EE 5340 Exam II

1. Find expressions for $v_{df}$ and $v_{d2}$, assume $f_i = 2$ MHz: (10 pts.)

\[
\theta_t = 45^\circ, \quad \theta_r = 180 - 120 = 60^\circ, \quad c = 1570 \text{ m/s}
\]

\[
v_t = \cos \omega_t t, \quad v_r = \cos (\omega_i + \omega_d) t
\]

\[
v_{d1} = \cos \omega_t t \cdot \cos (\omega_i + \omega_d) t = \frac{1}{2} \cos \omega_d t + \frac{1}{2} \cos (2 \omega_t + \omega_d) t
\]

\[
\downarrow \text{LPF}
\]

\[
v_{a1} = \frac{1}{2} \cos \omega_d t = \frac{1}{2} \cos \left[ \frac{\pi}{1570} \left( \cos 45^\circ + \cos 60^\circ \right) \times 10^4 t \right]
\]

\[
= \frac{1}{2} \cos \left[ 91661.7 t \right]
\]

\[
v_{d2} = \sin \omega_t t \cdot \cos (\omega_i + \omega_d) t = \frac{1}{2} \sin (-\omega_d t) + \sin (2 \omega_t + \omega_d) t
\]

\[
\downarrow \text{LPF}
\]

\[
v_{a2} = -\frac{1}{2} \sin (\omega_d t) = \frac{1}{2} \cos \left( 91661.7 t \right)
\]

\[
\omega_d = 91661.7 \text{ rad/s}
\]

\[
\omega_r = \frac{1570 - \cos 60^\circ}{1570 + \cos 45^\circ} \\
= 1.9947 \times 10^6 \times \frac{2\pi}{12.5597 \times 10^6}
\]

\[
\omega_d = \omega_r - \omega_i = -91657.4 \text{ rad/s}
\]

* I agree to abide by the Southern Methodist University Honor Code.
2. Design the MSMV and output circuit for an atrial synchronous pacemaker. Assume the input to the MSMV is \( v_2 \) as shown in slide 307 of the notes. The pacemaker should deliver 2 ms constant current pulses of 10 mA. Your design should include an OP amp and a comparator. The comparator output is +/- 5V. (10 pts.)

\[
\tau = 2 \times 10^{-3} = RC \ln \left( \frac{1 + V_i/V_C}{1 - \beta} \right)
\]

\[
\ln \left( \frac{1 + V_i/V_C}{1 - \beta} \right) = \frac{\tau}{RC}
\]

\[
1 + V_i/V_C = (1 - \beta) e^{\tau/RC} = 1 + 0.7/5 = 1.14 \Rightarrow any \ choice \ of \ R_1, R_2, R \ which \ satisfies \ works
\]

\[
\text{Ex}) \quad R_1 = R_2 = 10k \Rightarrow \beta = \frac{1}{2}
\]

\[
RC = \frac{\tau}{\ln \left( \frac{1 + V_i/V_C}{1 - \beta} \right)} = \frac{2 \times 10^{-3}}{\ln \left( \frac{1.14}{0.5} \right)} \Rightarrow \text{pick } R = 10k
\]

\[
C = \frac{2 \times 10^{-3}}{\ln \left( \frac{1.14}{0.5} \right) \times 10^4} = 24.3 \mu F
\]
3. In a Fleisch pneumotachometer, assume that the relation between flow and ΔP across the capillary bundle is \( \Delta P = 0.1f \), where \( \Delta P \) is in Pa and \( f \) is in m\(^3\)/s (assume the relationship is purely resistive). Assume that the center plate in the differential capacitor undergoes a displacement of \( \Delta x = 0.5 \Delta P \), where \( \Delta x \) is in meters. Assume the plate area and equilibrium distance of the differential capacitor is 0.1 m\(^2\) and 0.01 m, respectively. Determine the sensitivity of the pneumotachometer in V·s/m\(^3\). (10 pts.)

\[
\Delta P = 0.1f \\
\Delta x = 0.5 \Delta P
\]

From slide 76: \( V_0 = V_i \left( \frac{\Delta x}{2d} \right) \), assume \( V_i = 1V \)

Overall:

\( V_0 = \frac{1}{2d} \cdot \Delta x = \frac{0.5 \Delta P}{2d} = \frac{0.5 \cdot 0.1 f}{2d} \)

Sensitivity:

\[
\frac{dV_0}{df} = \frac{0.1 \times 0.5}{2 \times d} = \frac{0.05}{2 \times 0.01} = 2.5 \text{ V·s/m}^3
\]

Independent of plate area.
4. Design a device for non-invasively measuring the inner diameter of the Brachial artery in the arm. Sketch a block diagram of your design. Include all transducers used and indicate all signal processing devices necessary to generate the artery diameter in meters. Your design should be very specific. (10 pts.)

**Diagram Description**

- **BRACHIAL A.**
- **SKIN**
  - **PULSE GENERATOR**
  - **TRANSODER**
  - **ATTENUATION COMPENSATION**
  - **ENVELOPE DETECTOR**
  - **INTERVAL TIMER**
  - **PICK-UP DETECTOR**
  - **COMPARATOR**

**Waveforms**

- **V_p**
- **V_e**
- **V_r**

**Formulas**

- Timer counts time between rising edges of V_p.
- \( C_{avg} = \text{avg. sound velocity in tissue} \)
- Divide by 2 since \( \Delta t \) is round-trip transit time.