IEEE Phoenix Capstone Project, Spring 2013

Blood Pressure Sensor Utilizing a Pulse Transit Time Technique

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UMN EE Senior Design syllabus

- – Students Choose Project
- – “Customer” describes the needs/desire
- – Design Proposal (reply with requirements)
- – Design product
- – Design Review (technical review)
- – Implement
- – Acceptance Test (with customer)
- – Product Launch Presentation
- – Design Show (Presentation)
- – Final Report

Overall Phoenix Requirements

- Design a "cABPM", an Chronobiological Ambulatory Blood Pressure Monitor that is
  - Inexpensive ("two bushels of yams", $10 to $50)
  - Unobtrusive (e.g., wristwatch, patch, jewelry)
  - Easy to use
  - Takes a week's worth of measurements every half hour
    - Day and Night
  - Measure Systolic & Diastolic BP to within ±3mmHg
    - Systolic Range: 60-280mmHg, Diastolic Range: 40-160mmHg
  - Measure Heartrate to within ±3%, range 30-200 bpm
- Traditional cuff-based monitors fail the first three requirements

Sensor Project Requirements

- Identify turning points on the pulse waveform
  - Representation of the full pulse waveform, or a derivative of the full pulse waveform
  - Sample at 1000Hz or more
  - Useful for Pulse Transit Time, Pulse Wave Analysis
- Comfortable to wear, Unobtrusive, Noninvasive
- 350 readings (1 week at ½ x 24 x 7)
- Battery voltage and power consumption

Typical Project Risks

– Errors in PCB require rework or new board
– Faulty or burned-out components
– Scheduling conflicts (e.g., spring break)
– Failures during important demonstrations
– Budget overruns

– *Plan to mitigate your specific project risks*

Typical Project Deliverables

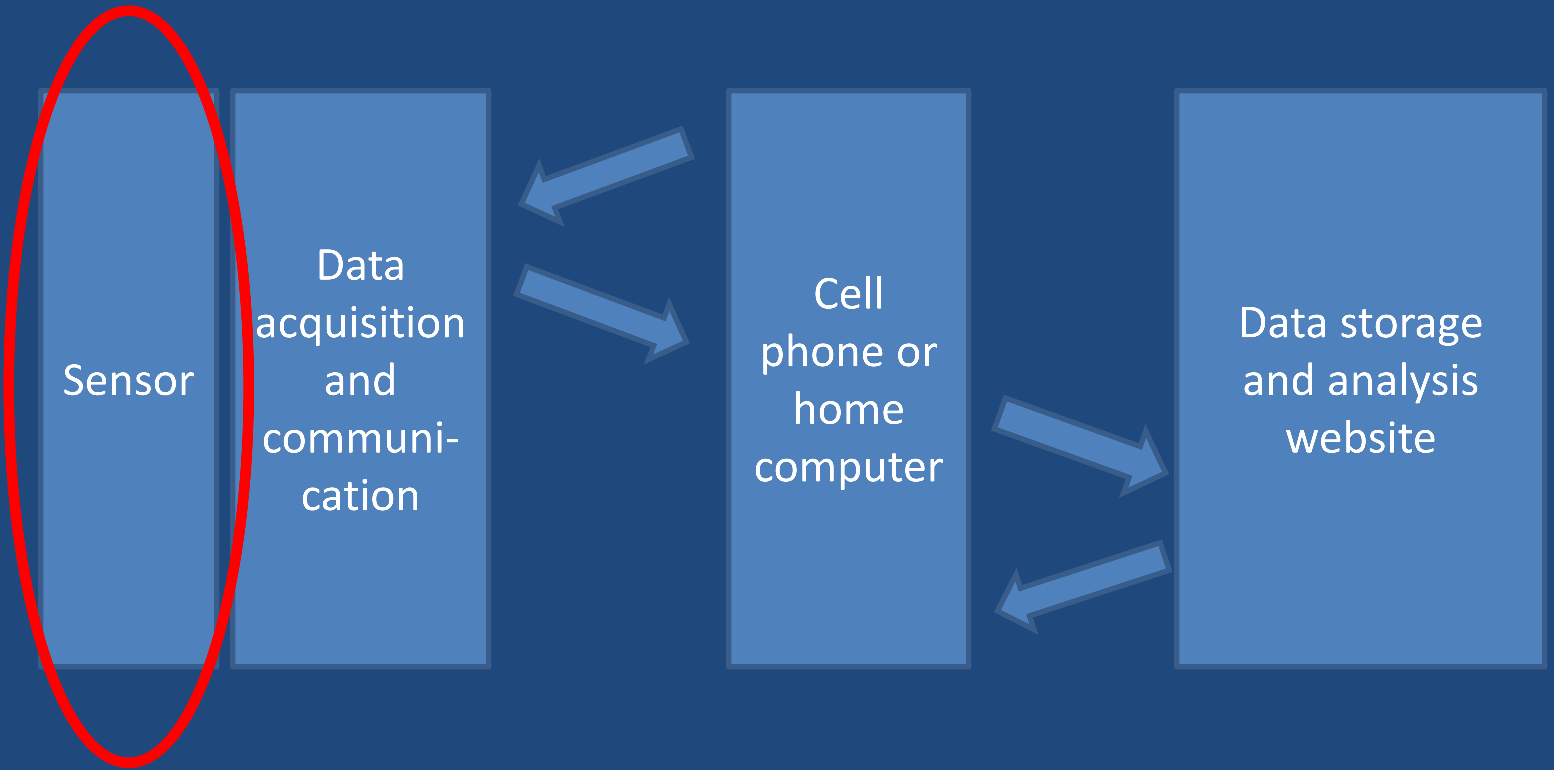
– Project management plan, schedule, risk management plan
– Requirements in engineering language
– Design specification
– Block diagram
– CAD files
– Working circuit boards
– Bill of materials
– Final paper
– Presentations

