MEMS Wireless Transceiver for Use of Non-Invasive System Diagnostics

Critical Design Review -
Summer 2019

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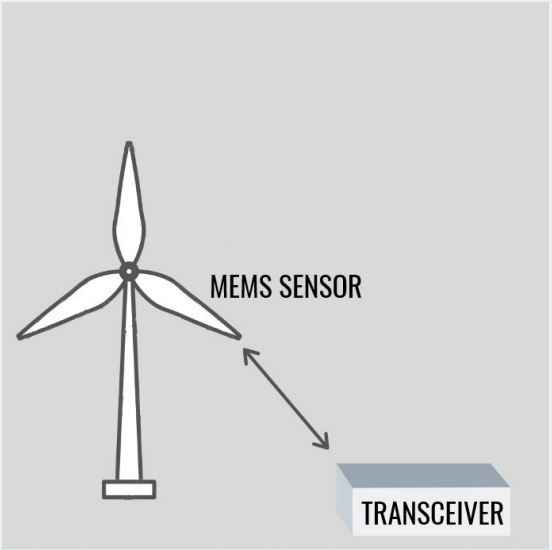
MOTIVATION

- Noninvasive testing utilizes small sensors within a system avoid catastrophic failures
- Our sponsor requires a method of communicating with a MEMS sensor that is placed inside a rotating motor.



REQUIREMENTS

- Design a transceiver that transmits and receives frequencies within the 27 MHZ ISM band
  - Modified the design for a 1 MHZ due to hardware complications
- Visualize the received signal for analysis
- Transmit data to computer for potential further analysis

DESIGN SPECIFICATIONS

CATEGORY:	SPECIFICATION:
Power	Consume less than 10 watts
Production Cost	Cost less than $1,500.00
Deliverables	Microcontroller code Hardware

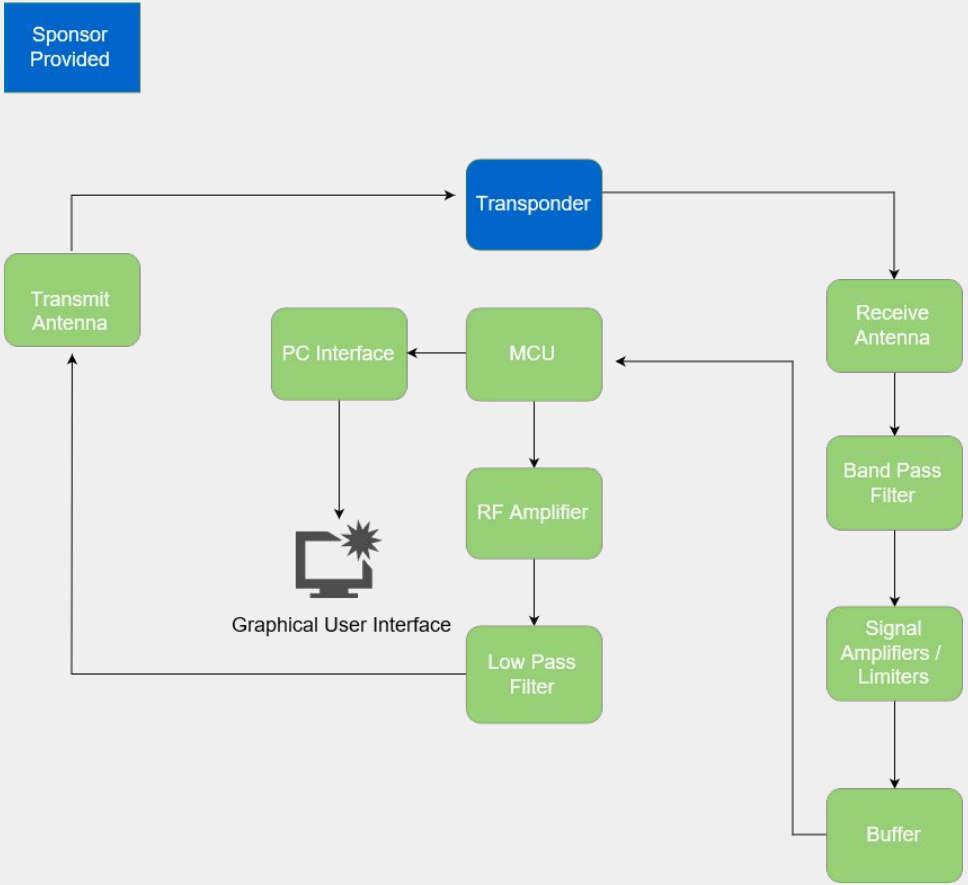
STANDARDS

- IEEE 1118.1-1990 IEEE Standard for Microcontroller System Serial Control Bus
  - Defines a protocol for the interconnection of independent devices
  - Ensures that they devices can reliably communicate with one another
- IEEE C95.1-2005 Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz
  - Restricts the amount of energy that can be absorbed by a person
  - To comply with the FCC, the specific absorption rate (SAR) is 1.6 W/kg
- FCC 15.221 Operation in the band 525-1705 kHz
  - Intentional radiators in the AM band can operate if:
    - The measurement distance is less than 30 meters
    - The field strength is less than 24000/F(kHz)

