KING FAHD UNIVERSITY OF PETROLEUM & MINERALS
Electrical Engineering Department

EE 380 - Control Engineering **Experiment # 6**

Servo Motor Position Control Using a Proportional Controller

OBJECTIVES:

1. To study the influence of the gain on the transient response of a position servo.
2. To study the effect of velocity feedback.

APPARATUS:

1. The 33-002 Servo Fundamentals Trainer shown in Fig. 1, which consists of 2 Units:
    a. Analogue Unit 33-110
    b. Mechanical Unit 33-100 supplied with a 34-way Terminated Cable
2. Power Supply ± 15 V DC, 1.5A; +5V dc, 0.5A
   (Feedback PS446 04 01-100)
3. Storage Oscilloscope or X-Y Plotter.

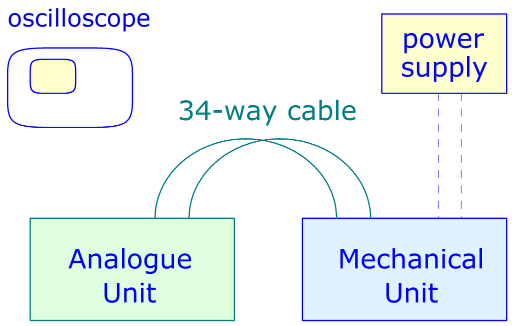


Fig. 1 Principal system interconnection of the 33-002

Part I INFLUENCE OF GAIN

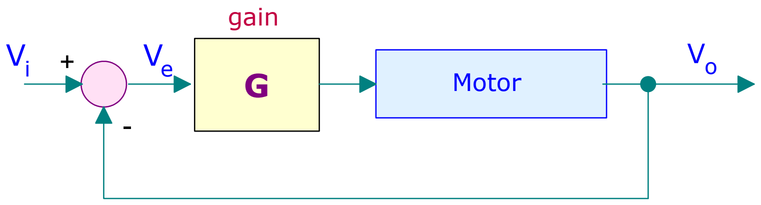
Introduction

The design and performance characteristics of control systems are often considered in terms of the response to a step or ramp input. The step response of a system gives useful information about the general system characteristics and is often required to meet some demands in the system response specifications. To generate the step response, a very simple input is required, and for these reasons much consideration is given to the step response.

Copyright © Electrical Engineering Department, KFUPM.

For a given system, the form of the step response is greatly affected by the system gain. The gain essentially determines how much power is applied to move the output for a given error. For an electrical system, such as the 33-002, the gain determines the voltage applied to the motor for a given error.

A purely electrical system may be represented as in Fig. 2, where the input V_i, output V_o, and error V_e are all voltages and the forward path gain (G) is shown separately. Note that if a step V_i is applied, the initial value of the error is equal to V_i as in (b), since V_o is zero.



(a)