Safety

- Medical Device Development is regulated in U.S.
  - FDA for commercial development
  - IRB for academic research, hospitals
  - Development is regulated to protect human subjects
- The Phoenix Project is not currently regulated
  - Not far enough along for regulation
  - HOWEVER, THIS PLACES REQUIREMENTS ON YOU!
    - Do literature search to determine if a sensor is safe to use
    - Do not use sensors on anyone outside the team
    - If there is ANY question, ask for verification first
      - labeaty@ieee.org

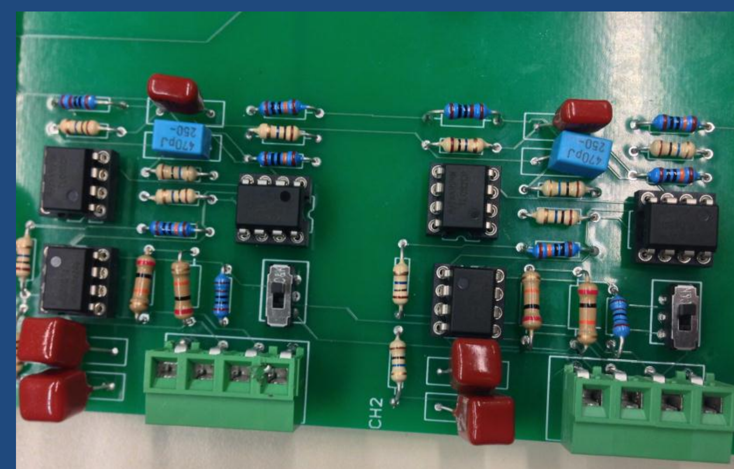
Where the student project fits in

Over-Simplified Block Diagram of the System



IR Sensor Project (for UMN)

– Last semester, students designed IR sensor, amplifier, filter circuit, which needs some improvements in circuit design and packaging



IR Sensor Project (for UMN)

1) Label the connections and parts on last semester's board. Capture data from 2 channels (two locations on the body, e.g., forearm and wrist) with a DAQ from last semester's board early in the project. Develop Labview program to capture data. Develop a primary and secondary peak & trough detection algorithm (e.g., in Matlab).

2) Develop accuracy and precision requirements for recording the shape of individual pulses at two locations on the body to determine adequate blood pressure readings early in the project. Express these requirements verbally in a formal requirements statement.

3) Starting from last semester's design, simulate the analog filter with Spice and adjust the design to eliminate DC drift. Use a new bandpass filter with a steep rolloff (active multi-pole, brick-wall filter) if the existing design can't be adjusted sufficiently. Redesign to lower the voltage to a 3-volt range or 1.5 volt range without saturating the amplifier.