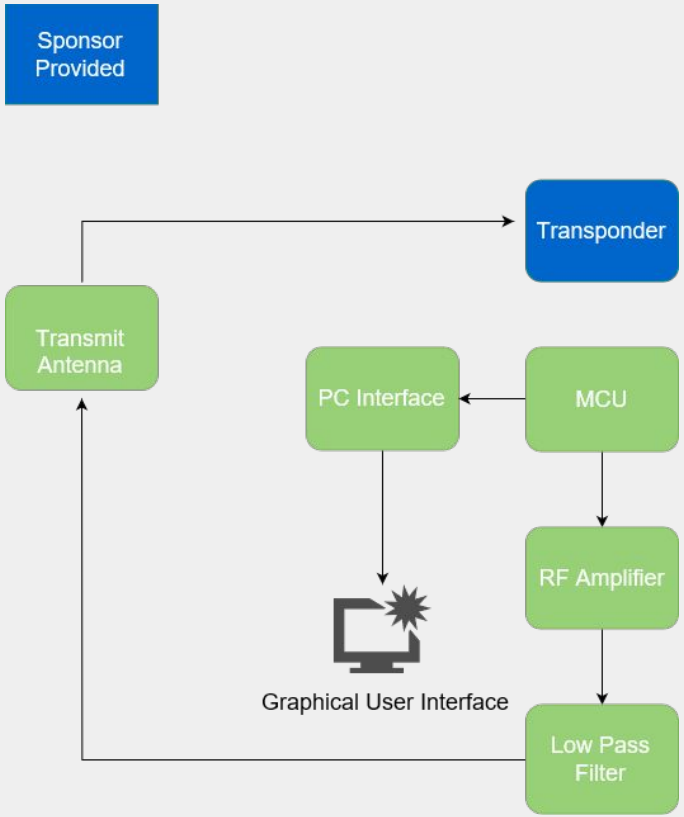
DESIGN CONSTRAINTS - FREQUENCY

- Availability of components is limited at this frequency band
  - Self-resonant frequency of inductors limits components even more
  - Inductors must have a self-resonant frequency 10x the higher than the operational frequency
- Gain Bandwidth Product limits the amount of gain attainable from operational amplifiers as the operational frequency increases.
  - GBP = Gain x Frequency