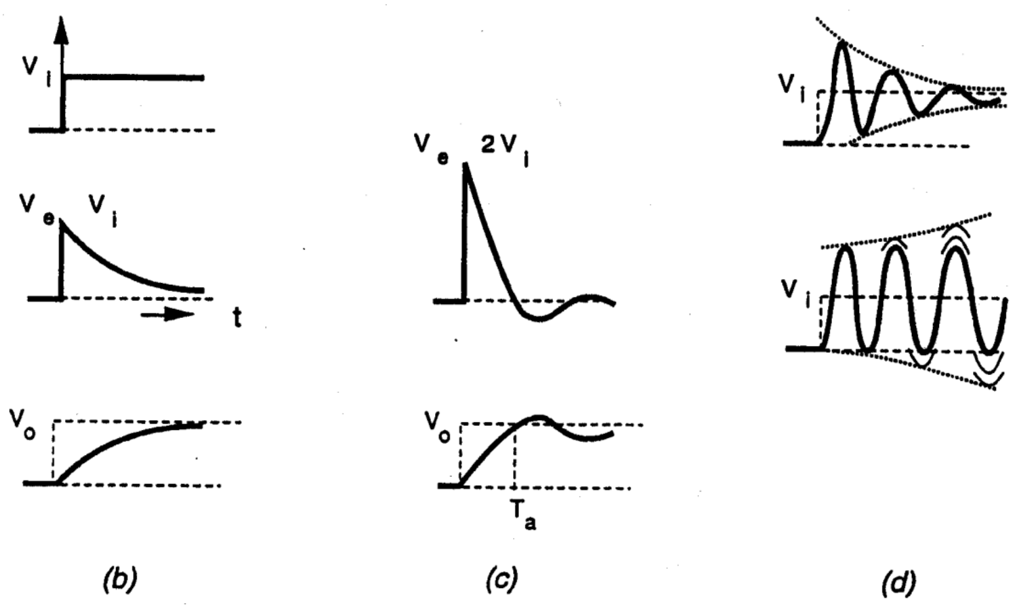


Fig. 2 Effect of varying proportional gain on step response

- If $G = 1$, the power amplifier input is initially V_i and as the motor rotates, the output gradually aligns with input, with the motor slowing up as the error decreases.
- If $G = 2$, the initial input to the power amplifier is $2V_i$, causing the motor to move faster and although the error decreases, the motor may overshoot the required final position due to the delay in the motor. When the motor finally stops, the error is reversed in sense, so that the motor reverses and the system aligns or may undershoot, but will finally settle as shown in (c).

Copyright © Electrical Engineering Department, KFUPM.

- If G is increased further, the system may take several oscillations to settle, as shown in (d). For higher order systems, the result may be a steady oscillation at the output, or even an increasing oscillation. Systems with the characteristics of (d) are useless for control purposes.

PROCEDURE

1. Connect together the Analogue Unit 33-110 and the Mechanical unit 33-100 using the 34-way ribbon cable supplied.
2. Connect the Mechanical Unit 33-100 to the power supply using the 4mm lead provided.
3. Ensure all of the fault switches on the Analogue Unit are off (down).
4. Switch on the power supply. The motor on the Mechanical Unit 33-100 may revolve and the speed/rpm display should light.
5. Adjust the power amplifier zero control to be found on the right-hand side of the Analogue Unit 30-110. The motor should drive in both directions, controllable by the zero knob. Set the zero control so that the motor is stopped.
6. Arrange the system with the solid connections of Fig. 3 with the error amplifier feedback resistor $100\,\mathrm{K}\Omega$, giving $G = 1$.

