Lab 5/6: Blood Pressure

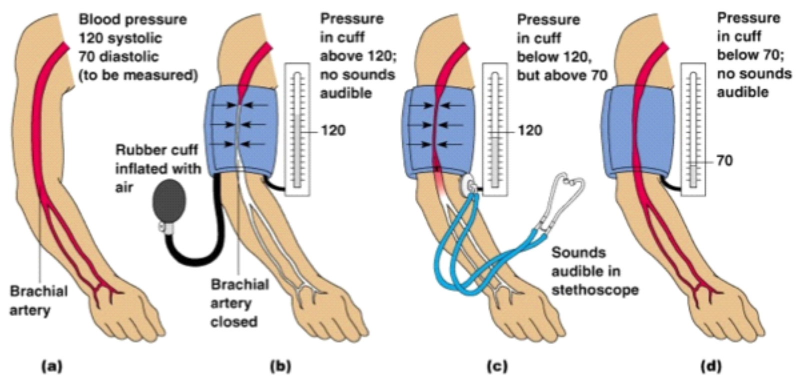
Wednesday, April 7, 2021 9:29 PM

Lab5-Blood Pressure

Lab: Blood Pressure

<u>Goal:</u> Design and test a bandpass filter that can isolate a blood pressure signal.

This week you will design and build a system to estimate your mean arterial pressure (blood pressure). Typically a medical professional will measure the systolic and diastolic pressure. These pressures correspond to the maximum and minimum pressures in the arteries when the heart beats.



Source:www.3.bp.blogspot.com

High blood pressure is a risk factor for a number of diseases, thus blood pressure monitoring is one of the most common measurements in health care. Many of the automated blood pressure machines that you see for sale at the pharmacy don't measure pressures directly, but calculate these pressures empirically from the resulting oscillations in your pulse.

The simplest oscillometric technique is as follows: If you inflate a cuff on your arm above the systolic pressure and then deflate the cuff, you will feel the pulse in your arm increase quite dramatically as the pressure is lowered.

If we monitor the total pressure on the cuff, we will see the overall decay of the pressure signal (Figure 1, left), but embedded in this decay is the small pressure change due to your pulse (Figure 1, right). In Figure 1 we show a raw trace of the cuff pressure and then a zoomed in version at a certain time.

Mark the points in the zoomed-in data (Fig. 1, right) that represent the heart pulse.

Approximately, what is the frequency of this pulse in Hz (cycles/second)? 1 Hz

Sounds like color

RC = Low CR = High

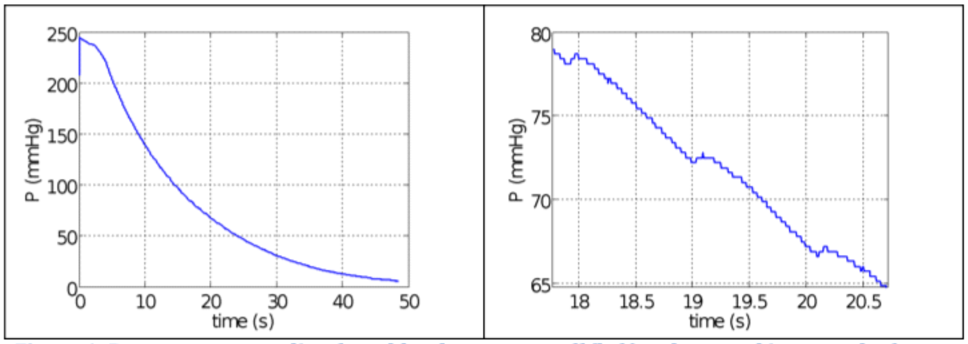


Figure 1: Raw pressure reading from blood pressure cuff (left)and zoomed in around a few seconds (right).

We can process the raw pressure signal to remove the slow decay.

What type of filter would we need for this? High Pass

Which of the circuits below could serve to remove the slow decay, if R and C were properly chosen? CR

We can process the raw pressure signal to remove the noise seen in the zoomed in data.

