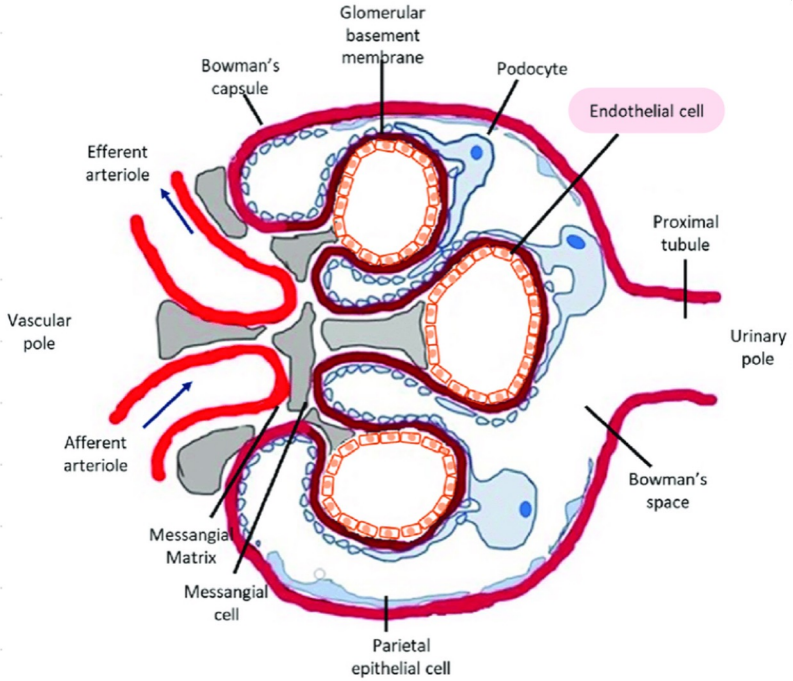
Blood Pressure Monitor for Pre-eclampsia

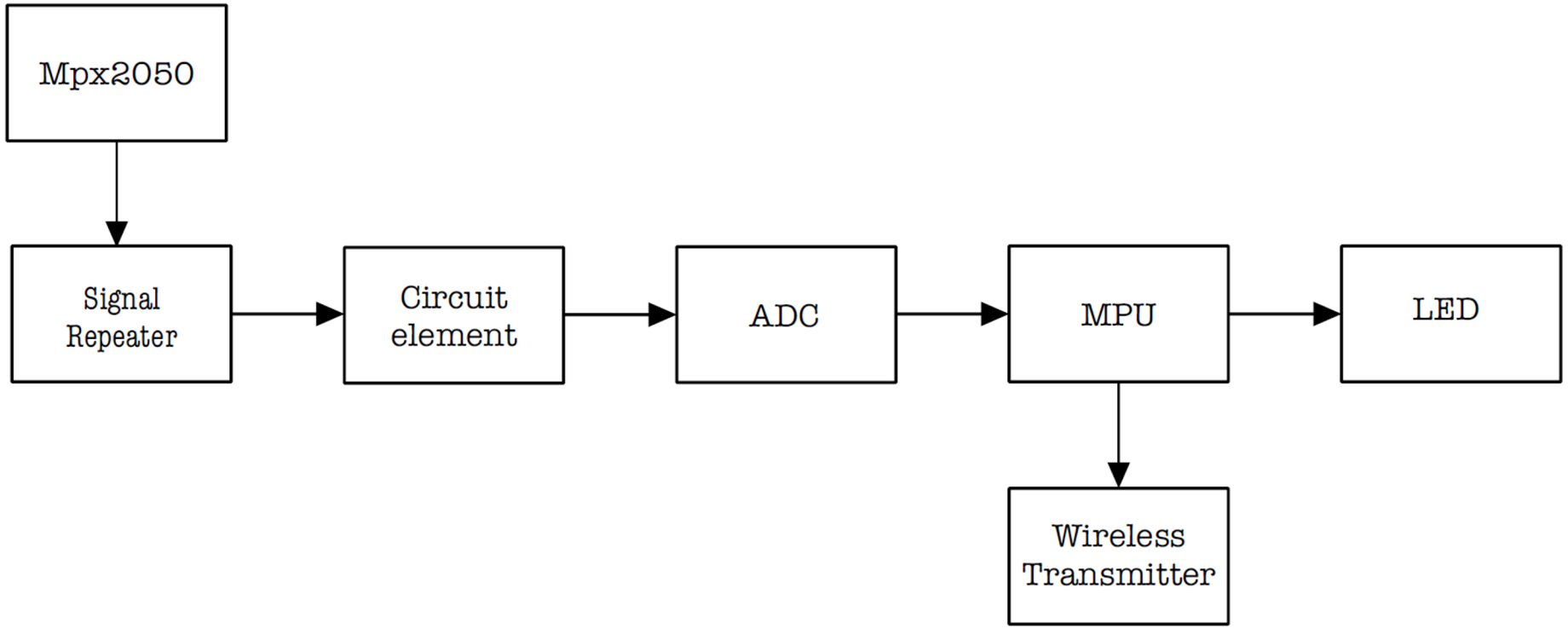
Megan Wu, Armando Ramil, Millicent Salvino, Mason Faust

