

Electrocardiograph (ECG) Demonstration Board

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**TEXAS
INSTRUMENTS**

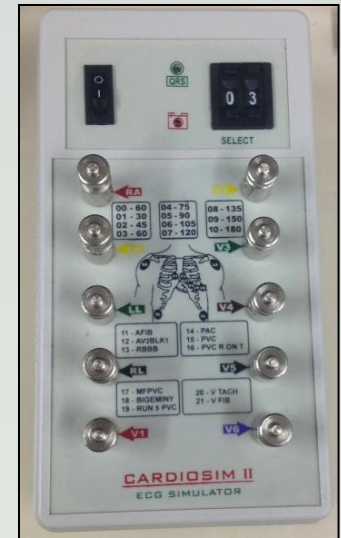
Project Background



- Develop an ECG demonstration board for the Precision Analog group at Texas Instruments.
- TI intends to showcase their integrated circuit (IC) performance using the demonstration board. Provides TI with customer interest in specific precision analog components.

Definition of Success

- Expectations
 - Functionality
 - Professional Display
 - Process signals from CardioSim II (simulator)
 - Display ECG output signal with Stellaris EVB Oscilloscope
 - Include TI components in design
- Project Objective
 - Develop several iterations of analog front-end (AFE) circuits to interface a cardio simulator with an oscilloscope
 - Simulate, build, and test to optimize a final design



Development Strategy

Research ECG Systems

Software and Simulations

Breadboard Testing

Develop AFE Printed Circuit
Board

Measure System Performance

Optimize Design

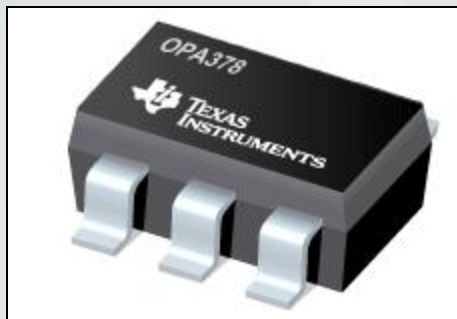
Develop Final Solution

Research

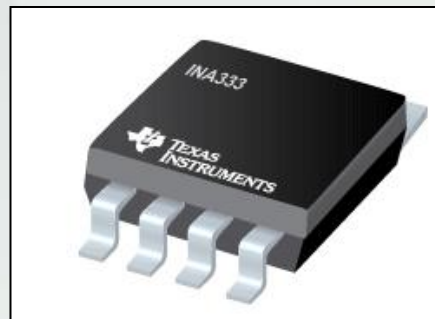
- Studied ECG systems to observe functionality
 - ECG signals
 - Noise Artifact Mitigation
 - Battery-Powered Applications
- Observations
 - Bandwidth: 0.7 – 100 Hz
 - Amplitude: 1.0mVpp – 1.5mVpp
 - Active and passive filtering
 - Linear dropout regulator or Buck converter (9V to 5V)

TI Components

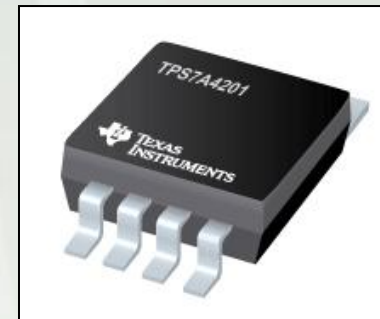
- Final Texas Instrument Circuit Components
 - Instrumentation Amplifier – INA333
 - Operational Amplifier – OPA378
 - Linear Drop-Out Regulator (LDO) – TPS7A4201
 - Buck Converter – TPS62120



OPA378

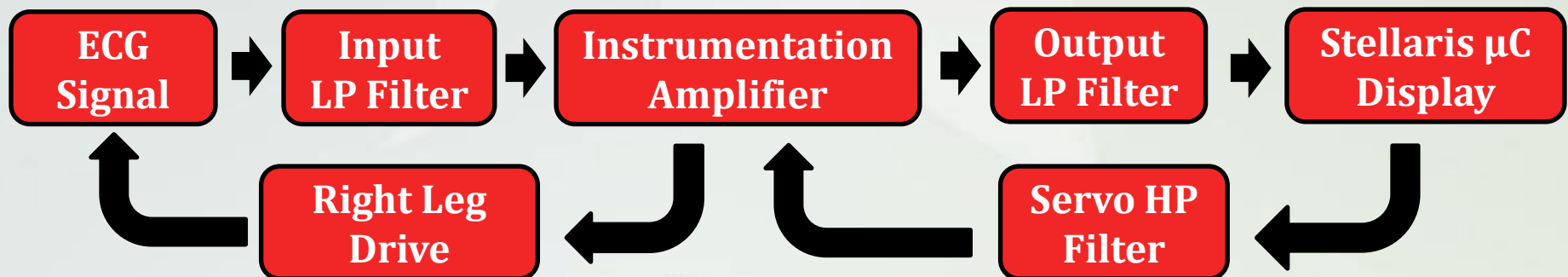
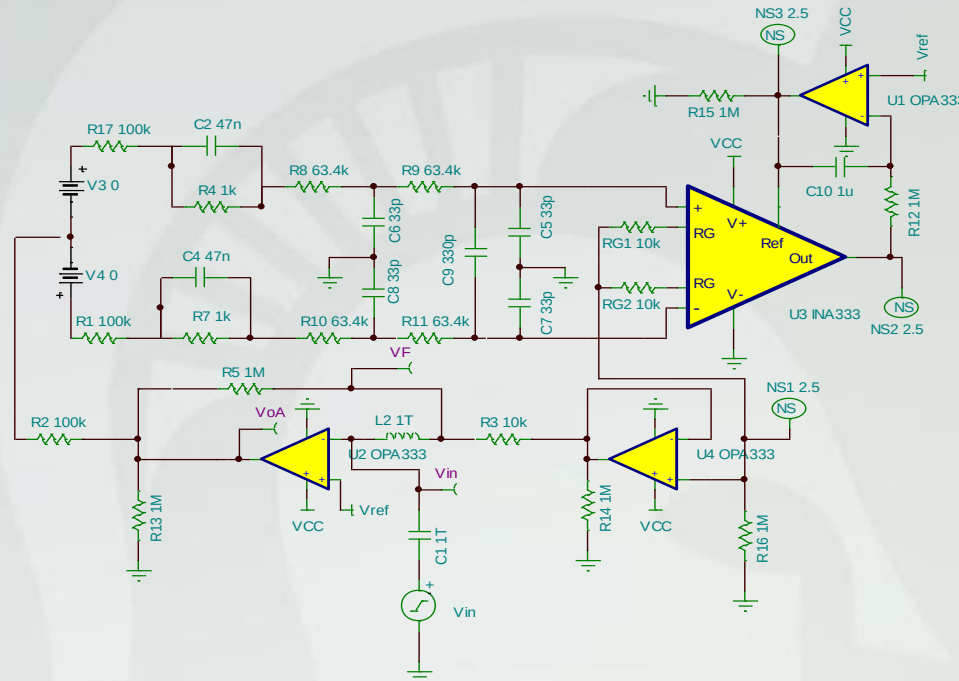


