The project challenge for the semester was to research, design, fabricate, and test the analog circuitry needed to develop an electrocardiogram (ECG) demonstration board for Texas Instruments (TI). The precision analog group sponsored the project’s development throughout the semester. Texas Instruments intends to use the demonstration board to showcase the INA333 instrumentation amp as well as the OPA378 operational amplifier.

**Project Requirements**

- Design and fabricate the analog front-end (AFE) circuitry
- Select a TI power management integrated circuit to utilize a 9V battery
- Measure the ECG signals from the CardioSim II (simulator)
- Condition the analog ECG input signals for accurate display
- Interface the AFE with a Stellaris Oscilloscope evaluation board (EVB)

**System Components**

**CardioSim II ECG Simulator:**

Provides realistic chest electrode ECG signals as inputs to the system

**Analog Front-End Circuit:**

Amplifies and filters the noisy input ECG signals to output a clean signal for display

**Stellaris EKS-LM3S3748:**

Displays the filtered ECG signals using a programmed oscilloscope application

**TI Integrated Circuits Featured:**

- OPA378 Low-Noise Op-Amp
- INA333 Instrumentation Amplifier
- TPS7A4201 Linear Dropout Regulator

**Cost Table**

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acrylic Display</td>
<td>$45</td>
</tr>
<tr>
<td>Battery Pack for Stellaris EVB</td>
<td>$30</td>
</tr>
<tr>
<td>Stellaris Evaluation Kit</td>
<td>$0</td>
</tr>
<tr>
<td>Analog Front-End PCB (4)</td>
<td>$220</td>
</tr>
<tr>
<td>PCB Passive Components</td>
<td>$96</td>
</tr>
<tr>
<td>PCB Integrated Circuits</td>
<td>Free</td>
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<tr>
<td>Accessory Components</td>
<td>$70</td>
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<tr>
<td>Active ECG Finger Sensors</td>
<td>$24</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$485</strong></td>
</tr>
</tbody>
</table>

**Summary of Results**

The final PCB combined with the acrylic display fulfills and exceeds the project requirements. The final demonstration board successfully filters and amplifies an input ECG signal from the CardioSim II simulator and can display the signal on the Stellaris EKS-LM3S3748 LCD screen using the oscilloscope application. The design team successfully implemented the analog circuitry needed to capture a live ECG signal from a user’s fingers tips. Texas Instruments plans to use the board to showcase the performance of their precision analog components.

**Final ECG Demonstration Board Solution**

![Final ECG Demonstration Board Solution](image)

**System Block Diagram**

![System Block Diagram](image)

**Project Results**

- **System Bandwidth:** 0.7 Hz - 50 Hz
- **Passband Gain:** 64.3 dB
- **Battery Life:** 211 hours

**Bode Plot of System Bandwidth**

![Bode Plot of System Bandwidth](image)

**Successful live ECG measurement**

![Successful live ECG measurement](image)

**CardioSim II output through final AFE system**

![CardioSim II output through final AFE system](image)

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