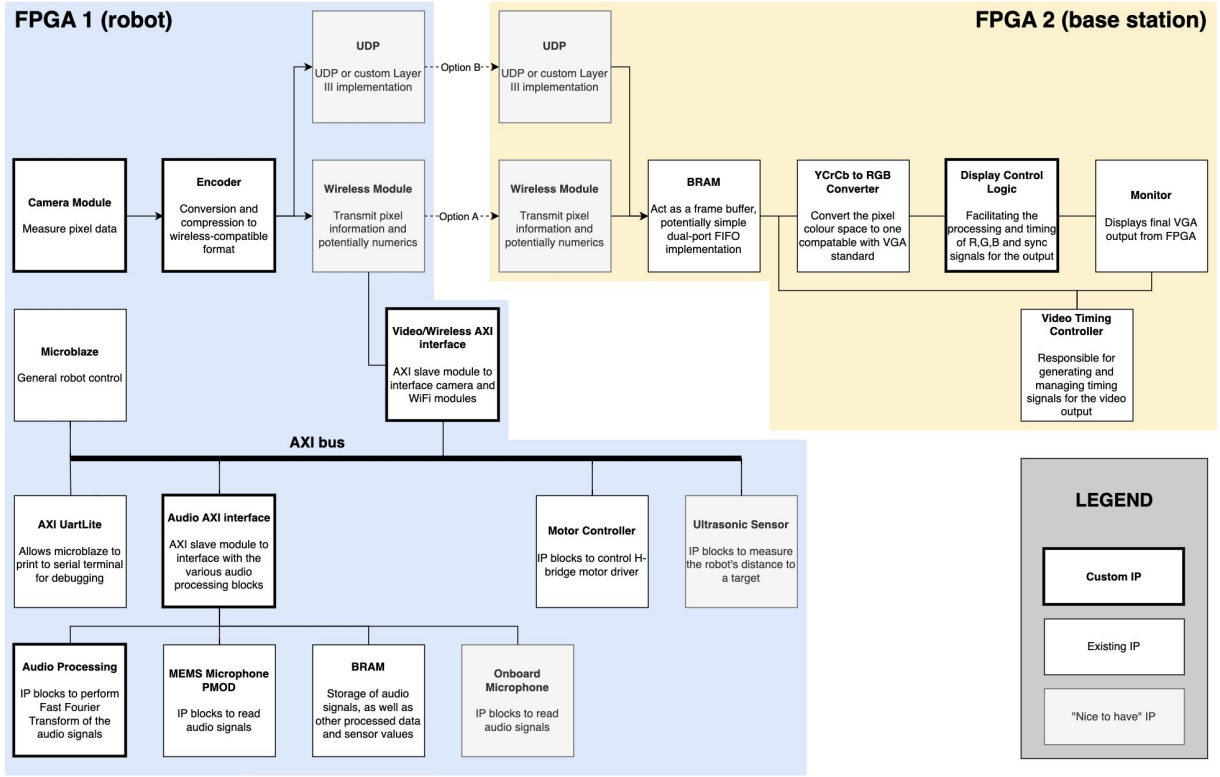
High Level Project Description

Audio-guided search-and-rescue robot with video stream to base station

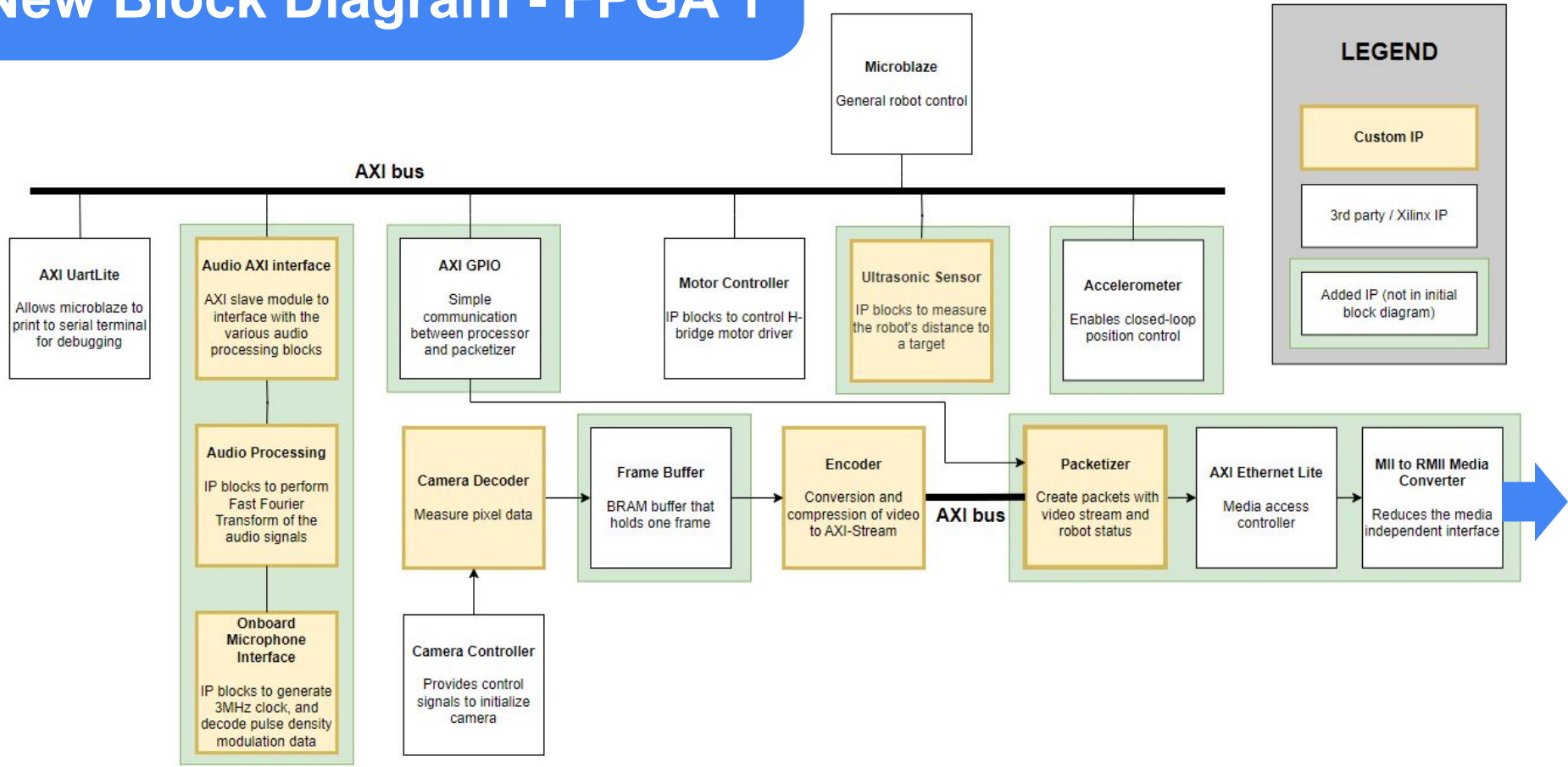


Initial Goals

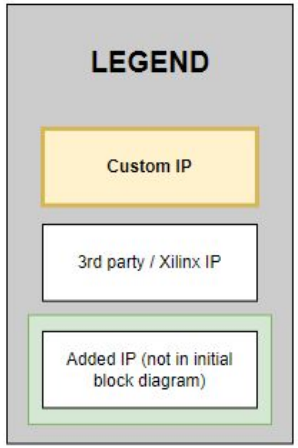
- Move robot to find a speaker in a 2-D space
- Stream live video from the robot back to the base station
- Display video on VGA monitor