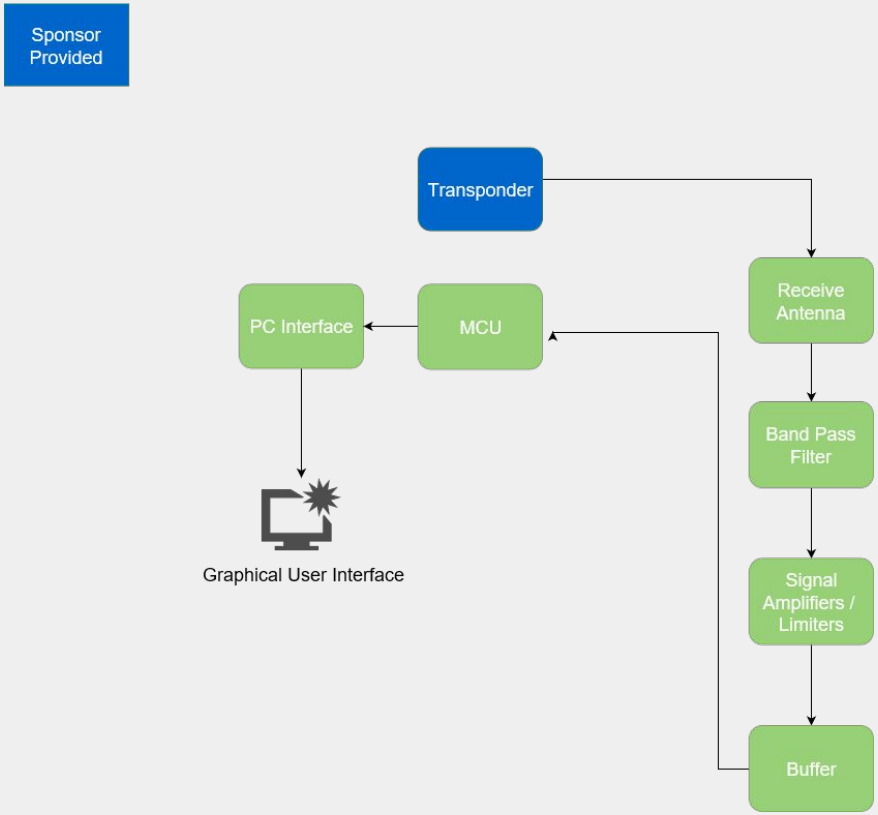
DESIGN IMPLEMENTATION



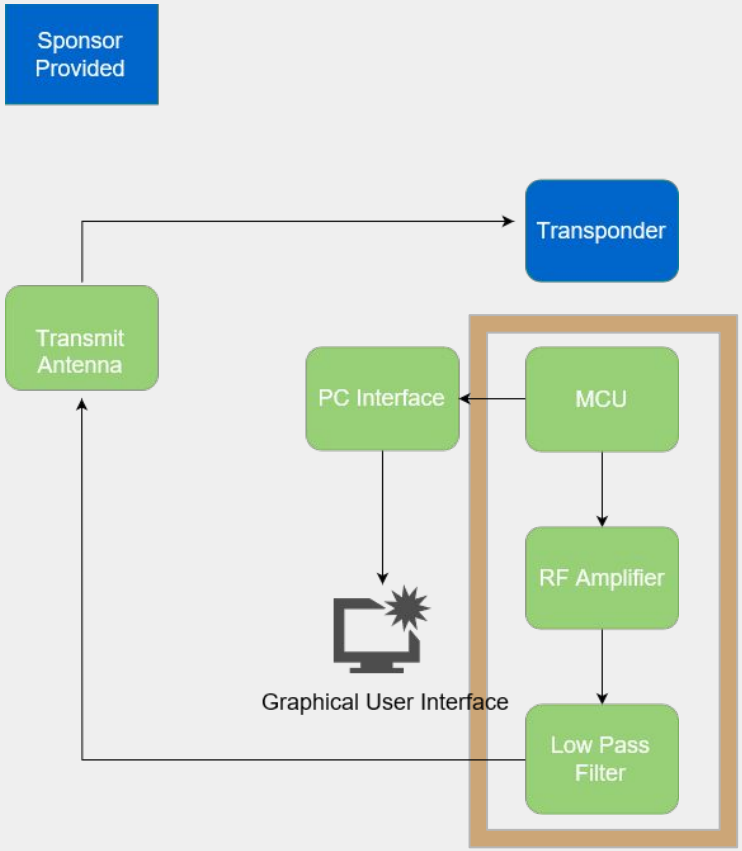
DESIGN IMPLEMENTATION: Transmission



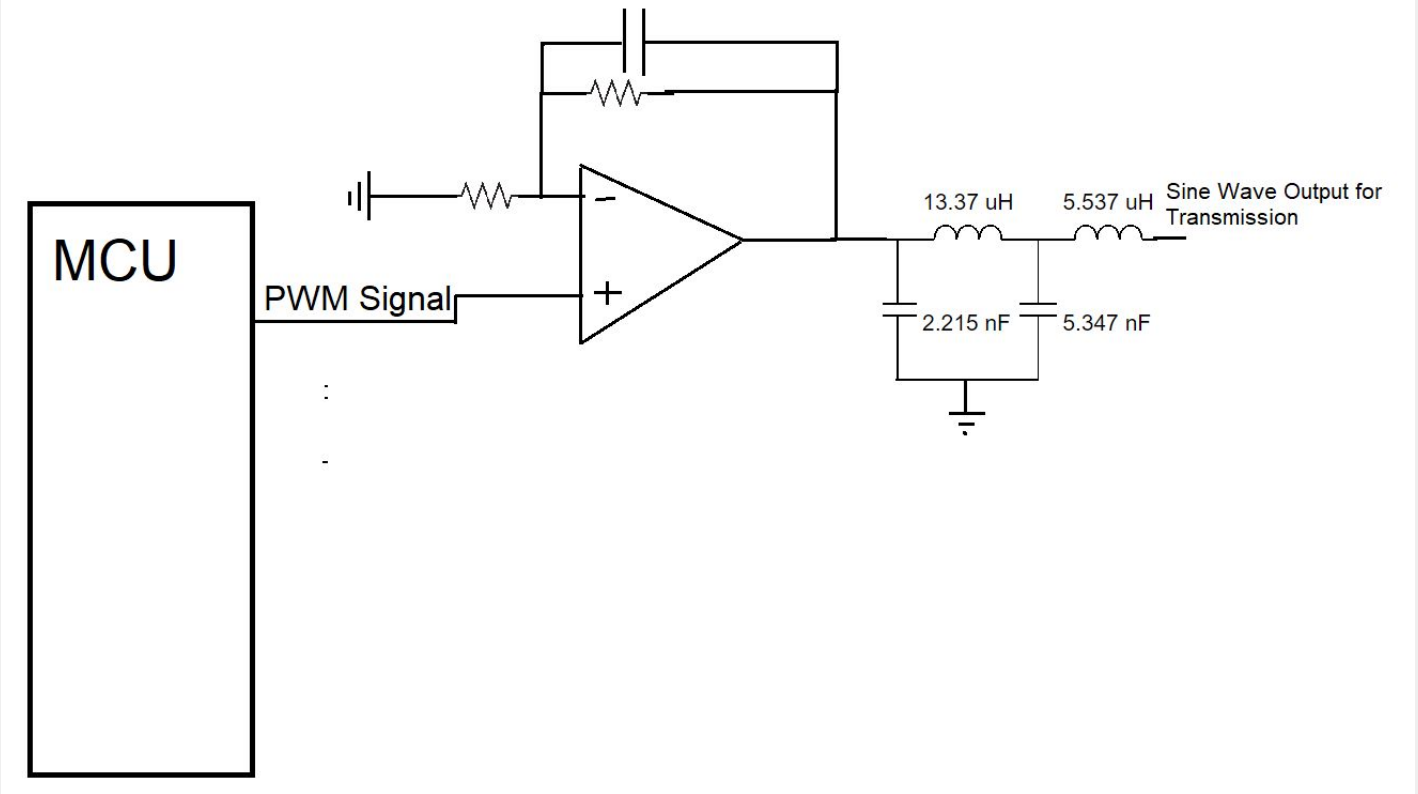
DESIGN IMPLEMENTATION: Signal Reception



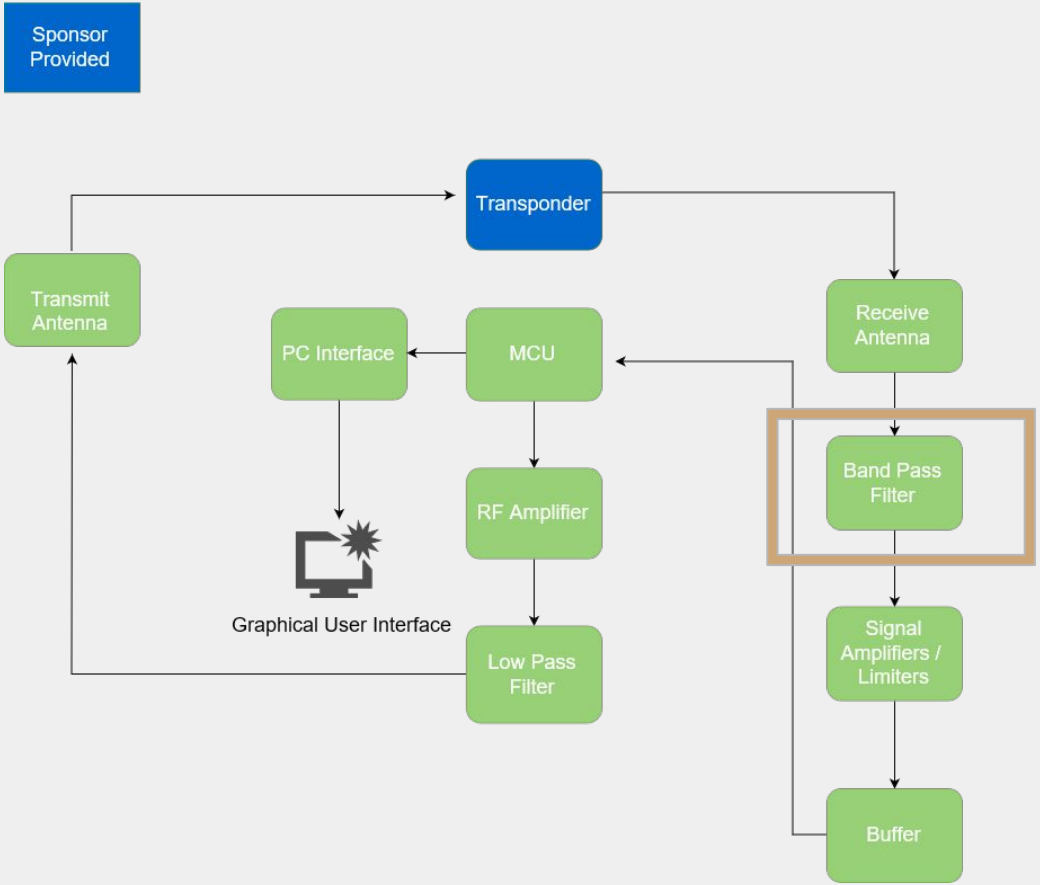