INA333

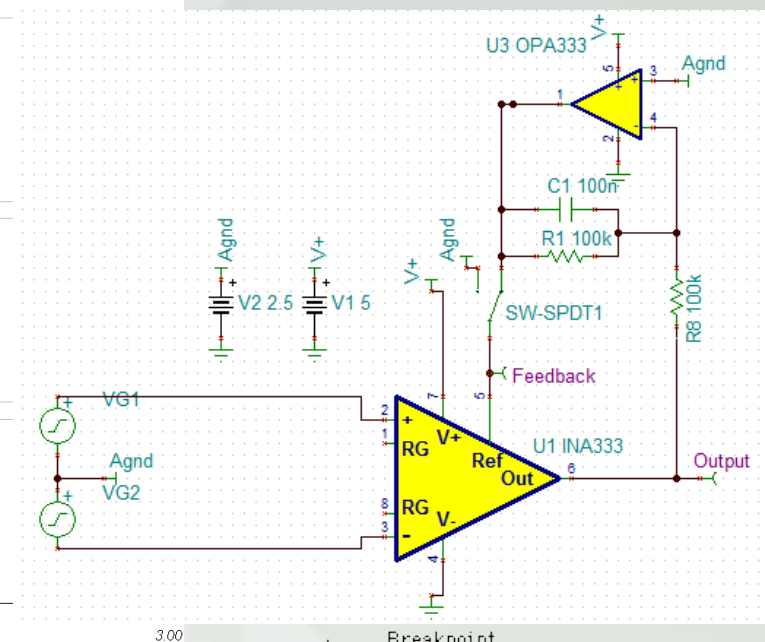
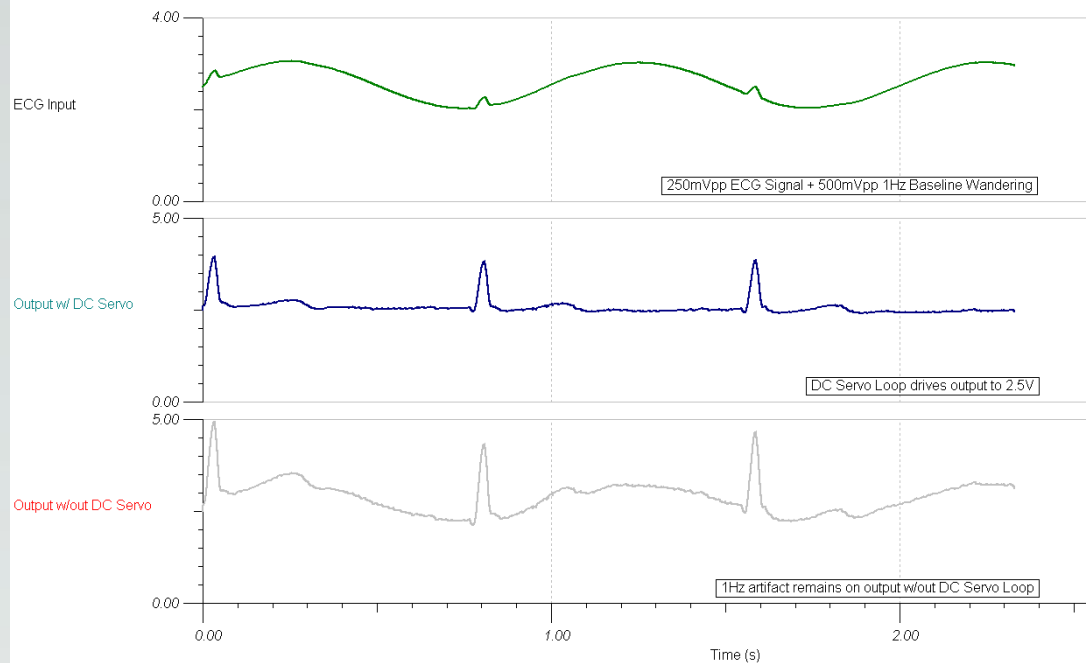


