Blood Pressure and Heart Rate Monitor for Hypertension

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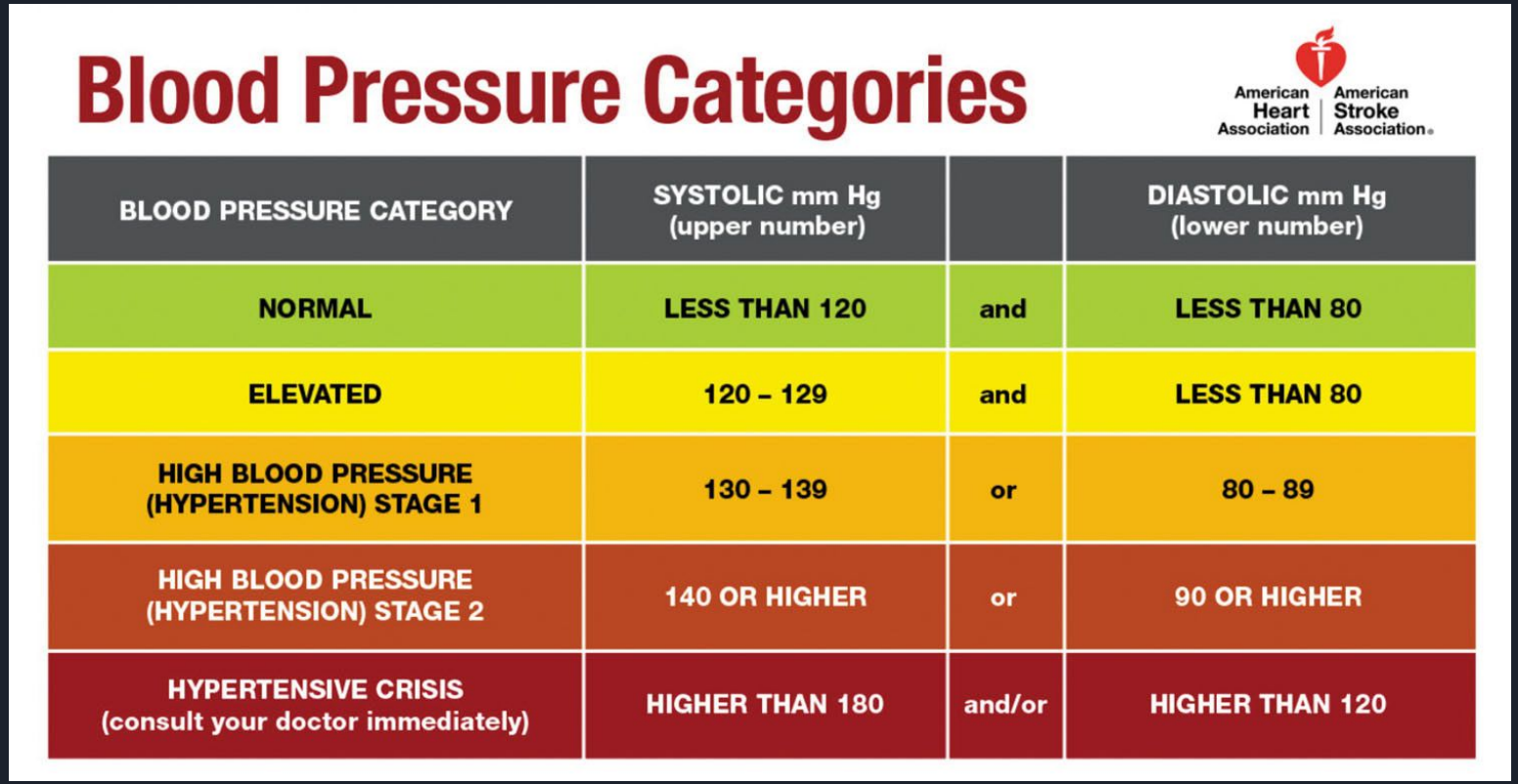
Design Intent: Track Hypertension

- Hypertension: abnormally high blood pressure
  - Systolic BP > 130 mmHg or diastolic BP > 80 mmHg [1]
- Common in the US – affects 47% of adult population [1]
  - Need diagnosis and prescription to begin treatment
  - About 1 in 5 adults do not know they have high blood pressure
- Long term effects [1][2]
  - Damaged arteries, increased risk of aneurysms
  - Increased risk of heart disease, heart failure
  - Increased risk of stroke, dementia
  - Kidney failure
  - Loss of vision