SIGNAL GENERATION



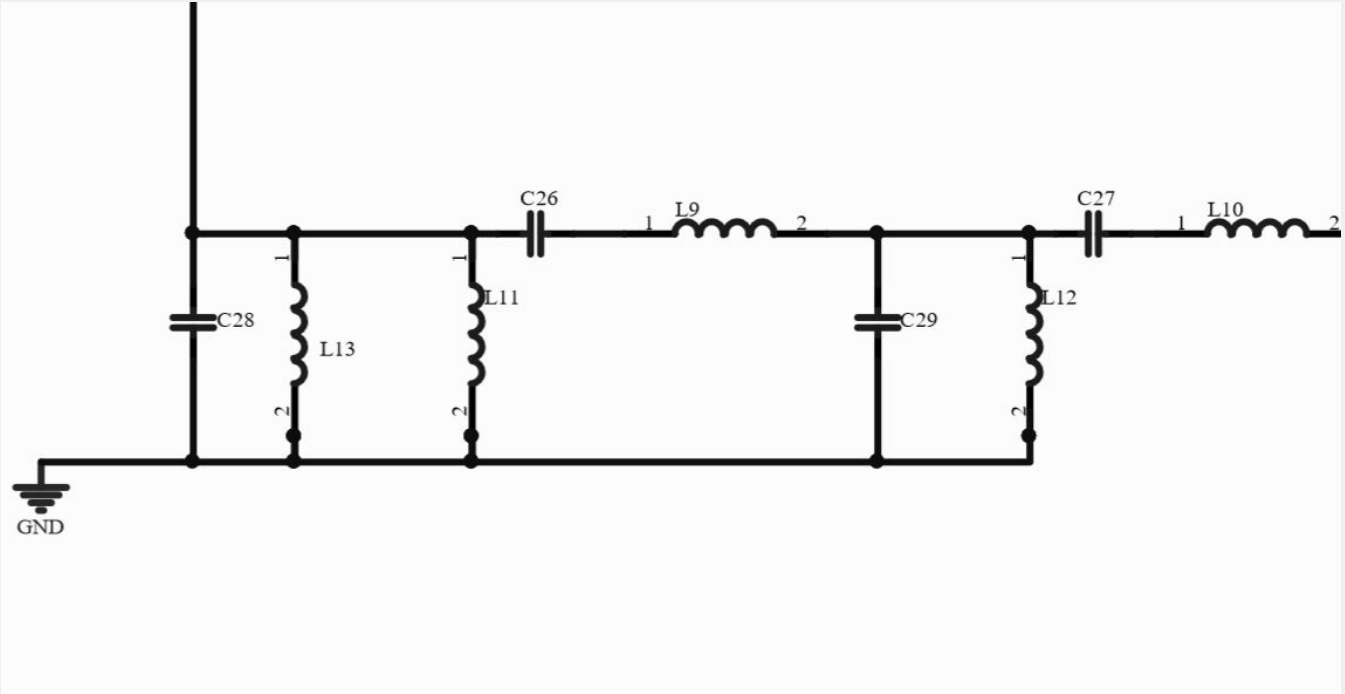
SIGNAL GENERATION



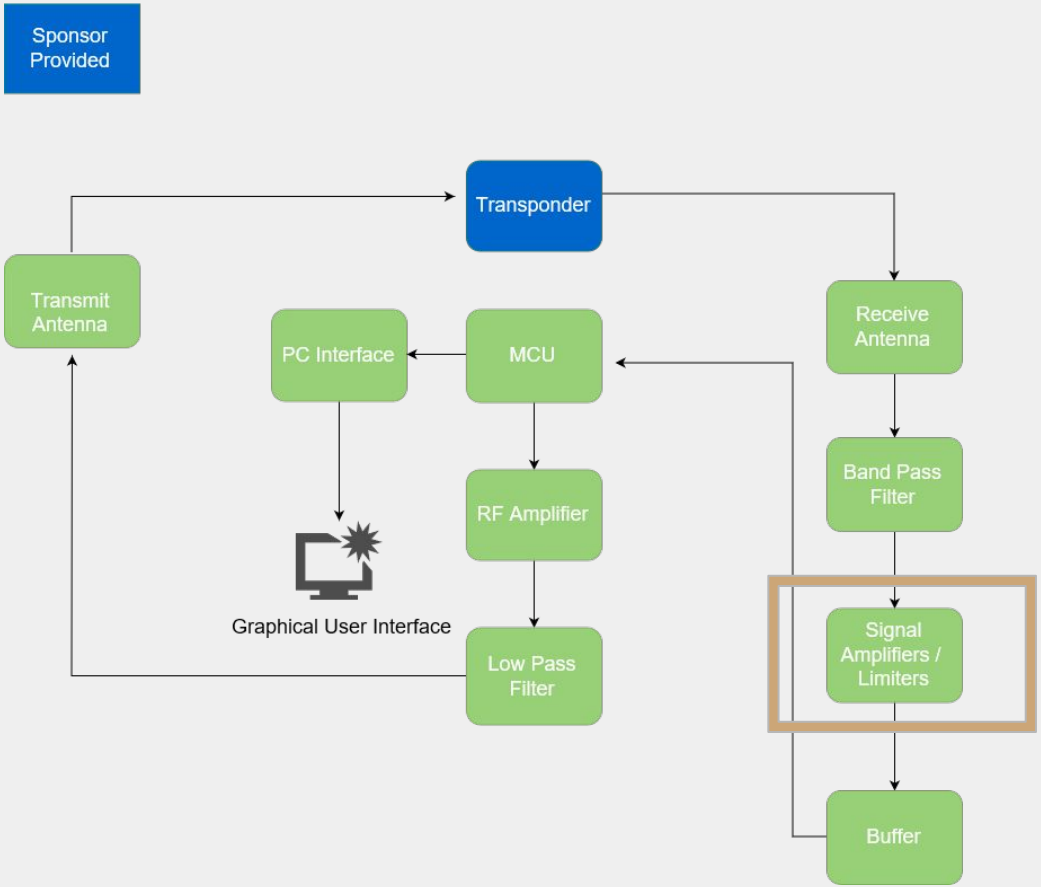
INCOMING SIGNAL FILTER

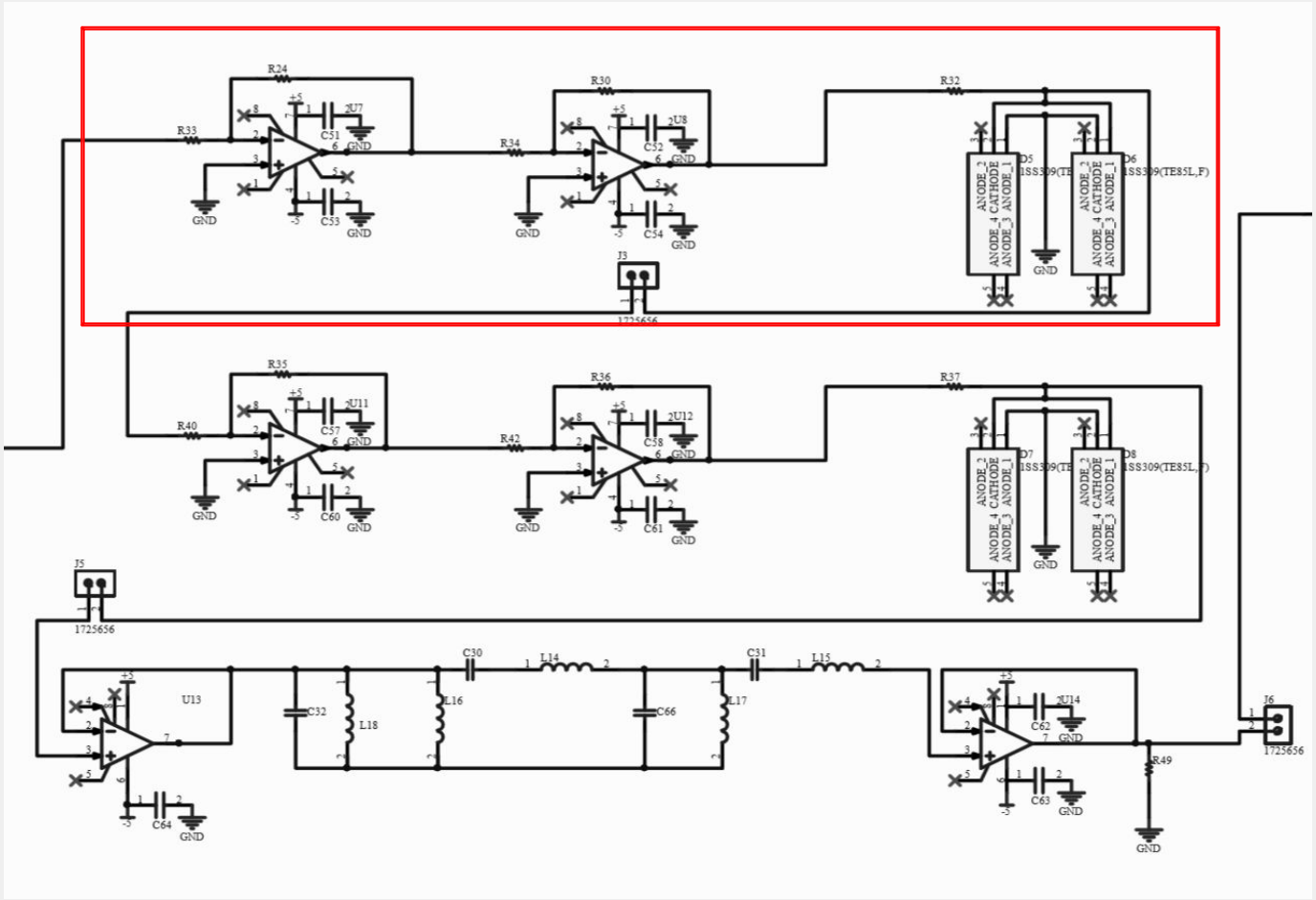


BANDPASS FILTER

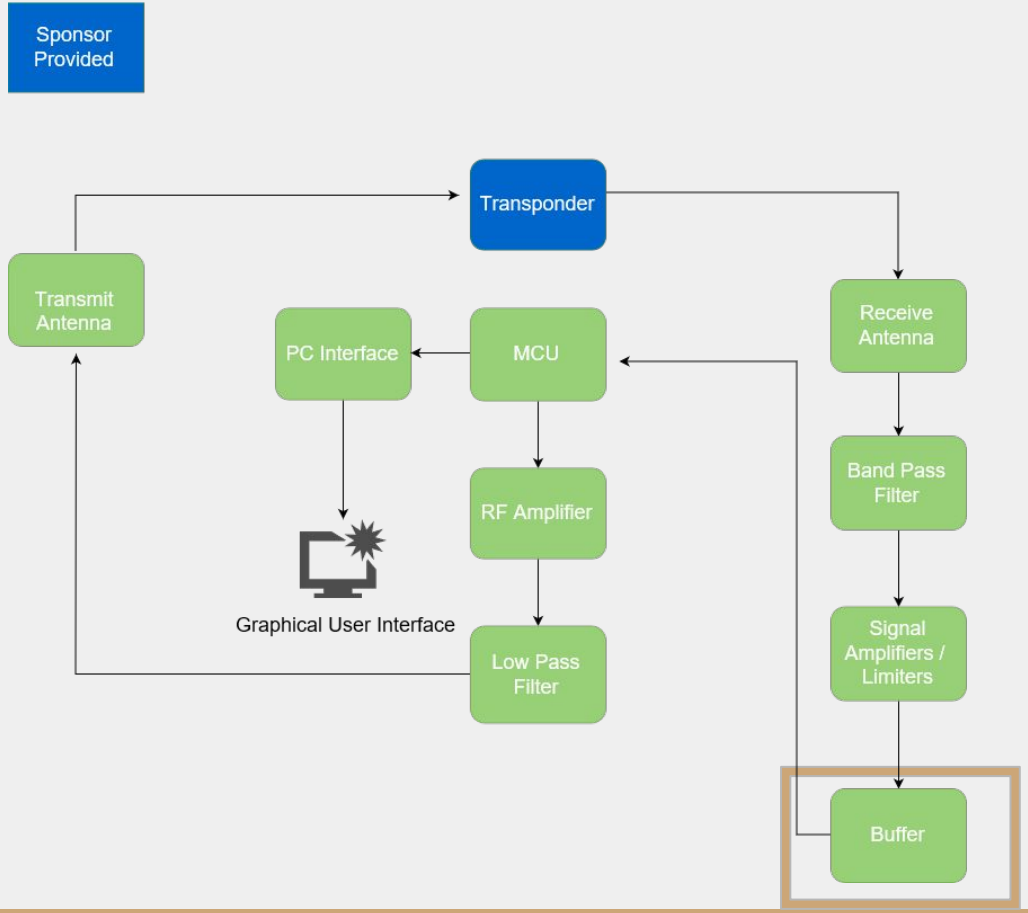


INCOMING SIGNAL CONDITIONING