Background: Pre-eclampsia

- Common complication during pregnancy that is recognized by the new onset of gestational hypertension and protein in urine
  - More than pregnancy-induced hypertension
- Two-stage disorder
  - Reduced placental perfusion
  - Maternal syndrome
- Risk factors: Obesity, existing medical problem, fertility treatment, age, etc.
- Early detection (preferably in first trimester) → preventative therapy



Proposed Blood Pressure Monitor Device



Device Design: Pressure Cuff

MPX2050D
CASE 344-15

- Wrist pressure cuff
- MPX2050 pressure sensor range: 0 kPa - 50 kPa
- Range of interest: 20mmHg (2.67 kPa) - 200 mmHg (26.66 kPa)
- Linear relationship between input pressure and output voltage (Figure 1) :

$$V_{out} = 0.8P_{in,\,kPa}$$

- Expected range of input voltages to circuit: **2.13 mV - 21.33 mV**

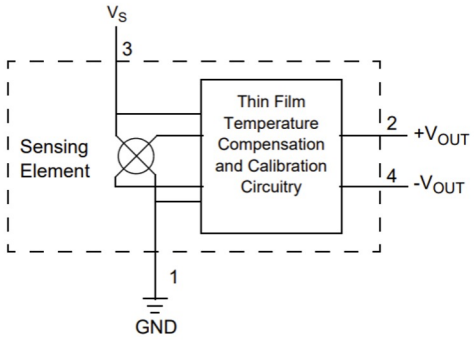


Fig. 2: MPX2050 to measure differential pressure

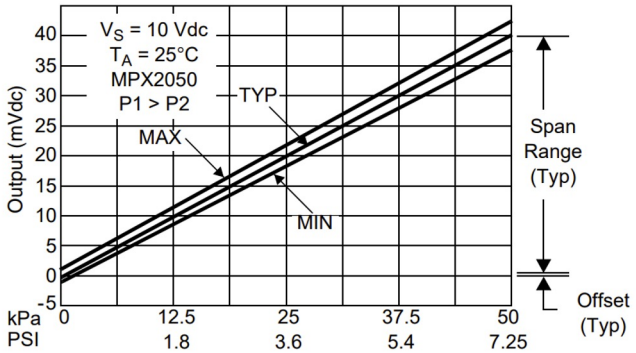
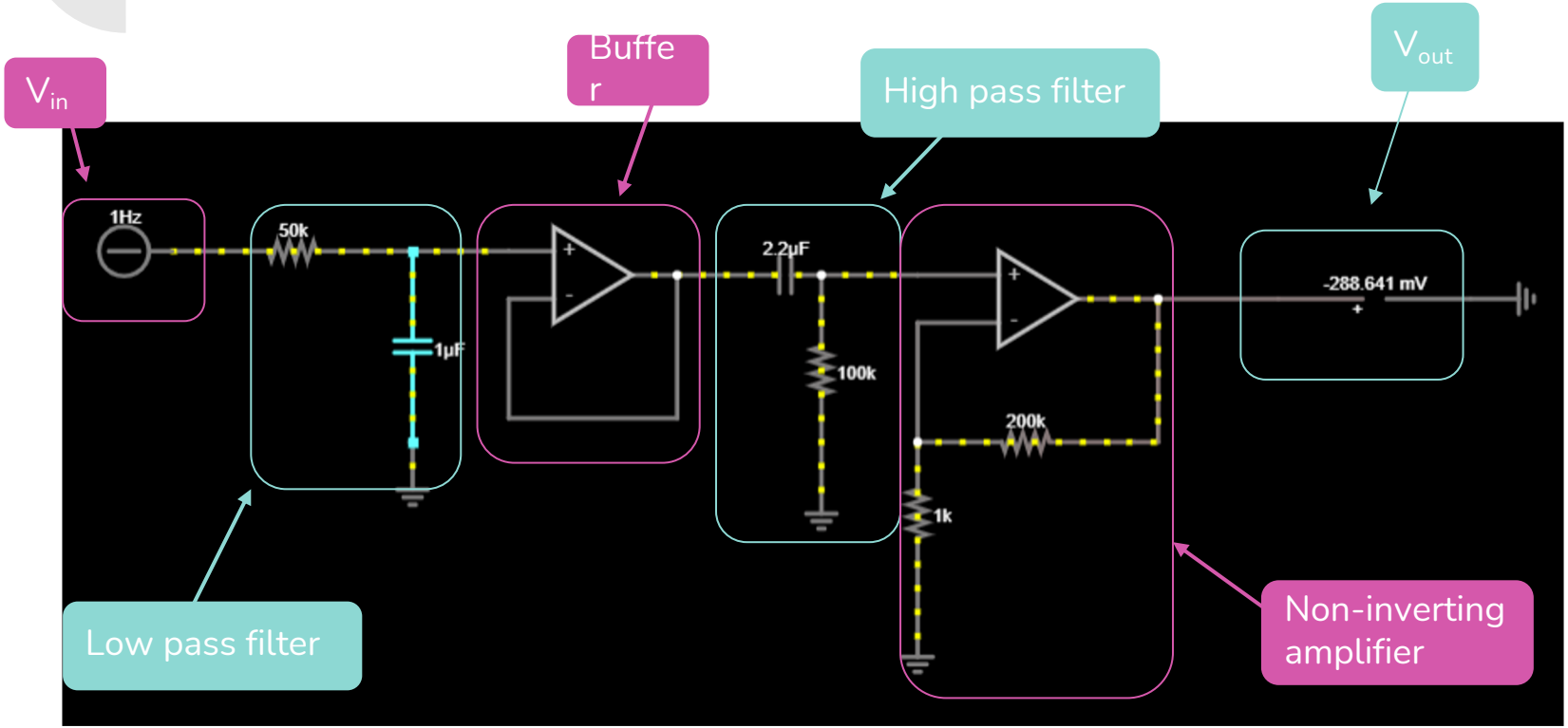


