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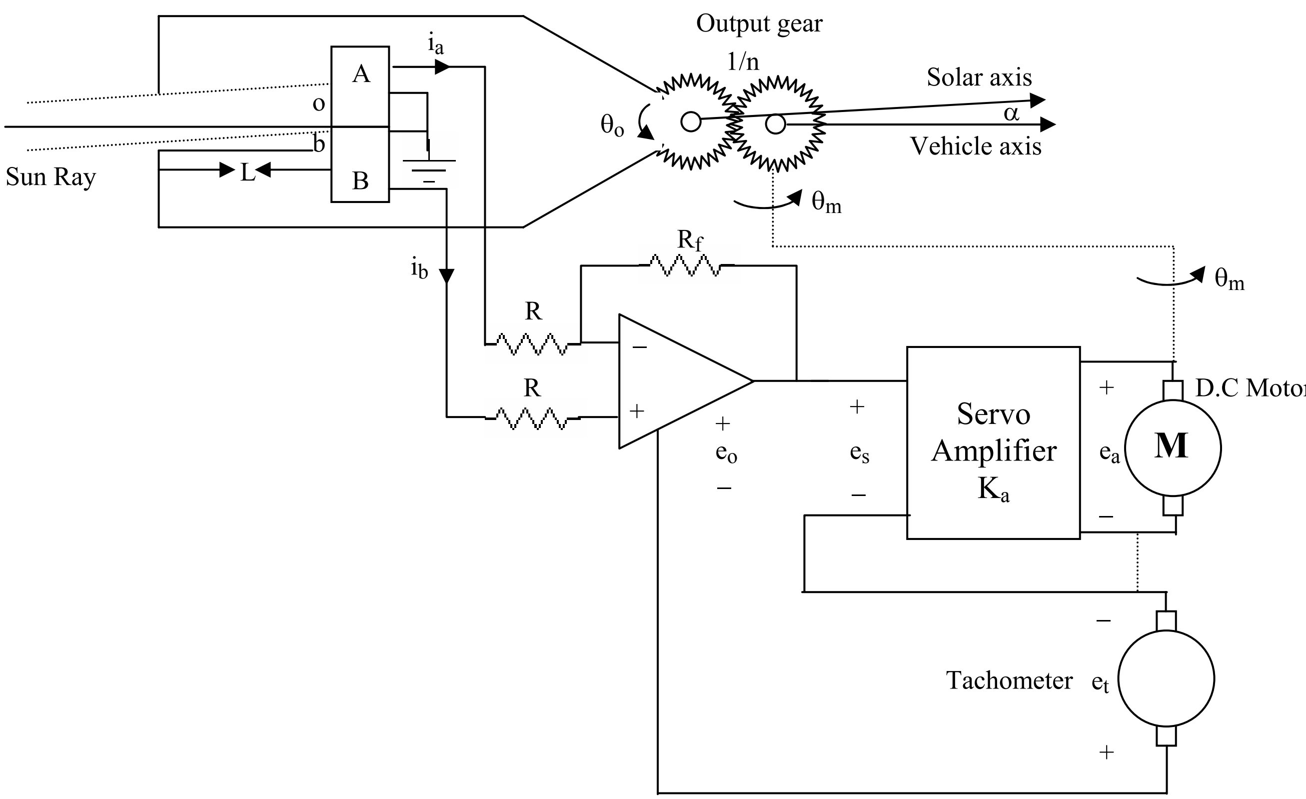
DEPARTMENT OF ELECTRONIC & TELECOMMUNICATION ENGINEERING
MEHRAN UNIVERSITY OF ENGINEERING & TECHNOLOGY, JAMSHORO
Feedback Control Systems (1st Term, Third Year, 03TL)
Lab Practice # 07

Mathematical Modeling of Sun Seeker Control System

1. Introduction

The position of an aircraft or a space vehicle is always guided my some automatic means. Sun seeker control system is one of the automatic control systems whose purpose is to control the attitude of a space vehicle. The control system is designed to track the sun with high accuracy. In this particular control system tracking the sun in only one plane is accomplished (for simplicity) unlike practical systems in which height and the direction are controlled simultaneously. The system is shown in the following figure.



2. Working Principle

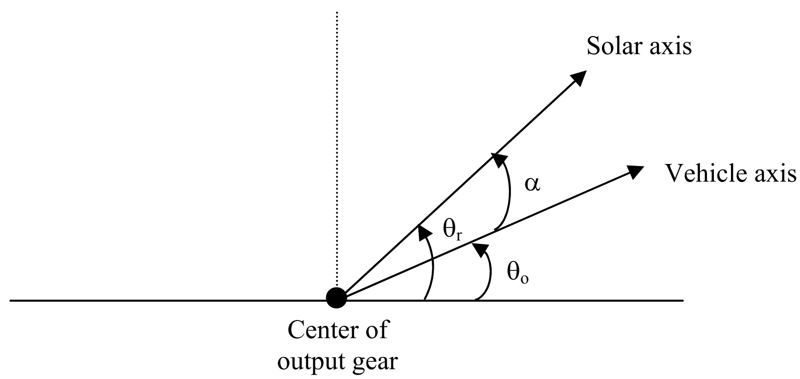
Two silicon cells are used as light sensors. The cells are mounted in such a way that when the sensor is pointed at the sun, the beam of light overlaps both cells. The silicon photovoltaic cells are used as current sources and connected in opposite polarity to the input of the op-amp. Any difference in the short circuit current of the two cells is sensed and amplified by the op-amp. Since the current of the each cell is proportional to the illumination on the cell, an error signal will be present at the output of the amplifier when the light from the slit is not centered precisely on the cell. This error voltage, when fed to the servo amplifier, will cause the motor to drive the system back into the alignment.