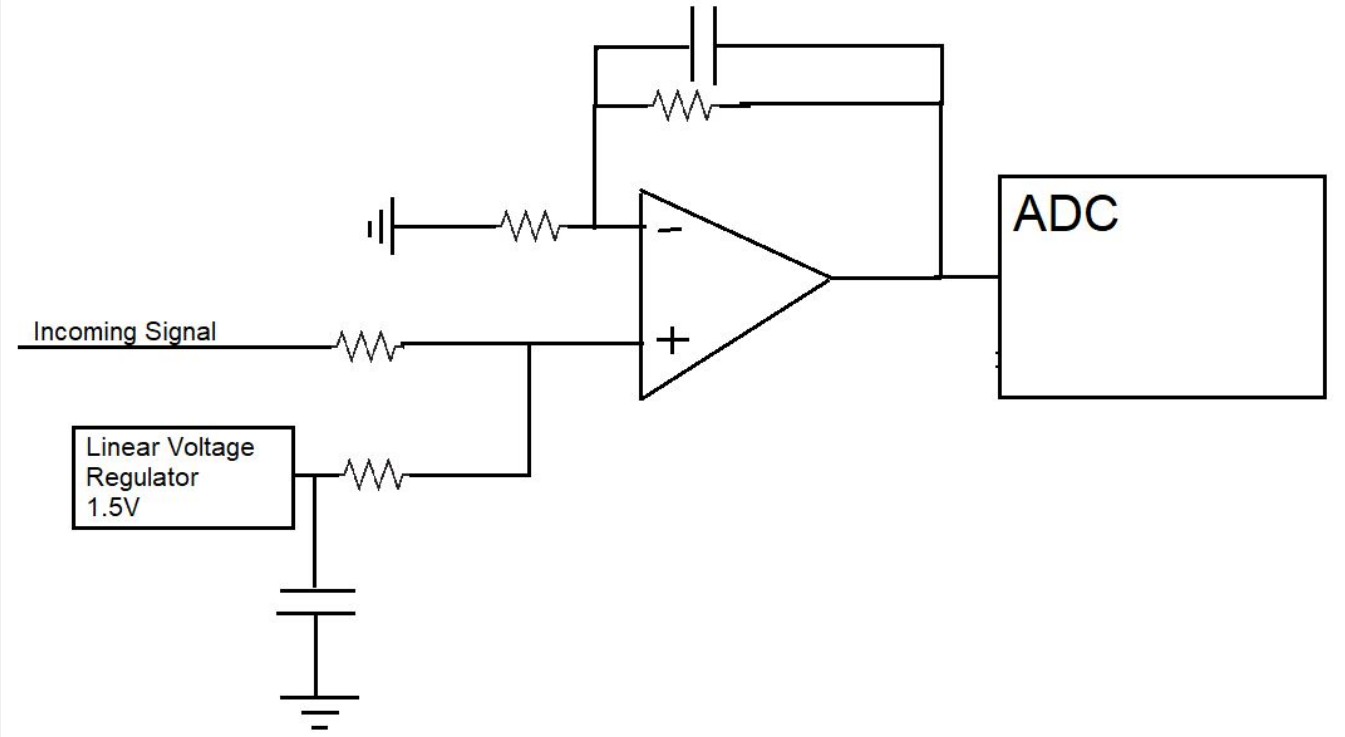



R24
R33
R30
R34
R32
U7
U8
C51
C52
C53
C54
GND
J3
1725656
D5
D6
ANODE_2
CATHODE_4
ANODE_1
ANODE_3
R35
R40
R36
R42
R37
U11
U12
C57
C58
C60
C61
D7
D8
J5
C30
L14
C31
L15
U13
C32
L18
L16
C66
L17
C64
U14
C62
C63
R49
J6