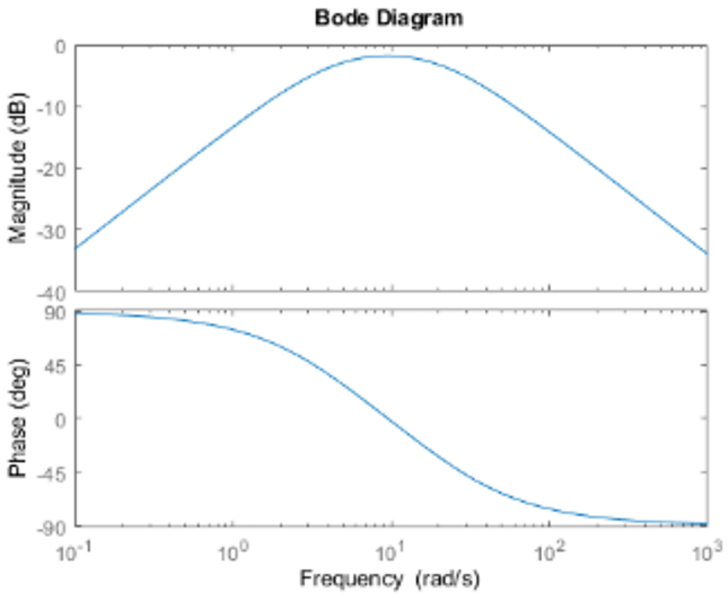
Fig. 1: Linear relationship between input pressure from transducer and output voltage, $V_{out} = 0.8P_{in,\,kPa}$ [1].

Device Design: Circuit Topology

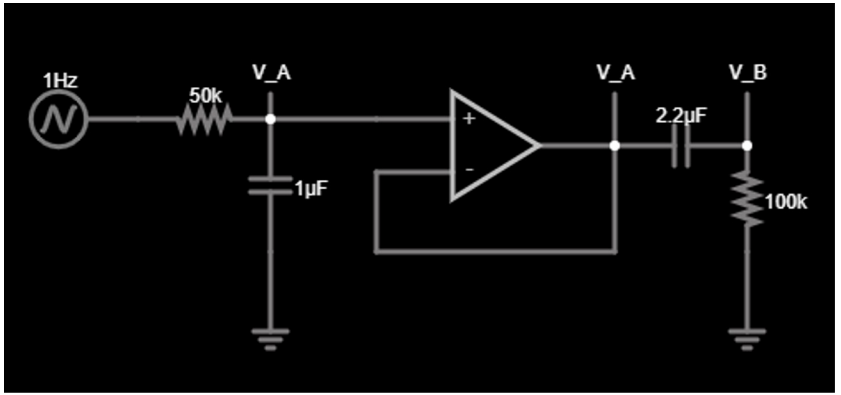


https://tinyurl.com/2n2ug4rs

Device Design: Transfer Function & Bode Plot



Poles: 4.55 rad/s & 20 rad/s
Zero: 0 rad/s



$$V_A = \frac{\frac{1}{jwC_1}}{\frac{1}{jwC_1} + R_1} V_{in} = \frac{1}{1 + R_1 C_1 s} V_{in}$$