Stages of Blood Pressure [3]



Blood Pressure Categories

American Heart Association | American Stroke Association

BLOOD PRESSURE CATEGORY	SYSTOLIC mm Hg (upper number)		DIASTOLIC mm Hg (lower number)
NORMAL	LESS THAN 120	and	LESS THAN 80
ELEVATED	120 – 129	and	LESS THAN 80
HIGH BLOOD PRESSURE (HYPERTENSION) STAGE 1	130 – 139	or	80 – 89
HIGH BLOOD PRESSURE (HYPERTENSION) STAGE 2	140 OR HIGHER	or	90 OR HIGHER
HYPERTENSIVE CRISIS (consult your doctor immediately)	HIGHER THAN 180	and/or	HIGHER THAN 120

Developing the Hypertensive Blood Pressure Monitor

- **Goals**
  - Measure Heart Rate
  - Measure Blood Pressure
  - Indicate stage of Blood Pressure
    - Use LED lights for the three hypertension stages
- **Methods**
  - Measure blood pressure using catheter & micromanometer
  - Filter signal with respect to heart rate frequency
  - Divide signal to indicate Blood Pressure stage

Basic Components

1) **Pressure Transducer**

- MEMS-based micromanometer used for continuous time waveforms [4]
- Allows collection of the heart rate and blood pressure

