Automated Blood Pressure Monitoring System

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Link

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01

Clinical Motivation

48.1%

Of Americans adults have high blood pressure

685k+

Deaths in 2022 cite hypertension as a primary or contributing cause of death in the US

BP Measurement Tools

Standard Systems

Cuff + Stethoscope –

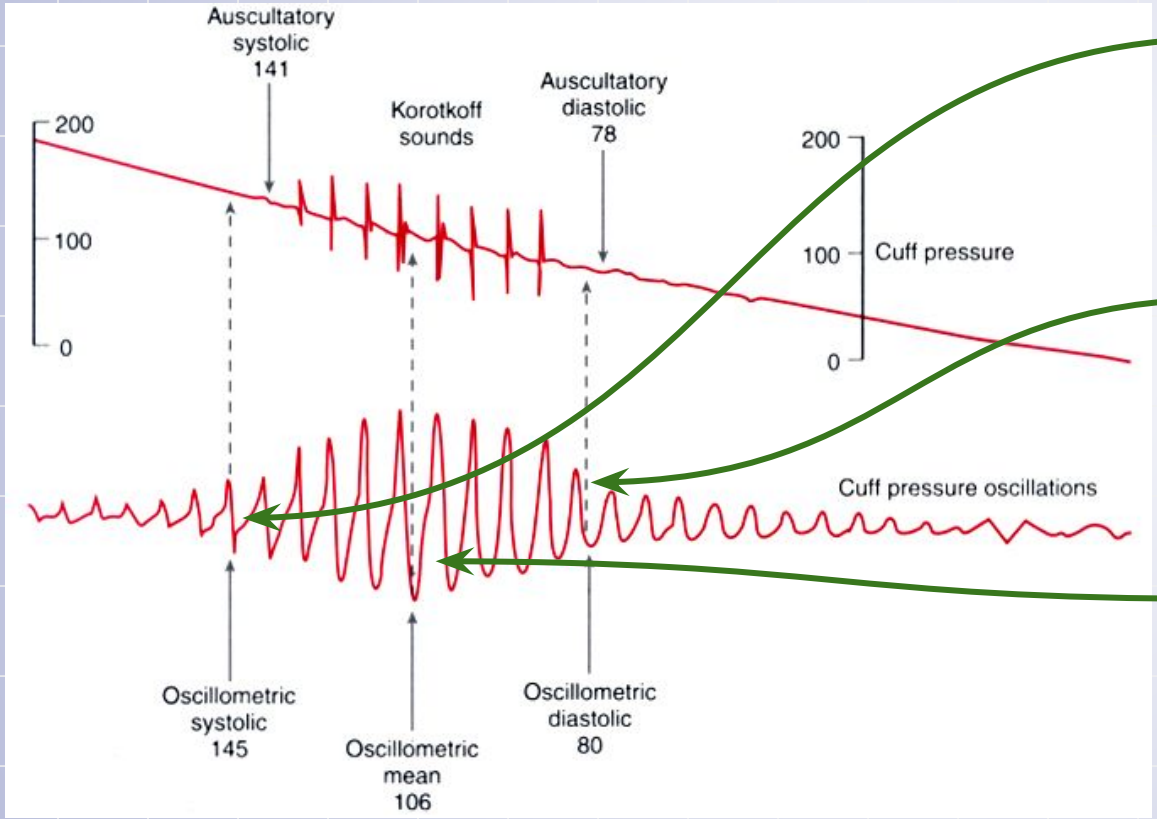
Use Korotkoff sounds to identify when systolic and diastolic pressure values

Automated Systems

Gauge Pressure Sensor –

Using the oscillatory peaks to determine when systolic and diastolic pressure values

Blood Pressure Components



Systolic Pressure

Cuff pressure at the time of **first peak** measured, or the first Korotkoff sound heard

Diastolic Pressure

Cuff pressure when **oscillation amplitude at threshold of the max amplitude**, or Korotkoff sounds are no longer heard

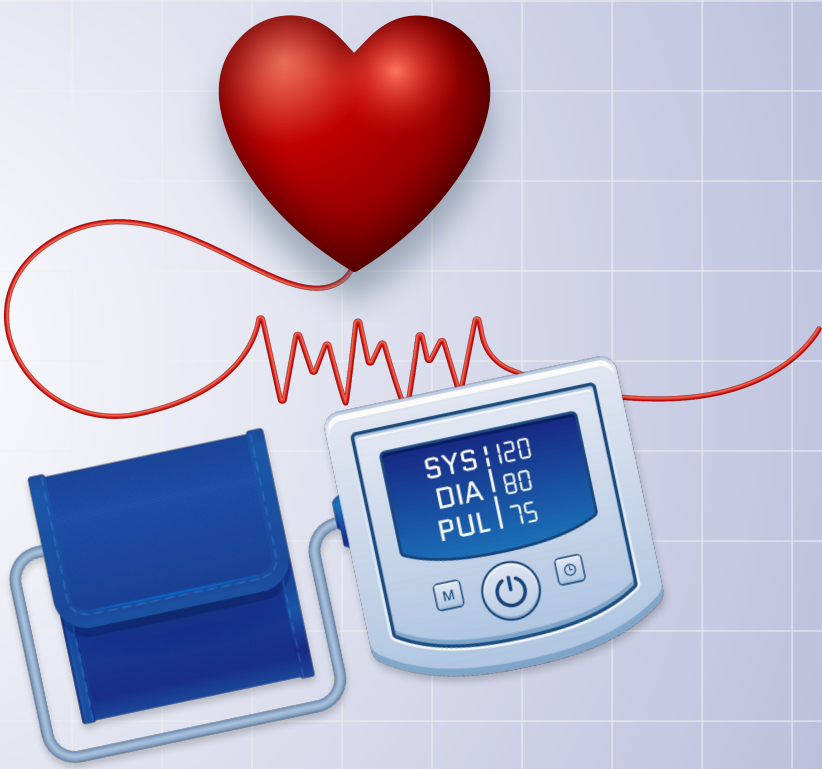
Mean Arterial Pressure

Cuff pressure at the time of **highest amplitude oscillation** peak (calculated based on S & D for Korotkoff method)

Automated BP Monitor System

Design a **user-friendly** device to

- **Automatically inflate** a BP cuff
- **Record pressure oscillations**
- **Display** systolic/diastolic/mean arterial pressures
- **Deflate** cuff



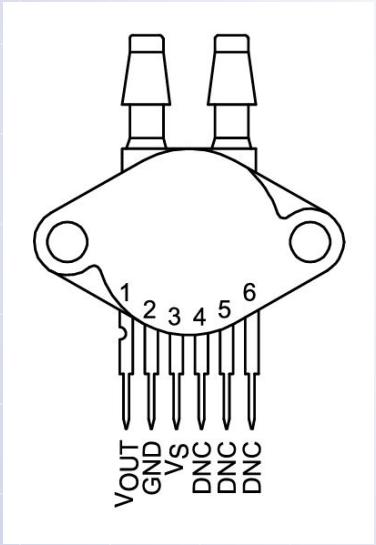
02

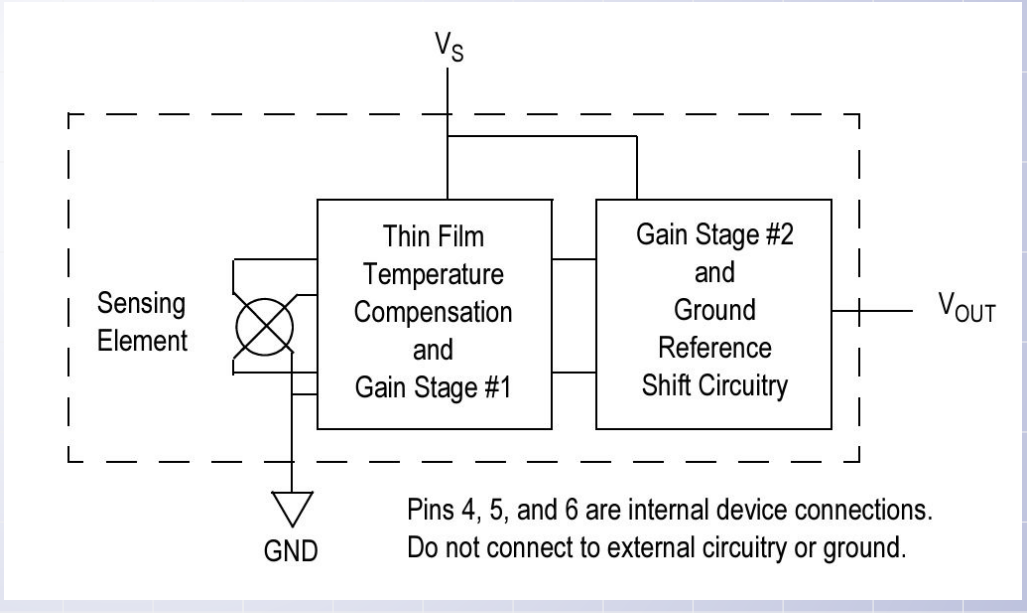
Hardware Design

Circuits & Specs

Pressure Sensor: MPX5100GP

A **piezoresistive** transducer that uses an **integrated circuit** to convert an **applied pressure** into a corresponding **analog voltage output**.