TPS7A4201

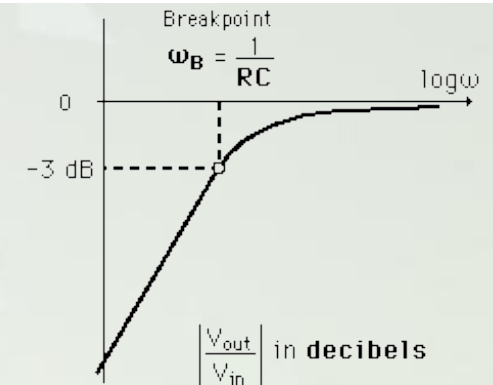
ECG System Structure



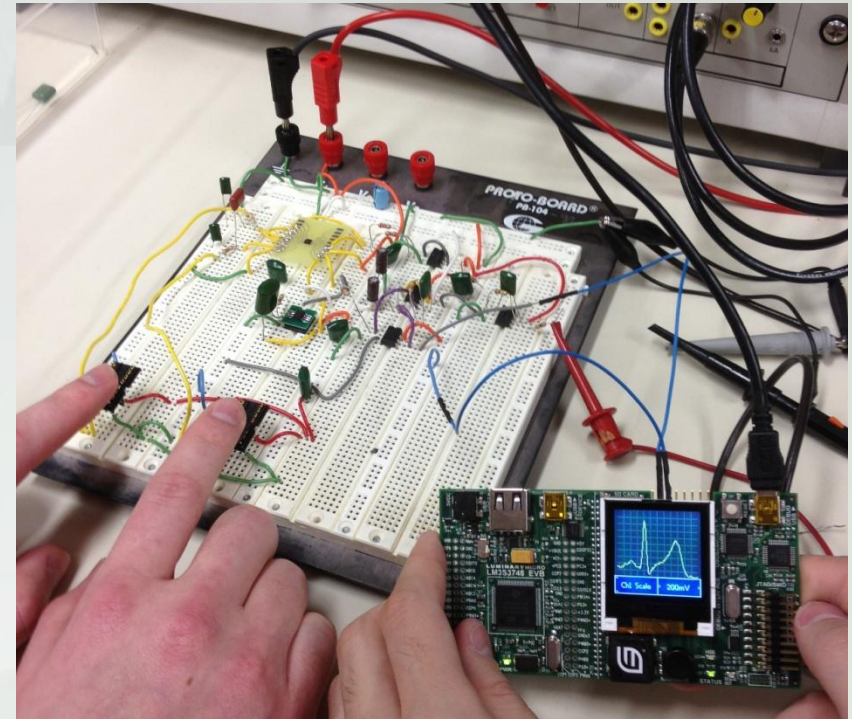
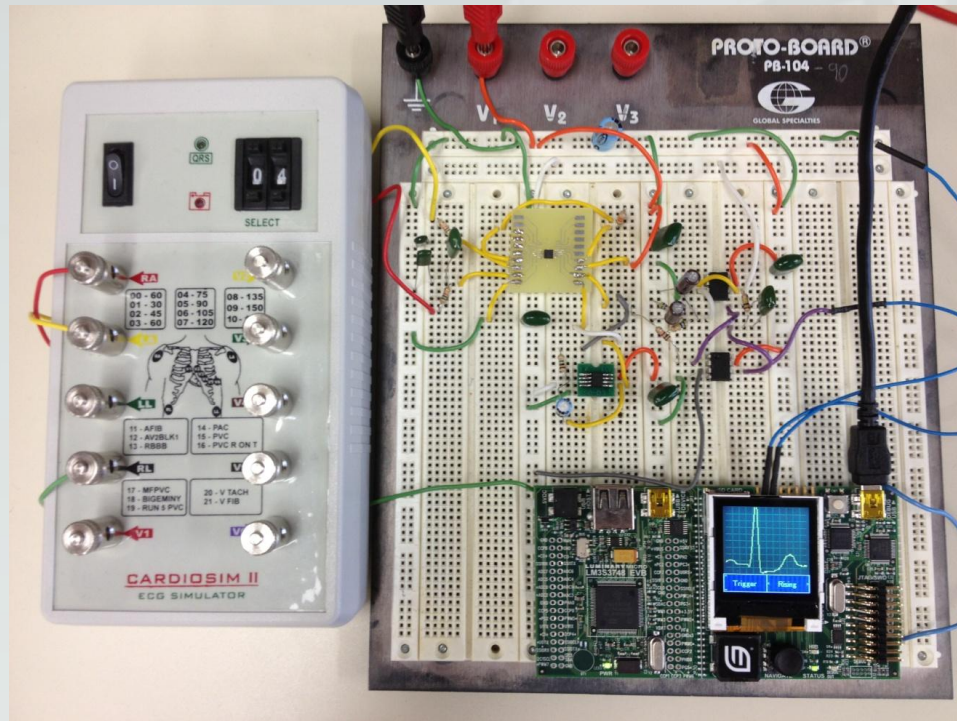
Simulation Results