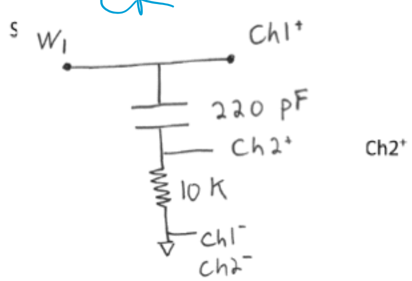
What type of filter would we need to do this? Low Pass

What would you suggest for the cutoff frequency of the filter? ~ 10HZ

Maybe 5HZ

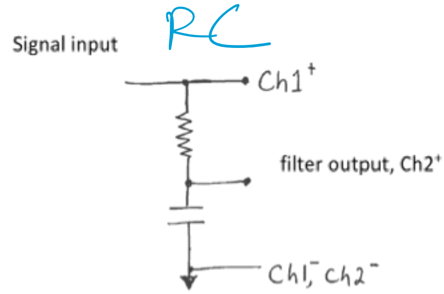
Filter circuits: Which filters out high frequency input? Which filters out low-frequency input?

CR



High

RC



Low

A processed signal is shown in Figure 2 (right), bottom.

upper signal = raw pressure signal

lower signal = processed signal

Look at the shared time axis.

In the lower signal, what causes each individual cycle? Pulse

The lower signal, Figure 2, is what you will feel during the measurement; your pulse intensifies and then decays.

The pulse amplitude grows as the cuff pressure releases and more blood is able to enter your artery. The pulse amplitude decreases as your artery fills to its normal state. It is at the time when the pulse amplitude is maximum that we call that pressure the *mean blood pressure*.

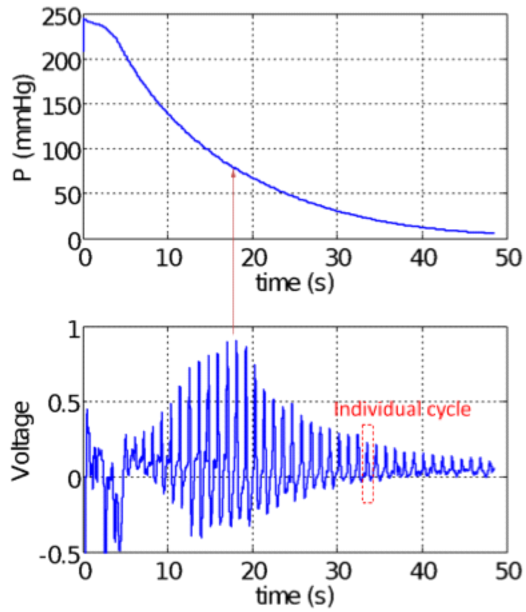


Figure SEQ Figure * ARABIC 2: Raw pressure signal and processed signal. (For this lab, you'll turn in your own version of this figure.)

In this case, the pulse maximizes around 18 seconds. If we then look at the total cuff pressure at this time, we find the cuff pressure was about 78 mmHg. This value of the pressure is then assumed to be the mean arterial pressure.

The mean blood pressure is taken to be about 2/3 of the diastolic plus 1/3 of the systolic.

Disclaimer

We are not medical doctors.

Please don't attempt to interpret anything other than your mean blood pressure.

Your privacy rights

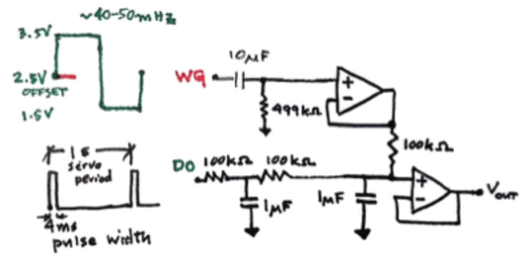
The blood pressure plot could be construed as medical information protected under privacy laws. If you are AT ALL concerned about submitting your personal data with your lab report, YOU DO NOT HAVE TO DO SO. You may borrow one of the instructors who will happily serve as your data source if you wish.

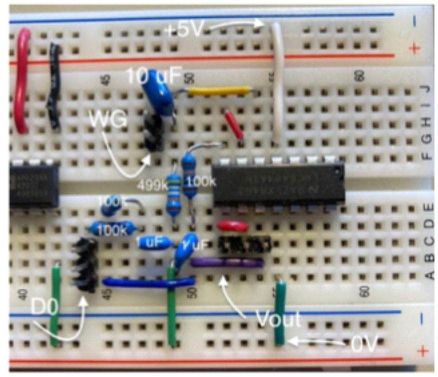
Overview: We will first build a circuit that simulates the output of a blood pressure cuff. You'll used the output of the simulation circuit to test the circuit that you design. When you're assured it is working, use the blood pressure cuff to take your own blood pressure, if desired.

