wDAQ: Wireless Data Acquisition System

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CLIENT: AVISHEK DAS

FACULTY ADVISOR: PROFESSOR MANOJIT PRAMANIK

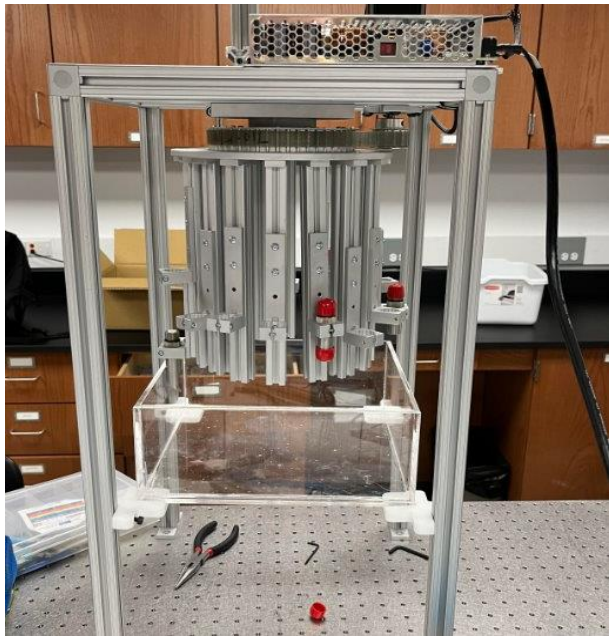
Problem Statement

Problem: Traditional oscilloscopes use BNC (coaxial) cables, a power cord, a built-in display, and buttons

- Impractical for mobile data gathering
- Eliminate cords & buttons to achieve mobile data acquisition within user applications

Goal: Create a compact, battery-powered, software-connected data acquisition system

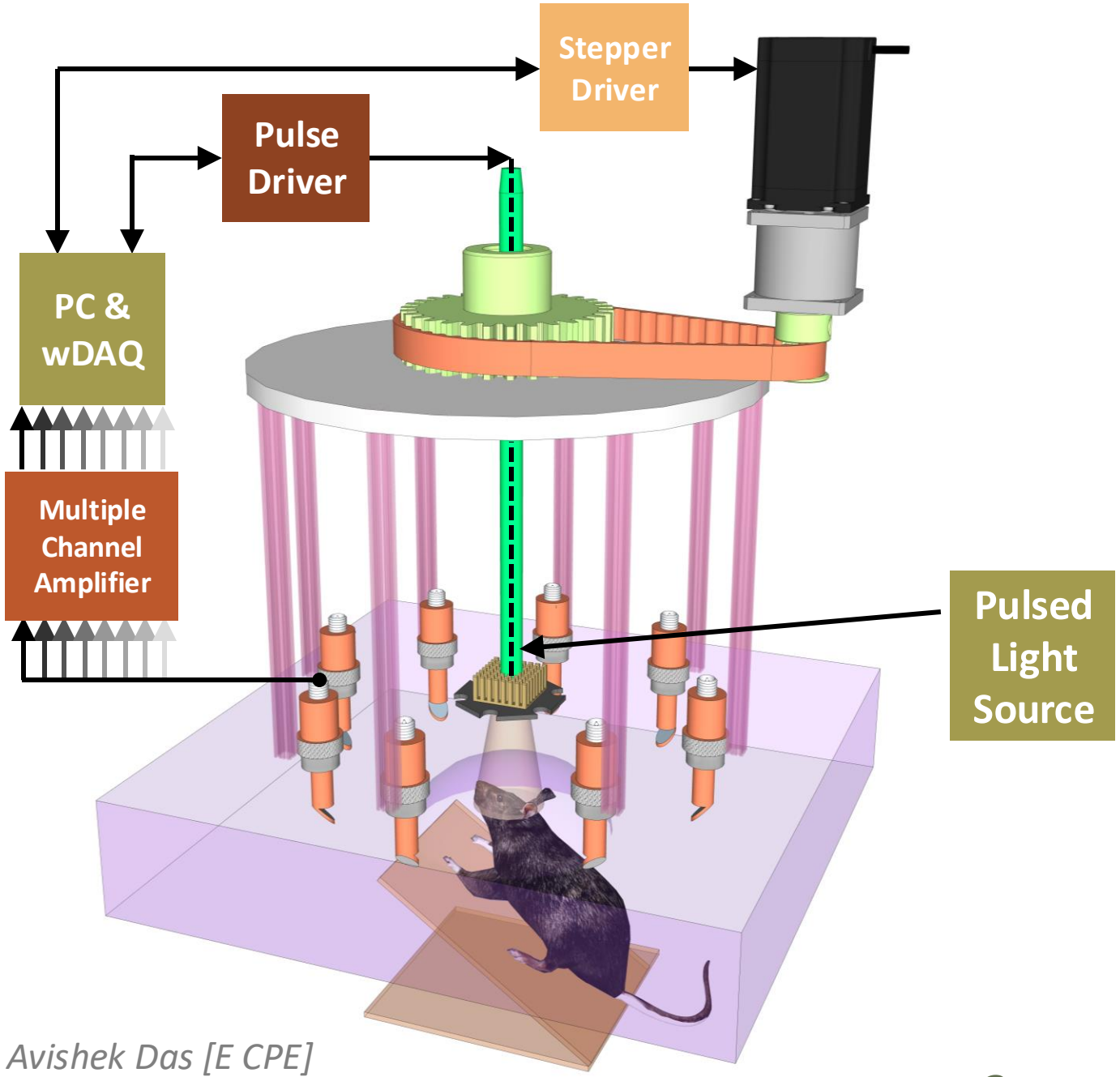
- Use: **ultrasound-like machine*** for animal cancer detection