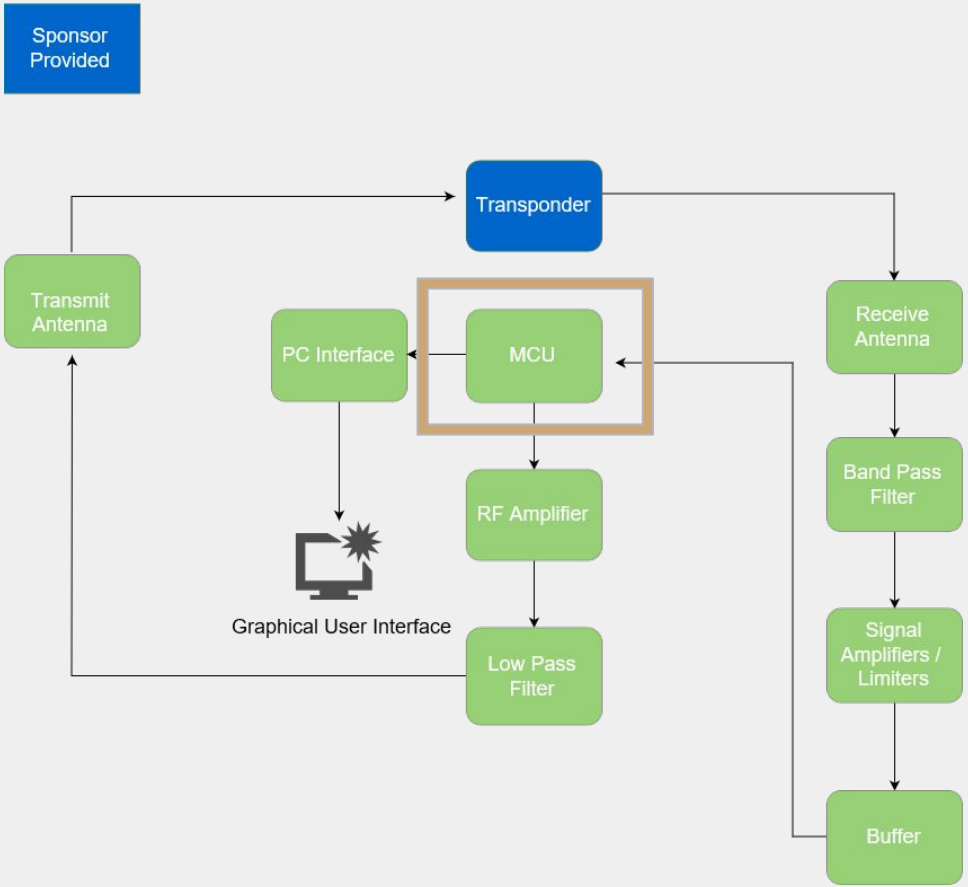
ADC SIGNAL BUFFER



ADC SIGNAL BUFFER



MCU


Sponsor Provided
Transponder
Transmit Antenna
PC Interface
MCU
Receive Antenna
RF Amplifier
Band Pass Filter
Graphical User Interface
Low Pass Filter
Signal Amplifiers / Limiters
Buffer

