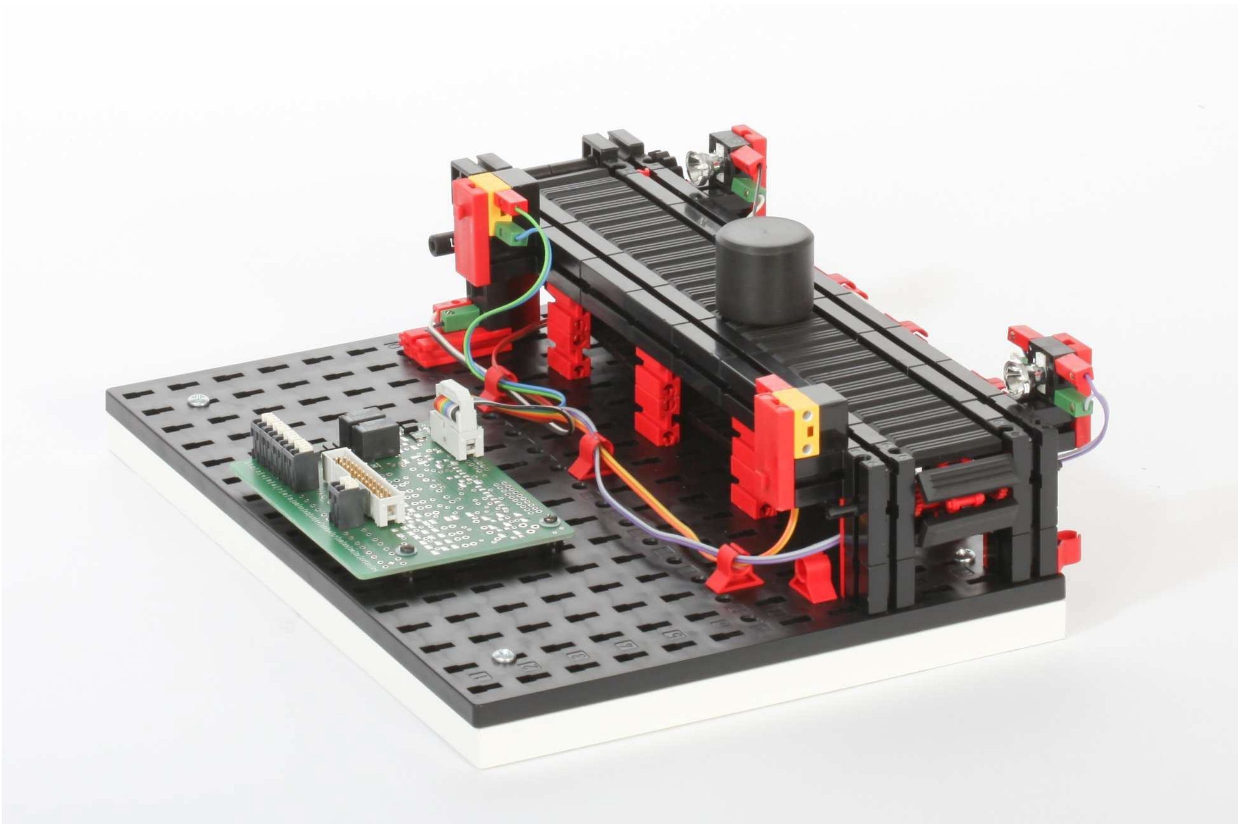
ISE 589-006 Introduction to Modern Industrial Automation
Homework Assignment 2
Due: March 3rd, 2023



This homework assignment is related to the electrical-mechanical design of a conveyer system for industrial automation. In this assignment you will explore the theory of sensors and actuators to build such system.

Problem 1. **(10 points)**

A length measuring device comprises of a tracking wheel and a shaft encoder that is attached to the wheel. This shaft encoder generates 360 pulses per revolution. When measuring the length of a 5 – meter conveyer system, 18,000 pulses were observed at the encoder. What is the radius of the tracking wheel in mm?