**Photoacoustic Imaging[1] System with Transducer[2] Array*

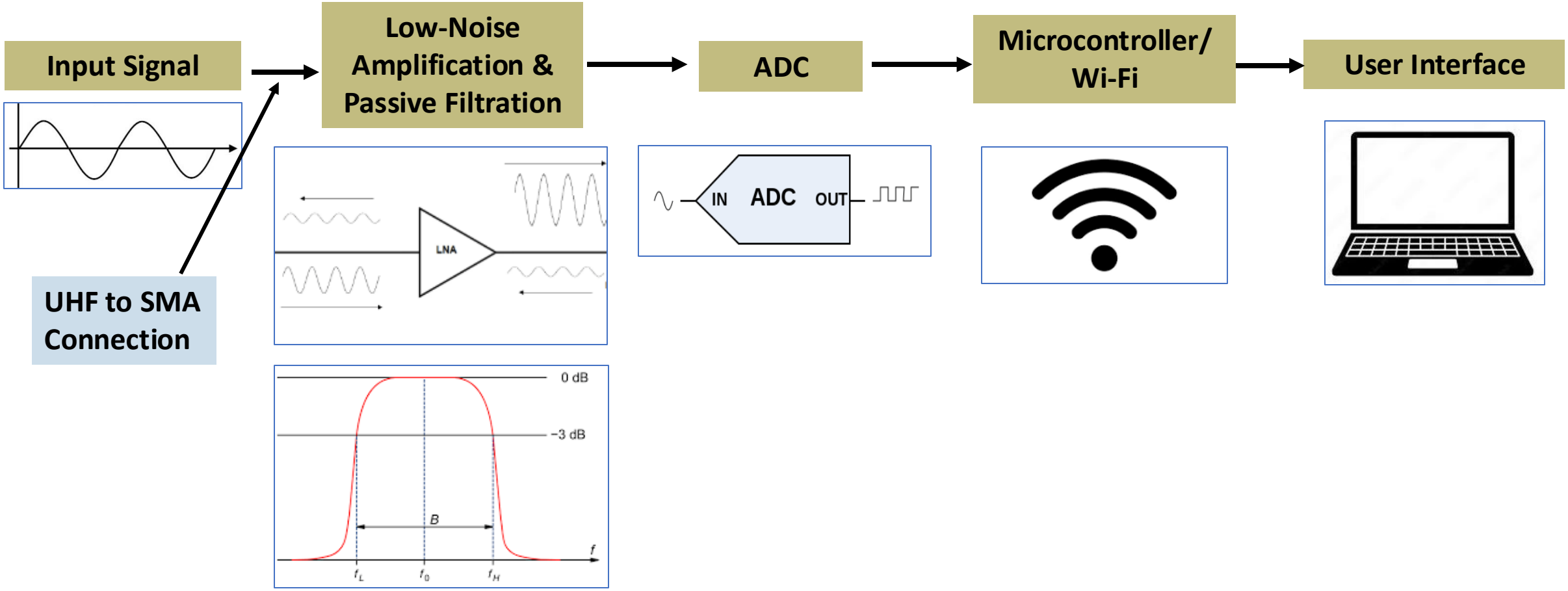
[1] **Photoacoustic Imaging:** Combination of Optical Illumination & Ultrasonic Detection
[2] **Transducer:** Device that converts physical signal to electrical signal