2) **Bandpass Filter/Amplification**

- Based off heart rate frequency
- 0.5 Hz to 2.5 Hz

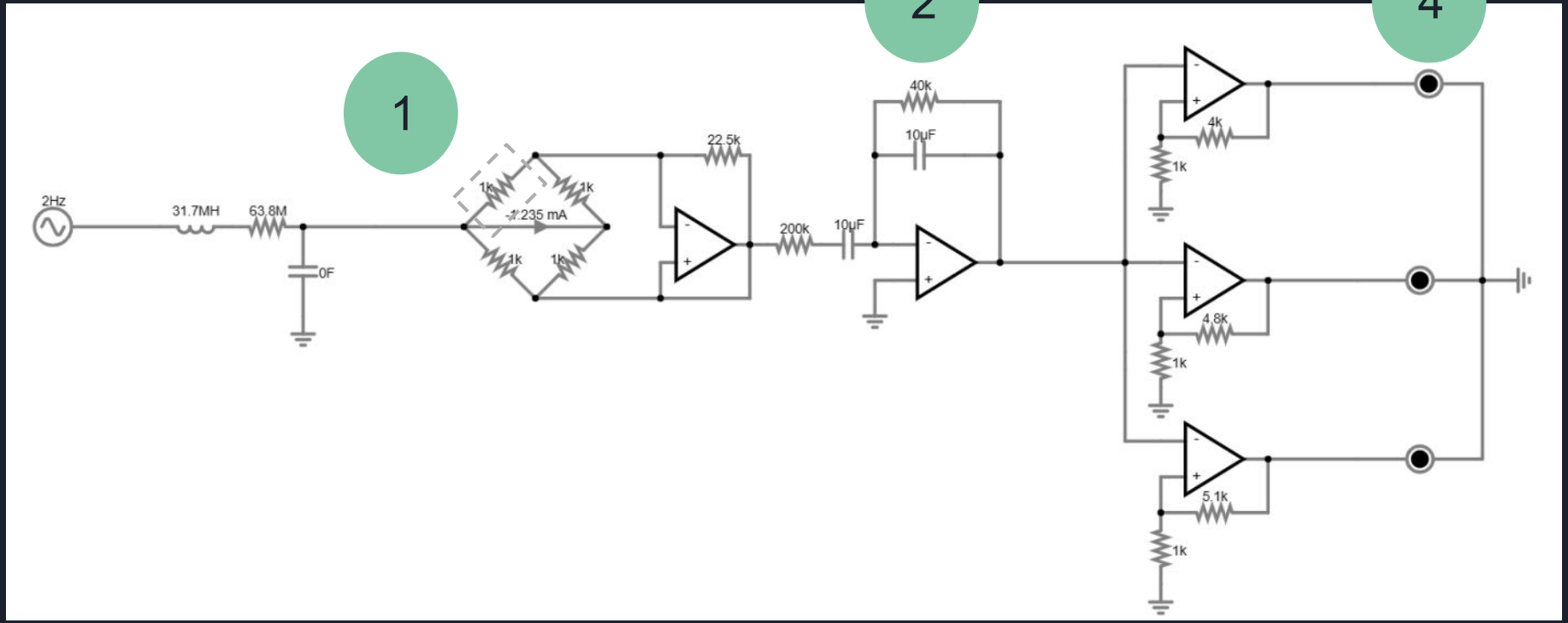
3) **Comparators**

- Dangerous levels of pressure
- Stage 1, Stage 2, Hypertensive Crisis

4) **LED Lights**

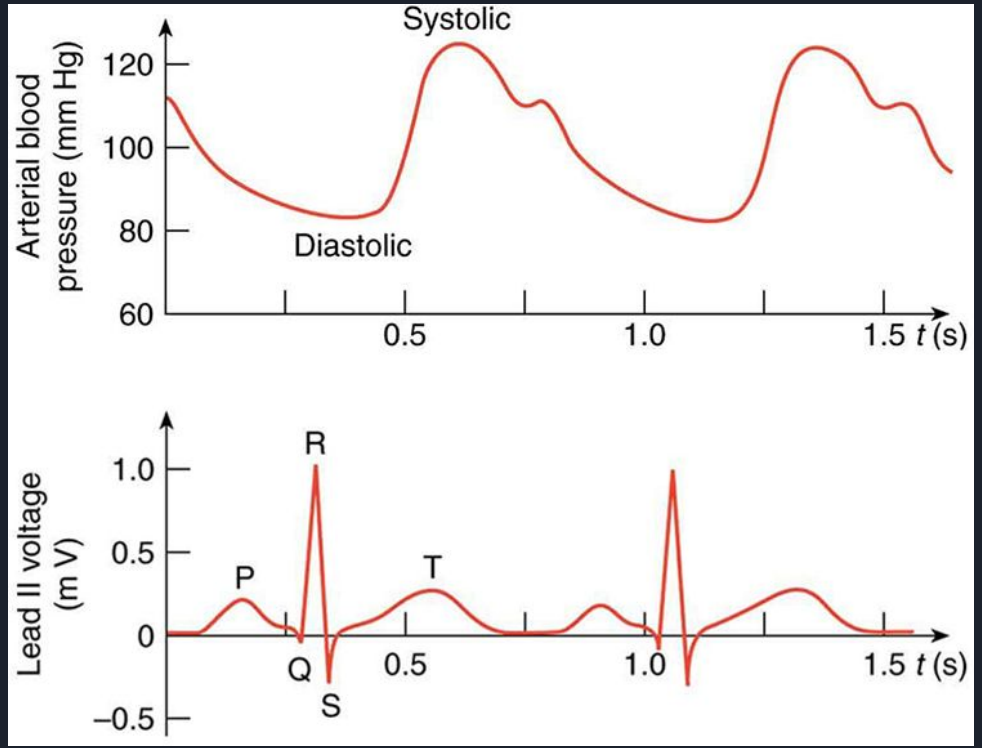
- Connected to comparators
- Light up at indicated stage of hypertension