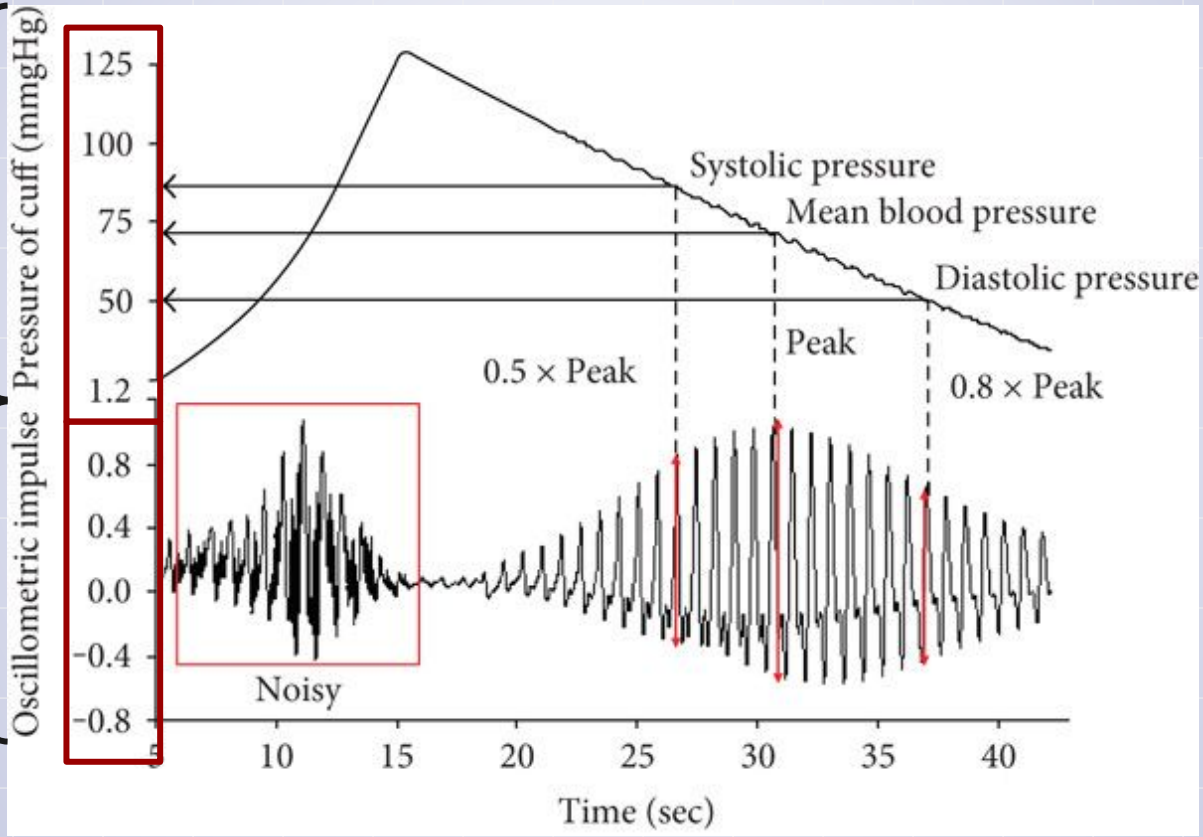


NXP Semiconductors. (2018). MPX5100, 0 to 100 kPa, Differential, Gauge, and Absolute, Integrated, Pressure Sensors (Rev. 14). Document Number: MPX5100.