- DC Servo loop attenuates low frequency wandering below 0.7 Hz



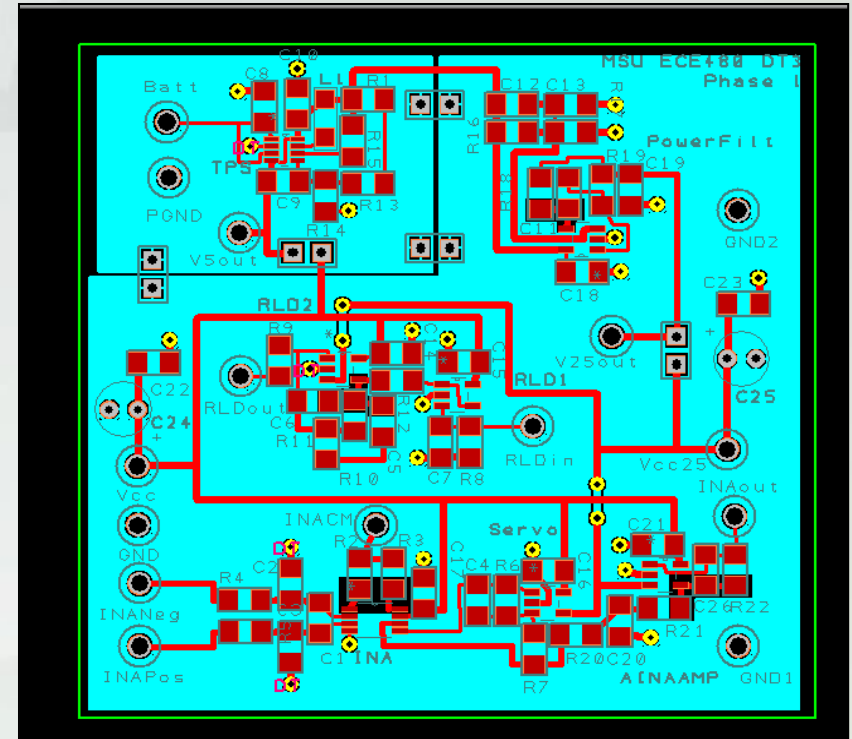
Breadboard Testing



Using adapters for INA333 and OPA333

Phase 1

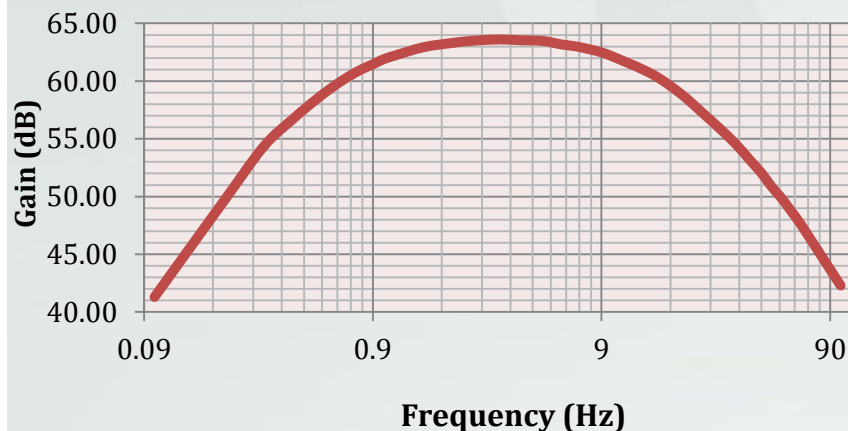
- Analog Front End Circuit (AFE)
- Printed Circuit Board (PCB) Layout
- Buck Converter Reference Design (TPS62120)
- Test Points & Jumpers