Big Picture Roadmap



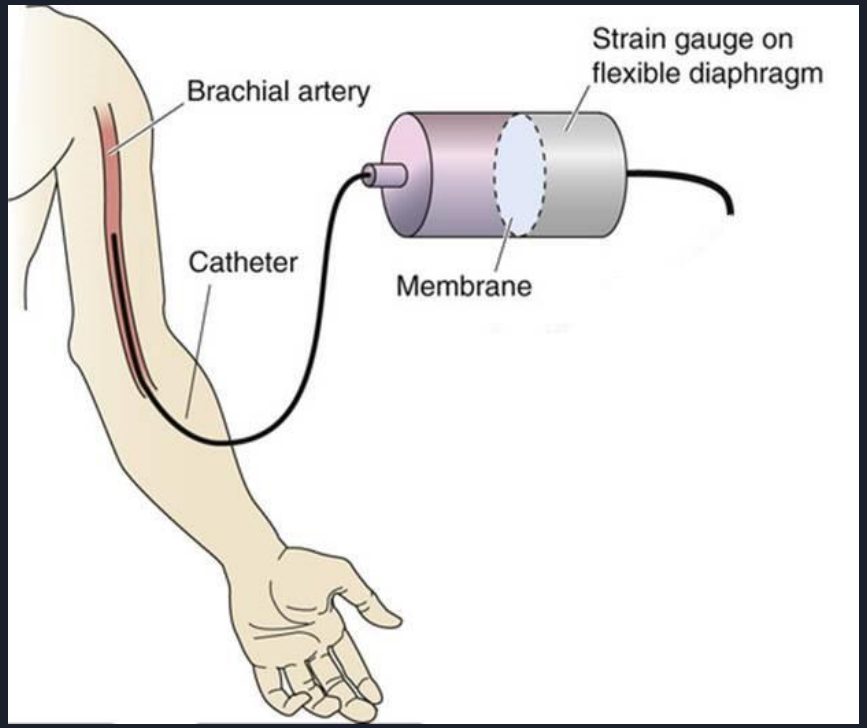
BP Monitoring and Heart Rate

- Comparison of PQRST wave vs. pressure signal [8]
- Peaks in signal correlate to time interval for heart rate
  - Allows filtering for signal within the heart rate frequency range



Catheter Tube

- **Setup**
  - Filled with fluid
  - Inserted into major artery
  - Connected to pressure transducer
- **Values**
  - Tube
    - Radius: 2 mm
    - Length: 40 cm
  - Fluid used: water [7]
    - Viscosity: 1.0016 mPa
    - Density: 997 kg/m^3
  - Equivalent
    - Capacitance: 3.35pF
    - Inductance: 31.7MH
    - Resistance: 63.8MΩ
  - Young's Modulus of membrane: 30 MPa



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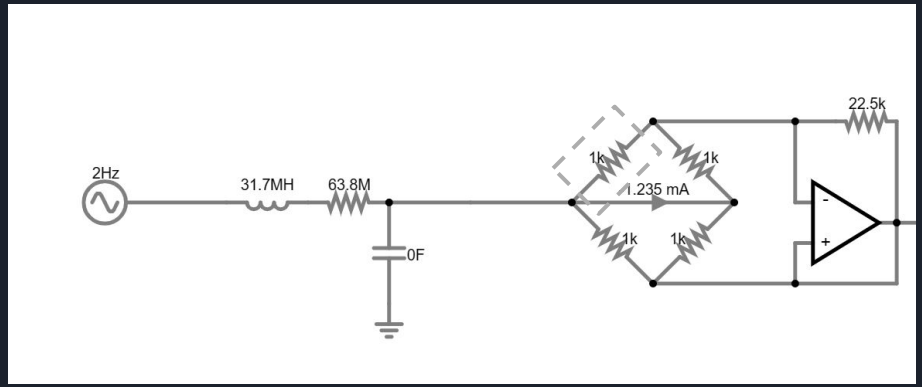
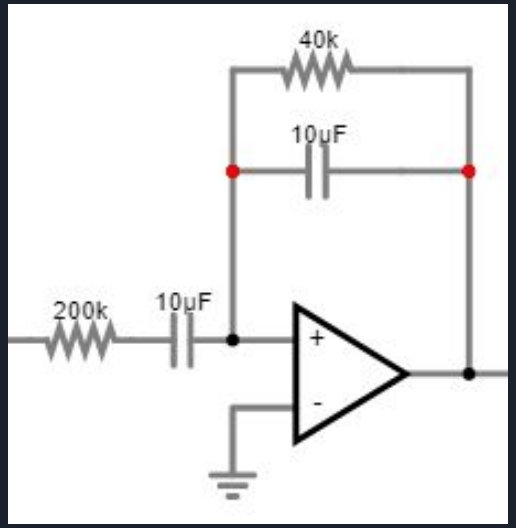
Pressure Transducer

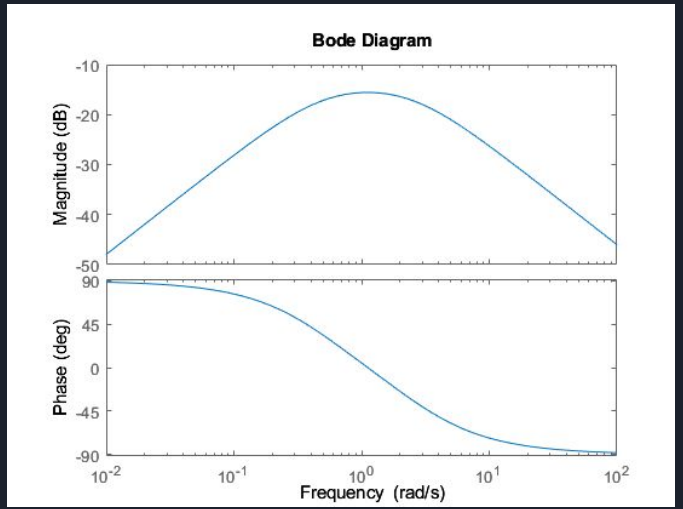
- Wheatstone Bridge
  - R values equivalent besides the feedback and strain gauge
  - Target Sensitivity: 22.5 mV/mmHg
- Values
  - Gauge Factor: 100
  - Wheatstone Feedback Resistor: 22.5kΩ
  - Other Resistors: 1kΩ
  - Op-amp powered by 5V battery