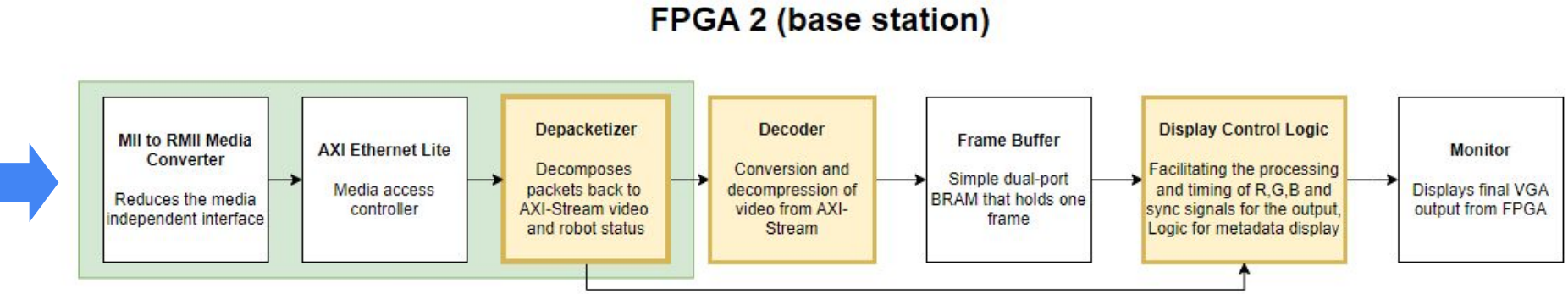


New Block Diagram - FPGA 1



Block Diagram - FPGA 2



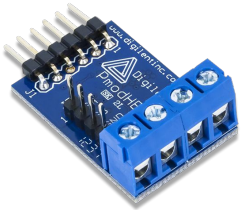


Major Components

Robotics Components

H Bridge

- Vivado IP was utilized to control the H-Bridge
- Through AXI the microblaze can control the speed and direction of the h bridge



Ultrasonic Sensor

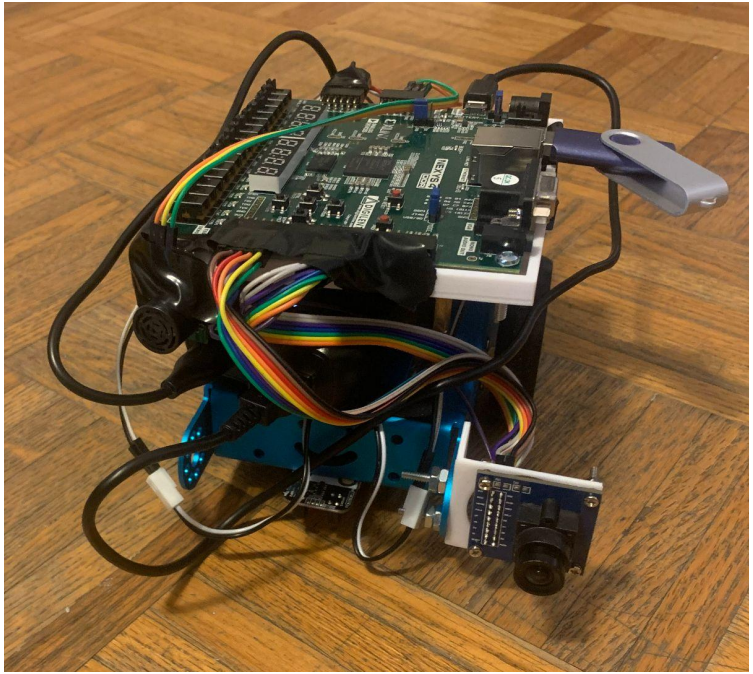
- Custom IP was created that constantly gets distance from the sensor
- Distance is stored in an AXI register which can be accessed by the microblaze

Robotics Components

Accelerometer

- To create a closed loop control for the robots navigation the onboard accelerometer was utilized.