4) Design and build a new 4-channel filter/amplifier circuit, with stronger, flexible, shielded cables and connectors (instead of loose wire and terminal blocks). Build into a shielded box or package.

5) Capture data from 2 channels (two locations on the body, e.g., forearm and wrist) with a DAQ from the new circuit board, Labview program, and your peak/trough algorithm. Derive numeric accuracy and precision requirements experimentally using data taken from the new circuit board.

Piezo Film Sensor Project

1) Research existing published designs, pick one or more designs whereby a piezo film sensor and pressure-inducing device (example, a cylindrical plunger) are placed on the skin over an artery in the wrist, forearm, ankle, neck, or earlobe. The pressure-inducing mechanism must be controllable, so a microcontroller could be used to activate the pressure mechanism while a reading is being taken.

2) Develop written implementation requirements, physical mounting requirements, power requirements, and accuracy/precision requirements from Phoenix Project information.

3) Construct or obtain a multi-channel filter/amplifier circuit, and perform experiments with an array of sensors at the wrist, forearm, and other locations, with analysis of how realistic and complete the pulse waveforms are.

4) Analyze how closely the Phoenix Project requirements of robustness, accuracy, cost-to-build, and manufacturability were met.

Relative location and motion detector

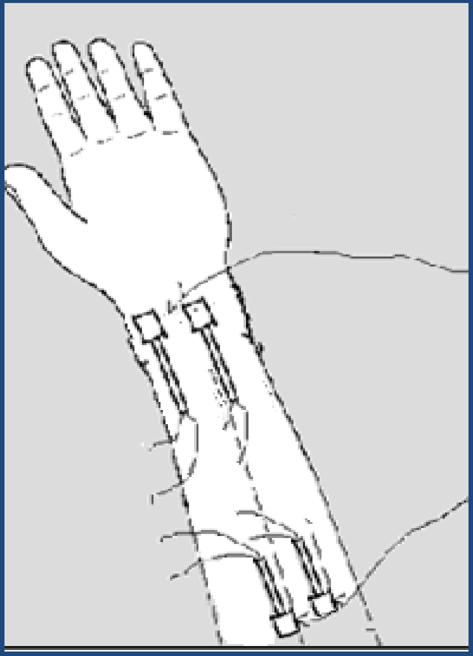
Determine where the BP sensor is relative to the heart in 2-D or 3-D space. (Height is all that's needed.)

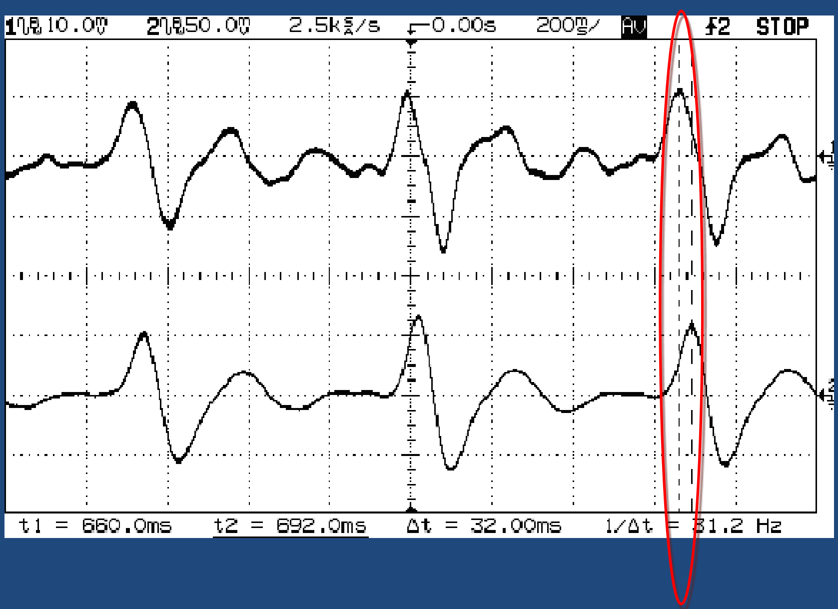
Determine if BP sensor is moving.