2 *Bandpass Filter*

- Range of Frequency
  - 0.5 Hz to 2.5 Hz
  - Based on heart rate of 30 bpm to 150 bpm
    - Range for abnormal heart rate [6]
- Values
  - Input Capacitor: 10μF
  - Input Resistor: 200kΩ
  - Feedback Capacitor: 10μF
  - Feedback Resistor: 40kΩ
  - Op-amp powered by 5V battery





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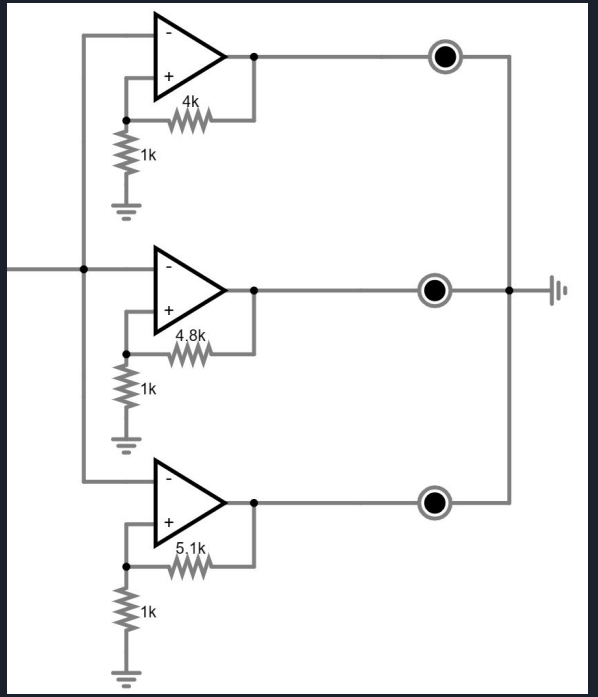
Comparator and LED Lights

- Inverting Hysteresis Comparator
- V_{out} for
  - BP=130 mmHg: -1.2289V
    - Stage 1 Hypertension
  - BP=140 mmHg: -1.3179V
    - Stage 2 Hypertension
  - BP=180 mmHg: -1.6667V
    - Hypertentative Crisis
- Stages indicated using LEDs
- Resistor values found by making reference voltage the hypertensive values
- Comparators powered by 5V battery



Advantages & Limitations

Advantages

- Indicators at unusual pressure levels aid in diagnosing hypertension
  - Intuitive, extremely user friendly for the common person
- Micromanometer provides accurate, continuous BP measurement
  - Direct contact with blood vessel

Limitations

- Only records systolic pressure
  - Hypertensive cases due to high diastolic pressures overlooked
  - Pressure not indicated by lights – other possible heart issues
- Invasive approach
  - More difficult to set up properly
  - May cause discomfort to patient

Future Improvements

- Measure Diastolic Pressure for hypertension
- Detect Hypertension and Hypotension
- Develop a non-invasive technique that provides accurate readings to replace the invasive catheter

Thank you Professor Cauwenberghs, Vikrant, Samira, and Adyant for all your help this quarter!

Works Cited

[1] Facts About Hypertension | CDC

[2] High blood pressure dangers | Mayo Clinic

[3] Understanding Blood Pressure Readings | American Heart Association

[4] Recommendations for Blood Pressure Measurement in Humans and Experimental Animals | American Heart Association

[5] How to Measure Blood Pressure, Blood Flow, and Cardiac Volumes | Medical Physiology, 3rd Edition

[6] Heart Rate Estimation from Incomplete Electrocardiography Signals | MDPI

[7] Relation Between Viscosity And Density | BYJU'S

[8] Build Log: Blood Pressure Triggering System for MRI | Arduino Forum

Questions?