MCU (TMS320F28335PGFA)

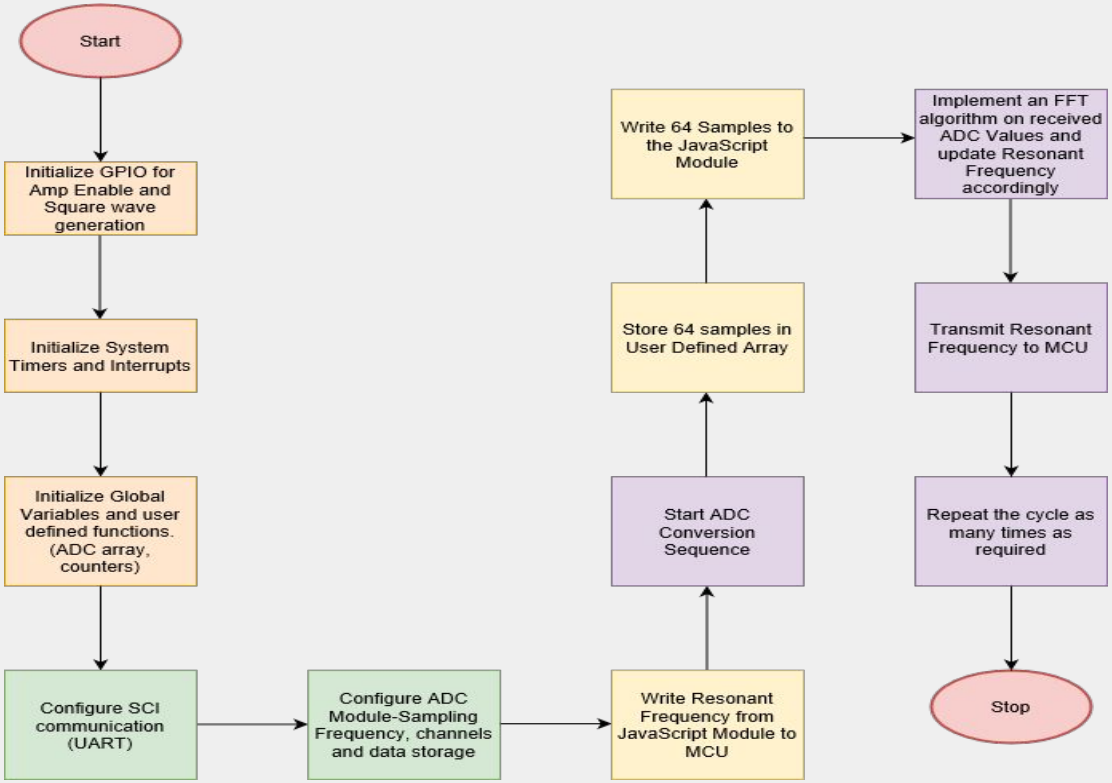
DEVICE	***TMS320F28335***	*TMS320F28332*
FREQUENCY (MHZ)	**150**	*100*
ON-CHIP FLASH MEMORY (kB)	**512**	*128*
# OF GPIO PINS	**88**	*88*
INSTRUCTION CYCLES (ns)	**6.67**	*10*
ADC CONVERSION TIME (ns)	**80**	*80*
COST	**$25.98**	*$17.60*

SOFTWARE CONCEPT DESIGN

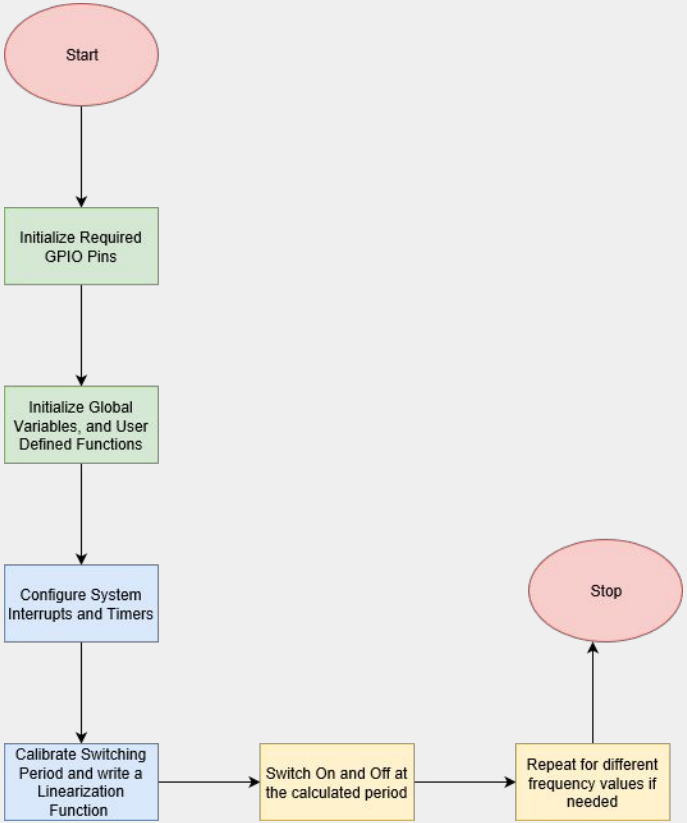
- The software design will make use of the following programs and interfaces:

Program Name	Function
TI Code Composer	Editing, debugging, linking, mapping, UART terminal, and compiling.
TI DSP software Overlay (C2000 Control Suite)	Provide device specific code, header files, and example projects.
JavaScript Module	Graphic User Interface (GUI) and signal processing.