2 Key Measurements

Cuff pressure

Amplitude of Oscillations

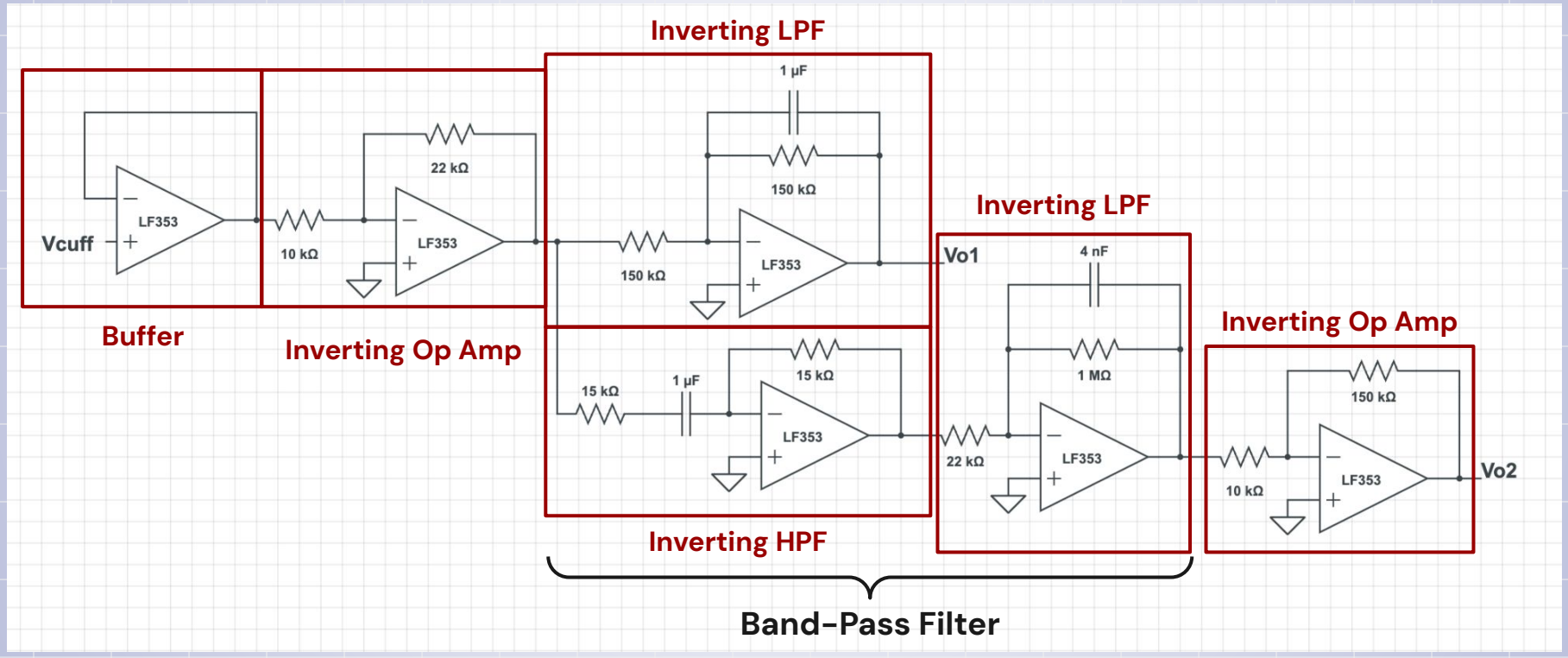


Low Pass Filter + Some Amplification

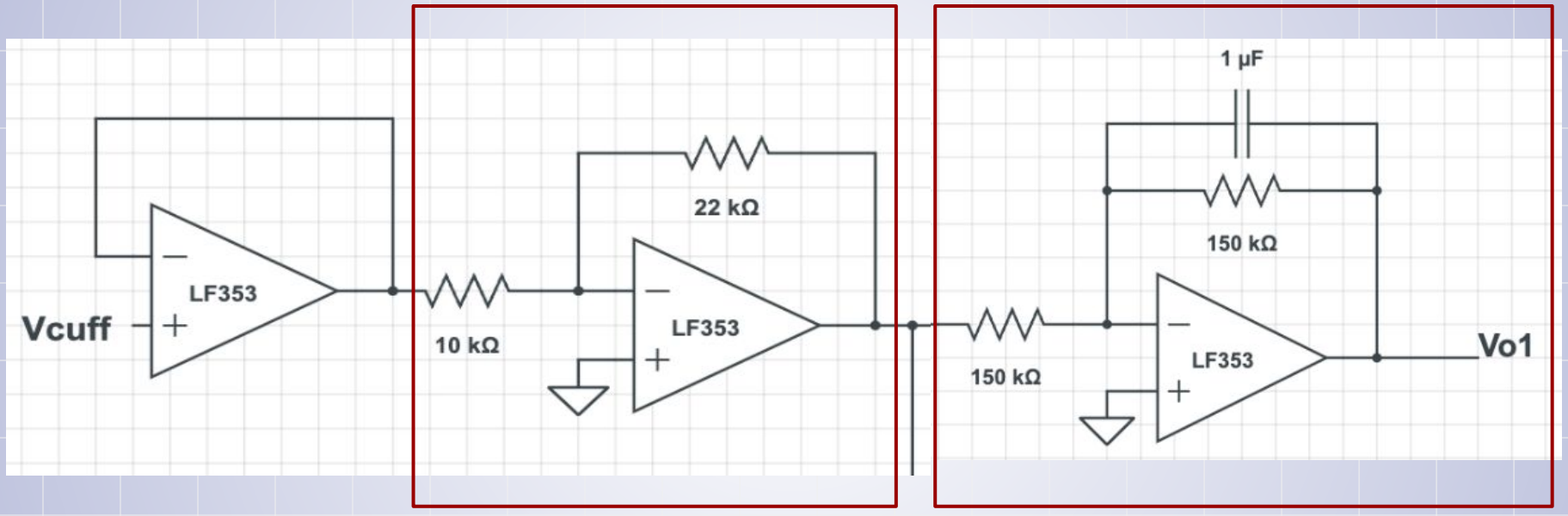
Band Pass Filter + A LOT of Amplification