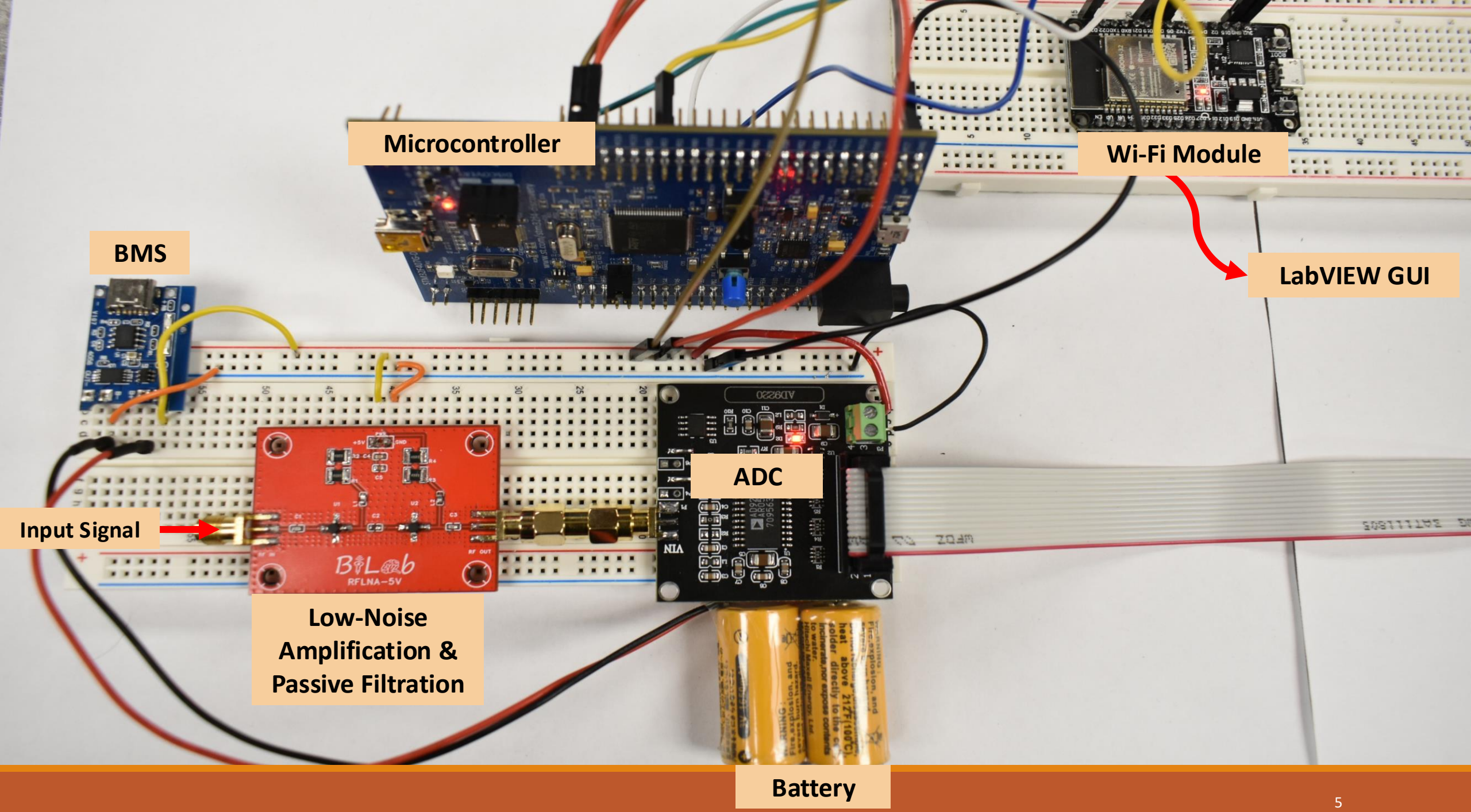
High-Level System Diagram



Source: Avishek Das [E CPE]

High-Level Block Diagram




Microcontroller
Wi-Fi Module
BMS
LabVIEW GUI
ADC
Input Signal
Low-Noise
Amplification &
Passive Filtration
Battery

Requirements

- **Amplifier Gain:** ~40 dB (100 V/V)
- **System Bandwidth:** 100 kHz up to 5 MHz
- **Digital Resolution:** 12 bits
- **Sampling Rate:** Up to 10 MS/s
- **System Channels:** 2 Channels per Module
  - First for software triggering, second for data acquisition
- **Input Impedance:** 50 Ω
- **Rise Time:** <100 ns
- **Record Length:** 50-100 µs
- **Connection:** UHF to SMA connection

Constraints & Considerations

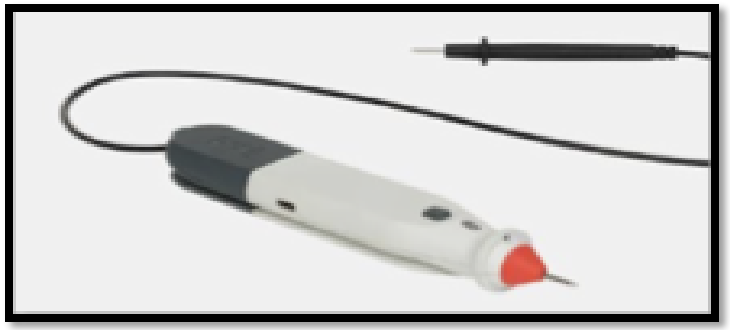
Key Requirement: Accessibility and Ease of Configuration

- Designed to cater to users with varying levels of expertise
- Features straightforward user interface with Wi-Fi connection and measurement setup
- Offers reliable data logging capabilities for convenient data storage

Key Constraint: Compact Size and Mobility

- Carefully selected components that can be integrated, allowing us to downscale to a compact design
- The wDAQ array will rotate during the photoacoustic imaging process

Market Research



[Pokit Pro]

Pros
- USB-C rechargeable battery

Cons
- Limited bandwidth
- Uses Bluetooth

[Digilent Analog Discovery 3]

Pros
- Major software compatibility
- Reputable manufacturer

Cons
- USB-C connection
- Larger size

[Mini-Circuits ZFL-500LN-BNC+]