Phase 1 Results

- PCB layout error
- Successful operation
- Buck converter measurements

Measured Bode Plot of System Bandwidth

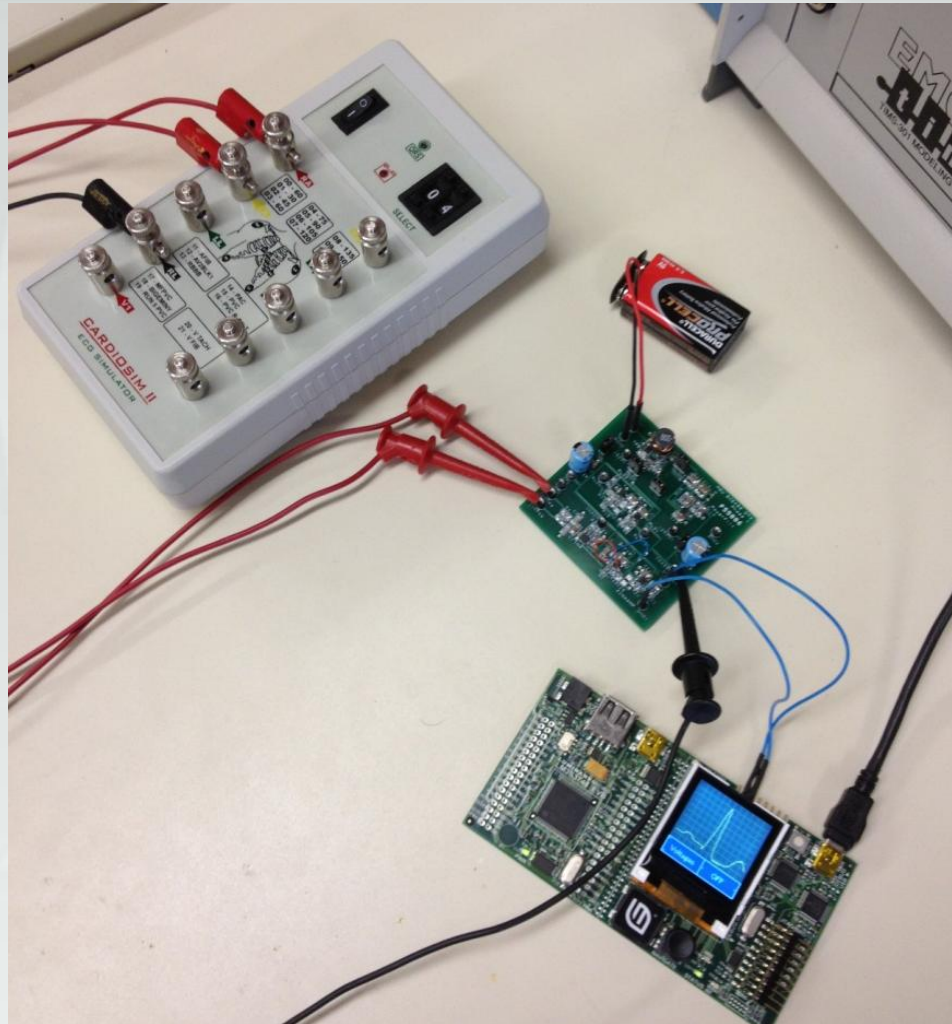


Phase 1 AFE output using CardioSim II

Bandwidth: 0.7 Hz – 23 Hz

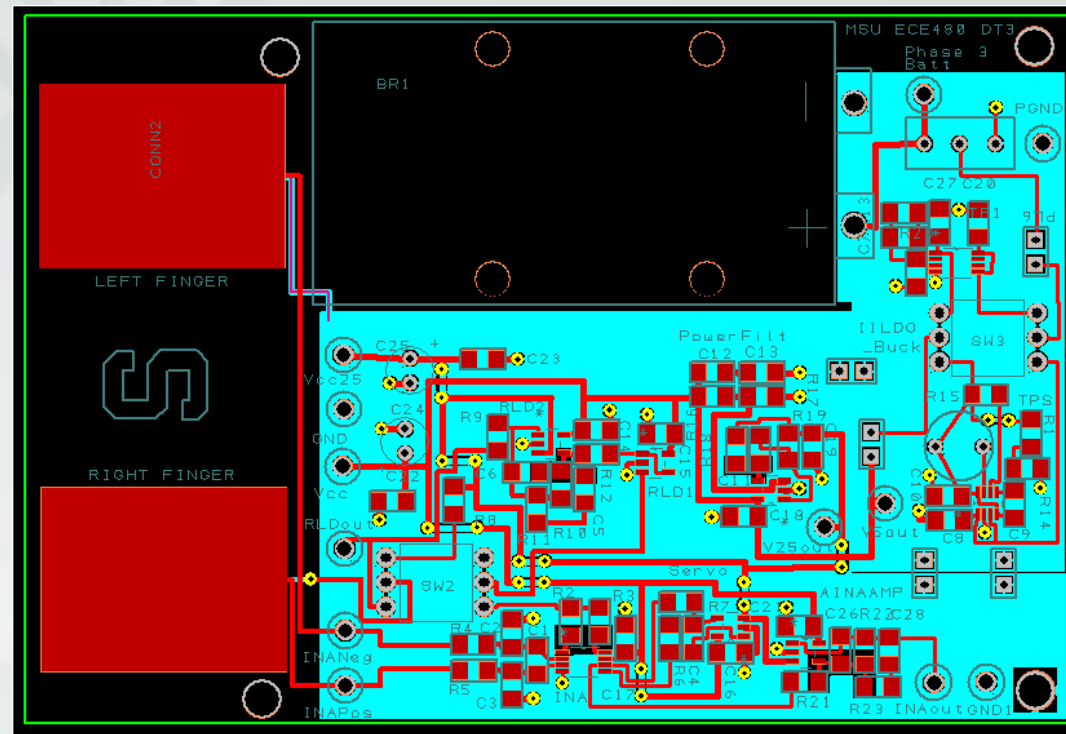
Passband Gain: 64 dB

Phase 1 Results



Phase 2

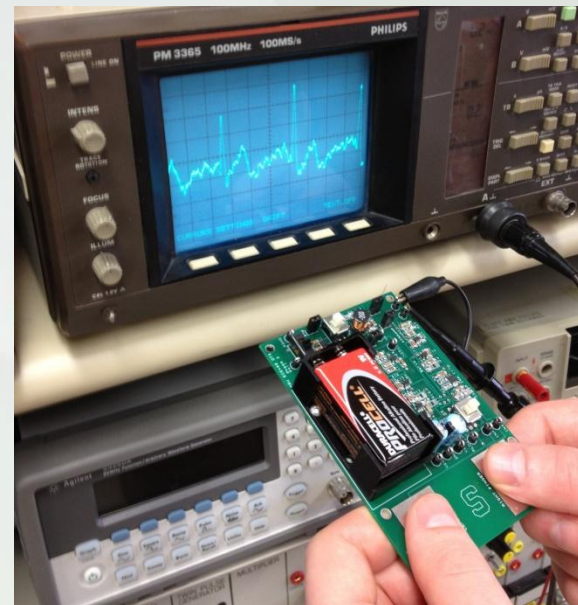
- Fixed PCB trace error
- Battery Connector
- Thumb Pad Test
- LDO vs. Buck Converter Comparison
- RLD switch
- Increased System Bandwidth to 50 Hz



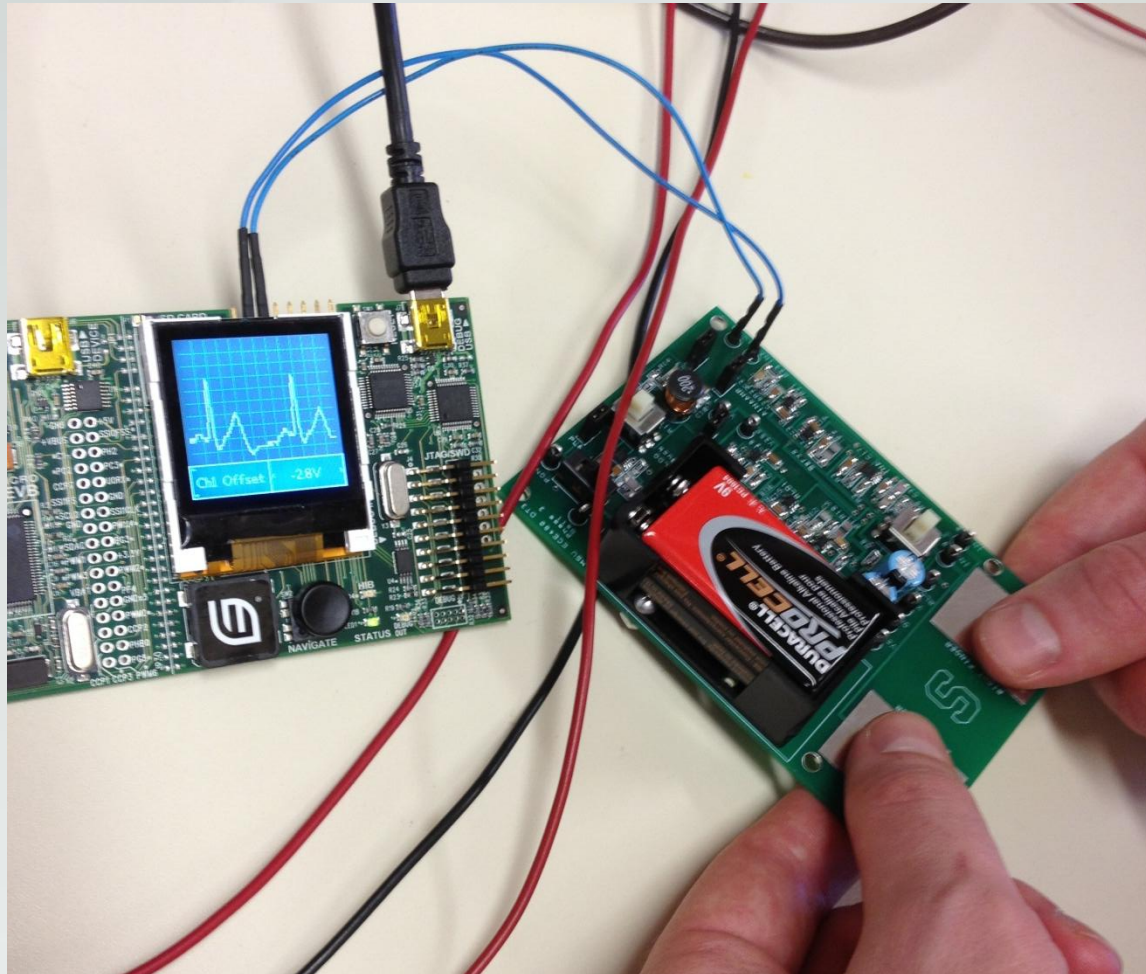
Phase 2 Results

- Successful implementation of thumb pad sensors
- Power circuit comparison
- Increase bandwidth to 50 Hz for more ECG spectral content