$$V_B = \frac{R_2}{R_2 + \frac{1}{jwC_2}} V_A = \frac{R_2 C_2 s}{1 + R_2 C_2 s} V_A$$

$$V_B = \frac{1}{1 + R_1 C_1 s} \frac{R_2 C_2 s}{1 + R_2 C_2 s} V_{in}$$

Device Design: Circuit Topology

Bandpass Filter:

- Cutoff frequencies: $f_c = 1/2\pi RC$: **0.72 Hz - 3.18 Hz**
- Normal resting heart rate for adults: 60 - 100 bpm = 1 Hz - 1.67 Hz

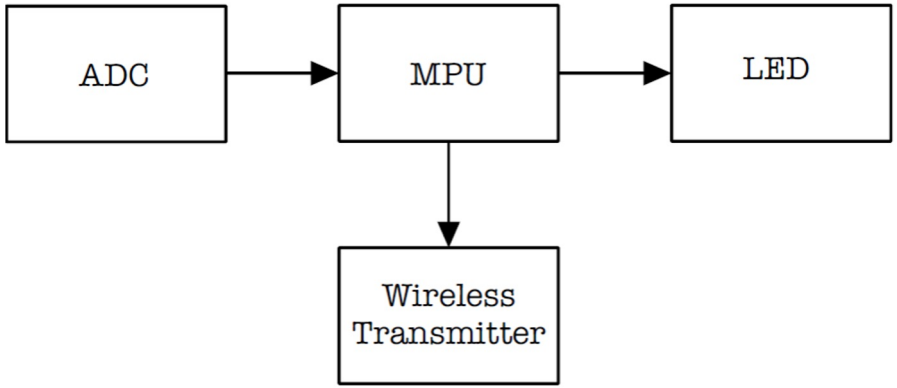
	R	C	f_c
Low pass	50 kΩ	1 uF	3.18 Hz
High pass	100 kΩ	2.2 uF	0.72 Hz

Non-Inverting Amplifier:

- Gain = $(1+R_2/R_1)$ = **201**
- R_2 = 200 kΩ
- R_1 = 1 kΩ

Device Design: Analog to Digital Conversion

- V_{out} from circuit mapped to a binary output
- Microprocessor unit (MPU) programmed such that a binary number exceeding a certain threshold triggers an LED on the device and sends a wifi signal to the patient's external digital device



Results: Circuit Output

- Incremental values between 20 mmHg and 200 mmHg tested to determine output voltages from the circuit

1. Pressure converted to voltage output expected from 2050 pressure transducer (V_{in})
2. Measured voltage output V_{out} for each V_{in} at 1 Hz (60 bpm)

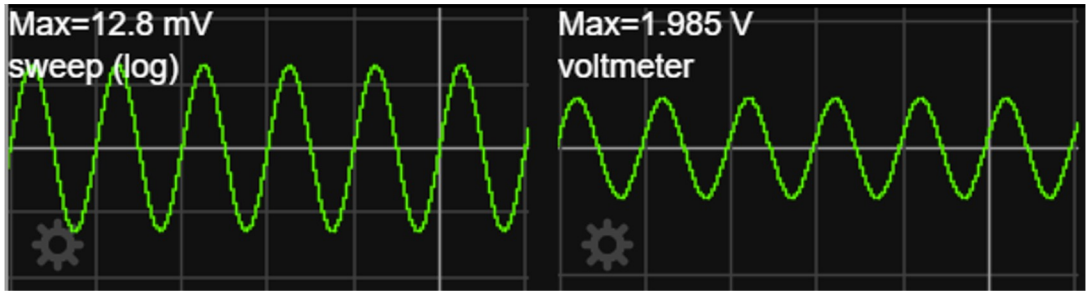


Fig. 5: Output of filter and amplification circuit from an input voltage of 12.7 mV corresponding to a normal blood pressure of 120 mmHg.