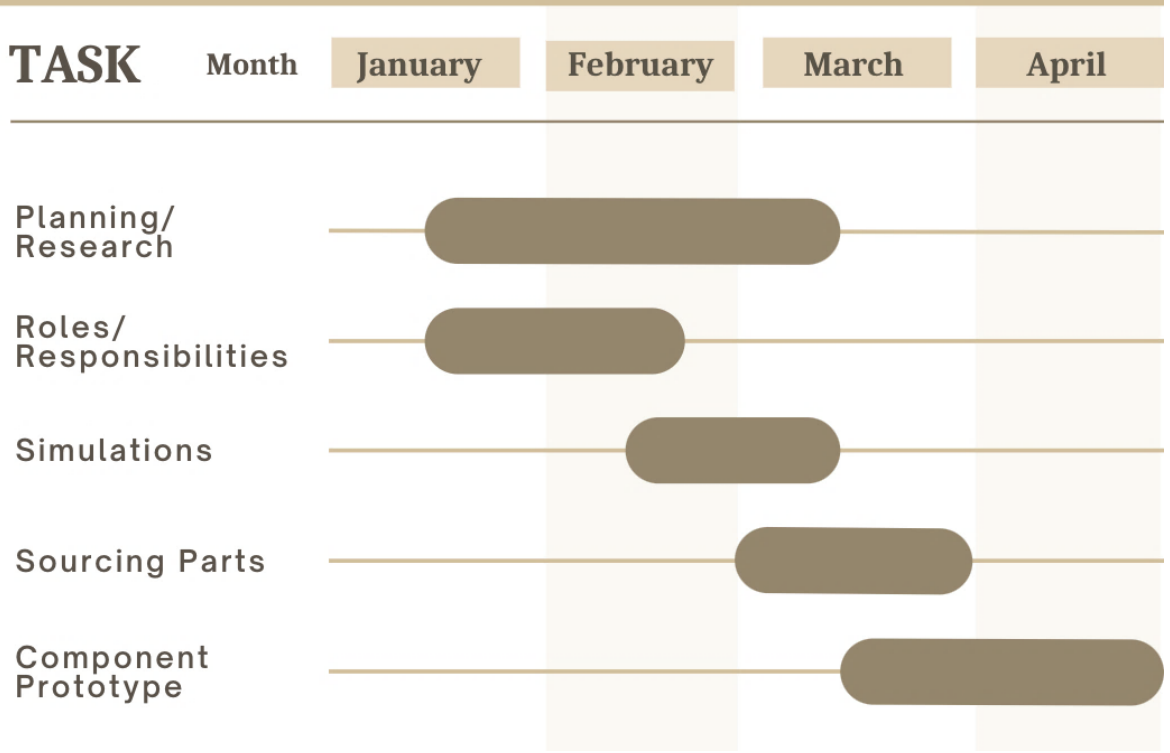
Pros
- Reputable manufacturer
- UHF (up to 500 MHz)

Cons
- $200
- 24 dB gain
- 15V power supply

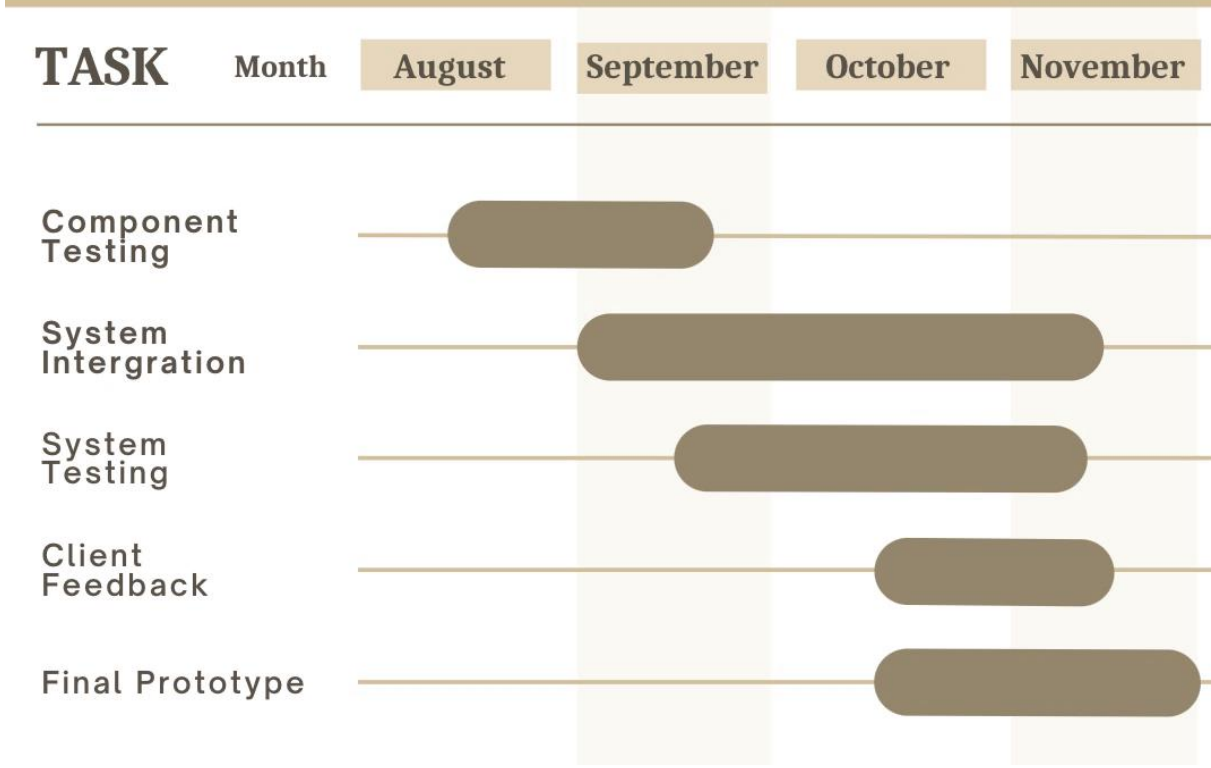
Project Milestones

Input Amplification & Filtration	Achieve functional requirements on IC amplifier with a single DC power supply
Digitization of Amplified Signal	Produce 12-bit digital output from differential analog input on IC while meeting specs
Wireless Data Transmission	Compare Wi-Fi and Bluetooth capabilities Program module to transmit data from server
Graphical User Interface	LabVIEW Interface for server data transfer Data analysis (read, plot, record, and export data)

