ASSIGNMENT #3 SOLUTIONS

Winter 2000 (due March 13)

Design Proportional (P) and Proportional plus Integral (PI) cross coupling controllers (CCCs) to coordinate the x and y Robotool axes. Use the axis models developed in Assignment #1 and the proportional axis controllers developed in Laboratory #2. Include control signal saturation and quantization effects of the D/A converters and linear encoders. Design the CCCs such that the contour error is less than 100 $\mu$m. Simulate the CCCs in the Matlab-Simulink environment. Apply both controllers to a linear contour with a feedrate of 15 $mm/s$ and x and y axis travel lengths of 30 $mm$ and to a full circular contour with a feedrate of 15 $mm/s$ and a radius of 25 $mm$. Discuss the results.

Simulink Block Diagram for Linear Contours
Linear Contour: No Cross Coupling Controller

Linear Contour: \( K_p = 25,000 \text{ digital number/m}, \ K_i = 0 \text{ digital number/(m}^*\text{s}) \)
Linear Contour: \(K_p = 25,000\) digital number/m, \(K_i = 100,000\) digital number/(m*s)
M File for Linear Contours

% ccc1file.m

% This file simulates a cross coupling controller for linear contours
% for Assignment #3 for ME584 Winter 2000 semester.

% Last Update: February 21, 2000 by Robert G. Landere

Vr = 15/1e3; % feedrate (m/s)
lx = 30/1e3; % x axis travel length (m)
ly = 30/1e3; % y axis travel length (m)
L = sqrt(lx*lx+ly*ly); % total travel length (m)
vx = lx*Vr/L; % x axis reference velocity (m/s)
vy = ly*Vr/L; % y axis reference velocity (m/s)

nex = 1e-5; % x axis encoder resolution (m)
ney = 1e-5; % y axis encoder resolution (m)

Kpx = 10000; % x axis proportional gain (digital number/m)
Kpy = 10000; % y axis proportional gain (digital number/m)
Kp = 25000; % ccc proportional gain (digital number/m)
Ki = 100000; % ccc integral gain (digital number/(ms))

Xmax = 127; % x axis upper saturation limit (digital number)
Xmin = -128; % x axis lower saturation limit (digital number)
Ymax = 127; % y axis upper saturation limit (digital number)
Ymin = -128; % y axis lower saturation limit (digital number)

gx = 2.543e-4; % x axis DC gain ((m/s)/digital number)
tx = 0.04; % x axis time constant (s)
gy = 2.284e-4; % y axis DC gain ((m/s)/digital number)
ty = 0.045; % y axis time constant (s)

T = 0.01; % sample period (s)
Tf = L/Vr; % final time (s)

cx = ly/L;
cy = lx/L;

for i=1:Tf+1, t(i) = (i-1)*T; end;
sim('ccc1',Tf)
Simulink Block Diagram for Circular Contours

Circular Contour: No Cross Coupling Control

reference: blue solid line
actua: green dotted line

Dr. Robert G. Landers
Circular Contour: \( K_p = 125,000 \) digital number/m, \( K_i = 0 \) digital number/(m*s)
Circular Contour: \( K_p = 1,000,000 \ digital\ number/m \), \( K_i = 1,000,000 \ digital\ number/(m*s) \)

M File for Circular Contours

```matlab
% ccc3file.m

% This file simulates a cross coupling controller for a circular contour for Assignment #3 for ME584 Winter 2000 semester.

% Last Update: February 27, 2000 by Robert G. Landere

Vr = 15/1e3; % feedrate (m/s)
R = 25/1e3; % circle radius
nex = 1e-5; % x axis encoder resolution (m)
ney = 1e-5; % y axis encoder resolution (m)
Xc = R; % x position circle center (m)
Yc = 0; % y position circle center (m)
Kpx = 1e4; % x axis proportional gain (digital number/m)
Kpy = 1e4; % y axis proportional gain (digital number/m)
Kp = 1e6; % ccc proportional gain (digital number/m)
Ki = 1e6; % ccc integral gain (digital number/(ms))
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Xmax = 127; % x axis upper saturation limit (digital number)
Xmin = -128; % x axis lower saturation limit (digital number)
Ymax = 127; % y axis upper saturation limit (digital number)
Ymin = -128; % y axis lower saturation limit (digital number)

gx = 2.543e-4; % x axis DC gain ((m/s)/digital number)
tx = 0.04; % x axis time constant (s)
gy = 2.284e-4; % y axis DC gain ((m/s)/digital number)
ty = 0.045; % y axis time constant (s)

T = 0.01; % sample period (s)
Tf = 2*pi*R/Vr; % final time (s)

for i=1:Tf/T+1, t(i) = (i-1)*T; end;

sim('ccc3',Tf)