Problem 2. **(15 points)**

When a robot navigates a room by "dead reckoning", the robot's position in the room is estimated according to the movement of the wheels with respect to its initial position. The absolute encoder is used to keep track of the traveled distance.

a) If the robot is equipped with an 8-bit absolute encoder, what wheel size would the robot need to obtain a resolution of exactly 1 mm? (e.g., 1-mm change in distance would result in one-bit change in the 8-bit encoder) (5 points)

b) If the circumference of the wheel is 10 cm, to achieve a resolution of 1 mm or higher, how many bits does the absolute encoder need at least? (5 points)

c) Give two reasons why "dead reckoning" position tracking approach would NOT be a good idea in practice. (5 points)

Problem 3. **(15 points)**

The figure below gives the code disk for 4-bit binary code and gray code schemes. For gray code, it has the important characteristic that only one-bit changes between one segment and the next. Binary code, on the other hand, can have several bit changes between one segment and the next.

Binary code

Gray code

In the figure, let the black sectors represent a binary value of 1, and the white sectors represent a binary value of 0. The least significant bit (LSB) is on the outer track.

(a) Fill in the table below for the binary code and gray code for decimal values from 0 to 10. The first two rows are given as an example. (5 points)

Number	Binary code	Gray code
0	0000	0000
1	0001	0001
2		
3		

4		
5		
6		
7		
8		
9		
10		

b) When moving from number 7 to 8, how many bits change for binary code and gray code? Assuming for each bit change there is a chance for the encoder to misread, what is the total number of all possible results read by the encoder in Binary code and Gray code respectively when moving from number 7 to 8? (5 points)

c) Based on the example in (b), explain why the gray code scheme is more robust than binary code. (5 points)

Problem 4. **(60 points)**

You are task to select the optimal motor to drive the conveyor belt system. In your inventory you have the following Motors. You may use the sample MATLAB script found in the appendix to complete this assignment.

Motor	Torque Constant [Nm/A]	Motor Constant [Vs/rad]	Terminal Resistance [Ohms]
1	0.2	0.5	5
2	1.5	0.5	5
3	0.2	1.5	5
4	0.2	0.5	10

a) The load on the conveyer belt requires a torque of at least 2 Nm. What is the best motor for the system and why? (10 points)
b) What impact does the Torque Constant have on the system? (10 points)
c) What impact does the Back-EMF Constant have on the system? (10 points)
d) What impact does the terminal resistance have on the system? (10 points)
e) Which motor provides the maximum angular velocity? (10 points)
f) What happens to the system as the voltage was increases (10 points)

Appendix

```
% TorqueSpeedRelation.m
% Fred Livingston (fjliving@ncsu.edu) 2-19-2023

clc;
clear all;
close all;

Ke = 0.2; % Torque Constant Nm/A
Kb = 0.5; % Back-EMF Constant Vs/rad
R = 10;    % Terminal Resistance

counter1 = 1;
for spd = 0:1:50
    V = 3;
        counter2 = 1;
    T(counter1,counter2) = Ke / R * (V - Kb * spd);
    V = 6;
        counter2 = 2;
    T(counter1,counter2) = Ke / R * (V - Kb * spd);
    V = 9;
        counter2 = 3;
    T(counter1,counter2) = Ke / R * (V - Kb * spd);
    counter1 = counter1 + 1;
end
spd = 0:1:50;
figure;
hold on;
plot(spd,T(:,1),'k','linewidth',1.5);
plot(spd,T(:,2),'b','linewidth',1.5);
plot(spd,T(:,3),'r','linewidth',1.5);
xlabel('rotation speed \omega');
ylabel('Torque (T)');
xlim([0 22]);
ylim([0 0.4]);


counter1 = 1;
counter2 = 1;
for V = 3:0.05:9
% for V = 3
    for spd = 0.1:0.1:6
        T(counter2,counter1) = Ke / R * (V - Kb * spd);
        counter2 = counter2 + 1;
    end
    counter1 = counter1 + 1;
    counter2 = 1;
end

V = 3:0.05:9;
% V = 3;
spd = 0.1:0.1:6;
```

```
figure;
mesh(V,spd,T);
xlabel('V_a (V)');
ylabel('\omega (rad/sed)');
zlabel('T (Nm)');
```