Spring Semester



Fall Semester



Timeline

Risk Analysis & Mitigation Strategies

Risks:

- Wi-Fi Latency/ Instability
- GUI Needing Additional Functions
- System Decay

Mitigation Strategies:

- User study
- Longevity and Durability Testing

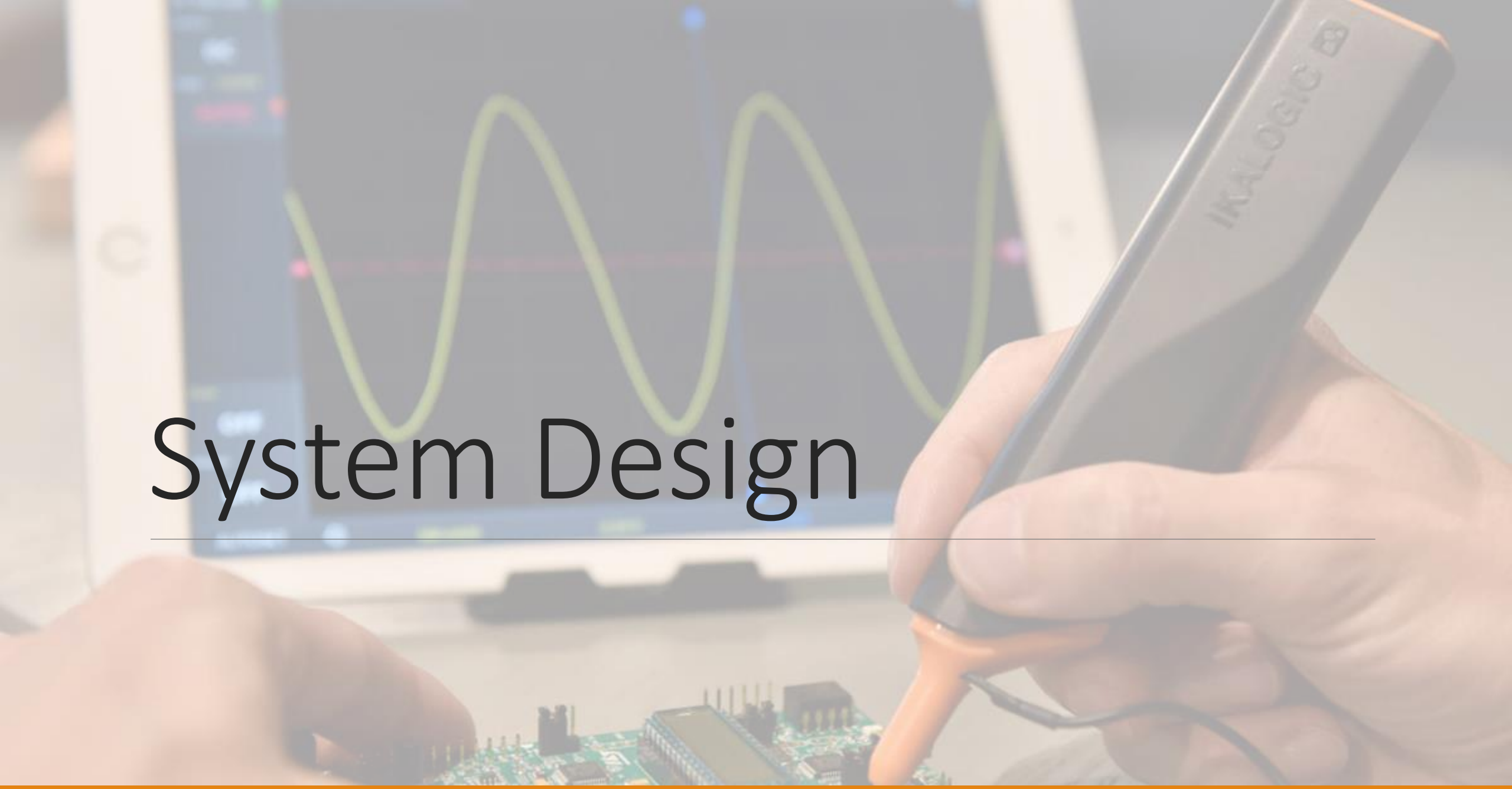
Resource & Cost Analysis

Resource	Qty.	Total Cost
Software	-	Free through ISU
Passive Circuit Components	168	$67.23
IC Chips	35	$116.96
Circuit Accessories (Cables, Pins, Connectors, etc.)	6	$63.79
Development Boards	37	$157.72
Assembled PCB Designs	10	$263.17

