KING FAHD UNIVERSITY OF PETROLEUM & MINERALS
Electrical Engineering Department

EE 380 - Control Engineering **Experiment # 8**

Speed Control with a Proportional plus Integral Controller

OBJECTIVES:

The objective of this experiment is to demonstrate that the use of a Proportional plus Integral (PI) controller will eliminate the steady state error.

APPARATUS:

1. Analogue Unit 33-110
2. Mechanical Unit 33-100
3. Power Supply +/-l 5V dc, 1 .5A, +5V dc, 0.5A

INTRODUCTION

The simple speed control system with a proportional controller of Fig. 1, has been investigated in Experiment 4. The results demonstrate that increasing the forward path gain will reduce the error V_e between the reference voltage V_{ref} and the speed voltage V_s . A possible problem associated with increased gain is the saturation of the power amplifier. This problem can be mitigated by the use of a PI controller. Provided that there is an integrator in the forward path, the system will always adjust so that V_e is zero, and hence the speed voltage V_s always equals V_{ref}.

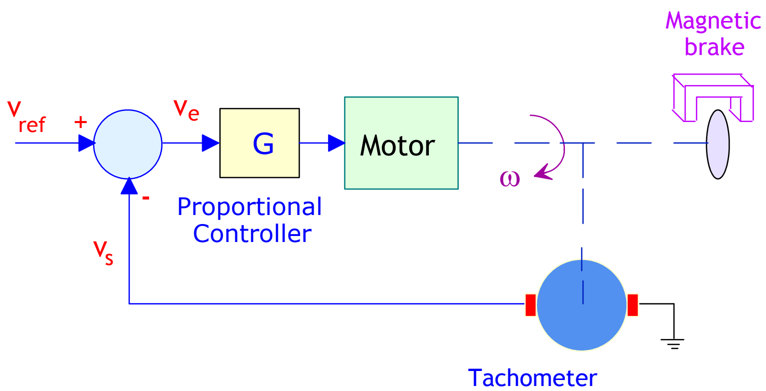

Fig. 1 Closed loop speed control system

PROCEDURE

Part I: PI Controller Implementation

A PI controller speed control circuit is given in Fig. 2 with connection diagram in Fig. 3.

1) Connect the circuit of Fig. 3 with controller amplifier feedback resistor 100K, which gives forward gain (G=1), and switch the integrator OFF. Set P_2 and P_3 at zero and P_1 at 100.
2) Set SW1 up to +10 and adjust P_3 to give 1000 r/min (31 r/min output), and turn P_2 slightly.
   - If the speed falls slightly, the feedback is negative as required.
   - If the speed rises slightly, change the polarity of the tachometer supply to P_2.
3) Set P_2 to 100 and readjust P_3 to give 1000 r/min.
4) Measure ,V_e, V_{ref}, and V_s. Note that the speed voltage V_s is much less that V_{ref} because the forward gain is low (G=1).
5) Using the voltmeter set P_3 (V_{ref}) to the value of $V_s$for 1000 r/min (about 2.5 V) and the speed will fall to about 500 r/min.
6) Change the controller feedback resistor to 500KΩ (G=5), and comment on the value of the motor speed compared to Step 4.
7) Reduce the controller feedback resistor to 100KΩ, set P_5 to 100, and switch the integrator ON. The speed will increase so that $V_s = V_{ref}$ andV_e will fall approximately to zero. The integrator is now supplying exactly the drive so that $V_s$matches .V_{ref}.