Circuit Design

Op Amps Powered by +9V & -9V



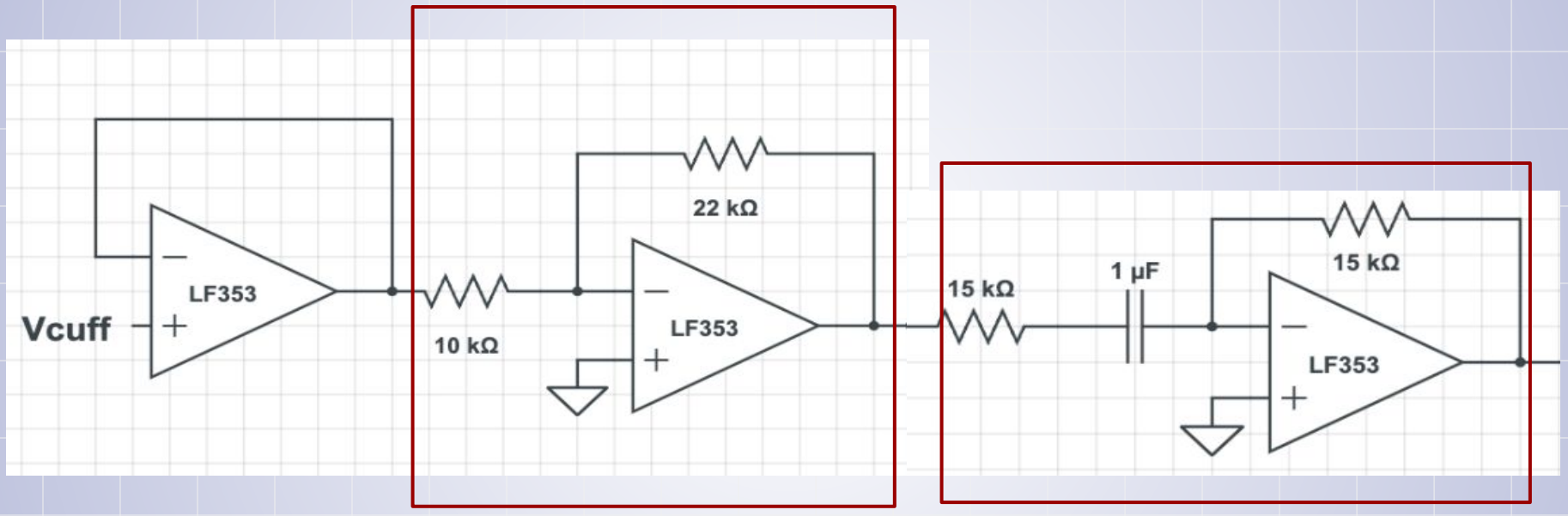
Circuit Design: LPF



Inverting Amplifier:
Gain of -2.2

Inverting Low Pass Filter:
Cutoff Frequency of 1.06 Hz, Gain of -1

Circuit Design: BPF

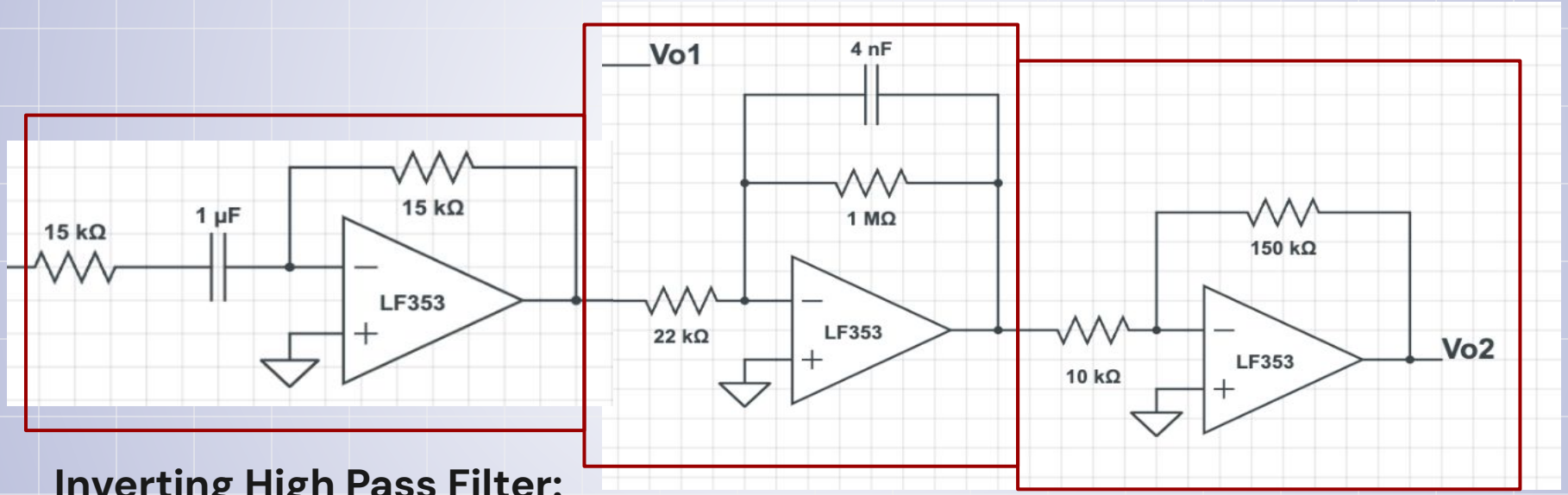


Inverting Amplifier:
Gain of -2.2

Inverting High Pass Filter:
Cutoff Frequency 10.6 Hz, Gain -1

Circuit Design: BPF

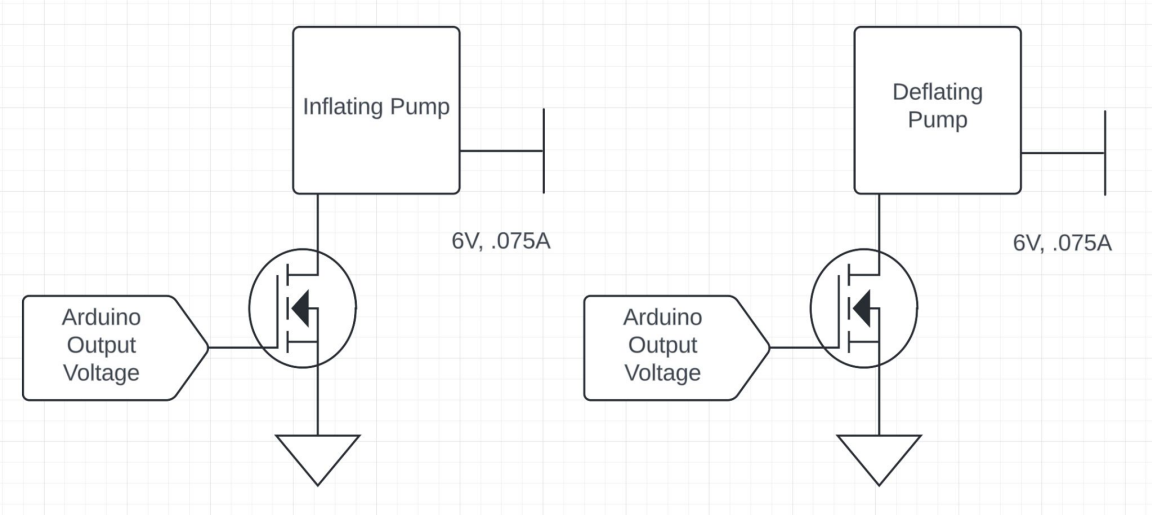
Inverting Low Pass Filter
Cutoff frequency 40 Hz, Gain 45.5

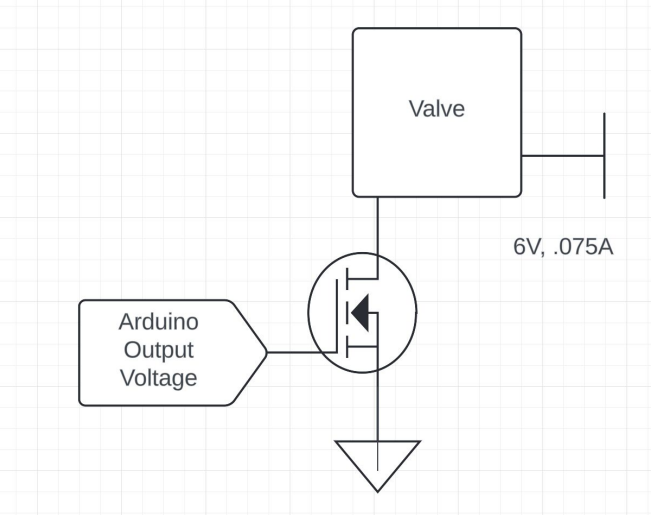


Inverting High Pass Filter:
Cutoff Frequency 10.6 Hz, Gain -1

Inverting Op Amp:
Gain = 15

Circuit Design: Pumps & Valve





3 MOSFETs to switch current based on digital output voltage from Arduino

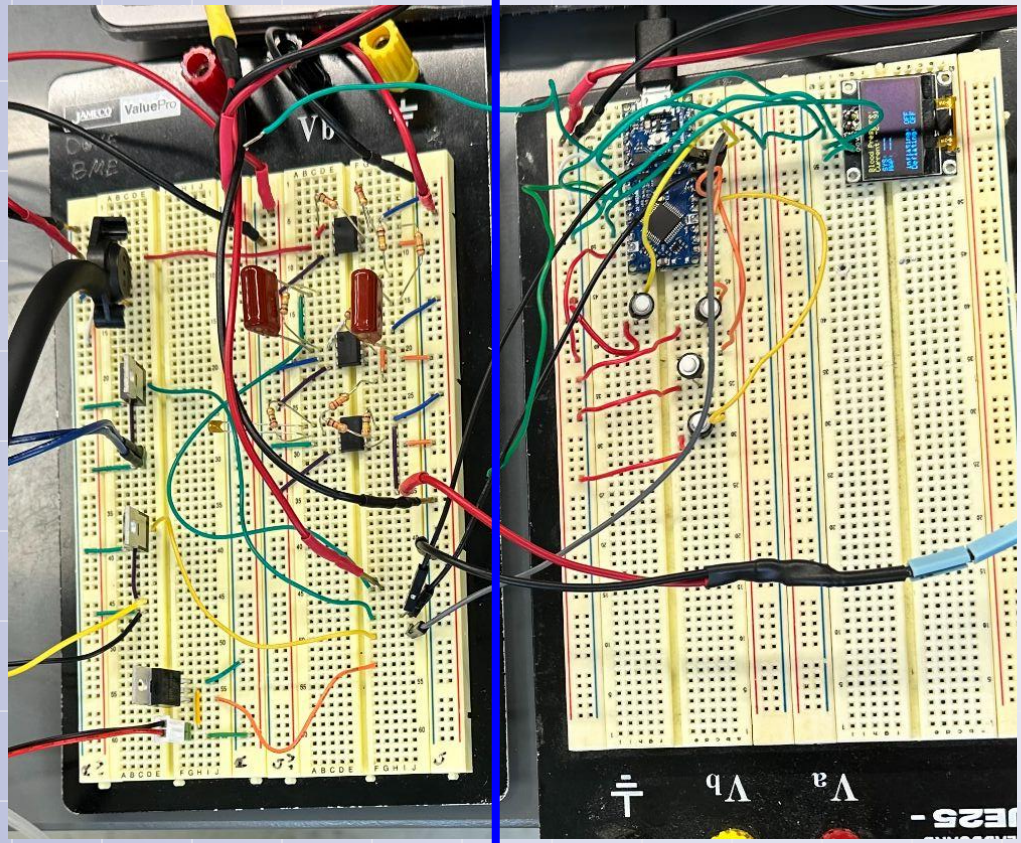
Powered by: 6V, .075 A
(1 rail for pumps, one rail for valve)

03

Implementation

Building the circuit

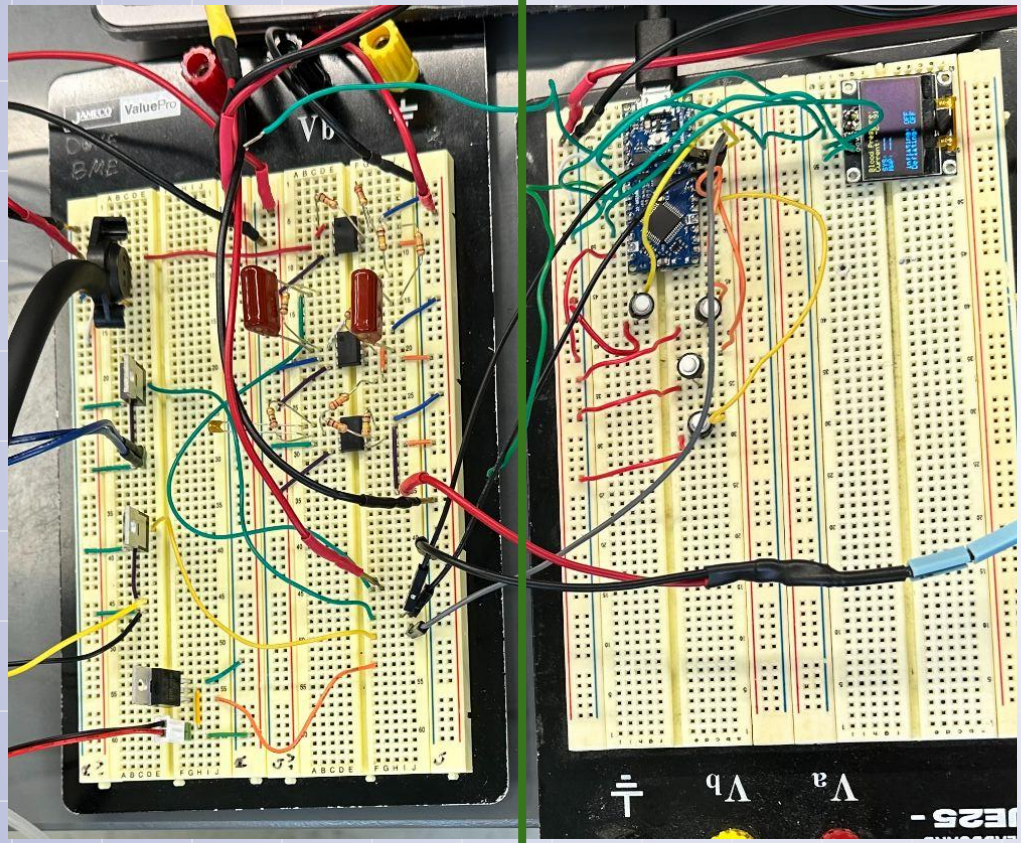
Actual Circuit



User Interface

- Buttons
  - Start measurements
  - Inflate manually
  - Deflate manually
  - Automatic inflation and measurement
- OLED
  - Displays pressures
  - Indicates status of pumps
  - Countdown for automated inflation