1. Build the blood pressure SIMULATION circuit below.

For your safety, this circuit will output a simulated blood pressure to use for the testing of the filtering circuit that you will design below. .

While measuring your blood pressure is safe, measuring several times in a row is not a great idea.

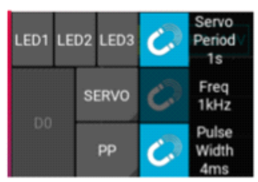




Here is one way to make this circuit (right):

Set up the wave generator to produce the signal shown above (2.5V offset square wave, 1V Amplitude, ~40-50 mHz)

Using the pullout on the bottom left, choose SERVO for the output, D0: 1 second servo period, 4 ms pulse width. These setting provide the pulse shown above.



2. Verify the blood pressure simulator works with the O-scope

Hook up Wave Gen and D0 to the circuit points as shown. In the scope, you can monitor the simulated blood pressure output at V_{out}. If you get a reading like Figure 3, you're ready to proceed. You will use this data as the input to your circuit; it will help you ensure your circuit is functioning before you take your own data.

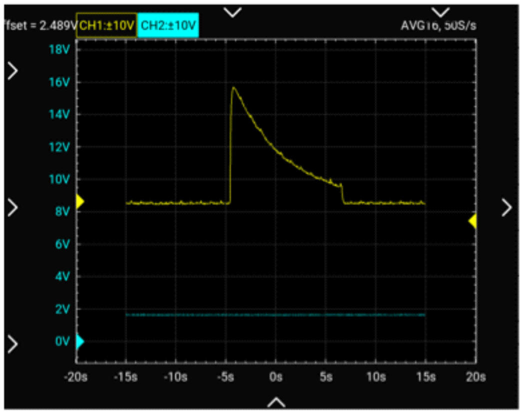
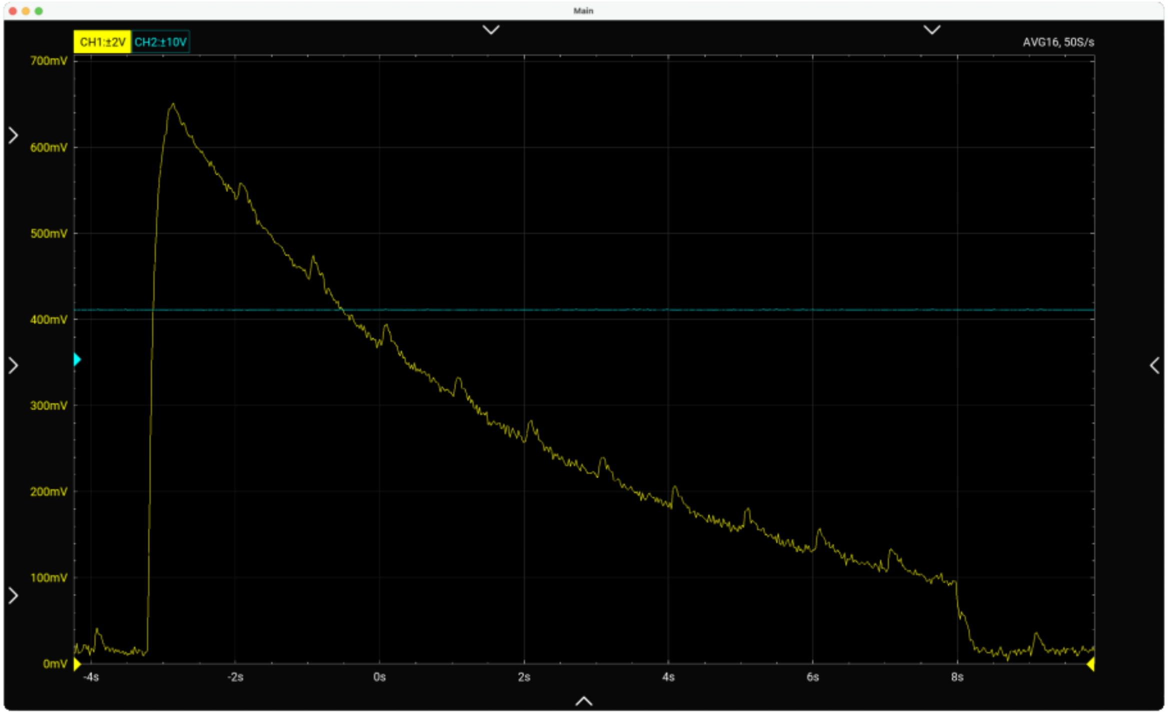


