EE4445 Quiz 3
April 13, 2009

Professor Leach Name_____

Instructions. Print your name in the space above and at the top of all other pages in your quiz. Express all answers as a decimal number, i.e. do not give an answer that involves fractions, square roots, symbols such as π, etc. Draw a box around answers. Draw a horizontal line between problems.
Honor Code: *I have neither given nor received help on this quiz.* Initials _____

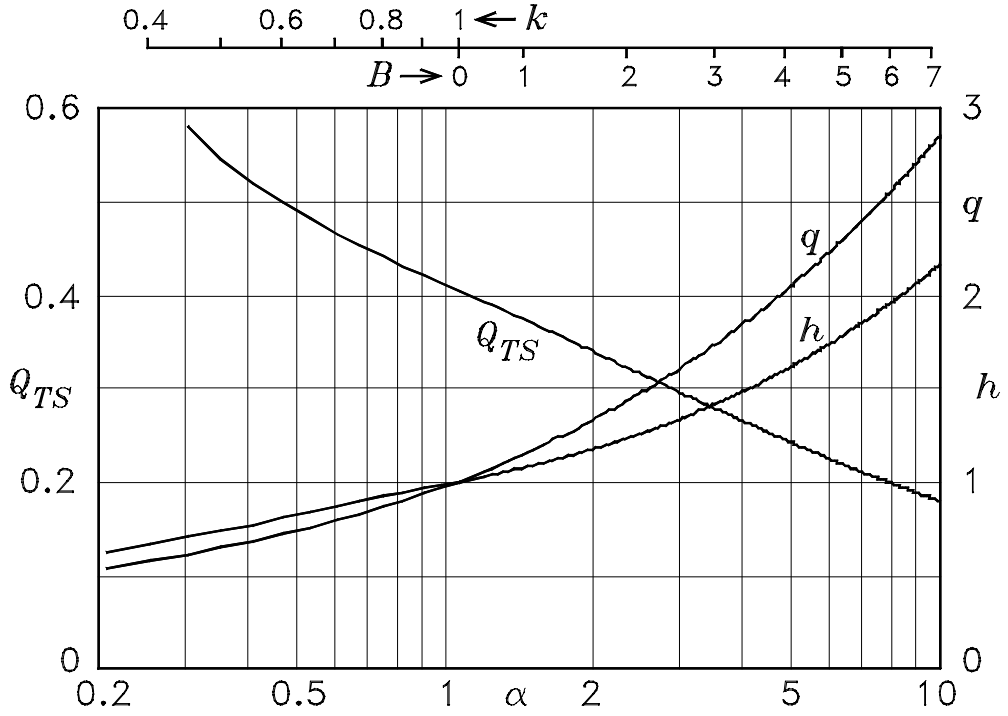
1. A loudspeaker driver has the parameters $f_S = 28\,\text{Hz}$, $R_E = 6\,\Omega$, $Q_{ES} = 0.45$, $Q_{MS} = 3.4$, and $V_{AS} = 7.8\,\text{ft}^3$. The driver is to be used in a closed-box baffle for which it is estimated that $Q_{MC} = 4$ and $M_{AC} = M_{AS}$.

   (a) Calculate the closed-box resonance frequency f_C and the system total quality factor Q_{TC} for a box volume $V_{AB} = 1\,\text{ft}^3$.

   (b) Calculate the lower $-3\,\text{dB}$ cutoff frequency.

   (c) Sketch the Bode magnitude plot for the low-frequency transfer function $|G_C(j2\pi f)|$. Label the resonance frequency, the relative response at the frequency of peak response, and the $-3\,\text{dB}$ cutoff frequency.

2. A driver has the infinite baffle resonance frequency $f_S = 30\,\text{Hz}$. A vented-box enclosure having an acoustic volume $V_{AB} = 1.5\,\text{ft}^3$ and a lower $-3\,\text{dB}$ cutoff frequency $f_\ell = 40\,\text{Hz}$ is to be designed for the driver. It is estimated that $Q_L = 7$. (See the design chart included with the quiz. Draw any vertical and/or horizontal lines on the chart and circle the pertinent points to show how you obtained your answers.)



$Q_L = 7$ design chart.

   (a) Specify the volume compliance V_{AS} of the driver.

   (b) Specify the total quality factor Q_{TS}.

(c) What is the Helmholtz resonance frequency f_B?

(d) If it is estimated that $Q_{MS} = 4$, calculate the system reference efficiency η_0.

3. A midrange in a closed-box baffle has the a voice-coil resistance $R_E = 7\,\Omega$ and parameters such that the relative phase shift in its acoustical transfer function is $+45\,^\circ$ at $f = 450\,\text{Hz}$.