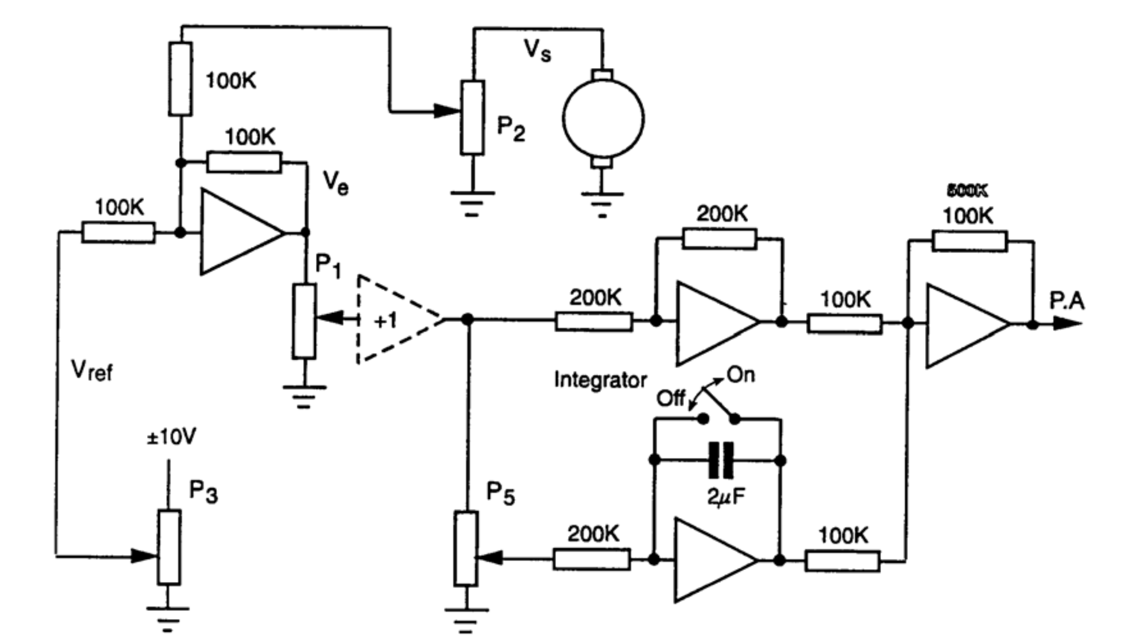

Fig. 2 Speed Control Circuit

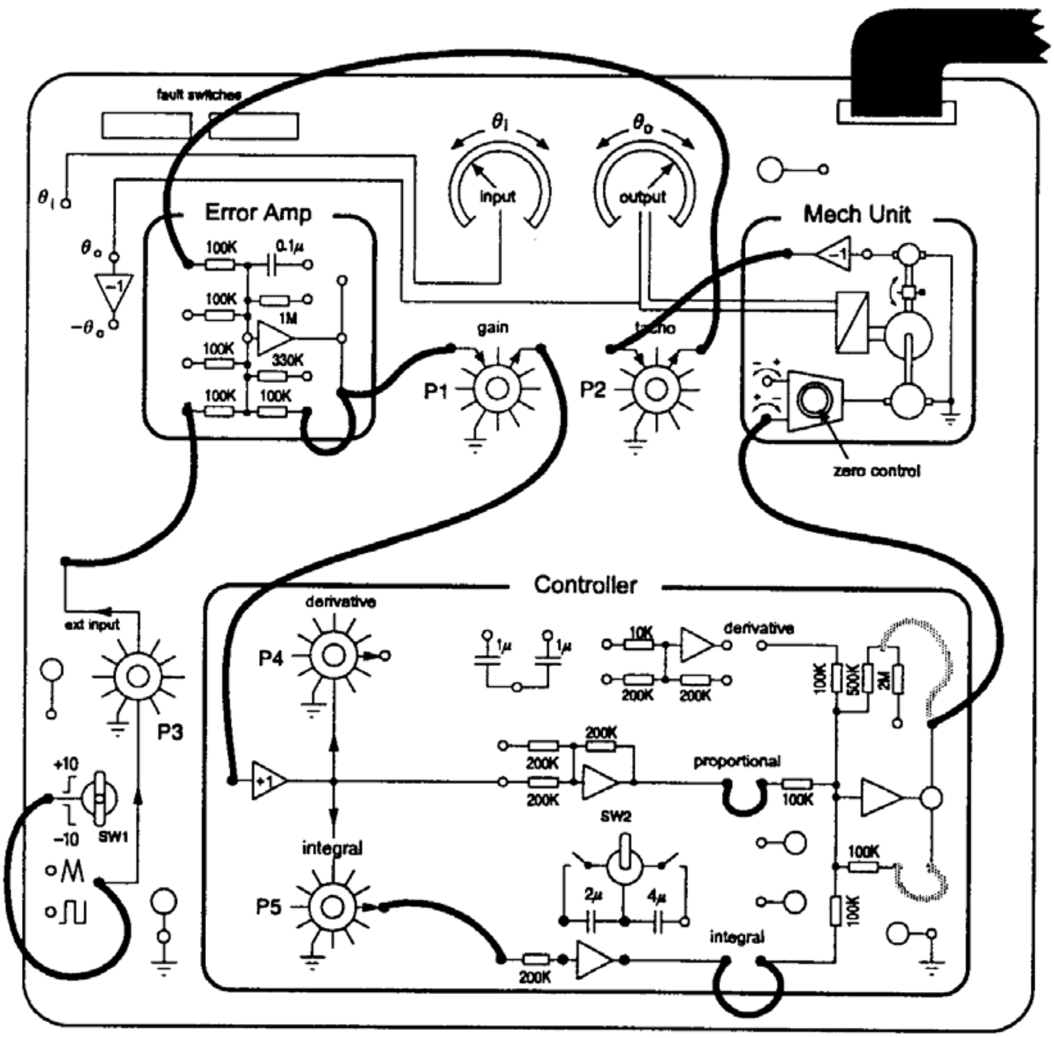

Fig. 3 Connection Diagram

Part II: Response to Output Loading

The common requirement for a speed control system is to maintain a constant speed against load variations.

1. Arrange the system as in Fig. 3 with brake OFF, integrator ON, P_5 to 100, P_3 set to give 1000 r/min, and controller feedback resistor 100KΩ.
2. While the system is in operation, set the brake quickly to full ON.
3. Comment on the behavior of the motor speed.
4. Set the brake quickly OFF.
5. Comment on the behavior of the motor speed.
6. Change the controller feedback resistor to 500 KΩ, and repeat Steps 2 to 5.
7. Comment on the effect of increasing the forward path gain in Step 6.

Report:

1) What is the effect of increasing the gain from G=1 to G=5 on the performance of the closed-loop system of Part I ?
2) Discuss the effects of the use of PI controller on the motor speed control system.
3) What is the effect of increasing the gain from G=1 to G=5 on the performance of the closed loop system of Part II ?