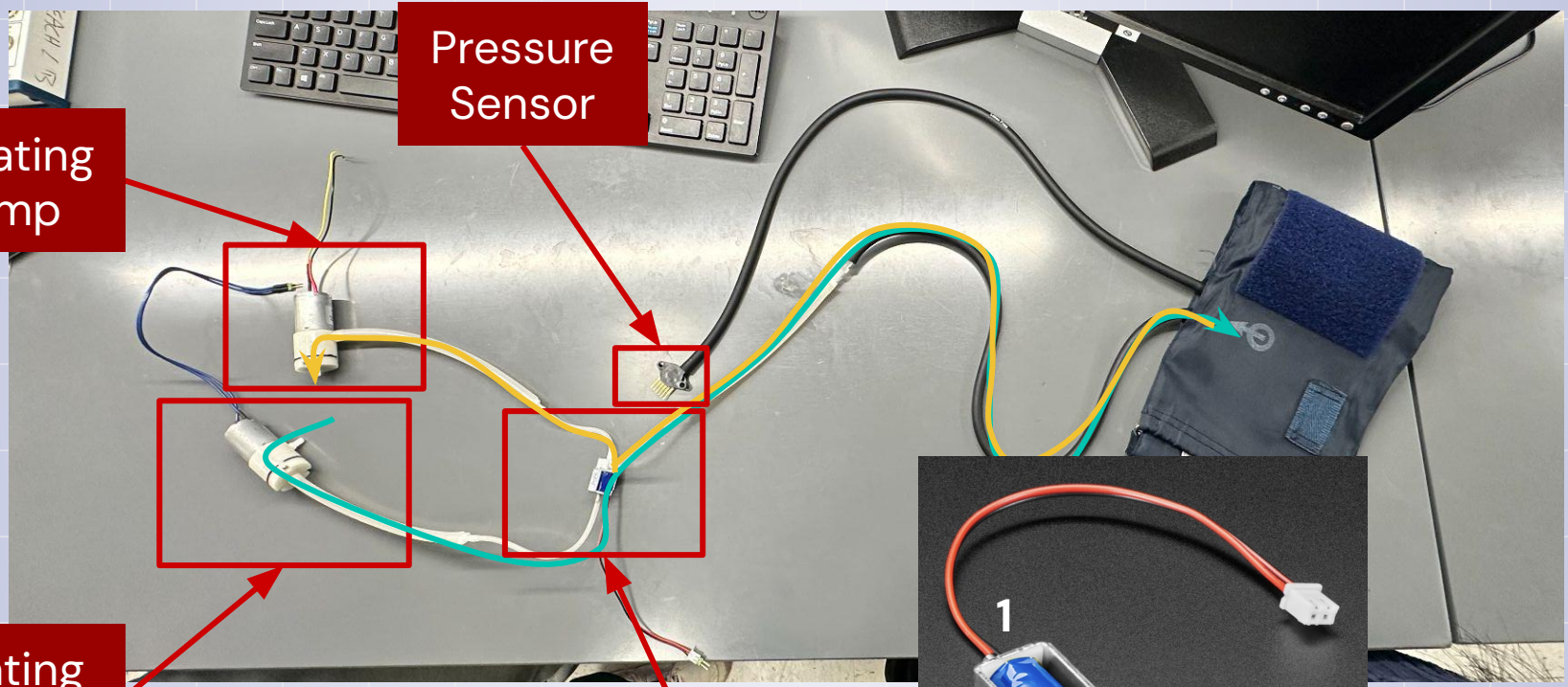
Actual Circuit



Analog Front-End Circuit

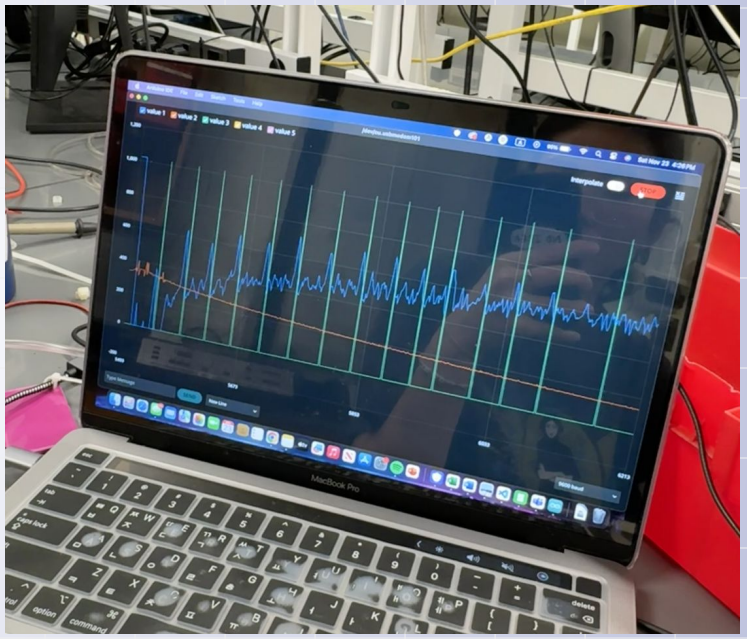
- Op Amps, Resistors & Capacitors
  - LPF
  - BPF
  - Inverting amplifiers
- Pressure Sensor
  - Transduces cuff pressure changes to analog voltage changes
- MOSFETS
  - Turns on/ off depending on control signal from Arduino
  - Amplifies current from Arduino to power pumps and valve

PVC: Pumps, Valve, Cuff



Arduino Signal Processing

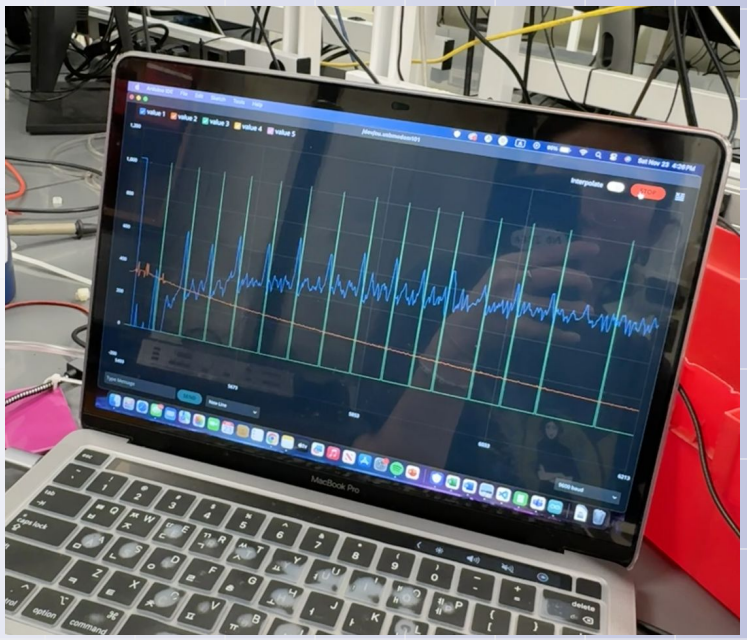
1. Takes oscillometric readings within a **sliding window of 10 samples**
2. **Sample spacing:** samplesAfterPeak > MIN_DISTANCE ensures **at least 30 samples** before detecting another peak.
3. **Amplitude filtering:** peakAmplitude > THRESHOLD (100) ensures **only oscillations stronger than 100 ADC units are peaks** to filter out minor signal fluctuations.