E.g, passive element (RFID) on chest, active element(s) on peripheral body parts, accelerometer to detect motion & direction of "up"

Pulse Transit Time

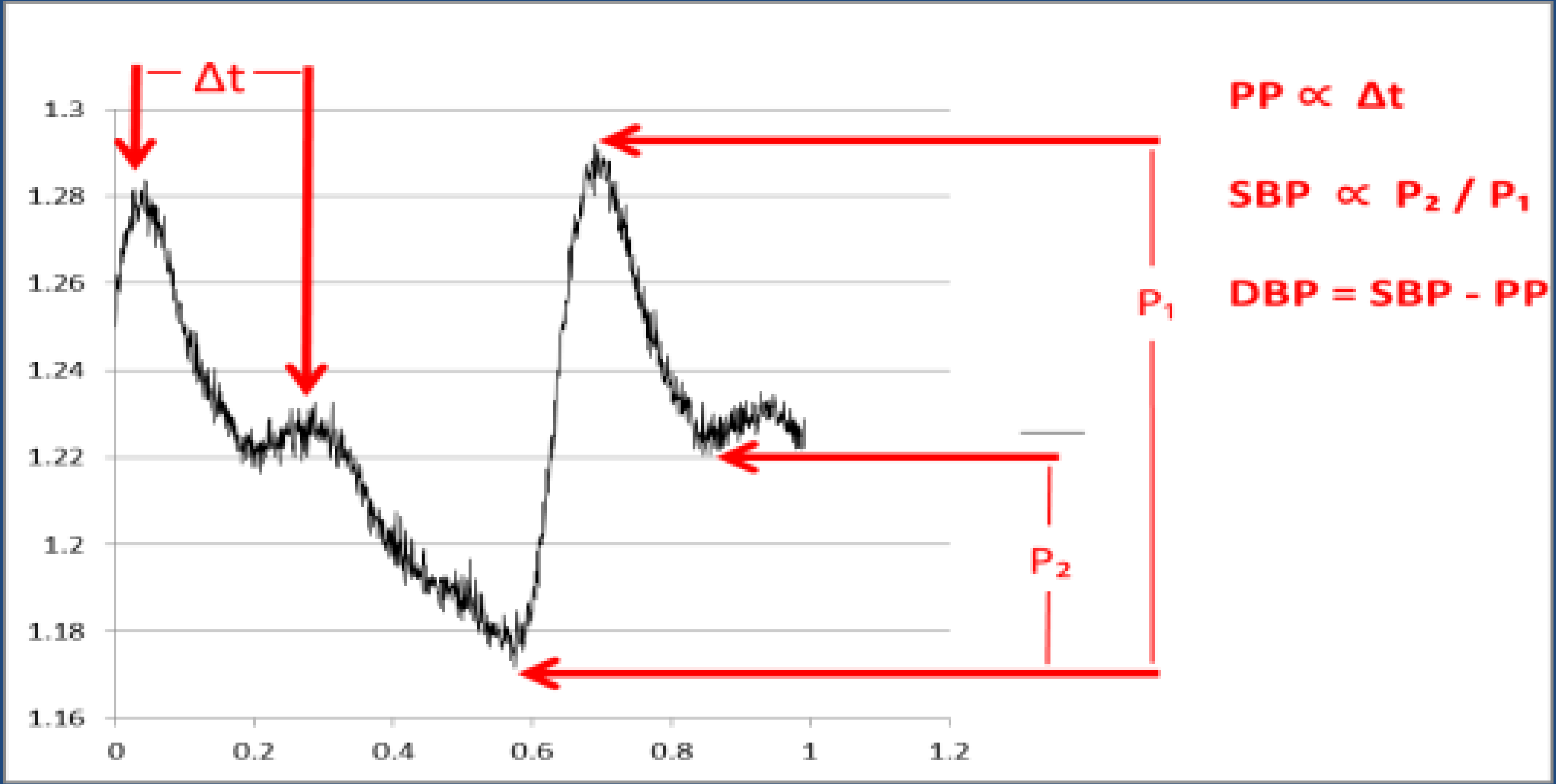
– The "Chen patent" (US 06599251)
  – P=a+b*ln(T)





Pulse Wave Analysis

– Looking for reflection waves in a single pulse



Discussion

– What is your impression of the projects mentioned so far?