4) Use SIMULINK to simulate the behavior of the motor speed control system shown in Fig. 4, with a PI controller. (Assume $K_t = 1$ volt/rad/sec). [set $K_p = 0, 1, 4$; and let $K_I = 0, 1, 2, 5, 8$]. Describe the effect of the integral control action. [using a unit-step reference input and no disturbance].
5) **Design** the PI controller such that the following specifications are met:

$$K_v = 10\,;\zeta = 0.5$$

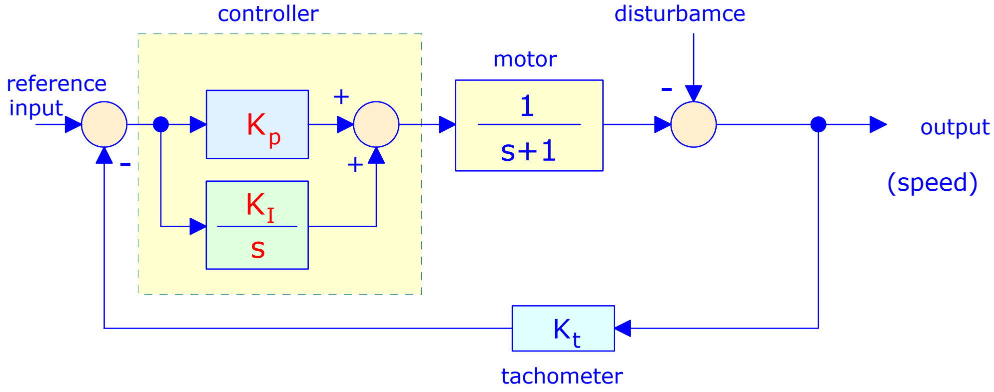

Fig. 4 Speed control system with PI control

6) **Verify** that the specifications are met via a time-domain simulation.
7) Using the settings of (5), comment on the behavior of the system when:
   - a step disturbance is applied after 1 second from the start of the simulation [using a unit-step reference input] .
   - a step disturbance is applied after 1 second from the start of the simulation [using a unit-ramp reference input] .
   - a unit-ramp disturbance is applied after 1 second from the start of the simulation [using a unit-ramp reference input] .
   - a unit-ramp disturbance is applied after 1 second from the start of the simulation [using a unit-step reference input] .