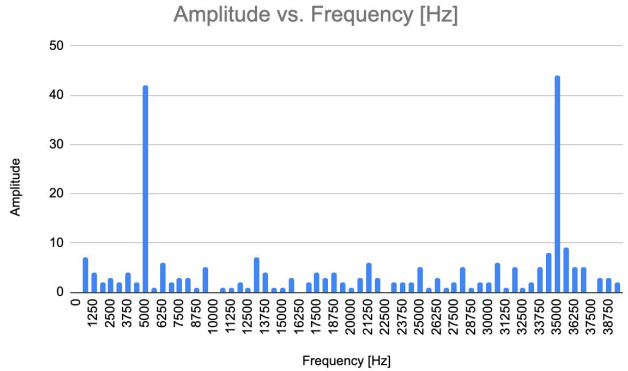
- Through a Vivado IP X and Y acceleration data was captured and utilized by microblaze



Audio Components

Microphone

- Custom IP to convert pulse density modulation output to 8-bit analog samples
- Synchronizer block interleaves sampling in time to achieve **40kSps (320kbps)**



FFT

- Pipelined streaming mode for low latency (real-time)
- Custom IP wrapper
  - Timing between two clock domains
  - Pipeline stalling
  - Input/output formatting
- AXI interface to access spectrum data