Figure 3: Simulated signal (full buffer, 50S/sec; trigger point is below 0 to stop the data from shifting**).**

This is the end of Lab 5a. You can continue if you like.

Deliverables for lab 5 submission. Please just turn in a plot that demonstrates your simulation circuit is working. There is no need to write anything this week - just get the simulation circuit working.

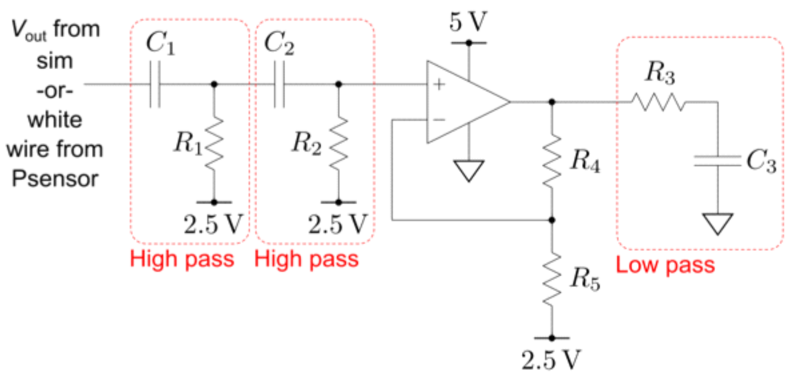


Lab 5a Deliverable: My working simulation circuit

This is the beginning of Lab 5b.

3. Design the RC filters for your circuit

Use the circuit model below to design the filtering circuit that will remove the unwanted slow decay and the noise from the input signal. (After you verify that your circuit functions properly using W1 as input, you will replace WG with the V_{out} from the digital pressure sensor, the MPX5050DP .)



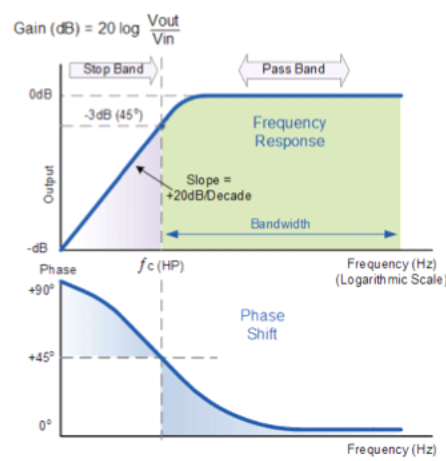
Where is V_{out} for this circuit?

H

That is, determine the values needed for C1, C2, C3 and R, R1, R2, R3, R4 and R5

The slow decay has frequency < 0.2 Hz.

If you were to draw an approximate Bode amplitude plot for an effective filter this application, what would it look like?



Remember, to compute the cutoff frequency of a filter, $\omega^* = \frac{1}{RC}$ *and* $f\,(Hz) = \frac{\omega}{2\pi}$

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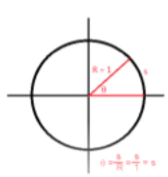
*If ω is in "radians/second," and RC is in "seconds", how does this equation work out in the units?



I'm glad you asked that. A radian is the angle, θ, within a unit circle, R=1, that produces an arc length, s=1:

$$1\ rad = \frac{s}{R} = \frac{1\ unit\ length}{1\ unit\ length} = 1$$

In other words, a radian has no units.

Attempt 1: R1 = 158kOhm, R3 = 1.58kOhm: not enough filtering of the big one

Attempt 2: R1 = 30kOhm, R3 = 1.58kOhm: not enough filtering of the big one, too much filtering of the small

Attempt 3: R1 = 49.9kOhm,, R3 = 1kOhm: not enough filtering of big, too much filtering of small

Since the slow decay and the pulse are not that widely separated in time scales, it is useful to have a strong high-pass filter – **second order** or higher.

