Electrocardiograph (ECG) Demonstration Board

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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
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

<table>
<thead>
<tr>
<th></th>
<th>TPS7A4201</th>
<th>TPS62120</th>
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<tbody>
<tr>
<td>Input Voltage (V)</td>
<td>9.5</td>
<td>9.5</td>
</tr>
<tr>
<td>Input Current (mA)</td>
<td>0.74</td>
<td>0.43</td>
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<tr>
<td>Input Power (mW)</td>
<td>7.03</td>
<td>4.08</td>
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<tr>
<td>Output Voltage (V)</td>
<td>4.93</td>
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<tr>
<td>Output Current (mA)</td>
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<tr>
<td>Output Power (W)</td>
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<td>Efficiency (%)</td>
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<td>88.98</td>
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</table>
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?