	TPS7A4201	TPS62120
Input Voltage (V)	9.5	9.5
Input Current (mA)	0.74	0.43
Input Power (mW)	7.03	4.08
Output Voltage (V)	4.93	5.12
Output Current (mA)	0.67	0.71
Output Power (W)	3.30	3.63
Efficiency (%)	47.00	88.98

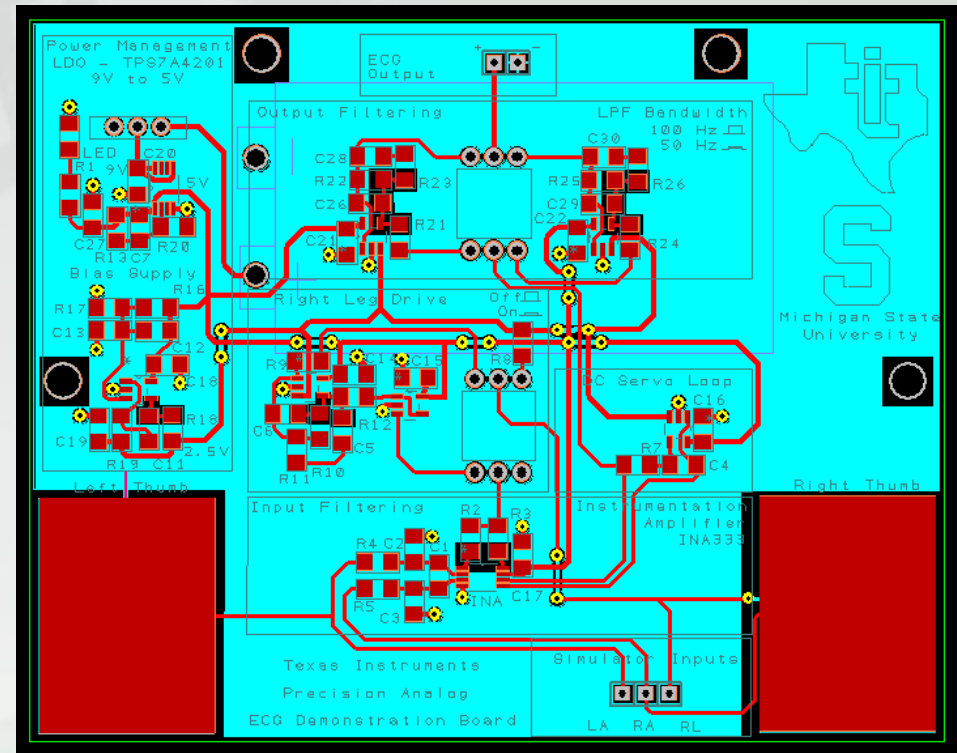


Phase 2 Results



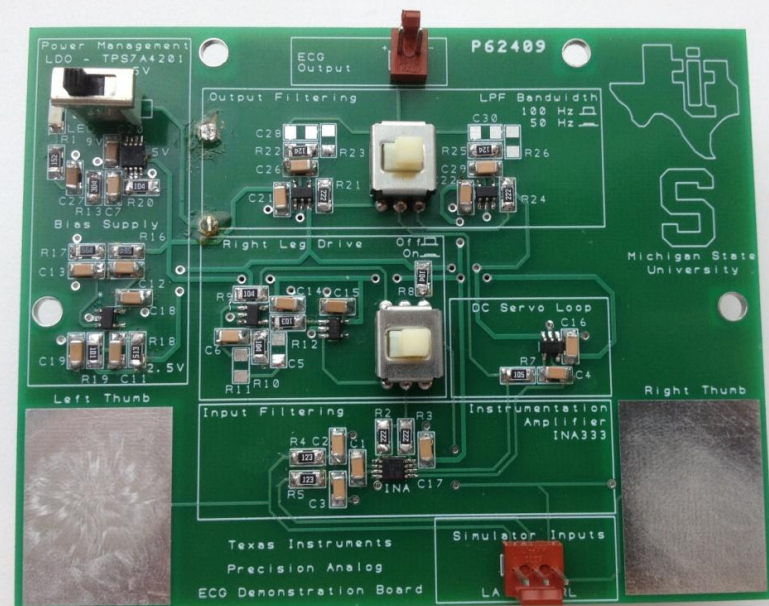
Phase 3

- LDO for Power solution
- Thumb pads orientation
- Organized layout
- Selectable bandwidth
50 Hz or 100Hz
- Created holes for board
mounting
- Battery on bottom of
board
- LED power indicator

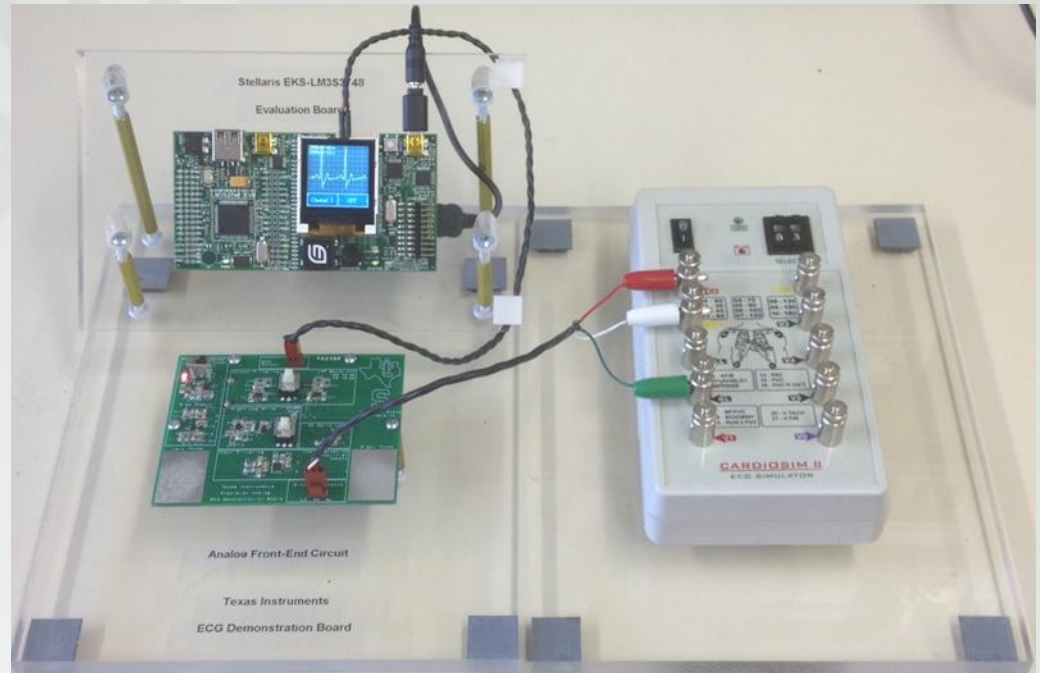


Phase 3 Results

- Selectable output filters
- Labeled sub-circuits for demonstration purposes
- Battery life of 211 hrs
- Optimized thumb pad position
- Improved connections for inputs and outputs