Attempt 2: R1 = 30kOhm, R3 = 1.58kOhm: not enough filtering of the big one, too much filtering of the small

Attempt 3: R1 = 49.9kOhm,, R3 = 1kOhm: not enough filtering of big, too much filtering of small

Since the slow decay and the pulse are not that widely separated in time scales, it is useful to have a strong high-pass filter – **second order** or higher.

A **second order** high pass filter means that for every factor of 10 in frequency you go below the cutoff frequency, you get a factor of 100 decrease in amplitude. You can get a second order high pass filter by simply chaining two normal RC high pass filters in a series.

Note that there is a range of cutoff frequencies that will work well, so maybe try a few different values and see what you like.

After the high pass filters, you should then amplify the result such that you get a reasonable level for the output signal. *We found an amplifier gain of about 25 worked well.* ***Important:*** *When choosing R4 and R5, remember that the op-amp's output limit is ~1 mA. That means the R4 and R5 must be on the order of kΩ.*

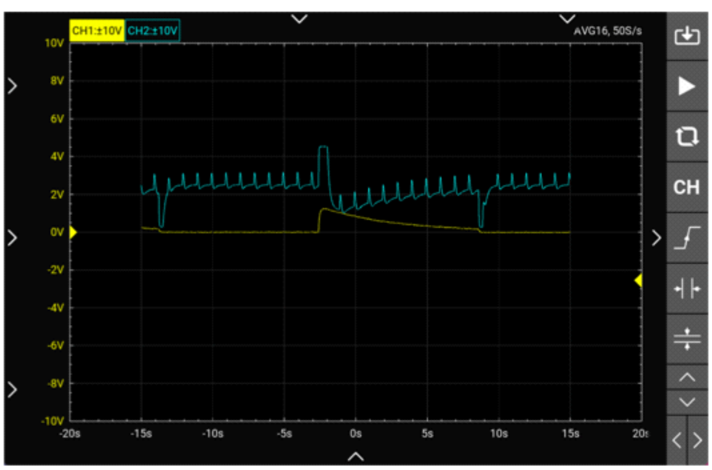
You can experiment with the gain that gives you a good result.

4. Build, test and debug your circuit

To build and debug the circuit it is best to build and test as you go.

Leave WG playing continuously and monitor the output as you build complexity.

You are trying to get an output that looks similar to Figure 2. Below is an example of a decently-filtered output.



5. Final data collection on you or a course assistant, if willing.

If you would like to test your system in real-time on yourself, get one of the blood pressure cuffs. If you don't want to test on yourself, that is fine and you can just use the playback data.

Warning: Blood pressure measurement is routine. However, note that when you take the measurement you shut off arterial flow to your arm. Therefore:

- Please ask one of the instructors to show you how to work the blood pressure cuff if there is any question after the demo we will do in lab.
- DO NOT continue to repeat the experiment over and over again. You also don't need to over pressurize your arm to a very high cuff pressure. You can test everything without putting the cuff on your arm or by inflating on your arm to a low pressure. Once you have things working, one test should be sufficient to get your data.
- DO NOT leave the cuff inflated on your arm for any period of time. There is a release valve that you loosen to allow the pressure to release slowly.
- DO NOT sit around with the cuff on your arm while you work, even if it is uninflated. For a small number of people the cuffs can irritate your skin. It is OK, and perhaps even recommended to have the cuff over your shirt sleeves.
- If anything feels uncomfortable, STOP.

We will make our blood pressure measurements using a standard blood pressure cuff; however we have replaced the dial pressure gauge with a digital pressure sensor, the MPX5050DP

Connect the sensor to your circuit. Page 5 of the specification sheet provides the recommended circuit coupling (Figure 4*):

V_s = wire to __________

GND = wire to __________

V_{out} = wire to __________

*The capacitors from Fig. 4 will not be needed.