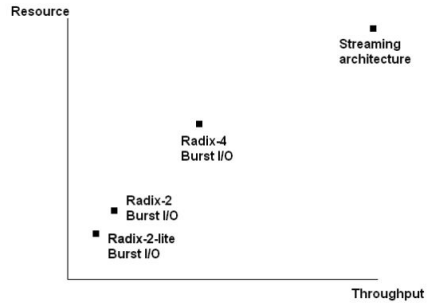
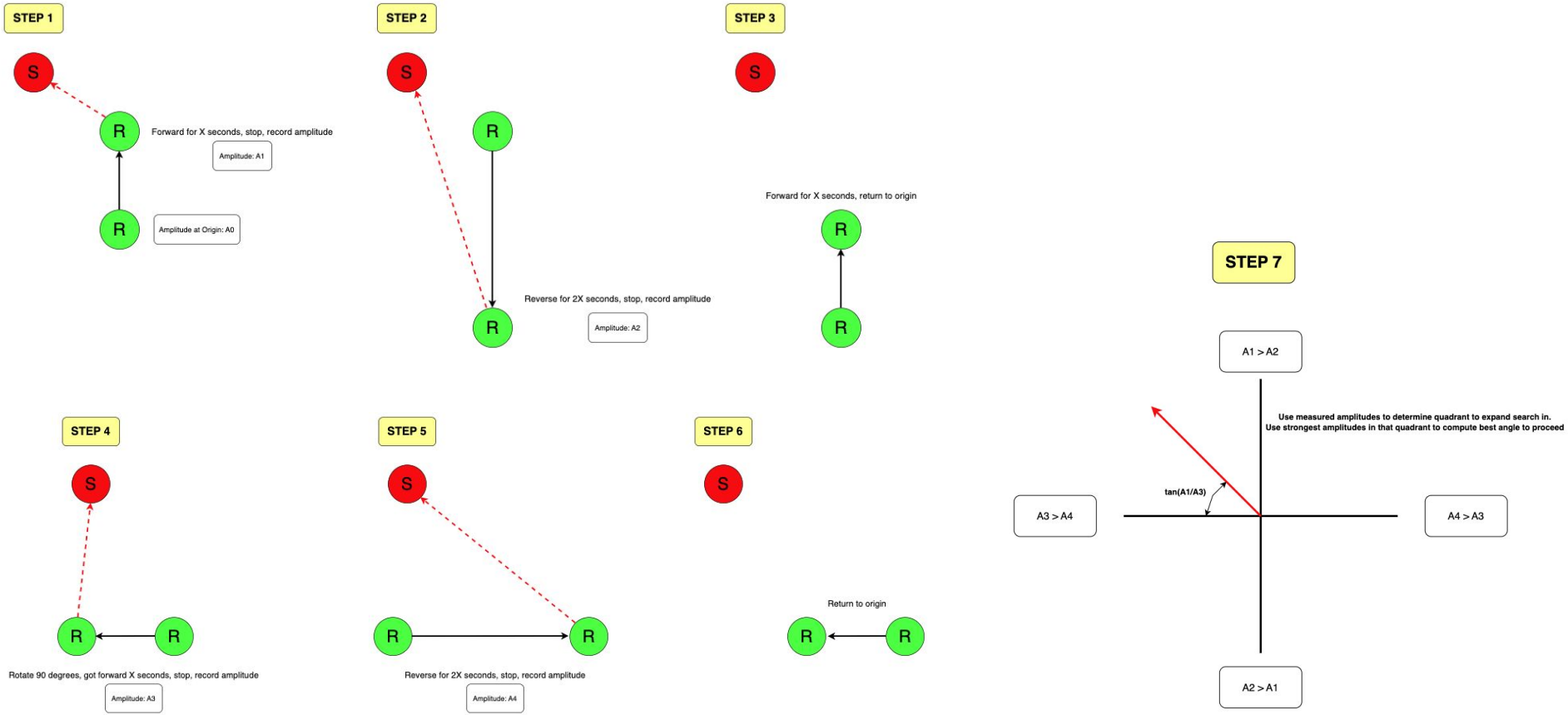
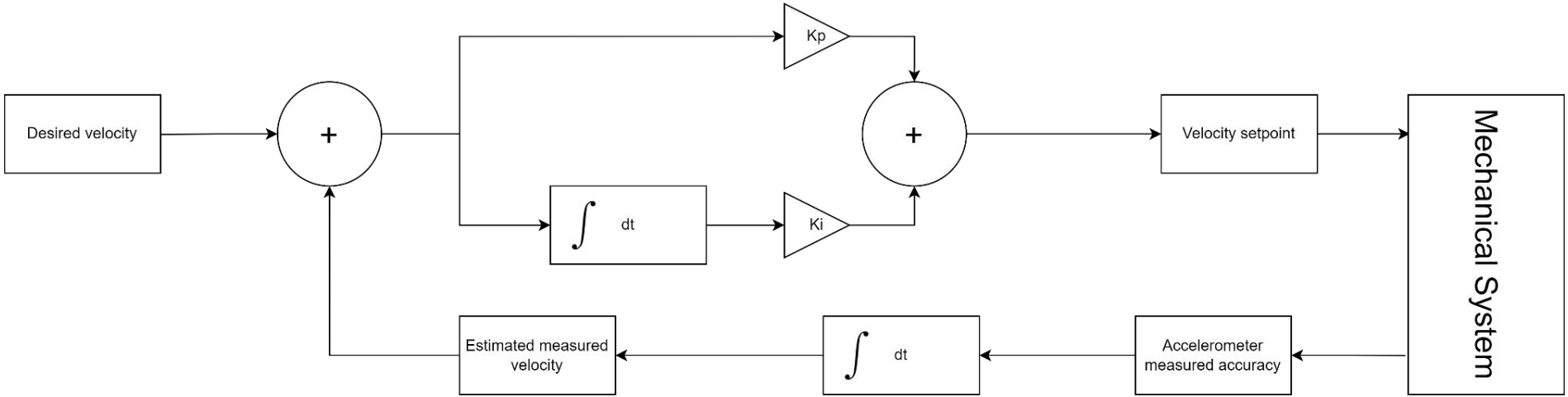


Figure 3-35: **Resource versus Throughput for Architecture Options**

Microblaze Development - Search Algorithm



Microblaze Development - PI Controller



- Utilizing the accelerometer we implemented a closed loop control scheme of the mechanical system
  - Utilized Kp = 100, Ki = 0.1

Streaming Components

Packetizer

- Interfaces with camera memory
- Interfaces with robotics through GPIO for sideband data
- Creates and sends ethernet frames using AXI Ethernet Lite

Depacketizer

- Interfaces with display memory
- Interfaces with display module for sideband data
- Receives and unpacks ethernet frames using AXI Ethernet Lite

Video/Display Components

Camera

- Transfer registers to module over I2C interface
- Capture stores pixels into BRAM (simple dual port)
- All hardware (no Microblaze)