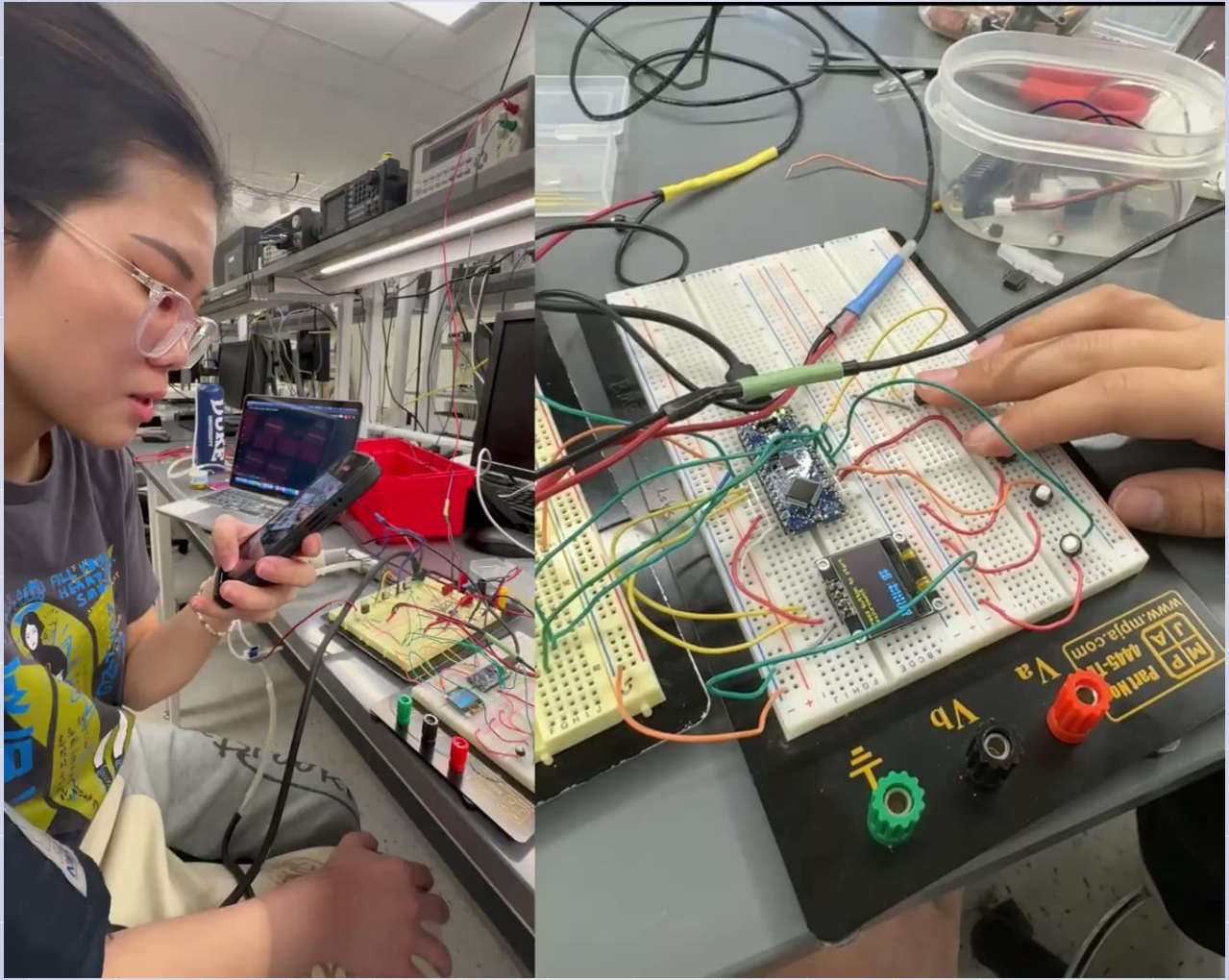
Arduino Signal Processing

4. Uses amplitude thresholds to determine blood pressure values:

- **Systolic:** First oscillation peak
- **MAP:** Point of maximum peak amplitude
- **Diastolic:** When peak amplitude drops below 55% of maximum amplitude



In Action:



04

Validation

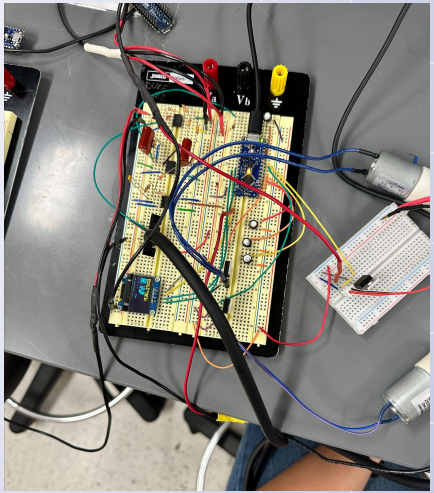
Woot woot

Validating Against Commercial Devices

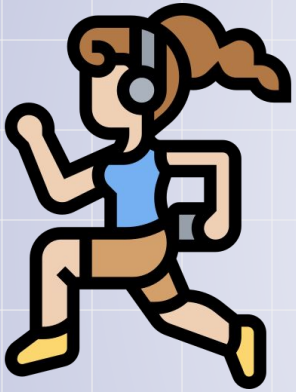
Walgreens Wrist BP Cuff

Omron Upper Arm BP Monitor

Our Device

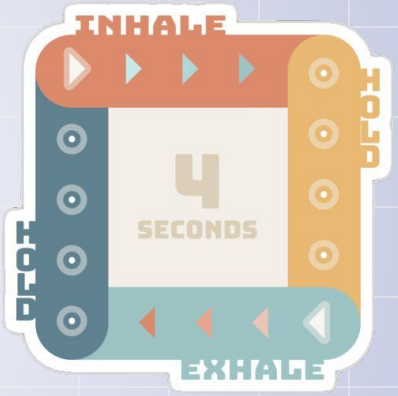


Physiological Response to Stimuli



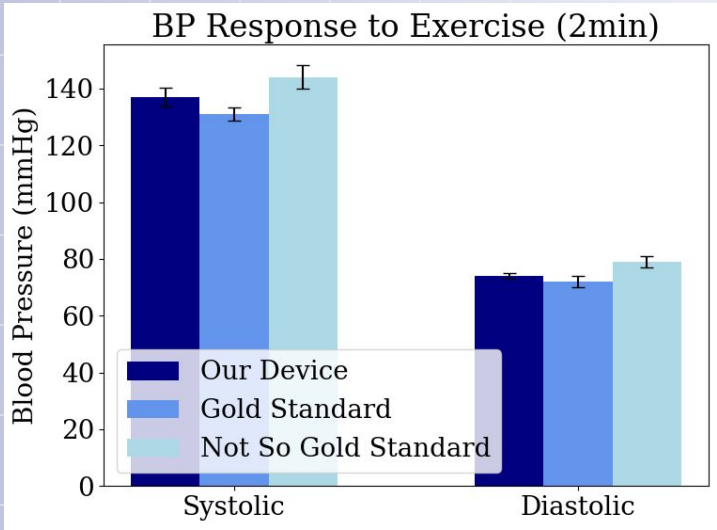
Exercise

Holding Breath



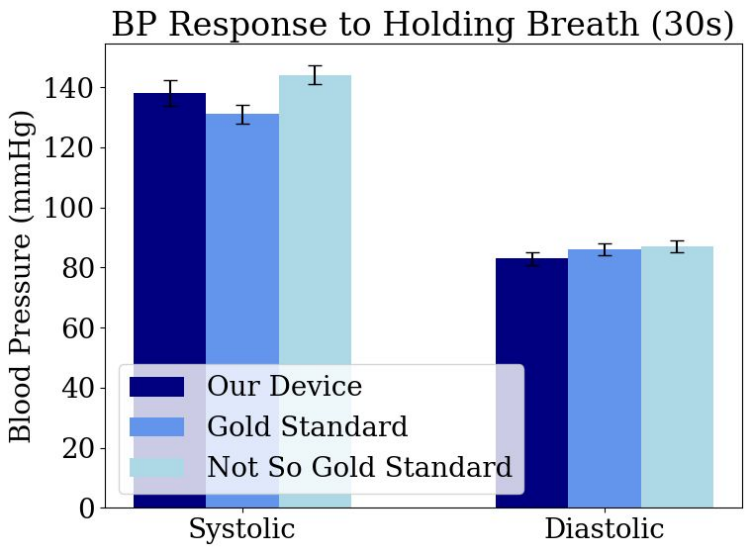
Box Breathing

Physiological Response to Stimuli



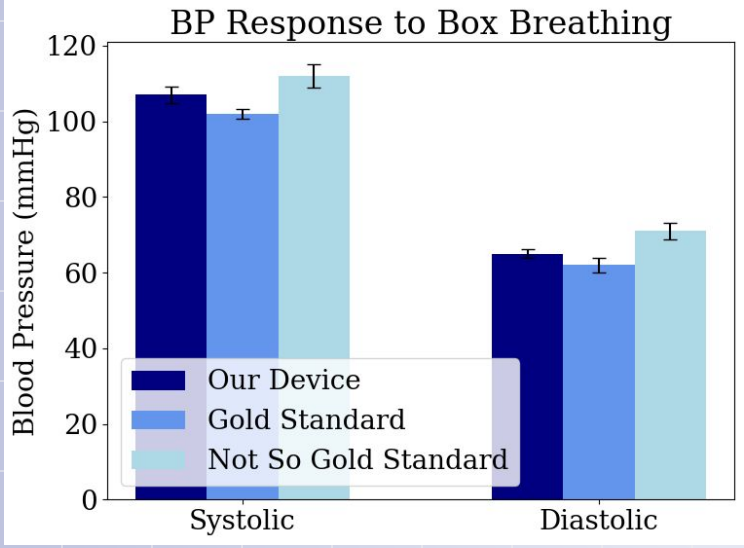
N = 8	Exercise (2m)
Our Values	[128-152] / [68-82]
Gold Standard Values	[123-155] / [65-82]
Not So Gold Standard Values	[120-164] / [61-89]
Mean Difference	+5.34 / +2.31
Statistically Significant Difference	Yes (p-value << .05)