Results: Analog to Digital Conversion Scale

P (mmHg)	V_{in} (mV)	V_{out} (V)	Binary	Digital
200	21.33	3.307	111111111111	4095
180	19.2	2.977	111000111000	3640
160	17.06	2.645	110001110001	3185
140	14.93	2.315	101010101010	2730
120	12.80	1.985	100011100011	2275
100	10.66	1.653	011100011100	1820
80	8.53	1.323	010101010101	1365
60	6.4	0.992	001110001110	910
40	4.26	0.661	000111000111	455
20	2.13	0.330	000000000000	0

- 12 bit ADC used to assign V_{out} to binary
- Linear relationship set by corresponding digital values of the maximum and minimum
  - MAX: 200 mmHg = 111111111111 = 4095
  - MIN = 20 mmHg = 000000000000 = 0
- MPU sends alert when digital value exceeds threshold

Low BP	90/60	warning
Normal	120/80	No alert
Stage 1 High BP	130/80	warning
Stage 2 High BP	140/90	alert
Hypertensive crisis	180/110	Alert to seek medical attention

Discussion

- Device can be used in two scenarios:
  - To detect patterns and early signs of preeclampsia → start preventative measures
  - If already diagnosed with preeclampsia → way of monitoring until time to give birth
- Preeclampsia only cured with delivery of fetus
- Monitoring of mean arterial blood pressure + maternal risk factors = predictive markers of preeclampsia
  - Detection rate of 76% for early onset preeclampsia during first and second trimester
- With device, patient would not have to stay at the hospital for close monitoring
- For the future:
  - Cuff designed to send continuous signals
  - Multi Diagnosis; not only used for preeclampsia

Acknowledgements

We would like to thank Dr. Cauwenberghs for his instruction and guidance this quarter

We would also like to thank Samira, Vikrant, Adyant and for their key assistance in both the project and the class as a whole

References

Fox, Rachael, et al. “Preeclampsia: Risk Factors, Diagnosis, Management, and the Cardiovascular Impact on the Offspring.” Journal of Clinical Medicine, vol. 8, no. 10, Oct. 2019, p. 1625, https://doi.org/10.3390/jcm8101625. Accessed 16 Mar. 2023.

CDC. “High Blood Pressure during Pregnancy.” Centers for Disease Control and Prevention, 15 Feb. 2023, www.cdc.gov/bloodpressure/pregnancy.htm. Accessed 16 Mar. 2023.

NHS Choices. Treatment - Pre-Eclampsia. 2023, www.nhs.uk/conditions/pre-eclampsia/treatment/. Accessed 16 Mar. 2023.

“Portable Digital Blood Pressure Monitor.” Cornell.edu, 2023, people.ece.cornell.edu/land/courses/ece4760/FinalProjects/s2005/ww56_ws62/Final%20Project%20Web/. Accessed 16 Mar. 2023.

Emery, E. F., and A. Greenough. “Non-Invasive Blood Pressure Monitoring in Preterm Infants Receiving Intensive Care.” European Journal of Pediatrics, vol. 151, no. 2, Feb. 1992, pp. 136–39, https://doi.org/10.1007/bf01958960. Accessed 16 Mar. 2023.

“What’s the Concern about High Blood Pressure during Pregnancy? An Ob-Gyn Explains.” Acog.org, 2022, www.acog.org/womens-health/experts-and-stories/the-latest/whats-the-concern-about-high-blood-pressure-during-pregnancy-an-ob-gyn-explains. Accessed 16 Mar. 2023.

The. “Can High Blood Pressure Cause Preterm Birth? | Sharp HealthCare.” Sharp.com, 8 Oct. 2020, www.sharp.com/health-news/the-link-between-hypertension-and-preterm-birth. Accessed 16 Mar. 2023.

Mikat, B., et al. “Early Detection of Maternal Risk for Preeclampsia.” ISRN Obstetrics and Gynecology, vol. 2012, July 2012, pp. 1–7, https://doi.org/10.5402/2012/172808. Accessed 16 Mar. 2023.

“Figure 1. Schematic Representation of the Glomerulus. The Glomerulus Is...” ResearchGate, ResearchGate, 2021, www.researchgate.net/figure/Schematic-representation-of-the-glomerulus-The-glomerulus-is-a-tuft-of-capillaries_fig1_348293259. Accessed 16 Mar. 2023.

Roberts, James M., and Hilary S. Gammill. “Preeclampsia.” Hypertension, vol. 46, no. 6, Dec. 2005, pp. 1243–49, https://doi.org/10.1161/01.hyp.0000188408.49896.c5. Accessed 16 Mar. 2023.

Roberts, James M. “Preeclampsia: What We Know and What We Do Not Know.” Seminars in Perinatology, vol. 24, no. 1, Feb. 2000, pp. 24–28, https://doi.org/10.1016/s0146-0005(00)80050-6. Accessed 16 Mar. 2023.