VGA

- Pixels retrieved from BRAM (simple dual port)
- 640x480 resolution from double-double scanning
- Logic for text display
- All hardware (no Microblaze)

Bus Configuration

AXI bus 1

- Most peripherals (robot, audio, etc)
- Low data rate requirements

AXI bus 2

- Video stream
- High data rate requirements

Communication between two busses

- Low data requirements (“found” signal)
- AXI GPIO outputs array of bits read by packetizer

Complexity

Feature	Associated Points
Peripherals	
Camera	1
VGA output without MicroBlaze involvement	1
H-bridge	0.2
On-board microphone	0.5
Ultrasonic rangefinder	0.5
Visualize meaningful results with a GU	0.75
Accelerometer	0.75
Custom IP Cores/software	
IP core for audio processing	1.5
IP core for camera control/wifi control and streaming	1.5
Software algorithm implemented on MicroBlaze	0.75
Total	**8.45**

Future Improvements

Audio

- More microphones + higher quality (bits)
- FFT configured for high performance, yet unused
  - PMOD microphone: 12 bit, 1MSps

Robotics

- Addition of gyroscope to have proper close loop control of robot

Stream

- Implement IP in order to make it compatible with WiFI

Video/Display

- More refined user interface (zoom, location information, etc.)

Demo

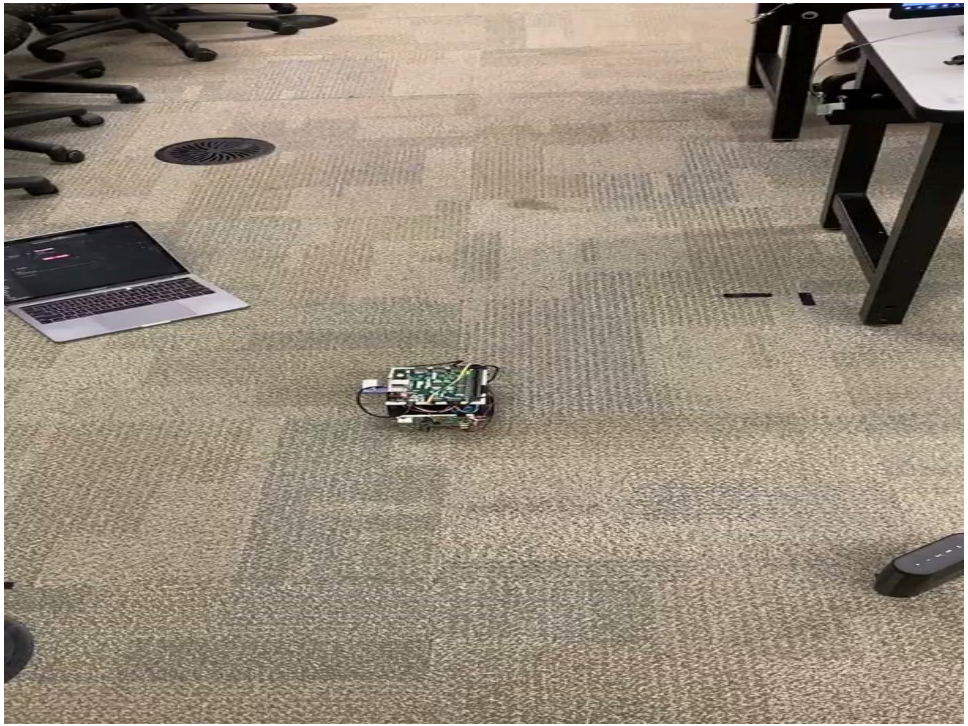
Demo Agenda

Individual Parts Demo	PI Controller Demo	Search and Rescue Demo
Each of the projects parts will be displayed and explained.	The PI controller will be displayed and compared to the open loop control of the robot.	The search and rescue capabilities will be demonstrated.

Questions

Demonstration Video

Demonstration Video



THANK YOU!