Physiological Response to Stimuli



N = 8	Held Breath (30s)
Our Values	[121-142] / [83-92]
Gold Standard Values	[118-144] / [82-94]
Not So Gold Standard Values	[112-153] / [75-99]
Mean Difference	+4.85 / +2.14
Statistically Significant Difference	Yes (p-value << .05)

Physiological Response to Stimuli



N = 8	Box Breathing (5-5-5-5)
Our Values	[97-113] / [57-72]
Gold Standard Values	[96-111] / [55-74]
Not So Gold Standard Values	[92-121] / [52-82]
Mean Difference	+2.19 / +3.02
Statistically Significant Difference	No (p-value > .05)

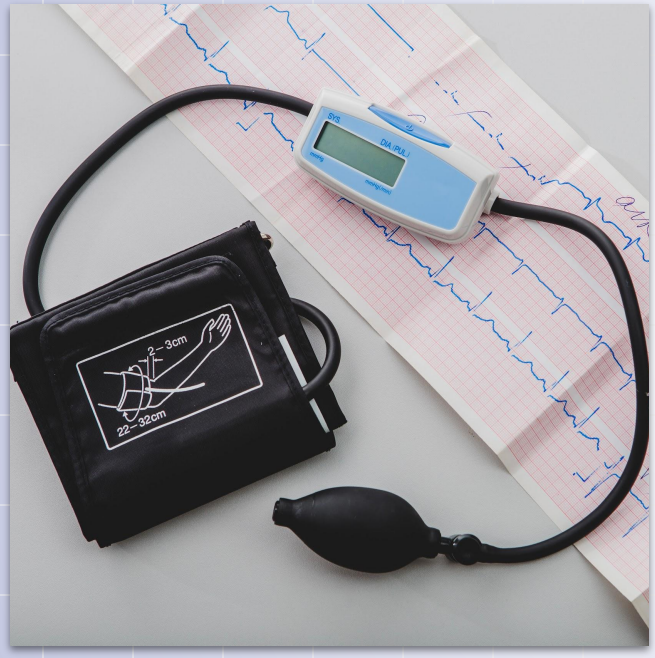
05

Future Directions

Device Limitations & Next Steps

Limitations and Next Steps

Current Limitations	Future Improvements
Arduino can only handle 0-5V BUT voltage output is sometimes negative or exceeds 5V	• Replace LF353 with MCP6100 • Add diodes • Use nRF Connect Nordic board
Circuit is a tad messy and not very compact	• Condense all components into a single breadboard after resolving Arduino smoking problem
Air Leakage through connections between cuff, valve and pumps	• Higher fidelity and more appropriately sized tubing and connectors
Need to manually calibrate threshold/ baseline offset for every cuff	• Program the microcontroller to detect the baseline and automatically determine an appropriate threshold



Conclusion

Acknowledgments

Heartfelt thanks to:

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Dr. Nightingale

Thank you!
Questions?

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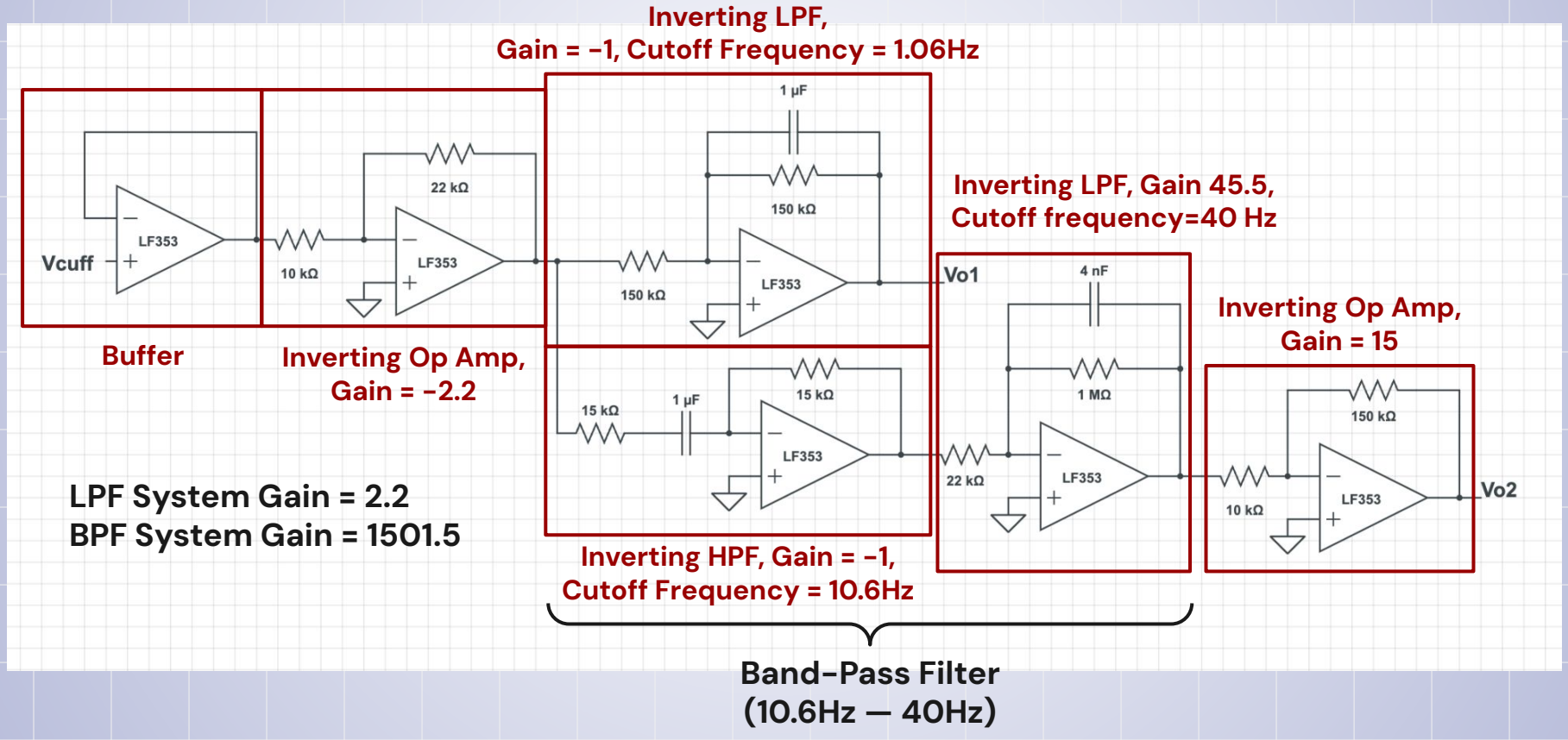
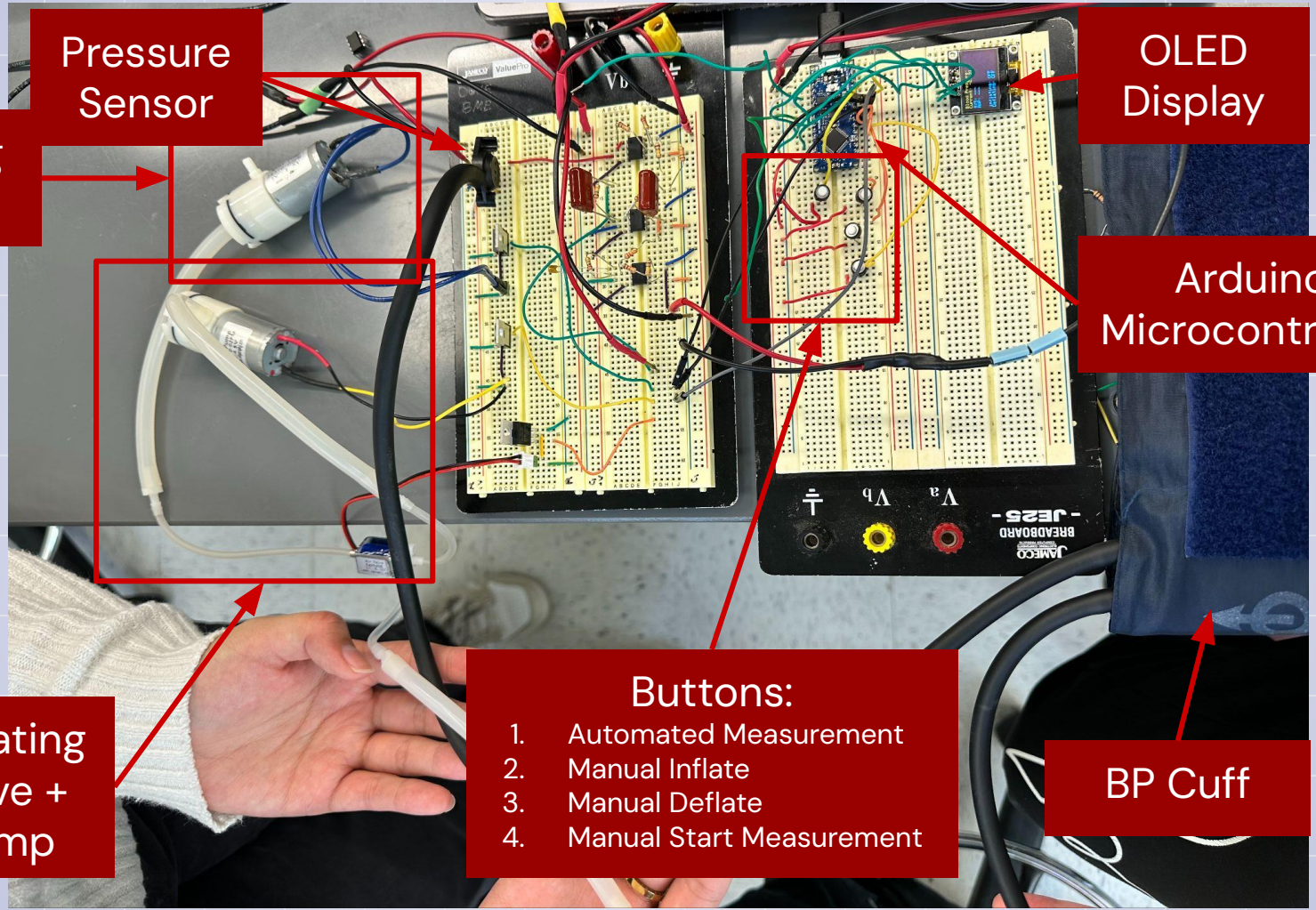
Circuit Design