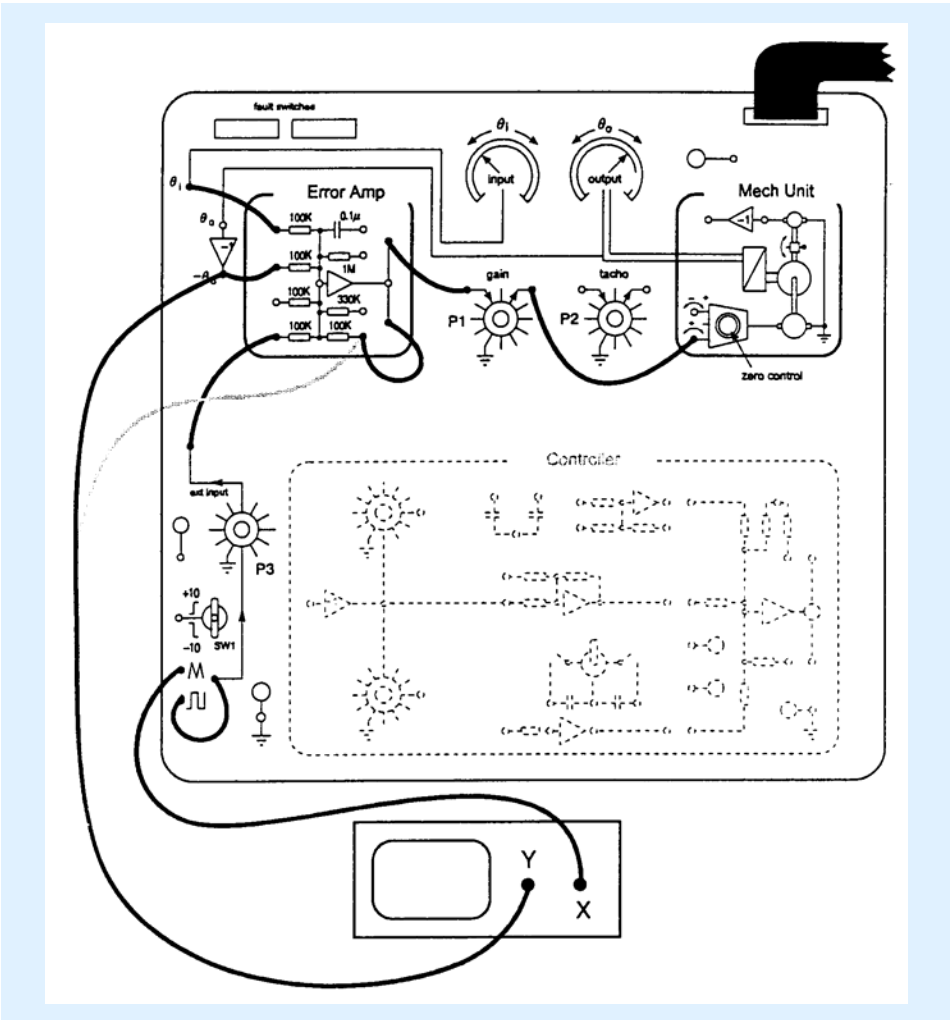


Fig. 3 Connections for influence of gain

Copyright © Electrical Engineering Department, KFUPM.

7. Set the test signal frequency to about 0.1 Hz and adjust P_3 to provide a square wave input of ±5V.
8. Set P_1 to zero and arrange an X-Y display.
9. Turn up P_1 until the motor just rotates and the system response is overdamped (Fig. 2b).
10. Increase P_1 until the system just overshoots and estimate the time to alignment T_a.
11. Finally set P_1 =100 and note the reduced T_a and the increased overshoot.
12. Set the amplifier feedback resistor to 330 KΩ giving $G = 3.3$. Connect the Y input to the error amplifier output and with P_1 =100 adjust P_3 until the peak amplifier error (GV_e) is about 10V. The response should have the general form of the top of Fig. 2d. The time to alignment is much reduced but the response is too oscillatory for a practical system.
13. Set the feedback resistor to 1MΩ giving $G = 10$, and repeat the test, adjusting P_3 to limit the peak error to 10V. The response is now more oscillatory, but the time to initial alignment will be reduced from the value $G = 3.3$ and can be estimated.
14. With $G = 10$, adjust P_3 to give ±5V. [Note that the theoretical initial output of the error amplifier would be 50V]. In practice, the error amplifier cannot provide outputs much exceeding ±10V and hence limits. Observe that the error limits and that the oscillation takes longer to die away.

Part II VELOCITY FEEDBACK

Background

All practical motors have friction, which has to be overcome to start the motor from rest. Therefore a minimum input voltage has to be applied to the motor before rotation starts; this is term dead-band. If the gain is high, the dead-band is reduced, which is advantageous, but the system may display unwanted oscillation in the response.

The form of the system response with high gain can be much improved by applying a feedback signal to the input, which is proportional to the output shaft velocity. This arrangement, shown in Fig. 4, is called velocity feedback or tachometer feedback. A tachometer is used for this purpose instead of differentiating the output signal..

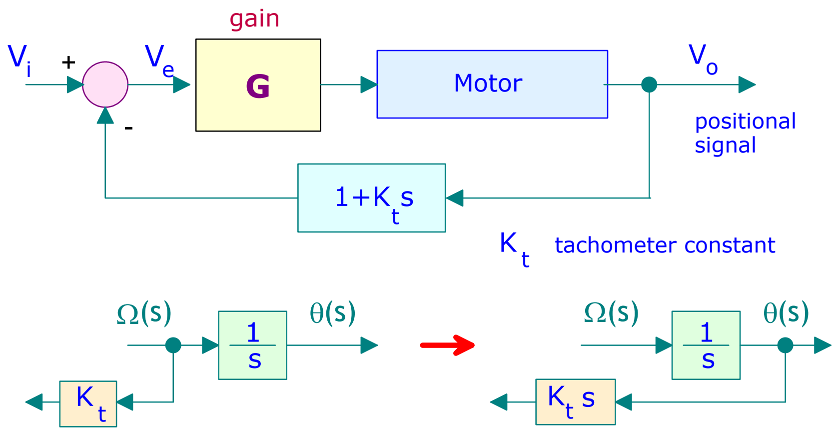


Fig. 4 Velocity Feedback

Copyright © Electrical Engineering Department, KFUPM.