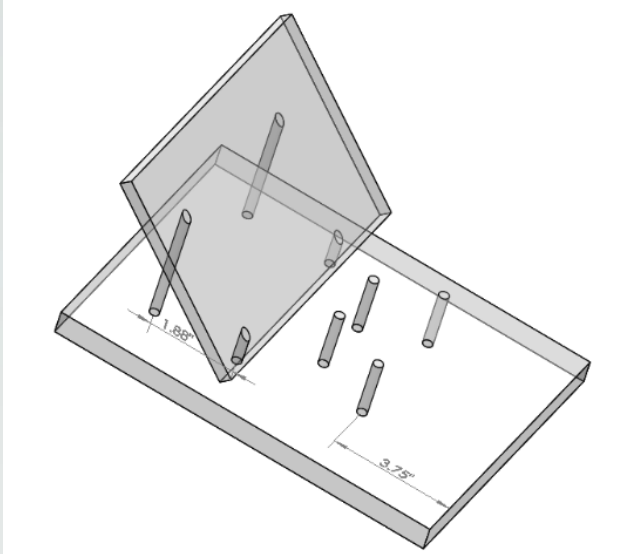


Phase 3 Results

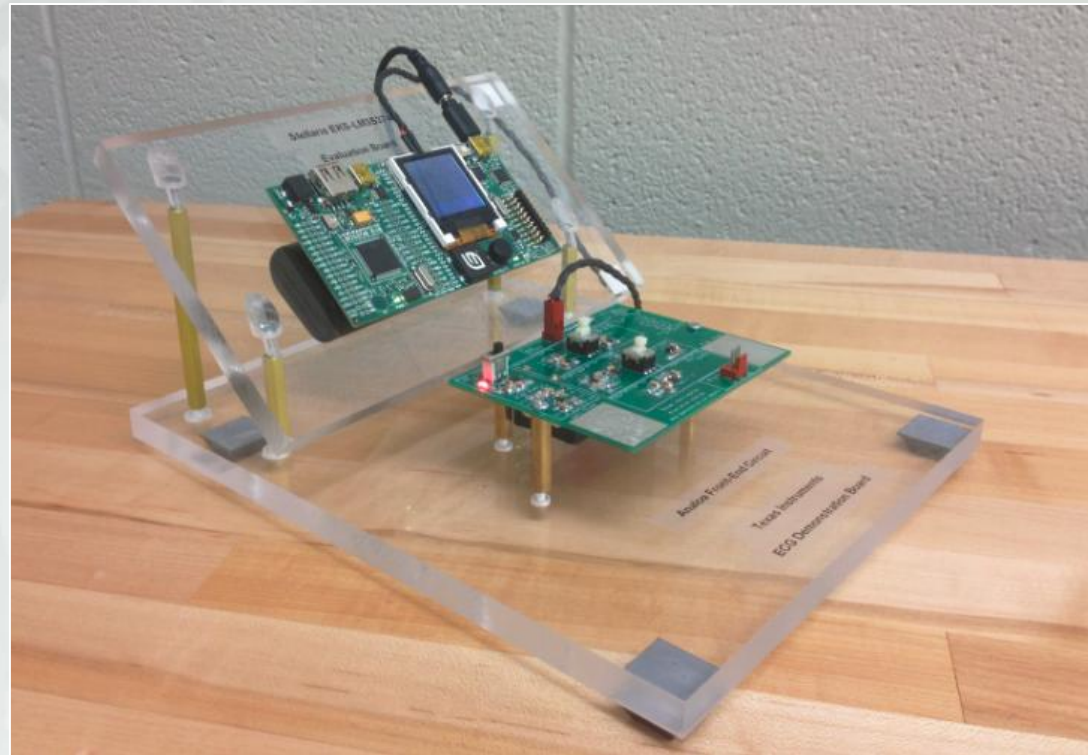


Acrylic Display

- Mount AFE on standoffs
- Display Stellaris at 45 degrees

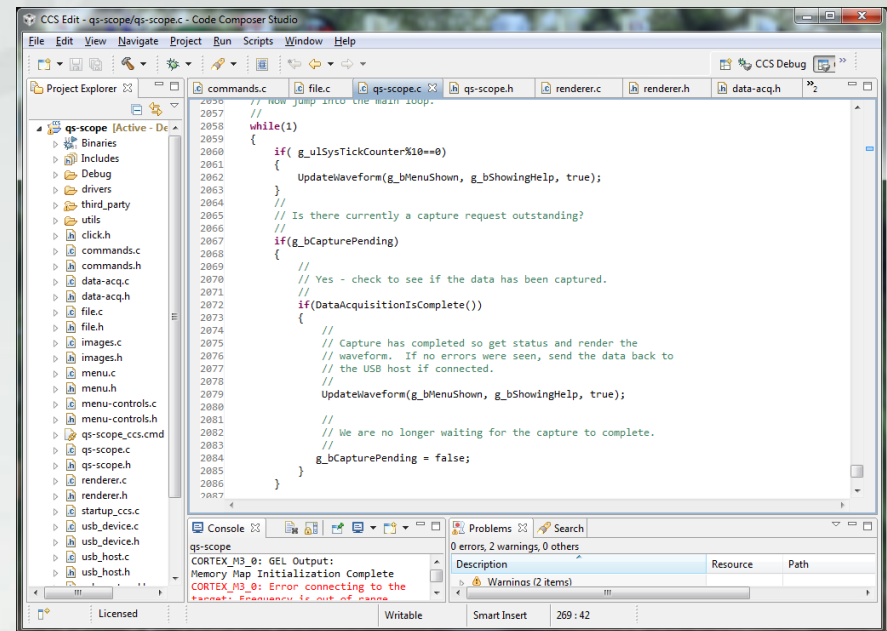


SolidWorks 3D model

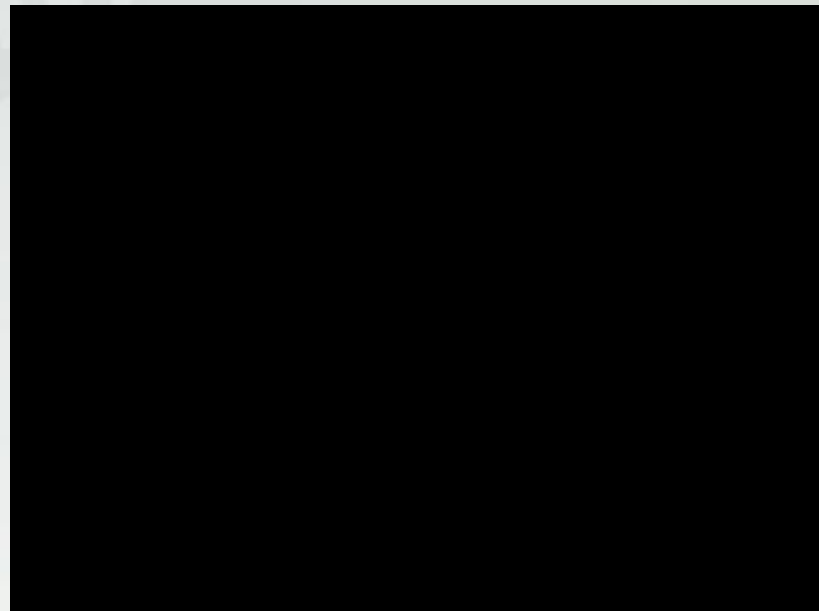
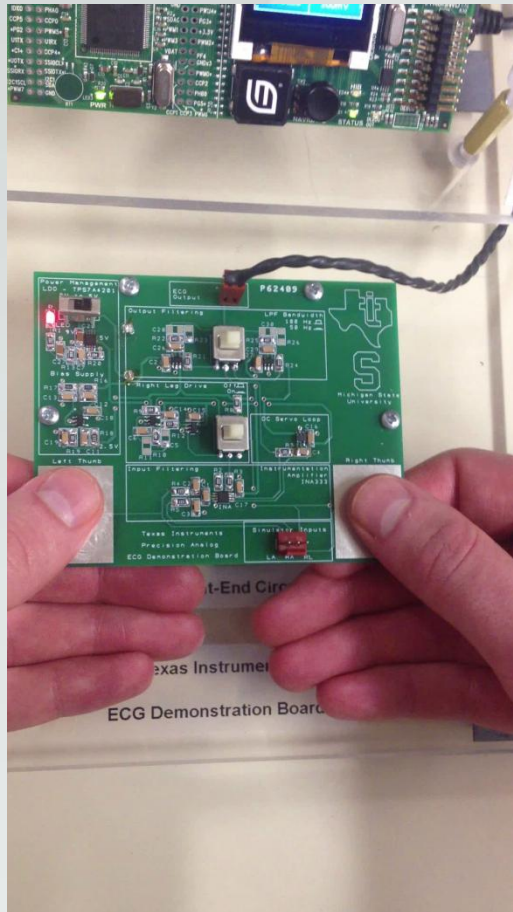


Code Modifications

- Larger timebase options including 100 ms/div and above