Figure 2 shows the TRANSFER FUNCTION of the sensor. The pressure units in the TRANSFER FUNCTION are kPa. (For the Report, you will compute the pressure.) *Write the equation for the* TRANSFER FUNCTION:

To convert to mmHg, this information should be helpful: 1 atmosphere = 101.325 kPa = 760 mm Hg

Transfer Function:

$V_{out} = V_S*(0.018*P+0.04) \pm$ ERROR

$V_S = 5.0$ Vdc

TEMP = 0 to 85°C

Before testing on your arm, close the valve on the cuff, pump some air in, and press on the cuff to make sure the pressure signal is responding. Once it is responding it may be helpful to have a volunteer (i.e. one of your friends or an instructor) help you.

1. Set the scope to read ±10V.
2. Put the cuff around your arm.
3. Close the valve.
4. Run the scope.
5. Pump up until the cuff is tight – you don't have to overdo it!
6. Stop and restart the scope so you get a clean screen.
7. Release the valve very slightly.
8. Hold as still as possible.
9. Let the cuff fully deflate.
10. Stop the scope and export the data.

6. Create a Bode amplitude plot

You will want to confirm that your final circuit is working as you expect by creating a Bode plot. However, since we are operating at low frequencies, the network analyzer will take a very long time to create the Bode plot automatically, so let's record the amplitude part of the Bode plot by hand.

Disconnect the pressure gauge.

Use Wavegen 1 as the V_input, W1 (pin 3)

Use Scope Channel 1 to monitor V_input, relative to V0 (O-scope);

Use Scope Channel 2 to monitor the V_out, relative to V0 (O-scope);

COLLECT BODE DATA ON AMPLITUDES

Step 1: Create a Vinput sine wave, ~100 mV Amplitude, 100 Hz, 2.5V_{offset}

- Set WaveGen for pure sine wave
- Set the amplitude to 100 mV. Set the frequency to 100 Hz.

Step 2: Set the Sampling rate to 100 x 100 S/sec & collect a single scan

- Zoom out on the time axis to ensure that you have several cycles.
- Record the Vrms for the input and output voltages in the table below.

Step 3: In the WaveGen, change the time base and repeat Steps 1 & 2 above to fill in the table below, from high to low frequency inputs. *Make sure you decrease the sampling rate as you decrease the input sine wave frequency.*

When you get to 0.1 Hz, Sampling rate 10S/s, it will take a minute to collect a single scan.

Frequency of input signal	V_{input} (volts, RMS) Amplitude Ch2	V_{out} (volts, RMS) Amplitude Ch2	Sampling rate (100 x f_{input})
[illegible]	57.74mV	38.95mV	10S/s

Frequency of input signal	V_{input} (volts, RMS) Amplitude Ch2	V_{out} (volts, RMS) Amplitude Ch2	Sampling rate (100 x f_{input})
0.1Hz	87.24mV	38.95mV	10S/S
0.2 Hz	87.44mV	121.5mV	20S/S
0.5 Hz	87.57mV	489.4mV	50S/S
1 Hz	87.12mV	991mV	100S/S
2 Hz	86.45mV	1.561V	200S/S
5 Hz	85.58mV	1.414V	500S/S
10 Hz	87.13mV	934mV	1KS/S
50 Hz	87.37mV	227.1mV	5KS/S
100 Hz	87.61mV	121.1mV	10KS/S

Note: V_{input} (volts, RMS) should be a stable number that ~$1/\sqrt{2}$ x Amplitude of the sin wave

Deliverables

For the lab report, you should include

- Your final filtering circuit schematic (can be drawn by hand); do not include the simulation circuit from Lab 5a. Denote the values of the resistors and capacitors that you used.
- A very short explanation of the overall measurement circuit and explain the cutoff frequencies and gain that you used.
- Briefly explain what advantage of 2.5 V as the reference (over 0V) for the two high-pass filters.
- Plot of the final blood pressure (BP) measurement (i.e., your version of figure 2). Option: Plot of the BP simulation data.
- Bode plot (amplitude only) of the whole circuit you designed. Annotate your Bode plot to show the different cutoff frequencies you designed for are represented in the result. Your amplitude Bode plot should plot amplitude of output divided by amplitude of input versus frequency. Your plot should have log-log axes. This plot will be generated from your table data – if you wish to collect more data to get a cleaner Bode plot, that is great but the table data is sufficient.

If you are concerned about the grade, here is a rough visual rubric.