RECEPTION AND PROCESSING SOFTWARE FLOWCHART

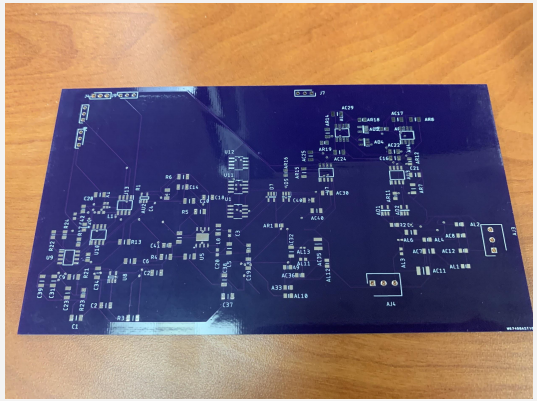


TRANSMISSION SOFTWARE FLOWCHART



PCB Design

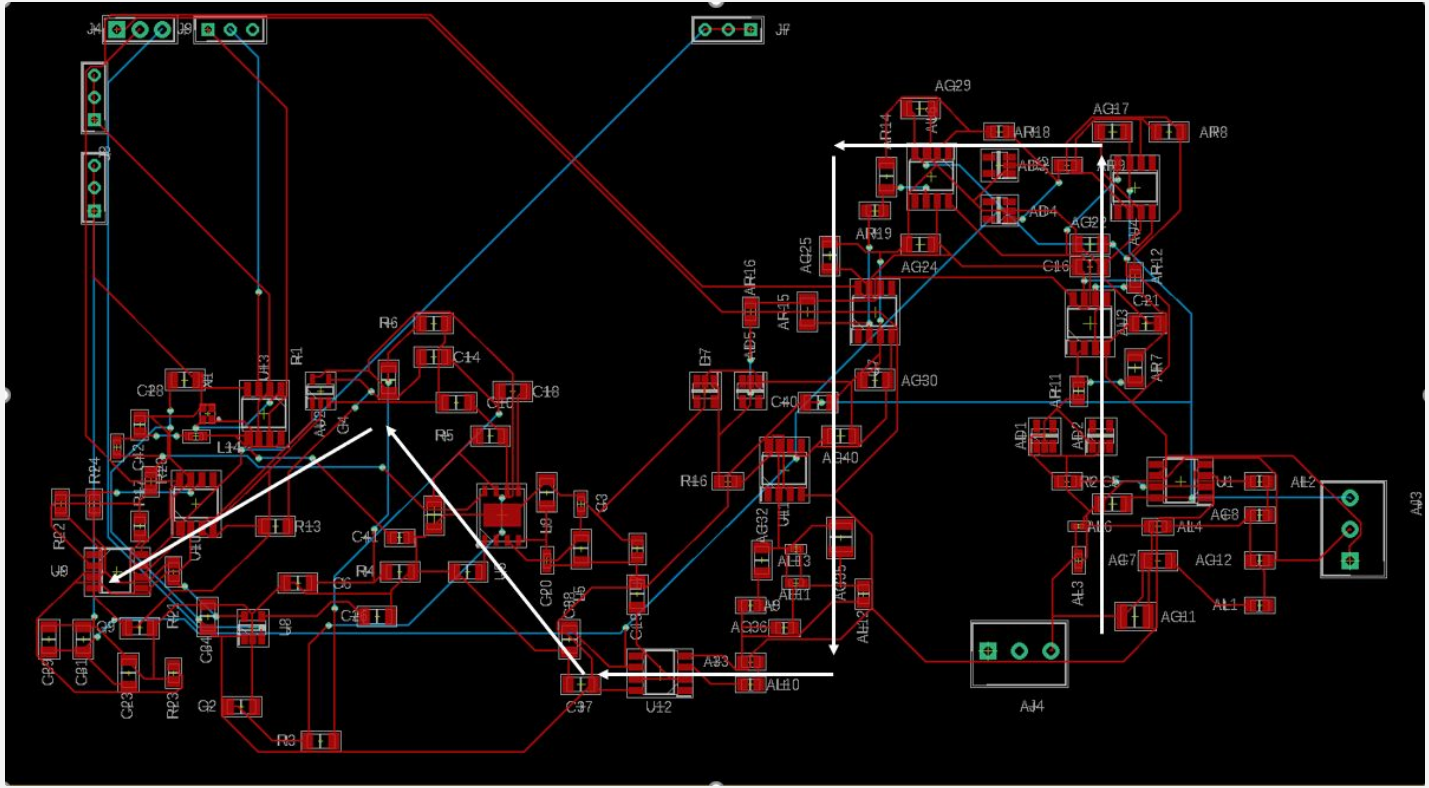
- Consisted of two daughterboards to interface with the microcontroller development board
- Transmit board
  - 3.05” x 2.19”
  - 28 SMD components
- Receiver board
  - 6.3” x 3.49”
  - 108 SMD components



PCB Design Considerations

- Minimize the length of the copper traces to minimize the inherent inductance and capacitance of the traces.
- Minimize the number of vias (where possible) to minimize the inherent inductance and capacitance of the vias.
- Minimize the current loop by avoiding long, winding traces.
- Place bypass capacitors as close as possible to amplifiers and ground.
- Avoid placing vias between bypass capacitors and amplifiers.

PCB - Receiver Board Signal Path



Difficulties

- Hardware
  - Operational amplifiers not providing the amount of gain expected.
- Software
  - Unable to implement serial communication and PWM at the same time.
  - FFT accuracy depends on large number of data points and causes processing delays.
- PCB
  - Documented bug in Altium Designer 19 that prevented NC drill files from being generated, so the schematics and PCB had to be redesigned in Eagle.
  - Faulty PCB manufacturing caused shipment delays.

ADMINISTRATIVE

ASSIGNMENT	PRIMARY	SECONDARY
FILTER DESIGN	JUSTIN	TOLU
SCHEMATICS	JESSICA	JUSTIN
SOFTWARE	TOLU	JUSTIN, JESSICA
PCB DESIGN	JESSICA	JUSTIN, TOLU

PROJECT EXPENSES

CATEGORY	ESTIMATED COST	ACTUAL COST	VARIANCE
Total Parts	$736.39	$558.37	-24.17%
PCB Software	$99.00	$164.00	+65.65%
PCB (5 boards)	$400.00	$509.00	+27.25%
Total Project Cost	$1,315.39	$1,231.37	-6.38%

QUESTIONS?