3. System Description

In order to analyze and the working of the system properly the system is divided into six main parts. The description of each part is given below.

- **Co-ordinate system: -** The center of the coordinate system is considered to be at the output gear of the system. The reference axis is taken to be the fixed frame of the D.C motor, and al rotations are measured with respect o this axis. The solar axis or the line from the output gear to the sun makes an angle $\theta_r(t)$with respect to reference axis, and $\theta_o(t)$ denotes the vehicle axis with respect to the reference axis. The objective of the control system is to maintain the error between $\theta_r(t)$ and $\theta_o(t)$, i-e $\alpha(t)$, near zero.

$$\alpha(t) = \theta_r(t) - \theta_o(t)$$



- **Error Discriminator: -** When the vehicle is aligned perfectly with the sun, $\alpha(t) = 0$ and $i_a(t) = i_b(t) = I$. From the geometry of the sun ray and photovoltaic cells shown in the schematic diagram of the system, we have

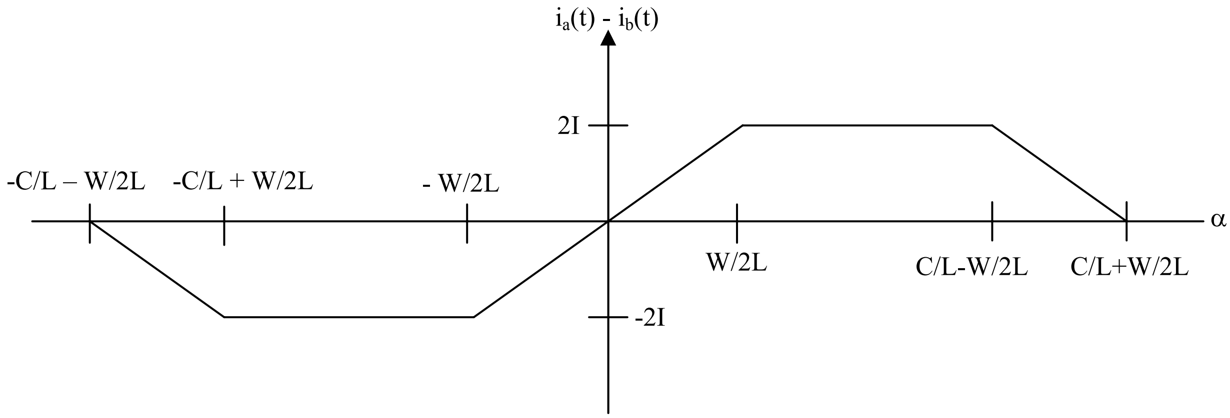
$$\mathbf{oa = W/2 + L \tan \alpha(t)}$$

$$\mathbf{ob = W/2 - L \tan \alpha(t)}$$

Where oa denotes the width of the sunray that shines on the cell A, and ob is the same on the cell B, for a given $\alpha(t)$. Since the current $i_a(t)$ is proportional to oa, and $i_b(t)$ to ob, we have

$$\mathbf{i_a(t) = W/2 + L \tan \alpha(t)}$$
$$\mathbf{i_b(t) = W/2 - L \tan \alpha(t)}$$

For $0 \le \tan \alpha(t) \le W/2L$. For $W/2L \le \tan \alpha(t) \le (C-W/2)/L$, the sun ray is completely on cell A, and $i_a(t) = 2I$, $ib(t) = 0$. For $(C-W/2)/L \le \tan \alpha(t) \le (C + W/2)/L$, $i_a(t)$ decreases linearly form 2I to zero. $i_a(t) = i_b(t) = 0$ for $\tan \alpha(t) \geq (C + W/2)/L$. therefore the error discriminator may be represented by the non-linear characteristic of following figure, where for small angle $\alpha(t)$, $\tan \alpha(t)$ has been approximated by $\alpha(t)$ on the abscissa.



- **Op-Amp: -** The relationship between the output of the op-amp and the currents $i_a(t)$ and $i_b(t)$ is

$$\mathbf{E_o(t) = - R_F\,[i_a(t) - i_a(t)]}$$

- **Tachometer: -** The output voltage of the tachometer, e_t, is related to the angular velocity of the motor through the tachometer constant K_1:

$$\mathbf{e_t = K_1\,\omega_n(t)}$$

The angular position of the output gear is related to the motor position through the gear ratio 1/n. Thus:

$$\mathbf{\theta_o = 1/n\;\theta_m}$$

- **D.C Motor: -** The mathematical model for the D.C motor is given by following equations:

$$\mathbf{e_a = R_a\,i_a(t) + e_b(t)}$$

$$\mathbf{e_b = K_b\,\omega_n(t)}$$

$$\mathbf{T_m = K_i\,i_a(t)}$$

$$\mathbf{T_m(t\,) = \frac{d\omega_m(t)}{dt} + B\,\omega_m(t)}$$

Where J and B are the inertia and viscous friction coefficients seen at the motor shaft. The inductance of the motor is neglected.