Initial R&D Cost: $247.98

Prototype & Build Cost: $420.89

Aggregate Cost: $668.87

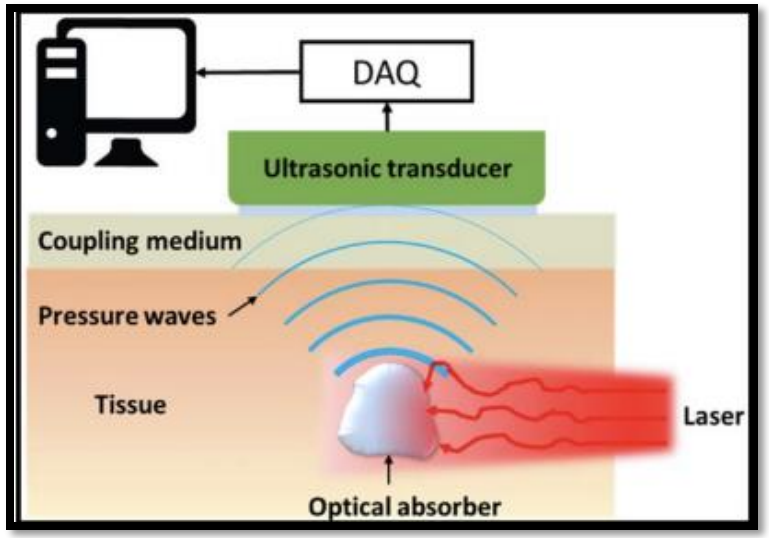


System Design

Functional Decomposition

User Context: Photoacoustic Tomography (PAT) System at ISU Biomedical Imaging Lab (BILab)

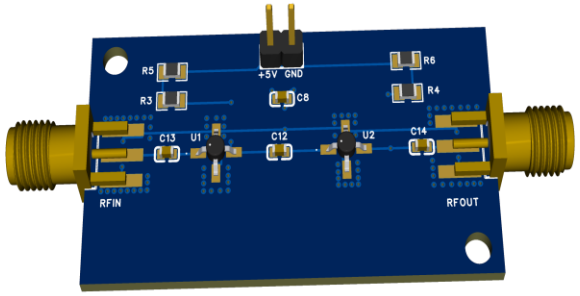
- 10-20 devices connected in a circular configuration to an array of transducers
- Primary users are lab technicians, but wDAQ should accommodate less skilled users
- Signal is amplified, digitized, and transmitted over Wi-Fi to GUI for analysis



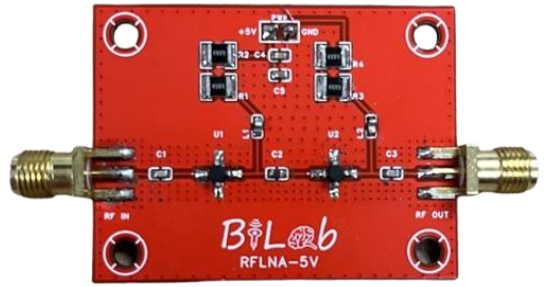
Implementation of wDAQ within PAT System

Detailed Design: Hardware

- **Low-Noise-Amplifier & Filter:** Mini-Circuits MAR-6SM+
  - Two cascaded for amplification (40 dB gain)
  - 16 mA recommended operating current
  - Noise Figure: ~2dB at 0.5 GHz



Original Low-Noise Amplifier PCB Design



Fabricated Low-Noise Amplifier PCB

- **ADC:** Analog Devices AD9220
  - 12-bit resolution
  - Conversion rate: 10 MSPS
  - Differential Input

AD9220 Development Board

Detailed Design: Microcontroller

STM32 Platform:

- High quality documentation for ST ecosystem
- Processing speed is higher than AVR boards
- C code is familiar and widely used

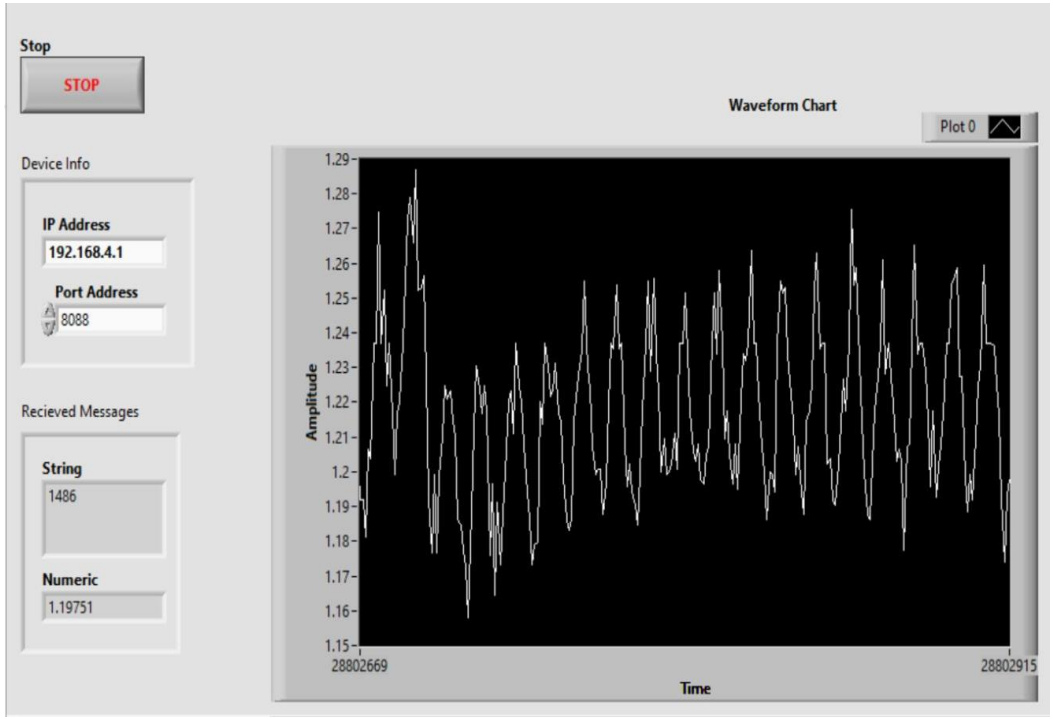
Communication:

- Parallel input from ADC
- SPI/serialized output to ESP32

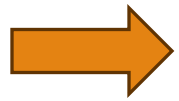
STM32-F4 'Discovery' Development Board

Detailed Design: Wireless Communications & User Interface

ESP32



LabVIEW GUI



Data Logging to text file

0.0001208000	0.5147145265
0.0001524000	0.5149231877
0.0001544000	0.1209546841
0.0001566000	0.1789349281
0.0001588000	0.9421782082
0.0001607000	0.0663913209
0.0001628000	0.0997831924
0.0001649000	0.9375863633
0.0001670000	0.0607266141
0.0001709000	0.1549143046
0.0001729000	0.7309735503
0.0001750000	0.0964675534
0.0001770000	0.7456573755
0.0001789000	0.1858176536
0.0001810000	0.3937141947
0.0001829000	0.3831291627

Exported Data File

Detailed Design: Battery

6 Volt Lithium Battery: *MR-BAT6V1*

- 1650 mAh
- Output Voltage: 6 V

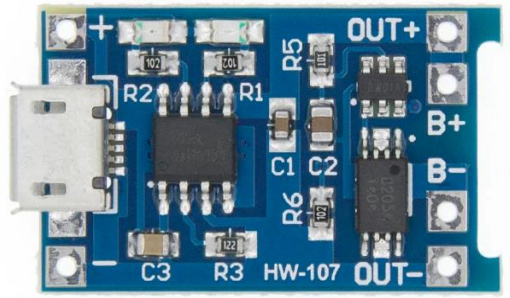
Battery Management System (BMS): *TP4056*

- Input Voltage: 4.35 V - 6.5 V
- Output Voltage: 5 V, 1 A
- Charge Port: USB Type-C
- Dual Protection against charging and discharging
- Light indicates charge status

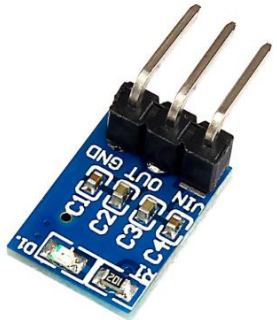
Linear Voltage Regulator: *AMS1117-3.3*

- Input Voltage Range: 4.75 V - 12 V
- Output Voltage: 3.3 V
- Current Output: 800 mA

Battery



Battery Management System (BMS)



Linear Voltage Regulator

Tools

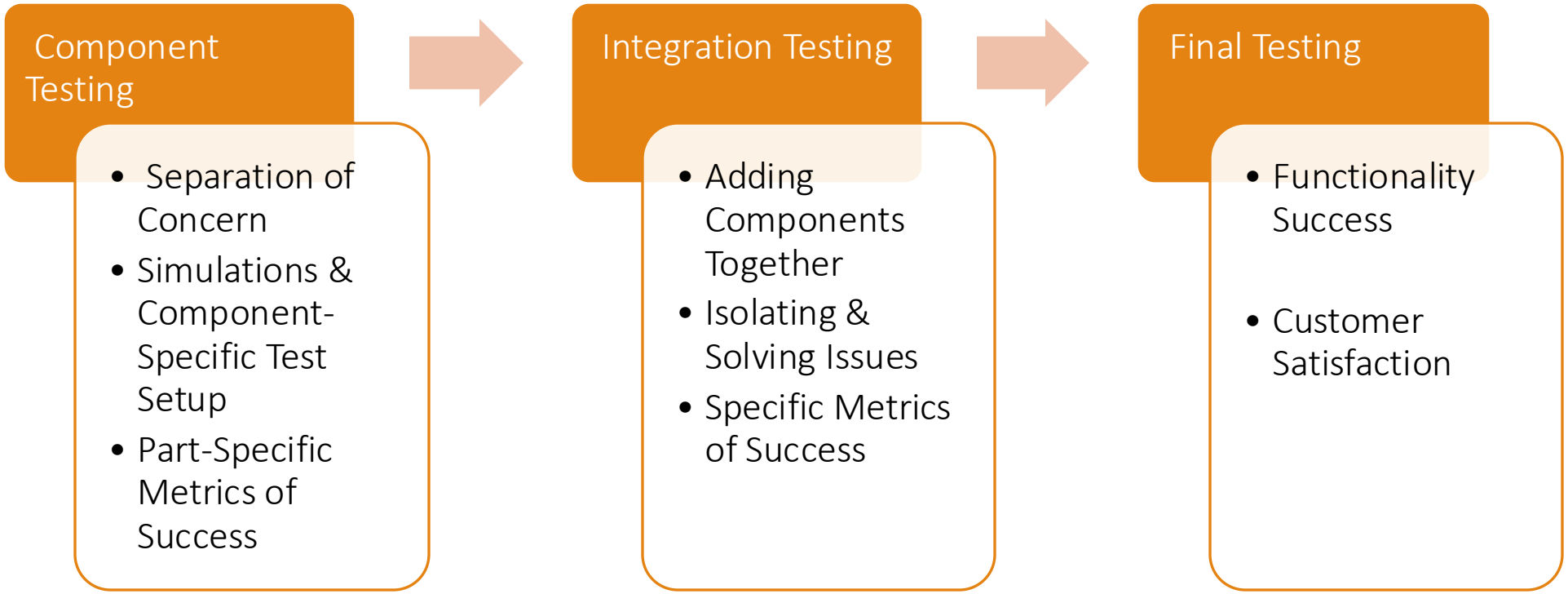
Hardware

- Oscilloscopes
- Waveform Generators
- Multimeters
- Breadboards & PCBs
- Soldering Equipment
- Circuit Components & ICs