- Smoother screen updating
- Default settings changed for optimized ECG viewing

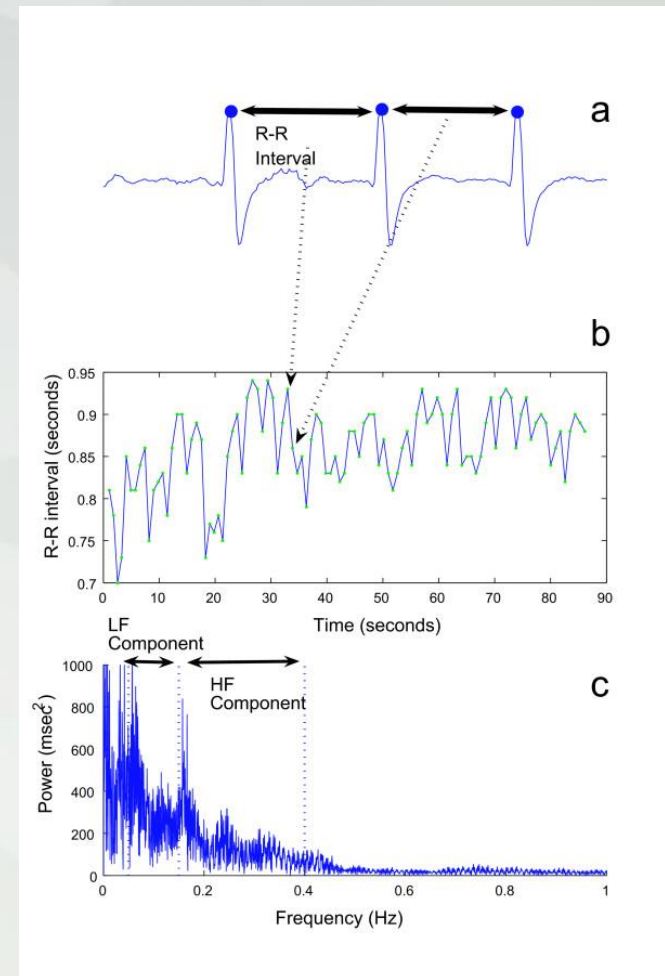


Demonstration



Future Design Improvements

- Implement a FFT for digital filtering on the Stellaris
- Calculate BPM from FFT and display on LCD screen
- Design the analog system using higher-order filters
- Integrating Stellaris display board and AFE board into one PCB





Questions?