   (a) A third-order high-pass filter crossover network is to be designed for the midrange. The crossover frequency is to be 450 Hz. Draw the circuit diagram for the midrange network and calculate the element values.

   (b) Draw the phasor representing the midrange pressure output at the crossover frequency.

   (c) What is the lowest order crossover network that can be used on the woofer in order for no phase cancellation between the pressure outputs of the woofer and the midrange at the crossover frequency? Assume the crossover frequency is at the midband region for the woofer transfer function. Draw the phasor diagram for the woofer pressure output and specify the required electrical phase of the connection of the drivers to the crossover network.

   (d) Draw the circuit diagram for the woofer crossover network.

4. An audio power amplifier has an open-loop gain of 2000 and a full-power distortion of 5%. Feedback is added to reduce the gain to 10.

   (a) If the amplifier is rated at 60 W average power into $8\,\Omega$, what rms input voltage is required for full output power before and after the feedback is added?

   (b) What is the amount of feedback in dB?

   (c) What is the closed-loop percent distortion at full power?

Problem 1

$f_S := 28 \quad R_E := 6 \quad Q_{ES} := 0.45 \quad Q_{MS} := 3.4 \quad V_{AS} := 7.8 \quad Q_{MC} := 4$

Part (a)

$V_{AB} := 1 \quad \alpha := \frac{V_{AS}}{V_{AB}} \quad \alpha = 7.8 \quad f_C := \sqrt{1+\alpha}\cdot f_S \quad f_C = 83.061$

$Q_{EC} := \sqrt{1+\alpha}\cdot Q_{ES} \quad Q_{EC} = 1.335 \quad Q_{TC} := R_p(Q_{MC}, Q_{EC}) \quad Q_{TC} = 1.001$

Part (b)

$x := \frac{1}{2\cdot Q_{TC}^2} - 1 \quad x = -0.501 \quad f_L := f_C\cdot\sqrt{x+\sqrt{x^2+1}} \quad f_L = 65.273$

Part (c)

$f_{p1} := f_C\cdot\frac{Q_{TC}}{\sqrt{Q_{TC}^2 - 0.5}} \quad f_{p1} = 1.174\cdot 10^2 \quad 20\cdot\log\left(\frac{Q_{TC}}{\sqrt{Q_{TC}^2 - 0.25}}\right) = 1.247$

Problem 2

$f_S := 30$ $V_{AB} := 1.5$ $f_L := 40$

$q := \frac{f_L}{f_S}$ $q = 1.333$ $\alpha := 2$ $h := 1.2$ $Q_{TS} := 0.34$

Part (a)

$V_{AS} := \alpha \cdot V_{AB}$ $V_{AS} = 3$

Part (b)

$Q_{TS} := 0.34$

Part (c)

$f_B := h \cdot f_S$ $f_B = 36$

Part (d)

$Q_{MS} := 4$ $Q_{ES} := \frac{Q_{MS} \cdot Q_{TS}}{Q_{MS} - Q_{TS}}$ $Q_{ES} = 0.372$ $V_{AS} \cdot \left(\frac{12}{39.37}\right)^3 = 8.495 \cdot 10^{-2}$

$\eta_0 := \frac{4 \cdot \pi^2}{c^3} \cdot f_S^3 \cdot \frac{V_{AS} \cdot \left(\frac{12}{39.37}\right)^3}{Q_{ES}} \cdot 100$ $\eta_0 = 0.593$

Problem 3

$R_E := 7 \qquad f_{CO} := 450$

Part (a)

$$C_1 := \frac{1}{3 \cdot \pi \cdot f_{CO} \cdot R_E} \qquad C_1 = 3.368 \cdot 10^{-5}$$

$$C_2 := 3 \cdot C_1 \qquad C_2 = 1.011 \cdot 10^{-4}$$

$$L := \frac{3 \cdot R_E}{8 \cdot \pi \cdot f_{CO}} \qquad L = 1.857 \cdot 10^{-3}$$

Part (b)

$45 + 135 = 1.8 \cdot 10^{2}$ phase shift in the midrange at crossover

Part (c)

first order out of phase or second order in or out of phase

Problem 4

$A_{OL} := 2000$ $D_{OL} := 5$ $A_{CL} := 10$ $P_E := 60$ $R_L := 8$

Part (a)

$V_o := \sqrt{P_E \cdot R_L}$ $V_o = 21.909$ $V_i := \frac{V_o}{A_{CL}}$ $V_i = 2.191$

Part (b)

$AmtFB := \frac{A_{OL}}{A_{CL}}$ $20 \cdot \log(AmtFB) = 46.021$

Part (c)

$D_{CL} := \frac{D_{OL}}{AmtFB}$ $D_{CL} = 2.5 \cdot 10^{-2}$