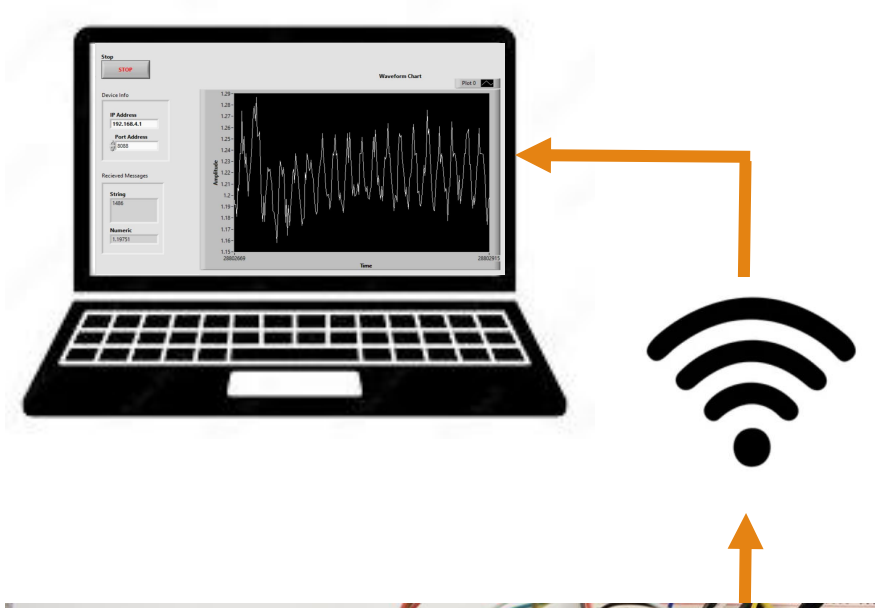
Software

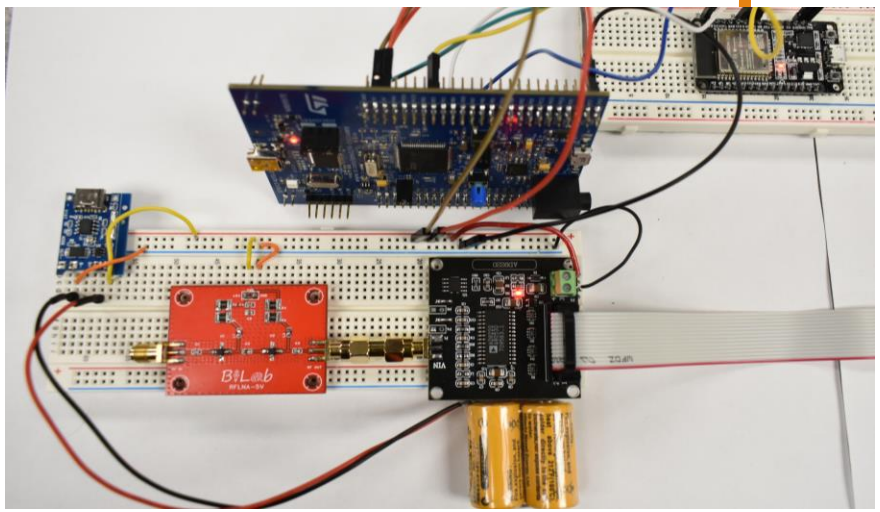
- LabVIEW
- Arduino IDE
- LTSpice
- Ni Multisim
- EasyEDA

Testing


Component Testing
• Separation of Concern
• Simulations & Component-Specific Test Setup
• Part-Specific Metrics of Success
Integration Testing
• Adding Components Together
• Isolating & Solving Issues
• Specific Metrics of Success
Final Testing
• Functionality Success
• Customer Satisfaction

Conclusion





Complete Proof of Concept System

Current Project Status

- Developed PCB & Schematics for Amplifier and ADC
- Device powered via rechargeable battery with protection systems
- Microcontroller program with base functionality and communication
- Interface LabVIEW with stable WIFI Connection and Data Logging Feature
- Testing and Evaluating Component Prototypes

Task Responsibility

Henry Chamberlain

- Circuit simulations
- Circuit testing & evaluation
- Part procurement

Adam Shoberg

- Circuit simulations
- Schematic & PCB Layout
- Circuit testing & evaluation

Lisa Tordai

- User Interface programming
- Wi-Fi programming & testing
- Embedded Systems programming

Vaughn Miller

- STM32 Microcontroller programming & testing
- Embedded Systems programming

Looking to the Future

- Our device demonstrates a functional proof of concept
- System can be fabricated onto one device and reproduced
- Development of enclosures to ensure device protection

Thank You! Questions?

wDAQ: Wireless Data Acquisition System

Team 19: Lisa, Adam, Henry, Vaughn

Client: Avishek Das

Faculty Advisor: Professor Manojit Pramanik

Lisa Tordai

Adam Shoberg

Henry Chamberlain

Vaughn Miller