

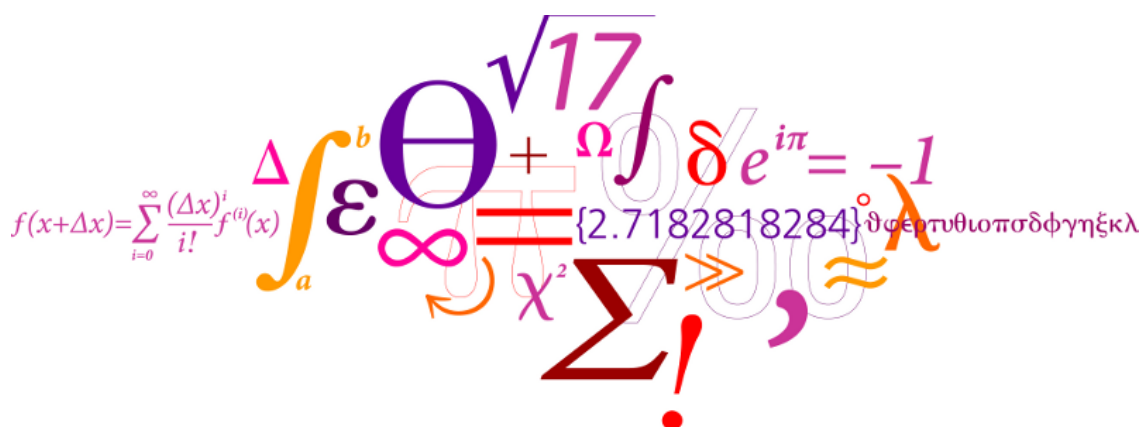
31310 LINEAR CONTROL DESIGN 2

COMPULSORY ASSIGNMENT 2015 : LOUDSPEAKER CONTROL

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November 17, 2015



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Contents

I	Exercise 1: Distortion Attenuation for Loudspeakers	1
1	Loudspeakers electrical equivalent circuit	1
1.1	Problem 1	1
1.2	Problem 2	2

Part I

Exercise 1: Distortion Attenuation for Loudspeakers

Moving-coil Loudspeakers

1 Loudspeakers electrical equivalent circuit

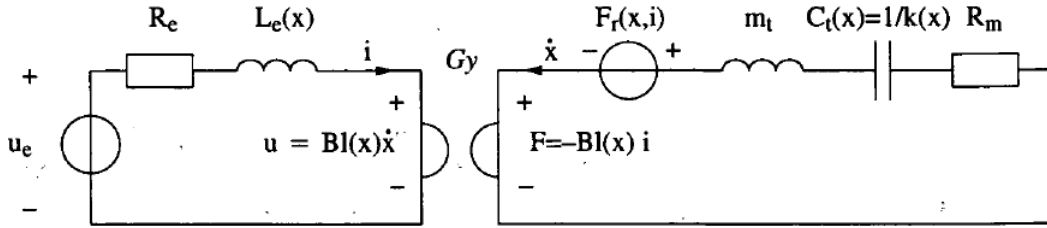


Figure 1: Electrical equivalent lumped element model of the voltage driven electrodynamic loudspeaker for low frequencies. The coupling between the electrical and mechanical domain is performed through the gyrator with gy-ration constant $Bl(x)$.

$$u_e = R_e i + \frac{dL_e(x)}{dx} \frac{dx}{dt} i + L_e(x) \frac{di}{dt} + Bl(x) \frac{dx}{dt} \quad (1)$$

$$Bl(x) i = m_t \frac{d^2 x}{dt^2} + R_m \frac{dx}{dt} + k(x) x - \frac{1}{2} \frac{dL_e(x)}{dx} i^2 \quad (2)$$

where

$$Bl(x) = Bl_0 + b_1 x + b_2 x^2 \quad (3)$$

$$L_e(x) = L_{e0} + l_1 x + l_2 x^2 \quad (4)$$

$$k(x) = k_0 + k_1 x + k_2 x^2 \quad (5)$$

1.1 Problem 1

By means of Eqs 1, 2, 3, 4 and 5, we can identify 3 state variables x , \dot{x} and i . We can also identify the input u_e .

$$\mathbf{x} = \begin{pmatrix} x \\ \dot{x} \\ i \end{pmatrix} \text{ and } \mathbf{u} = (u_e)$$

Then, we can derive the nonlinear dynamical state space model to obtain

$$\dot{x} = \dot{x} \quad (6)$$

$$\ddot{x} = \frac{(Bl_0 + b_1x + b_2x^2)i - R_m\dot{x} - (k_0 + k_1x + k_2x^2)x + \frac{1}{2}(l_1 + 2l_2x)\dot{x}i^2}{m_t} \quad (7)$$

$$\dot{i} = \frac{u_e - (R_e + (l_1 + 2l_2x)\dot{x}^2)i - (Bl_0 + b_1x + b_2x^2)\dot{x}}{L_{e0} + l_1x + l_2x^2} \quad (8)$$

In matrix format, we have

$$\dot{x} = f(x) + g(x)u \quad (9)$$

with

$$f(x) = \begin{pmatrix} x(2) \\ \frac{(Bl_0 + b_1x(1) + b_2x(1)^2)x(3) - R_mx(2) - (k_0 + k_1x(1) + k_2x(1)^2)x(1) + \frac{1}{2}(l_1 + 2l_2x(1))x(2)x(3)^2}{m_t} \\ \frac{-(R_e + (l_1 + 2l_2x(1))x(2)^2)x(3) - (Bl_0 + b_1x(1) + b_2x(1)^2)x(2)}{L_{e0} + l_1x(1) + l_2x(1)^2} \end{pmatrix} \quad (10)$$

$$g(x) = \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix} \quad (11)$$

1.2 Problem 2

References