PROCEDURE

1. Arrange the system as in Fig. 5, initially omitting the connection from P_2 to the tachometer and set P_1 to zero.
2. Set the error amplifier feedback resistor to 100KΩ giving $G = 1$, and set P_3 to give Vi = ±5V at 0.1 Hz. Set P_1=100 and a slightly oscillatory response should be obtained.
3. Connect P_2 to one tachometer output [watch for correct polarity], and increase its setting until deadbeat response is obtained, this occurs when the motor just does not reverse. Additional feedback can be obtained by disconnecting θ_i, and connecting the tachometer to that input as well.
4. Increase the feedback resistors to 330KΩ giving $G = 3.3$; 1MΩ giving $G = 10$, and in both cases deadbeat response should be obtainable.

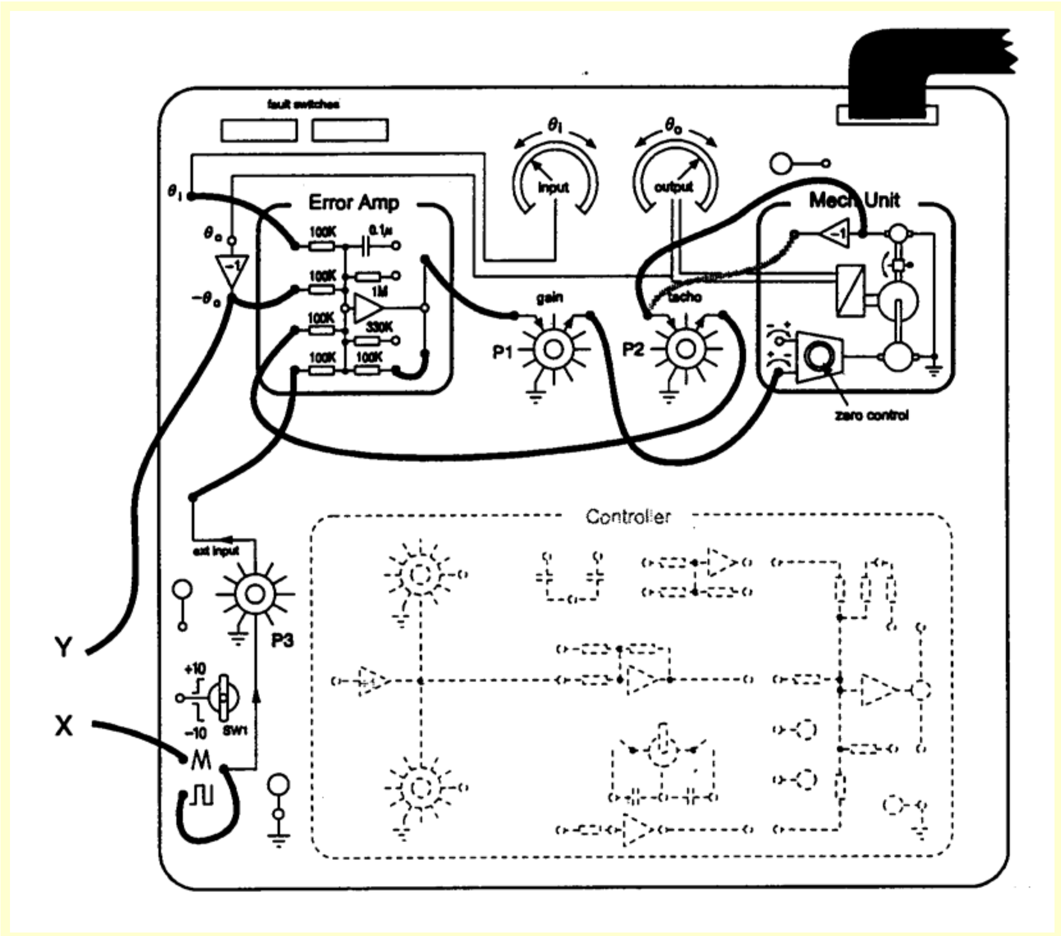


Fig. 5 Connections for velocity feedback

REPORT

1. Plot all the responses obtained in both Parts I and II using the X-Y plotter.
2. Based on the results of Part I, discuss the relationship between the gain, stability, speed of response, and steady-state-error.

Copyright © Electrical Engineering Department, KFUPM.

3. Based on the results of Part II, explain how velocity feedback improves the response of the closed-loop position control system. What is the disadvantage of velocity feedback?

Copyright © Electrical Engineering Department, KFUPM.