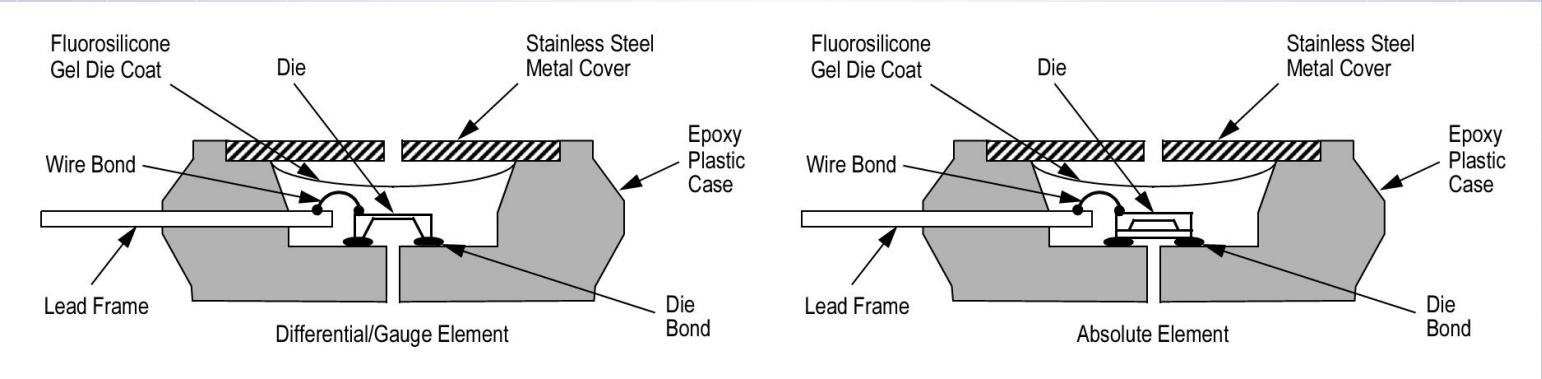
Op Amps Powered by +9V & −9V



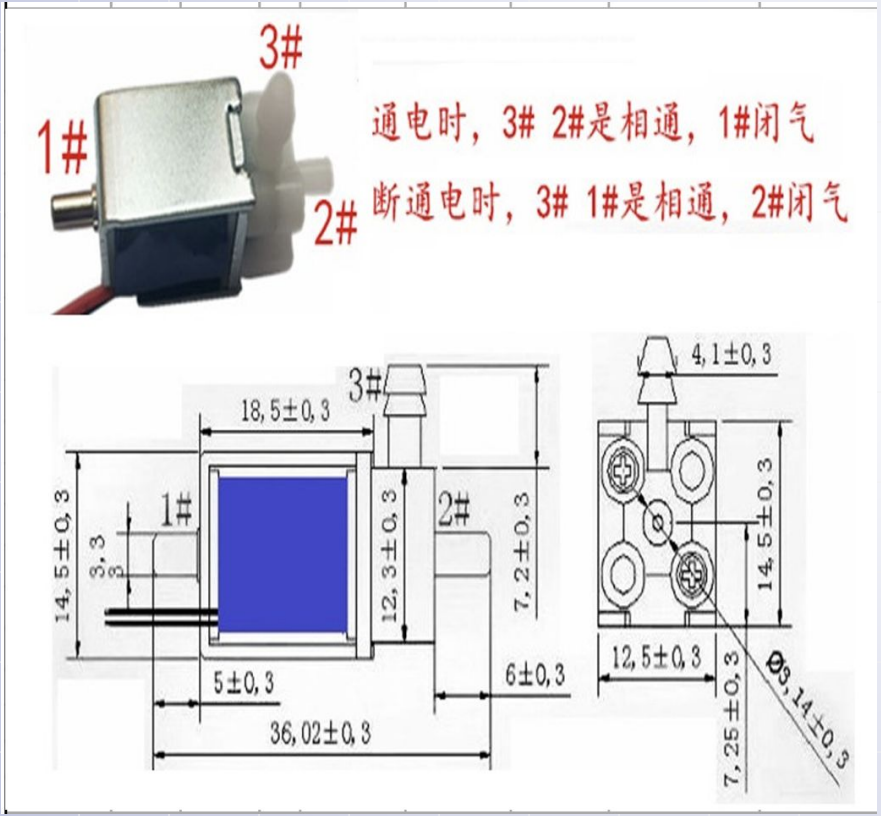

Pressure Sensor
Inflating Pump
OLED Display
Arduino Microcontroller
Deflating Valve + Pump
Buttons:
1. Automated Measurement
2. Manual Inflate
3. Manual Deflate
4. Manual Start Measurement
BP Cuff

How does the MPX5100GP work?

1. A silicon diaphragm contains integrated strain gauges that **deform under applied pressure**
2. This deformation **changes the resistance** of the strain gauges
3. The resistance change is **converted to a voltage output** through an integrated circuit
4. Temperature compensation and calibration circuitry ensure accuracy across operating conditions



How does the FA0520E air valve work?



- When **powered,** air flows through **3 and 2**, while 1 is blocked
- When **unpowered**, air flows through **3 and 1**, while 2 is blokced